A Study on Spatial Distribution and Prediction of Arsenic Concentration in Groundwater and its Associated Health and Societal Risk with Possible Mitigation Measures

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PROFORMA 1

"Statement of Originality"

I, **Paramita Chaudhuri** registered on **09.09.2015** do hereby declare that this thesis entitled "**A Study on Spatial Distribution and Prediction of Arsenic Concentration in Groundwater and its Associated Health and Societal Risk with Possible Mitigation Measures**" contains literature survey and original research work done by the undersigned candidate as part of Doctoral studies.

All information in this thesis have been obtained and presented in accordance with existing academic rules and ethical conduct. I declare that, as required by these rules and conduct, I have fully cited and referred all materials and results that are not original to this work.

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Dedicated to

Ma, Babu, Dadabhai

and

Jishu

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Abbreviation list

Full form	**Abbreviated forms**
Arsenic	As
Chloride	Cl
Iron	Fe
microgram per liter	µg/L
miligram per liter	mg/L
parts per million	ppm
World Health Organization	WHO

Conversion list

0.001 ppm	1 ppb
1 ppb	1 µg/L
1 ppm	1 mg/L

ABSTRACT

The groundwater of the Bengal Basin is found to be severely contaminated by geogenic sourced arsenic, which has been considered as the largest public health concern in the human history. The present study was done on the basis of the concerned situation of arsenic contamination in groundwater and its associated health risks. The natural contamination of arsenic in groundwater has been documented worldwide, but India is considered as one of the most arsenic contaminated region among them. In case of India, from the literature it was found that in West Bengal, the water from shallow aquifers has been treated as drinking water source for millions of people and the range of arsenic pollution in groundwater at that depth is 0 to 3200 µg/L. The provisional guideline value set by WHO (2012) for arsenic in drinking water is 10 µg/L. Chronic arsenic induced diseases are found to develop among the population due to the consumption of arsenic contaminated water more than the permissible limit for a prolonged time. While the adverse effects of arsenic induced illness on adult health are well documented, a little is known about the consequences of consumption of arsenic contaminated water among children. The arsenic contaminated tubewells present in the primary schools are one of the major source of arsenic contamination among the child population. So, there is a need for some mitigative measures to supply arsenic free water in arsenic contaminated region. With the view of this, the present study was done on spatial distribution pattern of groundwater arsenic and prediction at primary schools to assess the health risks and develop mitigative measures to lower the risk among the total population.

South 24 Parganas was found as the one of the most arsenic affected districts of West Bengal. A focus area was identified on the basis of arsenic concentration for the study as the total district was not arsenic contaminated. Higher level of arsenic concentration was confined in shallow aquifer (within 100 m bgl) and low arsenic concentration was reported in the deeper depth. The focus area was divided into four zones according to the distribution of arsenic concentration in shallow tubewell- zone I (0-10 ppb), zone II (10.1-100 ppb), zone III (100.1- 300 ppb) and zone IV (more than 300 ppb).

The estimation of arsenic concentration at unsampled locations were found very difficult due to the wide range of spatial variability of arsenic concentration between neighbouring tubewells at shallow depth. Geostatistics was found as one of the best methods that could estimate arsenic concentration at unknown spatial locations where no measurements were done. Ordinary kriging has been established as the best interpolation method to estimate the variable. For estimation of arsenic concentration at a spefic location in both shallow and deep depth, the major influential zone (critical angle) for estimation was oriented at 52.5^{o} -232.5^{o} (measured from east) line. The separation distance (critical range) was 6592 m for shallow tubewell and 7859 m for deep tubewell. The location points those are

present within the critical range and critical angle are called the influencing points and total 6-10 influencing points were considered for the estimation of arsenic concentration. The deviation between estimated and actual value was found higher in shallow depth than deeper depth, as the range of spatial distribution of arsenic was found higher in shallow depth. As the field samples were collected from the deeper depth, low deviation was observed between estimated and actual values. The higher discrepancies were observed where arsenic hotspot zones lie very close to low arsenic contaminated zone or vice versa. Appreciable cross correlation exists between arsenic and iron at different locations, but not so good cross correlation was observed between arsenic and chloride.

From the population projection of the year of 2022, only 15% population of the focus area were found safe (zone I) from arsenic concentration. 10 to 100 ppb (zone II) is the predominant concentration in the focus area and 57% population are observed to use arsenic contaminated water at this level followed by 100.1-300 ppb (zone III) and more than 300 ppb (zone IV). Around 1000 primary schools with approximately 110000 student populations were present in the focus area and they were found dependent on groundwater for drinking purposes and mid-day meal was also cooked with that water. Based on the kriging estimation in shallow tubewell, it has been found that in about 6% of schools, the estimated arsenic concentration was within permissible limit, in about 56% schools, the estimated concentration was in zone II (10-100 ppb), in about 32%, the estimated value was zone III (100.1-300 ppb) and in about 6% in zone IV (more than 300 ppb) with highest concentration was estimated as more than 1000 ppb in Sonarpur and more than 950 ppb in Baruipur. In case of kriging estimation in deep tubewell, it has been observed that in about 54% of schools the estimation was within permissible limit, in about 45% it was in zone II (10-100 ppb) and in about 1%, it was in zone III (100.1-300 ppb) with around 150 ppb arsenic concentration in Bhangar I and Jaynagar I. Exposure risk and health risk was assessed among the child and adult population as the population was affected by arsenic concentration. The school students from the 1000 schools were considered as the child (6-10 years) population and the adult (35 years) residing nearby to the schools were considered as the adult population. The ingestion rate of water for child and adult population was taken as 6 and 10 L/day considering only direct and indirect consumption of water. If a child consume 6 litre of water with 100 ppb arsenic concentration, the daily intake will be 1.5 fold more than the provisional daily intake value (2.1 μg/kg body weight). The value will be 4 fold more for the adult population when the consumption rate was 10 L/day. Hazard Quotient (HQ) more than 1 was found in 99% primary schools indicating that there is a risk to develop adverse non carcinogenic effects among the child population.The HQ was found 10 for child and 28 for adult population when they consume 100 ppb arsenic contaminated water. There is a chance to develop skin cancer in 125 adults among 10000 populations and 138 children among 10000 population if they consume 100 ppb arsenic contaminated water daily for 70 years. Early exposure to arsenic can reduce the Intelligence Quotient (IQ), cognitive development and neurobehavioral function over the life time of a child. Thus, IQ decreases with the increase of arsenic concentration in groundwater. In shallow aquifer when the range of arsenic concentration was 1 to 900 ppb, around 60% of school students were found to be present in average (90-109 IQ score), 23% in low average (80-89 IQ score), 10% in borderline (70-79 IQ score) and 7% in extremely low (≤69 IQ score) scale. In deep tubewell, 98% of school students were found to be present in 90-109 IQ score and 2% in 80-89 IQ score when the range of arsenic concentration was 1 to 150 ppb. The risk matrix was generated to develop the mitigative solutions against arsenic in primary schools. From the mitigative measure, it was observed that the distribution of student population would be based on the arsenic concentration in the schools, the students from higher arsenic contaminated schools could be transfered to low risk zone. Installation of arsenic removal plants was found mandatory for the schools where student population was found higher in elevated arsenic contaminated zone.

Electrochemical Arsenic Remediation (ECAR) which is one of the most effective Arsenic removal technologies used in this study for arsenic remediation. Social cost was determined from economic loss due to arsenic concentration in shallow tubewell, cost benefit due to the installation of ECAR in shallow tubewell, installation cost of deep tubewell, economic loss due to arsenic concentration in deep tubewell and cost benefit due to the installation of ECAR in deep tubewell. Per capita annual economic loss due to arsenic exposure as estimated as on 2022 considering daily consumption of water as 10 lpcd for adult and 6 lpcd for child were found as INR 387.28 in zone II (10-100 ppb), INR 947.07 in zone III (100-300 ppb) and INR 1746.94 in zone IV (more than 300 ppb). Different ECAR operation cost was observed for different arsenic contaminated regions (zone II, III and IV). As the water requirement is different among adult and child population, the annual arsenic treatment cost was also different. On an average the arsenic treatment cost for zone II, III and IV are INR 0.07/L, INR 0.075/L and INR 0.08 respectively. The estimated cost related to arsenic concentration was found as follows- total economic loss due to arsenic concentration in shallow tubewell was around 1300 million INR, operational cost of ECAR installed in shallow tubewell was around 520 million INR, total installation cost for deep tubewell was around 900 million INR when the shallow tubewell was arsenic contaminated. It was found from the study that despite of installation of deep tubewells with such huge expenses, arsenic contamination more than permissible limit was observed in 54% of villages in the focus area in deep depth aquifers. The estimated economic loss due to arsenic concentration in deep tubewell was around 560 million INR. The estimated remediation cost by ECAR in deep tubewell was found around 340 million INR. After the total cost analysis, it was observed that around 60 million INR would be assumed as total benefit from the economic loss due to arsenic concentration in shallow tubewell (1300 million INR), installation cost for deep tubewell (900 million INR) and installation cost for ECAR in deep tubewell (340 million INR). The results are expected to suggest certain regions where the health risk is higher which would help the authorities to develop more effective As remediation technologies.

CHAPTER 1
INTRODUCTION

Water has been considered as an insufficient natural resource, utilized as the fundamental requirement for life, livelihood, food security and sustainable development for ages. World's water has very little potentiality for human use, 97.5% of water in world are found saline and the remaining 2.5% is fresh water. Most of the fresh water lies in deep and frozen part of Antarctica and Greenland region, only 0.26% are found in rivers, lakes, soils and aquifers that are readily usable for man kind (Baker et al. 2016). India has more than 18% of world's total population, but has only 4% of world's water resources (National Water Policy 2012).

The water resources of India can be classified as surface water and groundwater.

Surface water- The average annual surface runoff of India was observed to be generated by rainfall and snowmelt. Among the total 1869 billion cubic meter (BCM) surface run off, only 690 BCM (37%) of surface water resource can be used (Chatterjee 2000).

Groundwater- The approximate amount of renewable groundwater resource in India is ~433 bcm and the annual draft of groundwater is ~245 bcm in 2011 (CGWB 2014b). Among these, ~223 bcm groundwater for irrigation and the remaining 22 bcm has been used for domestic and industrial purposes (Siebert et al. 2010; CGWB 2011). The Indo-Gangetic and Brahmaputra plains have enormous groundwater reserve.

India has been found as the highest groundwater user in the world (The World Bank 2012). Being a safe source in respect to microbial contamination, groundwater dependency increases with time for drinking and irrigation purposes. During the "Green Revolution", installation of tubewells in shallow aquifer throughout the soft alluvium tract (Chatterjee et al. 2017) was developed rapidly to meet the water requirement for irrigation. Groundwater is utilized extensively with a gigantic increase of withdrawal in the last 40 years due to the accessability of latest and low cost drilling and pumping technologies. This extreme change in groundwater utilization has been referred to as "the silent revolution" by the hydrogeologists and it took place in an unplanned and uncontrolled way in many countries (Shaji et al. 2021). The demand for acceptable quality of groundwater has a rise with population growth and other developmental activities across the globe. The population growth triggered the increasing demand of agricultural production almost four fold between 1950-2000 (Mukherjee et al. 2015). The agricultural areas of the region are facing the serious problem of groundwater depletion. Almost 4 m lowering of groundwater with respect to decadal mean has been reported from the various parts of the region. The immeasurable draft of groundwater from the aquifer is thought to be the principal origin of arsenic in ground water (Mukherjee et al. 2015).

The leaching of arsenic from sediments is dependent on microbial activity in anoxic condition, total organic matter, geomorphology of the region and local anthopogenic activity (Neidhardt et al. 2013). Arsenic concentration is high in the shallow aquifer (20-40 m bls) made up of young Holocene sediments whereas Pleistocene sediments are mainly arsenic free.

Arsenic is a colourless, odourless and tasteless mineral. It can be considered as “the only element in the periodic table that has been the centre of controversy for thousands of years” (Bhowmick et al. 2018). Arsenic is a widely distributed metalloid in the natural environment that exists in different oxidation states- the inorganic forms, arsenite (+3) and arsenate (+5) are mainly found in water. Organic forms of arsenic are rarely found in groundwater. Groundwater is usually more vulnerable to arsenic pollution than the surface water because groundwater comes more into contact with aquifer minerals and the chances increased for the generation of physicochemical conditions approving arsenic release in groundwater from aquifers.

In the recent context, arsenic contamination in groundwater has become one of the major concern in view of its human toxicity (Shaji et al. 2021). Arsenic concentration in groundwater has been considered as an environmental disaster and the list of effects on human being was found beyond the Bhopal gas tragedy in India (1984) where the people got exposed to MIC (Methyl Isocyanate) and Chernobyl Disaster at the Chernobyl Nuclear Power plant in Ukraine (1986) (Smith, Lingas and Rahman 2000). The International Agency for Research on Cancer (IARC) categorized arsenic as a “Group I” carcinogen (Rahman et al, 2018). According to The Agency for Toxic Substances and Disease Registry (ATSDR) Substance Priority List, arsenic was graded as first position among 275 substances present in the environment as arsenic causes the most significant potential threat to human beings (ATSDR 2007). High arsenic content in drinking water has been reported to develop adverse health effects on population.

The water from shallow aquifers has been treated as drinking water source for millions of people (Neidhardt et al. 2013). The major route of arsenic toxicity in human body was found by drinking arsenic contaminated water. Arsenic concentration is heterogeneously sparsed in the various regions of Bengal Delta Plain. The spatial distribution does not maintain any general direction with high arsenic patches diversified with low or no arsenic contaminated zone (Chatterjee et al. 2017). The provisional guideline value set by WHO for arsenic in drinking water is 10 µg/L, narrowed from 50 µg/L in 1993. Most of the developed countries settled at 10 µg/L as a guideline value but in the developing countries, the pre-1993 WHO guideline values have been used continuously because of the difficulties of getting alternate sources of drinking water (Smedley 2008). The number of people exposed to arsenic concentration more than 50 µg/L was estimated about 21 million on the basis of population density. The number would be exactly double if WHO’s standard of 10 µg/L were adopted for the study (Smith, Lingas and Rahman 2000)

High level of arsenic concentration in groundwater is widespread across the globe and at least 140 million of inhabitants from almost 50 countries are drinking arsenic contaminated water at levels above the WHO provisional guideline value of 10 µg/L (WHO 2018). Majority of the countries are belonged to South Asian and South American regions. The critically affected countries include Bangladesh, India, China, Nepal, Cambodia, Vietnam, Myanmar, Laos, Indonesia and USA. Argentina, Canada, Chile, Hungary, Pakistan, Mexico and South Africa have been considered as severely affected countries from the world (Shaji et al. 2021).

Chronic arsenic induced diseases developed by consumption of arsenic contaminated groundwater is considered as the major environmental health hazard throughout the world, including India. Pigmentation and Keratosis are the specific type of skin diseases developed from chronic arsenic poisoning. The other systematic manifestations such as chronic lung disease, liver disease, polyneuropathy, peripheral vascular disease, hypertension, weakness and anemia are found due to arsenic toxicity (Mazumder and Dasgupta 2011). Exposure to arsenic during development even at low quantity has been proven very dangerous. In comparison to an adult, the body of a child can absorb 40% to 90% more ingested arsenic. The mechanisms of metabolism and elimination of arsenic are found developing throughout the childhood stage. For example, the metabolism activity of absorbed arsenic in liver does not develop until mid childhood, the un-excreted arsenic then continues to flow and deposits in other organs (Rio et al. 2017).

While the adverse effects of arsenic induced illness on adult health are well documented, a little is known about the consequences of consumption of arsenic contaminated water among children. The children those are growing up in arsenic affected households are likely to be vulnerable to poor health and may have a poor probability to develop cognitive skills. The manifestation of arsenic induced skin diseases, particularly keratoses was found to develop after 10 years from the time of first exposure. (Smith, Lingas and Rahman 2000). Most of the children are exposed to arsenic largely by drinking arsenic contaminated water at home and school. Parents who are aware about the consequences of arsenic contamination, respond by migrating to safer neighbourhood or by accessing arsenic free water from alternative sources for home. When the children go to schools located at arsenic contaminated regions, they use to drink that arsenic contaminated water without knowing the presence of arsenic in it. Children who are exposed to higher level of arsenic concentration in their childhood, are 7-12% more likely to die from lung cancer or other lung related diseases in young childhood (Asadullah and Chaudhury 2011). The outcome of continuous exposure to arsenic may develop “a silent pandemic in the modern society”, resulting a subclinical and permanent decrease in IQ, eventually increasing the rate of school failure, lowered the productive capacity and increased risk of criminal and antisocial behaviour. So, this global nature of the pandemic can make a large impact on public heatlh. The elevated level of arsenic concentration leads to health impacts on malnourished children, cognitive skills and both inter and intra generation were affected, it lead to rise in sick days and wage loss.

Spatial variability of arsenic concentration in groundwater is exceedingly high in India. The study on spatial distribution pattern of groundwater arsenic and prediction at unsampled locations are found inadequately. Arsenic concentrations in the shallow aquifers (depth in less than 25 m below ground level) fluctuate considerably within a small separation distance even at close depths. The observed spatial variability of arsenic is very high within the nearly located wells, especially at local scale of 10-100 m below ground level. The spatial dependency of arsenic distribution is mainly observed consistent with geologic-geomorphic settings of the location. Prediction of arsenic concentration at unsampled locations are observed as one of the most challenging part as the concentration in the closely located tubewells bear very little similarities even if the wells are located within the same aquifer (Shamsudduha 2007). A complex pattern of spatial variability of arsenic concentration in groundwater was observed with significant differences between neighbouring wells, trends at the regional scale and depth of the well.

The complications regarding arsenic contamination in groundwater were appeared because of the combination of two important features: a) source of arsenic exists in the aquifer sediments (e.g. sorbed onto Fe oxides/hydroxides) and b) source of organic matter to drive Fe-reduction. Distribution of arsenic in groundwater is mainly dependent on the occurence of aqueous arsenic and the geology, geomorphology and hydrogeology of the region. In current years, naturally occurring arsenic in groundwater has been observed in the Indo-Gangetic Plain, West Bengal and the occurence is patchy in nature. Natural release of arsenic is mainly controlled by complex sets of conditions and biogeochemical processes. So, the arsenic release mechanism differs from location to location depending on the hydrogeological settings. The correlation of arsenic with several species like Fe, HCO_3, NO_3, SO_4, PO_4, dissolved O_2 were observed for assessing the likely mechanism of arsenic mobilization (Kar et al. 2010)

The efforts for measuring spatial distribution of arsenic in groundwater is very costly and time consuming. The prediction method is an alternative practice for very expensive and manual monitoring systems. A Geostatistical method based on kriging with variogram analysis is utilized for the spatial distribution of arsenic in groundwater. Kriging method was found satisfactory to evaluate the spatial distribution of arsenic. Thus, to find out the most potential arsenic affected area, Kriging, a geostatistical method would be the best option as it gives a linear unbiased prediction for the unsampled area. The use of GIS was extensive to appreciate the distribution of arsenic in groundwater

CHAPTER 2
REVIEW OF LITERATURE

This chapter contains a review of scientific information and available literature, which will be helpful to understand and analyse the experimental results in the coming chapters. The structure of the review work has been discussed in fig 2.1.

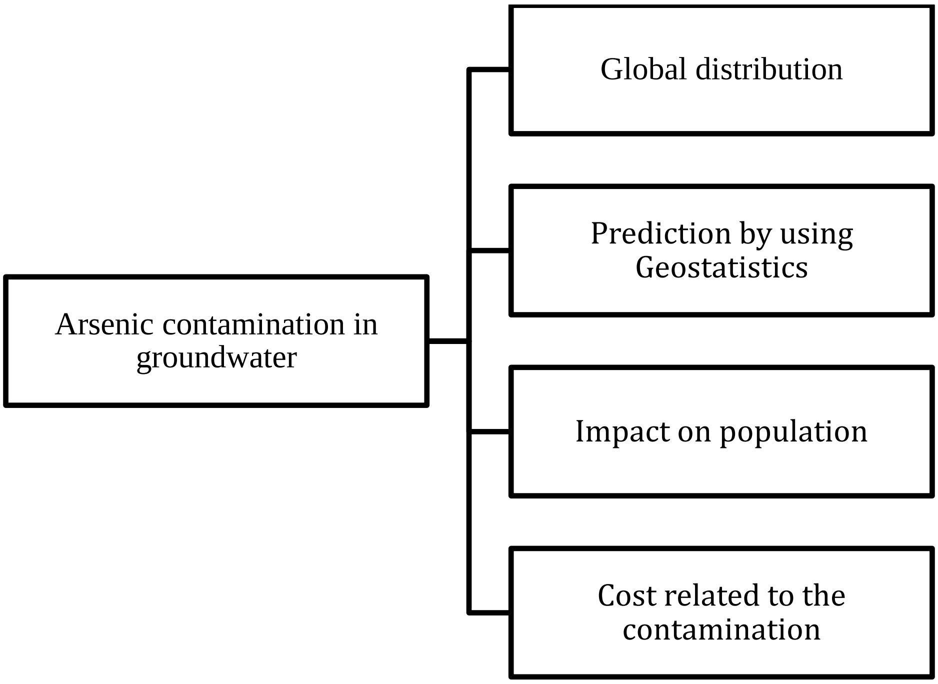


Fig: 2.1. Structure of the review work

Consumption of arsenic over a long period of time can develop arsenic induced illnesses and the effects can take many years to develop on the basis of arsenic concentration, level of exposure etc. People are manifested to higher concentration of arsenic through the consumption of groundwater, preparation of food with the help of the water and food crops those were irrigated by higher arsenic contaminated water. Spatial variability of arsenic in groundwater is exceedingly high. Human beings cannot identify the presence of arsenic in drinking water as the metalloid does not produce any colour, taste or smell after dissolving in water. The detection of arsenic is dependent on water testing through appropriate technology and they are expensive and time taking.

The study was done only with arsenic contamination in drinking water.

2.1. Arsenic (As) contamination in groundwater

2.1.1. Occurence

Mandal and Suzuki (2002) studied that arsenic was found present as "a component of more than 245 minerals" and they mainly found to be occured in ores containing sulfide, along with copper, nickel, lead, cobalt of other metals. As the compounds of arsenic were observed mobile in nature, arsenic sulphides were transformed into arsenic trioxide and got a chance to enter the arsenic cycle as dust or by dissolution in rain, rivers or groundwater. The source of arsenic contamination in groundwater was found natural and anthropological. Natutal distribution of arsenic was found throughout the earth crust, soil, sediments, water, air and living organisms. Arsenic was found to be co-precipitated with iron hydroxides and sulphides in sedimentary rocks. The occurrence of natural arsenic was found in over 200 different mineral forms, 60% of arsenates, 20% of sulfides and sulfosalts and the remaining 20% was arsenides, arsenites, oxides, silicates and elemental arsenic. Arsenopyrite was observed as the most common arsenic mineral. The average content of arsenic was reported varying among geographic regions- the lowest concentration was found in sandy soils and soil derived from granites, in alluvial and organic soils maximum arsenic concentration was found. The occurrence of arsenic was found deposited in soil by using arsenic containing pesticides, fertilizers, burning of fossil fuels, disposal of industrial and animal wastes through man made activities.

Smedley and Kinniburgh (2002) found that arsenic is the 20th most abundant element on earth crust and is "a ubiquitous element found in the atmosphere, soils and rocks, natural water and living organisms". The mobilization of arsenic is considered as a blend of natural procedures like weathering of the rocks, biological actions and volcanic eruptions as well as anthropgenic activities. The man made activities include mining, burning of fossil fuels, use of pesticide and herbicide that contain arsenic, crop desiccants and livestock feed for poultry**.** Arsenic contamination in groundwater is considered as the greatest threat to human health. Arsenic is a shiny metalloid that readily dissolves in water. Arsenic is considered as an oxyanion forming metalloid in its reactivity to mobilization at the pH values generally observed in groundwater (pH 6-9) and under both oxidising and reducing conditions. Arsenic can present in the nature in different oxidation states (-3, 0, +3 and +5), but in natural water the inorganic form as oxyanions of trivalent arsenite (As(III)) or pentavalent arsenate (As(V)) are found. Organic arsenic may be found after produced by biological activity in surface water, but are rarely quantitatively important .

Kim, Nriagu and Haack (2002) studied that arsenic is globally distributed in more than 320 minerals and arsenopyrite (FeAsS), orpiment (As_2S_3), realgar (As_2S_2) and solid solution in pyrite (FeS_2) were found as the most common forms. Arsenic was also observed in sedimentary setting of the environment adsorped by Fe(III) and Mn (IV) after weathering of sulfide minerals. Different processes have been identified as the reason for elevated levels of arsenic concentration in water. The processes are: reductive dissolution of arsenic rich iron hydroxides and oxidative dissolution of arsenopyrite, weathering of rocks containing other arsenic bearing minerals with water.

Singh (2006) observed that the mean arsenic concentration in the continental crust was 1-2 mg/kg. Inorganic arsenic was found to be present as arsenate (As^{5+}) and arsenite (As^{3+}). The transformation of As^{5+} and As^{3+} was come to occur by oxidation of As^{3+} and As^{5+} and reduction to As^{5+} to As^{3+}. The mobilization of arsenic in groundwater mainly depends on natural and anthropogenic sources. The sedimentary aquifer was identified by elevated concentration of Fe due to the reductive dissolution of Fe oxyhydroxides that mobilize the sorbed arsenic. Other than the natural occurrence, coal combustion, the emission from metallurgical plants, cement factories, incinenartion and chemical industries, leaching of arsenic from landfill sites and hazardous waste piles have been considered as the major sources of anthropogenic arsenic pollution in India. The natural and partly anthropogenic activities like over exploitation of groundwater, application of fertizars are recorded.

Nriagu et al. (2007) documented that the principle arsenic containing minerals were arsenopyrite (FeAsS), realgar (As_4S_4) and orpiment (As_2S_3). Other natural arsenic bearing minerals include loelligite ($FeAs_2$), safforlite (CoAsS), niccolite (NiAs), cobalite (CoAsS), enargite (Cu_3AsS_4), gerdsorfite (NiAsS) and elemental As. The mobilization of inorganic arsenic into soil was found dependent on parent rocks, man made activities, climate, different forms of arsenic and redox condition of the soil.

Brammer and Ravenscroft (2009) reported that reductive dissolution was the most important way of arsenic transportation in groundwater in south and south east Asia. It was found in the regions where arsenic adsorbed to iron oxyhydroxides in sediments was observed to be released into groundwater when the degradation of organic matter done by microorganisms reduced to ferric iron to the soluble ferrous form. High spatial variability of arsenic concentration in Bangladesh was appeared to be associated with the regional and local variations in the amount of organic matter in aquifer sediments, both laterally and vertically.

Aftabtalab et al. (2022) studied that arsenate was found predominating in aerated soils associated with iron oxyhydroxides. Arsenic was reported mostly in the form of inorganic arsenite in aquifer sediments. The mobility and toxicity of arsenite was found higher than arsenate. Microorganisms were found to reduce arsenate to arsenite during respiration under reducing conditions or methylation of organic arsenic compounds under oxidizing conditions. The most common methylated organic arsenic compounds were monomethylarsonic acid (MMA), dimethylarsinic acid (DMA), trimethylarsinic acid (TMA) and trimethylarsine oxide (TMAO). The methylated arsenic species was found less toxic than their inorganic counterparts.

2.1.1.1. Standard for arsenic concentration in drinking water

The collection of drinking water depends on the accessibility of the water. The main drinking water sources can be classified as surface water, groundwater and rainwater. Elevated level of arsenic concentration is mainly found in groundwater.

WHO (1999) recommended 10 ppb arsenic concentration as a guideline value **,** the value was elected as provisional because arsenic removal from groundwater was considered as a difficult issue. **EPA (2001)** also suggested that 10 ppb should be the permissible limit for arsenic concentration in groundwater.

According to **BIS (2012)**, the permissible limit was 10 ppb for As, but 50 ppb was legally enforced standard where no other alternatives were available. Then **BIS (2015)** has reduced the guideline value of arsenic in drinking water from 50 ppb to 10 ppb through an ammendment issued in 2015**.**

Chakraborti et al. (2016) observed that the guideline value of As in drinking water was set 200 ppb in 1958, it was reduced to 50 ppb and in 1993 the reduction occurred again to 10 ppb. It was found from the study that WHO set the guideline value for arsenic in drinking water was 10 µg/L on the basis of 2L of water consumed by a person daily.

Hassan (2018) studied that the guideline value of arsenic was lowered down to 10 µg/L in 1993. This provisional guideline value of 10 µg/L has been adopted as the national standard for drinking water by a number of countries. Many developing countries have retained the previous WHO guideline value of 50 µg/L as their national standard. In Bangladesh, Bolivia, China, Egypt, Indonesia, Nepal, Sri Lanka and Viet Nam, the arsenic standard was found 50 µg/L. In Australia, the standard was observed minimum, 7 µg/L.

Natasha et al. (2021) documented that the US EPA (New Jersey) suggested arsenic concentration 5 ppb as the guideline value in drinking water to protect public health in 2000.

2.1.2. Distribution

2.1.2.1. Distribution of arsenic in groundwater

Groundwater arsenic concentration depends on the source of arsenic, amount of arsenic and the regional geochemical settings. The highest range and the maximum concentration of arsenic in groundwater was generated as a consequences of strong impact of rock-water interaction and higher tendency in aquifers for the physical and geochemical conditions to be favourable for arsenic mobilization and accumulation.

A. Global Distribution

Smedley and Kinniburgh (2002) studied that natural arsenic contamination in groundwater was observed throughout the world and the most of those countries belongs to South Asian and South Ameriacan Regions. The presence of a big number of aquifers with arsenic concentration more than 50 ppb was recorded from different parts of the world. The occurences of arsenic are found in parts of Argentina, Bangladesh, Chile, northern part of China, Hungary, India (West Bengal), Mexico, Romania, Taiwan and south west part of the USA. The most arsenic contaminated region around the world was the South and Southeast Asian Belt including India, Bangladesh, Nepal, Vietnam and China. The aquifers of the developed countries like USA and Canada were also found contaminated with eleveted levels of arsenic concentration, but the extent of tthe concentrations were found characteristically lower than the Asian countries. Localised groundwater arsenic contamination have been found from an increasing number of countries and many new incidences are coming out into light. Arsenic was not included on the list of the elements those were routinely monitored in water testing laboratories and many arsenic rich aquifers are yet to be identified. So, there is a need to reassess the intended revision of the drinking water standard for arsenic in a number of countries.

Mukherjee et al. (2006) found that the picture of groundwater arsenic pollution around the globe, mainly in Asian countries has been changed after the discovery of newer sites. The major incidence of arsenic poisoning was recorded in Bangladesh, West Bengal, India and China before 2000. After 2000, the distribution of arsenic in groundwater was documented from other Asian countries including new sites of China, Mongolia, Nepal, Cambodia, Myanmar, Afghanistan, Korea and Pakistan. Elevated level of arsenic was also reported in Western Iran and Vietnam.

Halem et al. (2009) recorded the worldwide distribution of arsenic in groundwater. In Europe- Serbia, Hungary and Italy were recorded as the most arsenic contaminated countries. Other than those countries, most of the European countries contain arsenic less than the permissible limit.

Chakraborti et al. (2015) recorded the distribution of arsenic in groundwater in four geomorphological regions present in Bangladesh and the possible area for arsenic safe zone was identified. After a 9 to 18 years long study, the derived conclusions were as follows- a) the population was found more aware about the consequences of drinking arsenic contaminated water and the alternative arsenic free water sources were used more than before, b) there are a number of villagers from the affected villages were reported to be died of cancer c) the risk for development of future danger by using arsenic contaminated water for agricultural irrigation and arsenic exposure from food chain.

In fig 2.2, the distribution of arsenic throughout the globe has been mentioned.

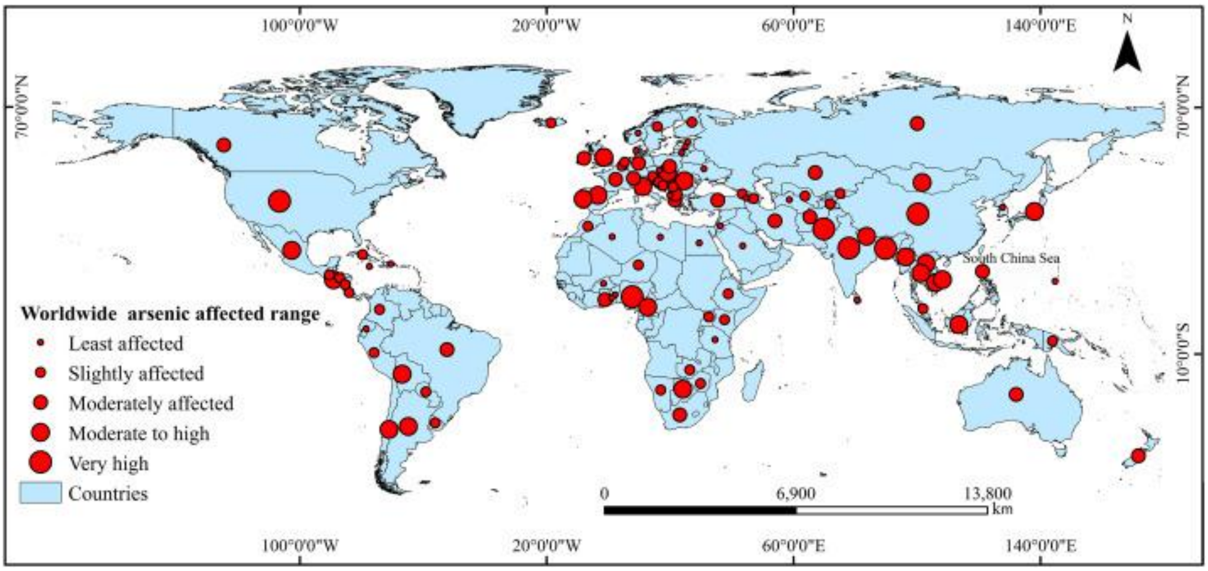


Fig: 2.2. Arsenic affected countries of the world with intensity shown by the size of the plots (Shaji et al. 2021)

Shaji et al. (2021) documented the natural contamination of arsenic in groundwater throughout the world and the most of the countries were found belonged to South Asian and South American regions. The severely affected countries were India, Bangladesh, China, Nepal, Cambodia, Vietnam, Myanmar, Laos, Indonesia, the USA. In addition, Argentina, Chile, Hungary, Canada, Pakistan, Mexico and South Africa were also found affected.

Sarkar, Paul and Darbha (2022) studied that the aquifers of Ganga-Brahmaputra-Meghna river basin of the Indian subcontinent was severely arsenic contaminated. Parts of Indian states i.e. West Bengal, Assam, Tripura and almost the entire nation Bangladesh within the Bengal Basin were reported to contain elevated level of arsenic in groundwater.

B. Distribution in India

Ahamed et al. (2006) observed that in Uttar Pradesh, the maximum arsenic concentration was found 3192 ppb. Arsenic concentration in 46.5% tubewells was found exceeded 10 ppb, in 26.7% tubewells exceeded 50 ppb and in 10% tubewells it was 300 ppb limits. The age of the tubewells were found ranged from less than a year to 32 years (average 6.5 years) and the depth of the tubewells were found varying from 6 to 60.5 m with a mean of 25.75 m. 19.8% adult and 5.7% child population was found to have typical arsenical skin lesions.

Sengupta et al. (2009) studied groundwater Arsenic contamination in different countries and states of GMB Plain. In West Bengal, Bihar, UP and Jharkhand, 48.1%, 33%, 46.02% and 30% tubewells respectively were found As conatminated with more than 10 μg/L As concentration.

Chakraborti et al. (2013) reported the consequences of arsenic contamination among a local community residing near gold mining activities in Karnataka. Arsenical skin lesions were reported among 58.6% individuals (n=181). The primary route of arsenic exposure was found via groundwater and high arsenic content in residential soil was supposed to be a significant source of arsenic exposure via ingestion.

Rahman et al. (2014) discussed about the distribution of As concentration in India. The most arsenic contaminated regions are mostly found to be confined into Ganga- Brahmaputra (GB) plain in India (Uttar Pradesh, Bihar, Jharkhand, West Bengal and Assam) and Padma- Meghna- Brahmaputra (PMB) plain of Bangladesh. The two of them formed Ganga- Meghna- Brahmaputra (GMB) plain and it comprises of 569,749 km^2 area with more than 500 million population.

Mukherjee et al. (2021) recorded the presence of arsenic contamination in the aquifers of West Bengal, Bihar, Assam, Uttar Pradesh, Jharkhand, Punjab and Haryana. Among those, the groundwater concentration in West Bengal and adjoining parts of Bangladesh, have been attributed to be the "largest mass poisoning in human history". The elevated level of arsenic concentration in groundwater were mostly found in the alluvial sedimentary deposits of major Himalayan river basins formed by the Indus and Ganga Brahmaputra river basins including the Bengal basin.

Goswami et al. (2022) studied about the factors related to the acceleration of arsenic leaching process into groundwater and the consequencing health risk in upper Brahmaputra floodplain. In monsoon season the minimum average arsenic concentration was found 4.7 ppb and in the post monsoon season, the maximum concentration was 18.5 ppb with 50% of the samples exceeding permissible limits. The local geological settings and groundwater flow was found as the most important factors to determinr the spatial variation of arsenic concentration. From the hazard index, it was observed that the child population had higher carcinogenic risk compared to adult population.

Kesari et al. (2022) collected sediments from "a 150 m deep litho-section of a coastal region and encompassing Quarternary, Tertiary and Cretaceous sedimentary formations" in a coastal region of Pondichery and observed that arsenic concentration was varying from <0.5 to 30 mg/kg . The maximum arsenic concentration was reported at a depth of 129-131 m bgl in Cretaceous formation. Positive correlation between As-Fe and S signified the presence of As sorbed to FeS mineral. The correlation between organic matter and As was found to suggest microbial mediated reduction process to prove future risk to water quality of the coastal fresh water aquifer system.

C. Distribution in West Bengal

Chakraborti et al. (2002) observed that more than 6 million people from nine arsenic contaminated districts of West Bengal were found to consume arsenic contaminated water (arsenic concentration more than 50 ppb) and around 300000 people might have developed different detectable arsenic induced skin lesions. The arsenic content in the physiological samples was found was found to be indicated that many more population might be sub-clinically affected. The children from the arsenic contaminated villages was found to be more affected. Many of the people who were consuming arsenic contaminated water was found unaware of the arsenic related facts and its consequences.

Samanta et al. (2004) observed that in West Bengal around 51% and 34% of the tubewells contain arsenic concentration above 0.01 mg/L and 0.05 mg/L respectively (n=105000). Approximately 63% of the total population of West Bengal were found to live in those arsenic contaminated regions. The people who were not drinking arsenic contaminated water also found affected by arsenic through food composites.

Rahman et al. (2005) studied the extent of arsenic concentration in groundwater and the consequences on human health in Murshidabad district. About 31% of the total hand tubewells, 77.8% were reported to contain arsenic above 10 ppb and 51% had arsenic above 50 ppb and 17% had arsenic at above 300 ppb. 20% of screened people (n= 7221) were found exhibiting definite arsenical skin lesions. 88% of biological samples (n= 1600) were reported containing arsenic concentration above the permissible limit.

Chakraborti et al. (2009) divided West Bangal into three zones on the basis of the intensity of arsenic concentration in groundwater. The zones were- highly affected (As concentration more than 300 ppb) and the districts were Maldah, Murshidabad, Nadia, North 24 Parganas, South 24 Parganas, Bardhaman, Haora, Hugli and Kolkata; mildly affected (As concentration mostly below 50, only a few above 50 ppb, but none above 100 ppb) and the districts are Koch Bihar, Jalpaiguri, Darjiling, Dinajpur- North and Dinajpur-South and unaffected (As concentration less than 3 ppb) and the districts are Bankura, Birbhum, Purulia, Medinipur East and Medinipur West. Most of the highly arsenic affected districts of West Bengal are present on the eastern side of Bhagirathi Hooghly River, only three districts (Haora, Hugly and Bardhaman) are located on the western side of the river.

Rahman et al. (2014) determined the gravity of groundwater arsenic pollution and the health hazards (mainly dermatological effects and neurological complications) from the population in Nadia district. All the 17 blocks from the district were arsenic affected more than 50 ppb and the maximum observed arsenic concentration was 3200 ppb. 51.4% and 17.3% of the tubewells were found arsenic affected with 10 and 50 ppb respectively. 0.048 million population was estimated to be at risk of drinking arsenic contaminated water above 300 ppb.

Chakraborti et al. (2017) reported the status on groundwater arsenic contamination in the Kolkata Municipal Corporation (KMC) and it was documented that in all 141 wards, 14.2% and 52% of water samples were found to contain arsenic >10 ppb and >50 ppb respectively in 77 and 37 wards. The daily consumption of arsenic from drinking water was found 0.95 µg/ kg bw and the estimated cancer risk was $1425/10^6$. The elevated level of arsenic concentration in hair, nail and urine samples indicated "the presence of subclinical arsenic poisoning predicting an enhanced lifetime cancer risk for the population" residing in the southern part of the KMC. The groundwater was found to contain higher level of iron, hardness and total dissolved solids.

De et al. (2022) studied the distribution pattern of fluoride and arsenic concentration in groundwater from Rajpur-Sonarpur Municipality. The range of fluoride and arsenic observed concentration was 0.01-2.9 mg/L and <3 to 213 µg/L respectively in groundwater samples. 13% and 16% of the collected samples were observed to have fluoride and arsenic concentration respectively more than the permissible limit. A moderate positive correlation was found between the distribution of both fluoride and arsenic concentration amd the relationship was observed dependent on the interrelationship between Ca and Fe. The highest concentration of arsenic and fluoride was observed in the depth range of 24-30 m.

2.1.3. Use of groundwater in India

The demand for water was found to increase both in urban and rural areas as a consequences of development and this might cause stress and dispute over sharing of water resources in India. The determination of water use on a household level was found important for water demand management.

Singh and Tukriya (2013) surveyed the pattern of domestic water expenditure in semi arid Dhani Mohabbatpur village of Hisar district, Haryana. The daily average water utilization was found 117 lpcd. It was observed that washing of clothes consumed the maximum amount of water, whereas 85% of the households were observed using governmental water supplies with safe water quality.

Patra et al. (2018) recognized urbanization as "one of the most significant anthropogenic alterations of the environmental framework". In recent times, the groundwater was found to go through the considerable changes, particularly with increasing demand due to population growth, expansion of irrigated area and economic development. The authors estimated the spatiotemporal characteristics of urban growth and its inference for the hydro meteorological parameters in the Howrah Municipal Corporation (HMC), West Bengal, India. It was observed that most of the urban built up area was increased during the last two decades with fluctuations in depth to groundwater level in northern, north westernand south western side of the city.

Rumbach and Follingstad (2019) studied the development of environmental risk due to urbanization in five fast growing towns and villages in the Darjeeling District, West Bengal. Though the attention was given on the India's large cities, urbanization was found to transform its villages and towns. It was reported that urbanizing towns and villages were classified by fast spatial growth, dynamic and challenging hazard contexts and limitations in governance capacity or resources to document, govern or adapt to emerging environmental threats. The risk was found accumulating in the built environment and economy might only be revealed after a major disaster. The characteristics and trends were found common in other small urbanizing places and might be managed to achieve national and international goals for sustainable and resilient development.

Roy et al. (2022) reported that groundwater has been used for domestic (50-80%) and irrigation (45-50%) purposes in India. The area under irrigation was found tripled between 1970 and 1999 in India. The population growth was found increasing more than 8 times since the turn of the century. The growth rate of urban population was found significantly higher than the national growth rate of India. Rural urban migration for better livelihood was supposed to be the main reason for the increase of urban population. As a result, the decling trend in groundwater depth was observed.

2.1.4. Hydrochemistry and arsenic mobilization in groundwater

Occurrence of arsenic in groundwater has been influenced by the local geological settings, hydrological and geochemical characters of the aquifer materials. The organic matter present in sediments and land use pattern are also considered as the important parameter that direct the mobilization of arsenic in alluvial aquifers.

Paul (2004) and **Ravenscroft et al. (2005)** explained two hypotheses for geological arsenic mobilization-

- 'Pyrite oxidation over-abstraction' contemplated the oxidation of arsenic rich pyrite and arsenopyrites in the floodplain sediment due to the lowering of water table caused by extensive pumping of groundwater.

- 'Oxyhydroxide reduction' considered the release of adsorbed arsenic by reductive dissolution of iron oxyhydroxides because of the floodplain sediments were buried and reducing conditions generated.

The hypothesis was carried out by the confirmation that

- Arsenic rich groundwater is reducing in nature and they contain high iron and bicarbonate concentration, but the sulphate or nitrate concentration was low.
- The spatial distribution of arsenic is not dependent either on the water table depth or the severity of groundwater irrigation, it is coupled mainly with the geological settings (Holocene floodplains and finer grained sediments).
- Maximum arsenic concentration were noticed 'within tens of metres below the depth of the deepest water table fluctuation even in the areas of little pumping'.
- A strong correlation happened between arsenic and iron content of Holocene aquifer.
- The Holocene sediments contained sand grains and they have ferruginous coatings with significant arsenic content.

The hypotheses by **Charlet and Polya (2006)** regarding the arsenic release mechanism are-

- the oxidation of Arsenic rich pyrite due to oxygen intrusion followed by groundwater table drawdown. The drawdown is mainly restricted within 3 to 5 m below ground level, whereas the higher Arsenic concentration are observed mostly at a depth of 20-30 m.
- mobilization of phosphate from irrigated paddy field and its competitive adsorption mechanism has been assumed to have led to the desorption of arsenic. But the presence of mass of sorbent material between the paddy field and the productive aquifer weaken the hypothesis.
- 'microbiologically mediated reductive dissolution of Arsenic rich hydrous iron oxides with production of bicarbonate' which aggravate the mechanism of Arsenic release. Direct DNA-based confirmation for this mechanism was reported for the sediments from Bengal Delta and Cambodia. A decoupling of iron mineral dissolution and arsenic mobilization has been noted in the sediments from Bengal Delta. The decoupling may be associated with inorganic sorption processes, which 'in turn may be directed by step decreases in redox potential or changes in the nature and specific surface area of secondary reduced iron phases or both'.

A source of degradable organic carbon is always required for the microbial reduction of hydrous iron oxides. The massive groundwater irrigation was reported to bring down the surface derived organic carbon into the aquifer system resulting in the acceleration of the process of arsenic release.

2.1.5. Spatial distribution of arsenic in groundwater in BDP

Mukherjee, Fryar and Howell (2007) developed the regional groundwater flow models on the basis of topography, seasonal conditions and inferred hydrostratigraphy in arsenic affected districts of West Bengal (Murshidabad, Nadia, North and South 24 Parganas and Kolkata). It was found from the result that the seasonally variable, regional, north-south flow across the basin was found dependent on the extensive pumping in the 1970s. The groundwater flow pattern was severely distrorted by uncontrolled pumping resulting high verical hydraulic gradients across wide cones of depression. The impact of pumping was also observed in irrigational return flow, inflow from rivers and sea water intrusion. As a consequence, downward flow of arsenic contaminated water intrudes into previously safe aquifers by a combination of mechanical mixing and changes in chemical equillibrium

Nath et al. (2008) illustrated the significance of hydrogeochemical features (groundwater flow and recharge) of an aquifer in the mobilization of arsenic in groundwater in Chakdaha block, Nadia, West Bengal where the variability of arsenic concentration was observed. The spatial distribution pattern of arsenic was found patchy with regions holding high arsenic contaminated groundwater (>200 μg/L) with close vicinity (within 100 m) to low arsenic contaminated groundwater (<50 μg/L). arsenic concentration in groundwater was observed to decrease with depth.

Kar et al. (2010) studied the analysis of ground water samples from shallow tubewells (depth 24.3-48.5 m) to understand the sources and mobilization of arsenic from sediments in Barasat, located in Gangetic Plain. High As and Fe concentration and low Mn concentration was evidenced in core sediments. The presence of NO_3^{-1}, SO_4^{-2} and NO_2^{-1} in lower concentrations along with elevated concentrations of DOC and HCO_3^{-1} indicated " the reducing nature of aquifer with organic matter that can promote the release of As from sediments into groundwater".

Nath et al. (2011) performed a comparison of geochemical characteristics of aquifers in groundwater samples collected from Chakdaha, West Bengal and Manikgonj, Bangladesh and Chianan Plains (CNP) (SW Taiwan). Large variations were observed between measured arsenic concentration in BDP and CNP. Average As concentrations in groundwater of Chakdaha, Manikgonj and CNP were 221 μg/L, 60 μg/L and 208 μg/L respectively. In Chakdaha, Fe-reduction mechanism was observed to be the major geochemical process to release arsenic from groundwater aquifer while Mn-reduction was dominant in Manikgonj. In CNP, a combination of geochemical processes (i.e. bacterial Fe-reduction, mineral precipitation and dissolution reactions) were observed that controls the releasing mechanism of arsenic in groundwater.

Hamidian et al. (2019) observed the elevated level of arsenic concentration in various parts of Iran. Arsenic concentration in some of the tubewells and springs were reported six times higher than the standards with an average of 290 ppb in north west part of Iran. The origin of this arsenic was found mostly geogenic due to the dissolution of arsenic containing compounds present in earth's crust, but mining has been considered as one of the important source of arsenic in the region.

Das, Banerjee and Roy (2021) studied the mobilization of arsenic and different arsenic contamination level in shallow groundwater in Nadia, located in the deltaic environment of West Bengal. Groundwater was Ca-Na(K)-Cl-HCO_3 type with highly reducing in nature. Lower level of correlation between arsenic, iron, manganese and higher associations between arsenic and organic matter were found as an indication of microbial decomposition of organic matter enhancing the weathering of shallow aquifer materials. Lower concentration of iron, manganese and sulphate indicated that the mobilization of arsenic was very complex in that region.

2.1.6. Presence of arsenic in shallow tubewell

Ravenscroft et al. (2005) observed that during the last three decades almost 3-4 million tube wells were installed at a depth range of 20-70 m. The naturally occurring water contaminants present beneath the Holocene flood plains are iron, salinity (near coastal area), arsenic, manganese and boron. A strong correlation was observed between occurrence of arsenic and depth of tube wells, though the distribution was different among regions. The arsenic concentration was found insignificant when the depth of the well is more than 200 m. The variation of arsenic concentration was observed highest in shallow groundwater.

Kar et al. (2010) studied that the arsenic contaminated regions were found to be confined the shallow aquifer (<150 m below ground level) in the eastern bank of Hooghly river. The arsenic concentration was observed in the range from <10-538 µg/L, elevated concentrations was found in the shallow to medium depth (30-50m) of the aquifer along with higher Fe (0.07-9.8 mg/L) and relatively low Mn (0.15-3.38 mg/L) as also detected in core sediments.

Roychowdhury (2010) observed the depth range of the tubewells installed in the range of 15.4-30.3 m and the As concentration was found high in that depth, even the shallow groundwater depth (7.87-15.1 m) was also arsenic contaminated. The concentration of arsenic and iron were reported to increase moderately from lower to higher depth upto 39.4 m and then the concentration decreased with depth increase. In some regions, the deeper aquifer were observed to have arsenic concentration, approximately 58% of the deep tubewell water samples (depth range 122-182m) showed arsenic concentartion more than 0.05 mg/L. About 72% of the arsenic contaminated tubewells were reported safe at first survey, but they were observed to become contaminated after a short span of 2-5 years at second survey.

Donselaar, Bhat and Ghosh (2017) observed that naturally occuring geogenic arsenic was found concentrated in the shallow aquifer of the sedimentary basin and distributed in Holocene fluvial and deltaic flood basin. The arsenic concentration in the aquifers were identified by large lateral variability over distances of 100s meters and a strong vertical decrease was observed when the wells penetrated the deeper Pleistocene strata.

Sarkar et al. (2022) studied that the presence of arsenic concentration in Bengal basin has been considered as a mass poisoning agent. Higher level of arsenic concentration was found in shallow tubewell water. The shallow aquifers were made up of Holocene reduces grey sands, having a lesser capacity to hold the arsenic brought from the Himalayas by the Ganga-Bramhaputra-Meghna river system. The deep aquifers below the late Pleistocene aquifers and the Paleo-interfluvial aquifers capped by the last glacial maximum Paleaosole generally contain arsenic free or low arsenic free water.

2.1.7. Correlation study of arsenic with other parameters in groundwater

Nag et al. (1996) observed a correlation study to find the correlation between arsenic and pH, iron, antimony, the pH value was found neutral, the concentration of iron and antimony was found as 0.3 to 10.7 mg/L and 0.03 to 0.9 µg/L.

Hossain et al. (2008) determined the spatial distribution of arsenic in irrigated water, soil and rice in a shallow depth tubewell area and the correlation between Fe, Mn and P were analyzed in Faridpur, Bangladesh. Arsenic present in the irrigation channel was found decreased with the distance from the tubewell point and the concentration was recorded 68-136 µg/L. For Fe and P concentration, the decreasing tendency was observed, but for Mn. Arsenic in soil was documented as significantly and positively correlated with arsenic present in rice grain (0.296±0.063 µg/g, n=56). The result showed that consumption of rice could be a probable source of arsenic vulnerability to the people residing in the arsenic affected regions, next to arsenic contaminated drinking water sources.

Roychowdhury (2010) studied a linear regression model by showing direct correlation between arsenic and iron concentration in groundwater (r^2= 0.8114, p<0.0001 and n=912)

Sankar et al. (2014) described the extent of occurrence of arsenic and Mn in groundwater from shallow depth (35-40 m) aquifer and the access to safe drinking water in Murshidabad district, West Bengal. High arsenic, total iron and low Mn concentrations were observed in groundwater from Holocene grey sediments aquifer while the opposites were noticed in the Pleistocene reddish brown aquifer. Arsenic was found associated with 'specifically sorbed-phosphate-extractable' phases (10-15%) and with 'amorphous and well crystalline Fe-oxyhydroxide' phases (around 37%) at arsenic contaminated shallow depth, indicating that the principle arsenic mobilization mechanism should be either competitive ion exchange with PO_4^{3-} or the dissolution of Fe oxhydroxides. Mn was predominantly observed in the easily exchangeable fraction in the Pleistocene sediments.

Rahman & Sultana et al. (2016) conducted a comparative study to correlate arsenic (As), Iron (Fe), Copper (Cu), Manganese (Mn), Calcium (Ca^{2+}), Magnesium (Mg^{2+}), Potassium (K^+), Nitrate (NO_3^-), Phosphate (PO_4^{3-}) and Ammonia (NH_3) by estimating their concentration at different depth of the tubewells at Singair, Manikganj Bangladesh. The range of arsenic concentration was found as less than detectable limit to 0.113 mg/L. The positive correlation between arsenic and Fe was mentioned as the indication of possible adsorption/co-precipitation of arsenic and Fe in shallow aquifer. Positive correlation was also found between Cu and arsenic. The relationship between arsenic and Mn, NO_3^- was not significantly found. The relationship between arsenic and PO_4^{3-} was found significant and the PO_4^{3-} was found to come from application of phosphate fertilizer and acted as arsenic contributor in the shallow aquifer. Significant relationship was found between As, Cu, Fe and PO_4^{3-} by PCA biplot. The result indicated that extensive withdrawal of groundwater from the tubewells along with aquifer dynamics and ionic interference was considered as the responsible for 'the mobilization of arsenic' in the study area.

2.2. Geostatistics

Baalousha (2010) studied that properly designed monitoring system was found to allow a characteristics comprehension of the state of the monitored area. The decision taking for the selection of maximum number of monitoring sites that are spatially distributed is considered as a major challenge for the hydrogeologists. Irregular distribution of monitoring sites or inadequate number of sites would not be able to furnish the characteristic view of the condition of the environment. On the other hand, too many information obtained from a region is unnecessary and the monitoring network is considered as expensive and ineffective. A new methodology integrated with vulnerabilty mapping and geostatistics was found to identify the most structured groundwater monitoring network on a regional scale. Vulnerability mapping recognizes the areas with high pollution indices and in turn, prioritizes for monitoring. A Geostatistical approach is used to elucidate the sampled data and to study the spatial distribution of monitored parameters at different sites. The perfection of spatial mapping considers the effectiveness of the distribution the monitoring sites

Zhang (2011) studied the basic difference between classic statistics and Geostatistics . Geostatistics was found to integrate both the statistical distribution of the sample data and spatial correlation among the sample data. On the basis of the problem, many earth scinece problems are productively addressed using Geostatistical methods. Most of the earth science data sets are often skewed and show spatial correlation among themselves. The property values from locations that are in close proximity, have a tendency to be more similar than the values from locations that are further apart. The objective of Geostatistics is to predict the possible spatial distribution of a property. The prediction method has two forms: estimation and simulation. In estimation, a single, statistically "best" estimate map of the spatial occurence is formed. The estimation process is dependent on both the sample data and a model (semivariogram) determined as the most precisely representing the spatial correlation of the sample data. This single estimate or map is generally formed with the help of the Kriging technique. In simulation, images or equal likely maps of the property distribution are formed by using the same model of spatial correlation as requirred for kriging.

2.2.1. Spatial structure

Jimenez-Espinosa and Chica-Olmo (1999) studied that Geostatistical analysis is based on variograms. Experimental and fitted variograms are evaluated by following the main directions of sampling grid. The directional variograms were found to display an important nugget effect showing that more than 40% of the spatial variation is due to small scale random functions. The longest range is displayed at the direction parallel to the main mineralized belt of the area with lower spatial variability.

Hassan and Atkins (2011) observed that variogram provides a means of evaluation of the atributes in which each estimate is a weighted average of the observed values in the neighbourhood. The weights mainly depend on fitting the variogram to the measured points. The variogram assesses the spatial variability of the varibles between two locations. The experimental variogram was found to fit with a theoretical model, γ(h), which may be spherical, exponential or Gaussian, to find the nugget effect (C_0), the sill (C_0+C_1) and the range (*a*). The variogram was calculated in different directions to detect any spatial anisotropy of the spatial variability. A geometric anisotropic study model was adopted which calculates variograms with the same structural shape and variability (sill+nugget) but a direction-dependent range for the spatial correlation. A kriging approach computes the variability of a sample in the form of semivariogram, which demonstrate the relationship between semivariance and the sampling separation distance schematically. The semivariogram, γ(h), is the half of the average squared difference between pairs of data $Z(x_1)$ and $Z(x_1+h)$ at locations x_1 and x_1+h. An estimate of the semivariogram with N(h) the number of sampling pairs separated by a distance of h(lag) is given by the following equation

$$\gamma(h)=\frac{1}{2N(h)}\sum_{i=1}^{N(h)}\{Z(x_1)-Z(x_1+h)\}^2 \quad \text{(Equation 2.1)}$$

Jangle et al. (**2016**) developed a geostatistical model based on the calculated arsenic concentration in the aquifers and hydro geomorphological factors in Bihar. Samples were reported to be collected from hand tubewells and arsenic concentration was measured. Maps was seen to be prepared by using the measured arsenic concentration from groundwater and the high spatial variabilty of the arsenic concentration was found to be based on hydro-geomorphological parameters i.e. close proximity to river, depth of hand tubewells. The model was found to estimate the risk developed by arsenic concentration in entire Bihar state.

McGrory et al. (**2017**) combined the readily accessible datasets from national and sub-national scales on concentration of arsenic in groundwater in the Republic of Ireland. The application of conventional statistical methods was reported to inhibit the generation of meaningful results due to the appearance of arsenic values lower than the analytical detection limit and changes in detection limits over time. Geostatistical methods were observed to detect the principal risk components of higher level of arsenic connected to lithology, aquifer type and groundwater vulnerability. Geographical statistical methods were found to control the geographical limitations made by the Irish Environmental Prorection Agency (EPA) sample database. 'Nearest –neighbour inverse distance weighting (IDW) and local indicator of spatial association (LISA)' methods were observed to determine the hazard in the regions where sampling was not done. Significant differences were found among aquifer types with 'poorly productive aquifers', the highest potential risk of elevated arsenic was observed in 'locally important fractured bedrock aquifers and regionally important fissured bedrock aquifer'.

Chattopadhyay et al. (2020) studied the spatial variability of arsenic concentration in groundwater from different georeferred samples on grid basis from varied water sources like dug well, bore and hand pumps from the river bank region of Ganga Basin. Elevated concentration of arsenic in groundwater was found in three sites of the study area. Spatial visualization of information was found to be made with the help of ArcGIS (Version 10.2.2) software to process maps along with the tabular data and the Geographical Information System (GIS) of arsenic was developed by using the tool. From the developed spatial maps it was observed that higher concentration of arsenic was more near the meandering point of Ganga.

2.2.2. Geostatistical Estimation

Deal and Sabatini (2020) considered Geostatistical methods as "a convenient technique for the making of maps with spatially distributed data in quite a few fields including mining, engineering, hydrogeology and soil sciences". Interpolations can be done with individual data points to estimate the pattern and determine the error of predictions. Kriging, a specific interpolation technique, has been elucidated as "a collection of linear regression techniques that take into account the stochastic dependence among data". The data of interest can be evaluated for its spatial dependence. The prediction at an unsampled location is based on the adjacent values by appropriately weighting the distance and variance of the neighbouring sampling points. Kriging has been considered as an unbiased estimator due to its potentiality to compare the range of spatial correlation and a numerical value that compares the accuracy of the model. Kriging is executed by using a semivariogram and cross validation techniques. The variogram, a geostatistical method, has been considered as a convenient tool for the analysis of spatial data and makes the foundation for kriging. Semivariogram is considered as half of the variogram. "The semivariogram is a graph that compares the distance between points and the variance between the values of the points. The maximum distance for which there is a correlation between the variables has been considered as the range of spatial dependence". Different algorithms like spherical, exponential and gaussian functions can be utilized to match the curvature of the graphs and create a predictive model. The predictive function can be used to execute to perform cross validation. In cross validation, every point except the point to be predicted are used. The predicted value is then compared to the original and the error was measured. The process has been repeated for every point in the dataset, by developing the estimates of mean error and other statistics for model evaluation.

2.2.2.1. Kriging

According to **Lichtenstern (2013),** the problem of getting unknown values appears and presents a big role in several scientific disciplines. For reasons of economy, there will always be only a limited number of sample points located where observations were measured. Hence, one has to predict the unknown values at unsampled locations of interest from the observed data to get their values or respectively estimates. For this sake, there exist different prediction methods for deriving accurate predictions from the measured observations. Kriging has been considered as the best linear unbiased prediction. The French mathematician Georges Matheron (1963) named this method Kriging and it has been considered as the mathematical interpolation technique named after the South African mining engineer Krige (1919-2013). He assessed the problem of interpolating results that were found at a restricted number of locations for gold mining.

According to **Webster and Oliver (2007),** Kriging can be classified as-

- **Ordinary kriging** of single variable that has been considered as the most robust and most used kriging method.
- **Simple kriging** is used in few cases because the mean is not known. It finds application in other forms such as indicator and disjunctive kriging in which the data are transformed to have known means.
- **Lognormal kriging** is ordinary kriging of the logarithms of the measured values that is used for strongly positively skewed data that approximate a lognormal distribution.
- **Universal kriging** recognizes both non stationary deterministic and random components in a variable, estimates the trend in the former and the variogram of the later and recombines the two for prediction.
- **Factorial kriging** is of particular value where the variation is nested and it estimates the individual components of variation separately, but in single analysis.
- **Ordinary cokriging** is the extension of ordinary kriging of a single variable to two or more variables. There must be some coregionalization among the variables for it to be profitable. It is particularly useful if some property that can be measured cheaply at many sites is spatially correlated with one or more others that are expensive to measure and are measured at many fewer sites. It enables us to estimate the more sparsely sampled property with more precision by cokriging using the spatial information from the more intensely measured one.
- **Indicator kriging** is a non-linear, non-parametric form of kriging in which continuous variables are converted to binary ones (indicators).

- **Disjunctive kriging** is also a non linear method of kriging, but is strictly parametric. It is valuable for decision making because the probabilities of exceeding or not exceeding a predefined threshold are determined in addition to the kriged estimates.

2.2.3. Application of Geostatistics for prediction of natural minerals

2.2.3.1. Arsenic

Yu, Harvey and Harvey (**2003**) studied the health crisis developed by arsenic in groundwater in Bangladesh by the application of geostatistical methods. The geostatistical map was found to construct arsenic concentration map by dividing Bangladesh into different zones and to determine the vertical concentration trends in the region. The long term exposure to higher level of arsenic concentration would result about hyperpigmentation, keratosis, skin cancer and deaths per year from internal cancers. The remedy of drilling deeper wells in selected regions of Bangladesh were examined and 31% of the wells in the country were found to be replaced by deeper wells that could reduce approximately 70% of arsenic concentration

Goovaerts et al. (2005) made a comparison between the execution of multi Gaussian and indicator kriging for probabilistical modeling of spatial distribution of arsenic concentration in groundwater of southeast Michigan. Factorial kriging was reported to filter the small range of spatial variation of arsenic concentration showing an increase (17-65%) in the percentage of variance by describing secondary details (type of unconsolidated deposition and nearing distance to Marshall Sandstone subcrop). The results from cross validation of the well data showed that the regional background did not influence the local prediction of arsenic by revealing the presence of unexplained sources of variability and the importance of modeling by the uncertainty connected to the predictions. More precise models of uncertainty were reported using indicator kriging. The well data were found to be compared to the prediction model and the best results observed for the indicator kriging had a mean absolute error of 5.6 µg/L. The result suggested the appearance of uncertainty due to laboratory error and gap of information regarding the sample origin , came up with the poor accuracy of the geostatistical predictions in the study area.

Hasan and Atkins (2007) studied the spatial pattern of arsenic toxicity by mapping compound problem regions in Bangladesh and explored the cokriging interpolation approach to analyze the suitability of isopleth maps for separate contaminated regions. Cokriging interpolation approach was reported to adopt as it possessed the exact interpolation capacity along with the GIS based buffering and overlay mapping processes. The paper suggested an interpolation approach based on ‘ regional estimates of arsenic data for spatial risk mapping that controlled the areal biased problems for administrative boundaries’ and the capability of the cokriging method was observed to exhibit the accepability of isopleth maps that was easy to study.

Hasan and Atkins (2011) explored the spatial variation of arsenic concentration in groundwater of Southwestern Bangladesh. Indicator Kriging (IK) was observed to be employed to determine the regionalized variation of arsenic concentration. The IK prediction map indicated a highly uneven spatial pattern of arsenic concentration in groundwater. The safe zones were found mainly concentrated in the north, central and south part of the study site in a patchy manner and the highly arsenic contaminated zones were lied in the west and northeastern part of the study area, the arsenic concentration pattern in the southwestern part was observed highly irregular. A Generalized Linear Model (GLM) was observed to investigate the relationship between arsenic concentration and depth of aquifers and a negligible negative correlation was found between arsenic concencentration and aquifer depth.

Gong et al. (2014) differentiated the accuracy of various commonly used interpolation approaches to estimate the groundwater arsenic concentration in Texas by the leave-one-out-cross-validation technique. The correlation coefficient between the calculated and estimated arsenic concentrations was found higher during the analysis of data from wells with inverse distance weighted (IDW) than kriging Gaussian, kriging spherical or cokriging interpolations. The result concluded that the precision in estimating groundwater arsenic concentration was found dependent on both interpolation methods and geographic distribution and characteristics of wells. The accuracy in groundwater estimation procedure was significantly increased when the well depth and elevation was put into regression analysis as covariates.

2.2.3.2. Other parameters

Kitanidis and Shen (1996) applied a practical methodology to estimate the solute concentration contour maps and volume averages that was essential for mass calculation derived from the data generated from the analysis of water and soil samples. The methodology was reported as an extension of linear geostatistics and created a point estimate (a representative value) as well as a confidence interval, which held the true value with a given probability. The result obtained from nonlinear kriging approach was found more easy than linear geostatistics. The results suggested a practical approach to determine all the essential parameters to select and test the model.

Jimenez-Espinosa and Chica-Olmo (1999) applied three univariate geostatistical approaches to estimate the probabilistic and spatial analysis of geochemical variables in gold rich areas in Spain. The studied methods i.e. ordinary kriging (cross-validation), factorial kriging and indicator kriging were used as a tool to identify the potential anomalous areas to detect the mineralization process. The result found that the application of kriging detected the possible location of the series of rich values situated along a N-S shear zone, indicating a structure connected to the presence of Au.

Goovaerts (2000) studied three multivariate geostatistical algorithms to incorporate a digital elevation model into the spatial prediction of rainfall: simple kriging with variation in local means, kriging with an external drift and colocated cokriging. Cross validation was found to be used to differentiate the 'prediction performances of the three geostatistical interpolation algorithms with the straightforward linear regression of rainfall against elevation and three univariate techniques: the Thiessen polygon, inverse square distance and ordinary kriging.' Prediction errors were observed to obtain for the two algorithms (inverse square distance, Thiessen polygon) that ignored both the elevation and rainfall records at nearby stations. The three multivariate geostatistical algorithms was found to outperform other interpolators, particularly in case of linear regression, which highlighted the importance of accounting for spatially dependent rainfall measurements in addition to the colocated elevation. Ordinary kriging was found to produce more accurate predictions than linear regression when the correlation between rainfall and elevation was moderate.

Tanny et al. (2009) evaluated 'the spatial and temporal variability of groundwater level fluctuations' in the Amman-Zarqa basin. As the basin was heavily populated from the earlier time and human and industrial activities were very prominent, the study was done to make wise use of groundwater resources to manage the present situation. From Kriging interpolation technique it was found that groundwater flow directions was almost constant over the years and the two main directions were SW-NE and E-W. The drop and rise events were found localized in the basin by Kriging mapped fluctuations. The results indicated the measures to reduce the fall and rise hazards in the detected regions.

Adhikary et al. (2011) differentiated the two non-parametric kriging methods- indicator and probability kriging to evaluate the possibilty of concentrations of Cu, Fe and Mn greater than the permissible value in groundwater. The integrated result of these two kriging approaches were observed to specify an average 26.34%, 65.36% and 99.55% area for Cu, Fe and Mn respectively and happened below the risk zone. The developed groundwater quality map was observed to classify the groundwater zones into "desirable" or "undesirable" for drinking purposes. The geostatistical method was found very much helpful for planners and decision makers to revise the policy guidelines for efficient management of the groundwater resources and to enhance groundwater recharge and minimize the pollution level.

Mini et al. (2014) studied the spatial and temporal variation of groundwater level in the coastal aquifer of India. Coastal aquifers over exploitation was reported to cause reversal of hydraulic gradient and seawater intrusion in coastal regions. The variograms and coastal maps were observed to prepare for pre and post monsoon period and a nugget to sill ratio of <0.25 was found from variogram analysis of water level specifing the strong spatial dependence of groundwater level. The average range of variogram was found around 10.5 km for spatial analysis. The result indicated that geostatistical analysis could help to describe the critical regions where supervised pumping and artificial groundwater recharge were to be performed to increase the groundwater level.

Ashrafzadeh et al. (2016) examined the acceptable quality of groundwater for the irrigation in paddy field by applying ordinary kriging and ordinary cokriging in Iran. The spatial variability map found to be prepared by the measured values from electrical conductivity (EC) and sum of major cations and anions (SCA)by using ordinary cokriging. From the result, it was observed that the risky class in which the average value of groundwater salinity was 25.4% and was expected to lessen the rice yield, was situated in the eastern part of the study area and the western part was found to have excellent quality of ground water quality for irrigation. The result suggested an integrated utilization of groundwater and surface water in the regions with the probability of rice yield reduction should be arranged.

Bodrud-Doza et al. (2016) explored the groundwater quality in Bangladesh. Water evaluation indices and several statistical approaches like multivariate analysis and geostatistics were reported to be applied to describe the distinct nature of the water quality which was the dominant factor for controlling the groundwater quality for drinking purposes. The study proposed that EC, TDS, Ca^{2+}, total arsenic and Fe values of groundwater samples exceeded the stipulated limit set by Bangladesh and international standards. The spatial distribution of groundwater quality variables were determined by geostatistical modeling, the exponential semivariogram model was observed to be validated as the best fitted models for majority of the indices values. The outcome of the study came up with the awareness assessment for decision makers taking appropriate measures for groundwater quality management in central Bangladesh.

Belkhiri et al. (2017) studied the factors and mechanism that controlled the spatial distribution of heavy metals in groundwater and their consequences on human health was determined by the application of multivariate statistical analysis and human health risk assessment in Algeria. The HQ indices of Cd and Pb were found higher than the safe limit which was reported to develop detrimental health hazards and potential non carcinogenic health risk for both child and adult population . The spatial variability map was preapared by using ordinary kriging illustrated that the safe zones were mainly located in the west and south western part of the study area and the contaminated zones were observed to be agglomerated in the east, north and south eastern part of the study area. The highly uneven spatial pattern of Pb and Cd concentration distribution was observed from the indicator kriging mapping.

Galal Uddin et al. (2018) estimated the spatial distribution and prediction of trace metals present in groundwater by using geostatistical methods in Bangladesh. The best fitted geostatistical model was found to be determined on the basis of experimental semivariogram values derived from twelve trace metal variables from groundwater. The best fitted semivariogram model values were found confirmed by the use of different parameters to analyze the quality of the geostatistical models [like mean square error (MSE), root mean square error (RMSE), average standard error (ASE) and root mean square standardized error (RMSSE)]. The concentrations of arsenic (max. 0.4983 mg/L), Iron (max. 0.4967 mg/L) and Barium (max. 420.30 µg/L) was observed exceeding the permissible limit for drinking water set by Bangladesh and World Health Organization. The results suggested that the groundwater of the study area was not accepatable for drinking purposes due to presence of high values of trace metals.

Masoud et al. (2018) explained the salinity influencing factors and their inter relationships in in Egypt. Factor analysis (FA) and hierarchial cluster analysis (HCA) were found to be combined with geostatistical methods for the characterization of chemical properties of the groundwater and soil samples and their spatial distribution, recognized the factors controlling the pattern variability and specified the salinization process. In groundwater, the salinity (av 885.8 mg/L), Fe^{2+} (av. 17.22 mg/L) and Mn^{2+} (av. 2.38 mg/L) concentration were found high and the soils were observed highly saline (av. 15.2 ds m^{-1}) and slightly alkaline (av pH=7.7). Salinization was obserevd to accompany the chemical variability of both the resources. The common geology, soil types, urban and agricultural practices were observed to be verified by the compatibility of the resource cluster.

Abu-alnaeem et al. (2018) identified the origin of salinity, major hydrogeochemical approaches influencing the salinity and deterioration of the coastal aquifer system with the help of combined processes of statistical and geostatitical approaches and hydrogeochemical study at Gaza. From the geostatistical analysis of the groundwater, it was recorded that the groundwater salinity highly increased in the study area by the intrusion of seawater across the coastline and 'salt water up coning inland'. The highest and lowest degree of salinization and the highest degree of nitrate contamination were reported in the northern part of the study area, reflecting the vulnerability of the area by natural and anthropogenic activities. Approximately 90.4% of the wells were found nitrate contaminated due to sewage inputs as the farming inputs were restricted in the sensitive part of northern area. The study would improve the effective utilization and management of coastal aquifer system as well as for the future work in other aquifer systems.

Busico et al. (2018) examined the shallow aquifers as the most accessible groundwater sources and susceptible to different pollution sources generated by human and natural sources at the watershed scale in Italy. The mineralization of groundwater was observed to be operated by several processes like geothermal activity, weathering of volcanic products and human activities. Multivariate statistical analysis was reported to compare the main hydrochemical processes happening in the area and three different outlooks were applied for factor analysis- major elements, trace elements and both major and trace elements. The results suggested the need for individual application of factor analysis when the large set of data was accessible for the study.

The impact of geothermal fluids on shallow aquifers were reported from the application of the factor analysis by trace elements.

Karami et al. (2018) studied that Geostatistical methods were considered as one of the advanced techniques applied for the interpolation of groundwater quality data in Iran. Ordinary kriging approach was found to assess the groundwater quality parameters, seven main water quality parameters (i.e. total dissolved soilds (TDS), sodium adsorption ratio (SAR), electrical conductivity (EC), sodium (Na^+), total hardness (TH), chloride (Cl^-) and sulphate (SO_4^{2-})) were evaluated and explained by statistical and geostatistical approaches. The best theoretical model was found to be fitted to each variogram based on the minimum RSS. Cross validation method was found to establish the accuracy of the estimated data. The results suggested that the kriging method was considered as more accurate than the traditional interpolation methods.

Bodrud-Doza et al. (2019) determined the threat of groundwater contamination developed by different trace metal by using geostatistical approach in Bangladesh. Pollution evaluation indices such as single factor pollution index (I), nemerow pollution index (NI), heavy metal evaluation index (HEI) and degree of contamination (C_d) was observed to evaluate the level of trace metal pollution in groundwater. The results from best fitted semivariogram model exhibited the average spatial dependence for Fe, Ni and HEI and low spatial dependence for Mn. Probability maps were evolved by using indicator kriging and the probability kriging approaches were used to estimate the possibility of groundwater pollution and similar trend like thematic maps were found. From the standard error map, indicator kriging was discovered as more acceptable than the probability kriging to evaluate the risk of groundwater metal contamination. The results indicated that geostatistical approaches could be suitable for planners and policy makers to mature the plan of actions for sustainable management of groundwater resources and reduce the polltion.

Boufekane and Saighi (2019) applied Geostatistical method (co-kriging approach) to investigate the spatial distribution of groundwater quality parametes like electric conductivity (EC) and sodium adsorption ratio (SAR) in Algeria. The study was done by the analysis of groundwater samples and co-kriging exponential model was found to generate accurate low RMSE in comparison to the other two methods, kriging and Inverse Distance Weighted. The electrical conductivity was found to be increased from the south to the north part of the study area from the prepared map by using co-kriging exponential model. The high values were detected being concentrated in the northern region of the plain (coastline)because of the sea water contamination. The spatial distribution of SAR was found exceptionally higher from the central to north part of the study area because of the anthropogenic contamination and marine invasion. The quality map for irrigation obtained from the study could be the essential tool for the farmers in agricultural irrigation. It was marked as important to recognize the main sources and amount of the pollution.

2.3. Effects of arsenic contamination on population

The effects of arsenic contamination can be classified as health effects and socio economic effects. The health effects of arsenic is not similar all over the world, i.e. Blackfoot is a characteristic vascular disease associated with chronic arsenic toxicity predominantly found in Taiwan. Health impact of chronic arsenic toxicity on adult and children are also different. Children usually do not develop skin lesions, but their organs are affected due to the toxicity.

2.3.1. Health effects of arsenic

Long term ingestion of arsenic contaminated water can cause different types of health issues among the population living outside India and in India.

2.3.1.1. Outside India

Nguyen et al. (2009) found that high arsenic concentration in groundwater was recorded in four villages in Ha Nam province in northern part of Vietnam and groundwater was utilized as one of the main source of drinking water in those villages. The arsenic concentration in groundwater was found significantly higher than the Vietnamese drinking water standard in three villages with average concentrations of 348, 211 and 325 µg/L respectively. The chronic and carcinogenic risks were assessed for arsenic through ingestion among the local population and 40% of people were found at chronic risk for arsenic exposure.

Huy et al. (2014) studied the risks related to arsenic contamination in drinking water in Hanam province, Vietnam. The range of arsenic concentration in tubewell water was found 8-579 ppb before filtration. Daily arsenic consumption rate of 40% adults was reported to exceed the level of Tolerable Daily Intake (TDI) at 1 µg/kg/day. The development of average skin cancer risk in adults by the consumption of filtered tubewell water was observed 25.3×10^{-5} (used only well water) and 7.6×10^{-5} (used both well and rain water). The skin cancer risk was observed 11.5 times higher if the filtered water had not been used.

Zhang et al. (2019) explored the occurence and spatial distribution of arsenic in groundwater in the Jinghui irrigation district, Shaanxi Province, China. The groundwater arsenic concentration was found in a range of 0.0012 to 0.0190 mg/L (mean 0.0054 mg/L) and 2.58% of groundwater was found exceeding the national guidelines (0.01mg/L) for drinking purposes. The national guidelines set for the development of carcinogenic risk of arsenic affecting adults was 1.00×10^{-4}, but value was observed to reach at 3.5×10^{-4} in adults. The health risks associated with oral exposure was observed higher than the dermal exposure. The development of carcinogenic risk was observed higher in adults than children, while the non carcinogenic effect was found higher in chidren than the adult. The area ratio was found as 42.82% was under carcinogenic risk and 69.19% as non carcinogenic risk.

2.3.1.2. In India

A. Adult population

Guha Mazumder et al. (1988) observed the arsenical dermatosis and hepatomegaly in 92.5% population (n=67) who consumed arsenic contaminated water from 200 to 2000 ppb from an As impacted region of Ramnagar Village, Baruipur block, 24 Parganas. In contrast only 6 out of 96 persons from the same area who consumed safe water with As concentration below 50 ppb had developed non specific hepatomegaly, while no one had any skin lesions.

Chakraborti et al. (2002) studied that approximately 6 million people from nine arsenic affected districts were consumed water with more than 50 µg/L arsenic and above 300 0000 people had visible arsenic induced skin lesions. The arsenic concentration in biological samples were reported to indicate that more people might be affected sub clinically. The children living in the arsenic affected regions were supposed to be more vulnerable than the adults consuming arsenic contaminated water for a long period . In Bangladesh, 2000 villages in 50 districts were found to contain arsenic concentration above 50 µg/L and more than 25 million inhabitants were dependent on the arsenic contaminated water for drinking purposes. The arsenical Skin Lesions (ASL) was found in the villagers who consumed water with arsenic concentration more than 300 µg/L for a sustained period. Four factors were documented to control the appearance of the skin diseases- a) the concentration of arsenic in drinking water b) period of exposure c) volume of daily intake and d) nutritional status. It was observed that arsenical skin lesions were not developed in chidren below 11 years of age, but exceptions occured where the concentration of arsenic in drinking water was more than 1000 µg/L and poor nutrition was associated with more than 500 µg/L arsenic concentration in drinking water. The concentration of arsenic in biological samples of the children residing at arsenic affected regions exhibited elevated levels of arsenic in 90% of the cases indicating the manifestation of external symptoms might be a matter of time. The symptoms are mainly melanosis, leucomelanosis, keratosis, hyperkeratosis, dorsal keratosis, non pitting oedema to gangrene and cancer. The skin lesions never reported on face. Cancer development in squamous cell, basal skin, lung, uterus, bladder and genitourinary tract is common in later phase of chronic arsenic toxicity.

Mitra et al. (2004) studied that consumption of dietary macronutrient and micronutrient has been regulated the risk of developing arsenic induced skin lessions including skin pigmentation alterations and keratoses in West Bengal and Bangladesh. The authors selected the patients by the presence of arsenical skin lesions and consumption of <500 µg/L arsenic in their drinking water. The results concluded that lower amount of calcium, animal protein, folate and fiber had the potential to develop arsenic induced skin lesions and arsenic free drinking water supply could only get rid of the situation.

Watanabe et al. (2004) studied that the exposure evaluation was considered as a crucial step for "the risk assessment of chronic arsenic toxicity". The amount of water consumption was treated as the base of the exposure calculation and the calculated total arsenic exposure exhibited no sex difference in arsenic exposure except the exposure from food. The results indicated that the sex difference in the manifestation of arsenic contamination was reported in the area might be related with the factors other than exposure level and the risks related with low arsenic concentrations of groundwater should be explained clearly because food found to be acted as the additional burden of arsenic.

Guha Majumder and Dasgupta (2011) reviewed the effects of chronic arsenic toxicity on human health including genotoxicity. Pigmentation and keratosis was supposed to be specific skin diseases developed by chronic arsenic toxicity. The other effects of chronic arsenic toxicity was observed to give rise different systematic manifestation including 'chronic lung disease mainly chronic bronchitis, chronic obstructive or restrictive pulmonary disease, bronchiectasis, liver diseases including non cirrhotic portal fibrosis, polyneuropathy, peripheral vascular diseases, hypertension, nonpitting edema on feet and hands, conjunctival congestion, weakness and anemia'. Consumption of high arsenic contaminated water (≥200 μg/L) during pregnancy was observed to be related with a 'sixfold increased risk for still birth'. Skin, lung and urinary bladder cancer were considered as the most important cancers correlated with chronic arsenic toxicity. Genotoxic effects were reported to be developed by chronic arsenic toxicity, chromosomal aberration and 'increased frequency of micronuclei in different cell types', probable mechanism to cause DNA damage were found significant. In table 2.1, the probability of occurrences of arsenic induced illnesses has been discussed.

Table: 2.1. Disease and probability of occurence of arsenic induced illnesses in West Bengal

Diseases or Symptoms	No of observations (n)	Probability of occurence (%)
Obstructive lung disease	29	58.6
Interstitial lung disease		31.2
Bronchiectasis		10
Dyspepsia	156	38.4
Hepatomegaly	67	92.54
Peripheral vascular disease	246	1.2
Gangrene	4865	0.02
Paresthesia	156	47.4
Anemia	156	47.4
Arsenic induced skin lesions	202	5.94
Weakness	110	70.5
Headache	32	20.5
Skin cancer	4865	4.35
Internal cancer		0.78
Burning of eyes	69	44.2
Pain in abdomen	60	38.4
Diarrhea	51	32.6

Samal et al. (2013) investigated the effects of arsenic toxicity on local community and their nutritional status in the two arsenic contaminated villages in West Bengal. The arsenic concentration was reported 870 µg/L and 1752 µg/L at a depth range of 50-100 ft. 27% of people was registered to have arsenical skin lesions dominant in 15-30 and 30-45 years old. The occurence of melanosis was found higher (23% and 32%) in comparison with keratosis (15% and 13%) among both the age groups. The dermatological manifestation was found in 27% people and the lesions were dominant in the age group of 15-30 and 30-45 years and the no of people diagnosed with melanosis was higher (27% and 31%) than keratosis (11% and 31%). The result of carbohydrate and protein intake assessment by local inhabitants were reported that 68% and 67% of the people from the villages belonged to poor nutrition.

Loveborn et al. (2016) observed that exposure to high concentration of arsenic at childhood level is considered as a critical period, developing arsenic induced health effects later in life including cancer and overall morbidity and mortality. The severe health effects among child population due to elevated arsenic exposure was found in the form of impaired immune function, growth and cognitive function, little is known about potential susceptibility factors including the efficiency of arsenic metabolism

Chakraborti et al. (2018) examined the extremity of arsenic pollution in the Ganga River Basin (GRB). The higher levels of arsenic concentration was found in the entire GRB- in groundwater (upto 4730 µg/L), irrigation water (~1000 µg/L) and in food stuffs (upto 3947 µg/kg) exceeding the permissible value set by WHO for drinking water. Dermal, neurological, reproductive, cognitive and cancerous effects were observed in the population, many children were found to develop a range of arsenic induced skin lesions and numerous deaths of youthful victims were reported from elevated arsenic concentration in the GRB. The sufferers from arsenic exposure was found to accept the critical social challenges like social isolation, hatred by their respective communities. The aggravation of arsenic calamity was found from the reluctance to establish arsenic standards and unsustainable arsenic mitigation measures, thus leaving the millions of life in danger. The results suggested a need for reduced standard for arsenic concentration in drinking water, regular monitoring of the drinking water sources and a sustainable and cost effective mitigation strategies that involved the public participation.

Das et al. (2020) determined the strong possibility of cancer risk development by arsenic and Uranium in drinking water and the mean Cancer Risk value (1.2×10^{-3} and 2.48×10^{-3} respectively) was found beyond the acceptable limit.

In fig 2.3 different stages of clinical features of arsenic toxicity has been summarized.

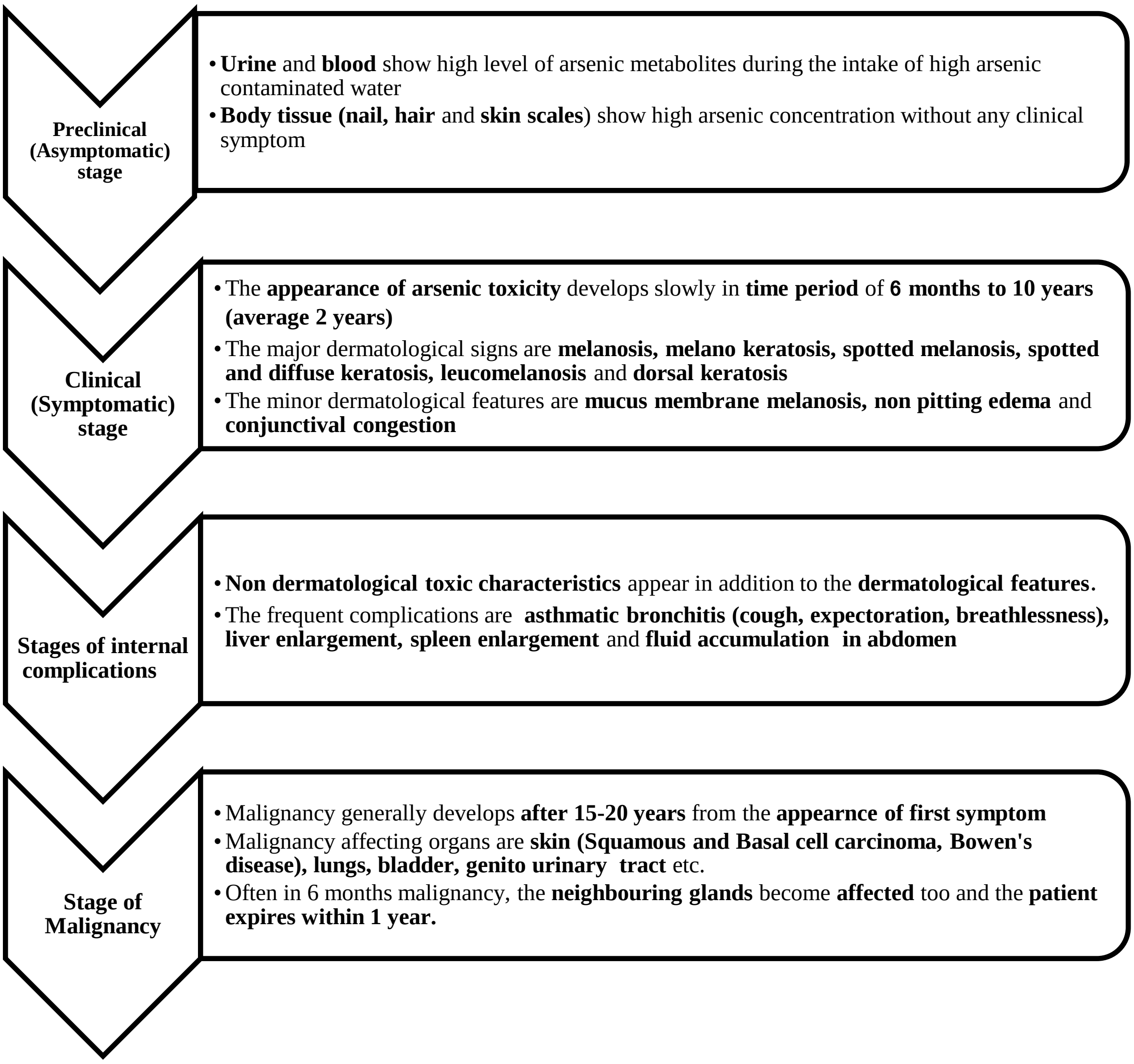


Fig: 2.3. Stages of clinical features of arsenic toxicity

B. Child population

Calderon et al. (2001) studied the impact of chronic exposure to arsenic (As) and malnutrition on the neuropsychological development in Mexican children. The study indicated that chronic exposure to arsenic and malnutrition might have an impact on verbal abilities and long term memory, while exposure to Pb might influence the attention process even at low levels.

Tsuji et al. (2004) reviewed the short term heath effect of arsenic exposure to the young children (age group 0-6 years old). The symptoms of acute health problems were included as gastrointestinal, neurological and skin effects, in some cases facial edema and cardiac arrhythmia. Dermatoses were most consistently delineated among children and adult population with subchronic arsenic exposure. The intensity of the disease was generally noticed to increase with duration of arsenic exposure (age of the individual) and arsenic concentration from the drinking water. At low doses, children were not reported to be more sensitive than adults on a dose per body weight basis, althogh the acute exposure data were limited and for quantifying the potential neurological and vascular effects at low level chronic exposure, the exixtence of uncertainty was noticed. Based on the data the reference levels for acute and subchronic exposure to arsenic in young children were decided 0.015 and 0.0005 mg/kg-day respectively.

Rahman et al. (2005) studied the effect of drinking arsenic contaminated water on children in Murshidabad. Infants and children were found more vulnerable to the adverse effects of arsenic than adult population. The estimated mean per capita ingestion rate of babies under 1 year were observed three to four times higher than the mean rate of total population. Among the children below 11 years, arsenical dermatosis and other symptoms were registered in 4.38% children. The symptoms of arsenic poisoning was not found to be manifested below the age of 11 years in the previous studies, but exceptions were detected where the arsenic concentration in drinking water was very high (≥1000 μg/L) or arsenic concentration was not so high (<500 μg/L) but the children were malnourished.

Liao et al. (2010) evaluated the potential risk of children skin lesions developed after the consumption of arsenic contaminated rice in West Bengal, India. The study was found as an amalgamation of arsenic concentration in irrigation water, bioaccumulation factors of paddy soil, cooking procedure and bioavailability of arsenic in cooked rice in gastrointestinal tract into a probabilistic risk model. The result showed that the children among the age group between 13 to 18 years was observed to create a relatively higher potential risk of skin lesions to arsenic contaminated cooked rice than those of 1-6 years children. The study revealed that the risk associated with arsenic induced skin lesions was found to be reduced considerably by adopting traditional rice cooking method as follwed in West Bengal and using water containing lower arsenic (<10 μg/L) for cooking.

Asadullah and Chaudhury (2011) determined the impact of arsenic contamination of tubewells, the primary source of drinking water at home and effect of arsenic on the learning outcome in school going children living in rural Bangladesh. A negative and statistically significant correlation was found between mathematics score and arsenic concentration in drinking water at home, socio economic status and parental background of the children and school specific unobserved correlates of learning. Close correlations were reported for a measure of student achievement and subjective well being of the student such as self reported measure of life satisfaction.

Rodriguez et al (2013) studied the significant effects of arsenic, cadmium and manganese on the neurodevelopment and behavioral disorders in children and estimated the magnitude of the effect on neurodevelopment. The study was observed to be based on a systematic review of articles assessing the effects on neurodevelopment and behavioural disorder due to pre or post natal exposure to arsenic, cadmium and manganese in children upto 16 years of age and a meta-analysis was conducted to assess the effects of exposure to arsenic and manganese on neurodevelopment. The result from meta-analysis indicated a 50% increase of arsenic levels in urine was related with a 0.4 decrease in the intelligence quotient (IQ) of children aged between 5-15 year, a 50% increase of manganese in hair was found associated with a decrease of 0.7 points in the IQ of children aged between 6-13 years.

In fig 2.4, the obstruction of educational development of a school going children has been mentioned.

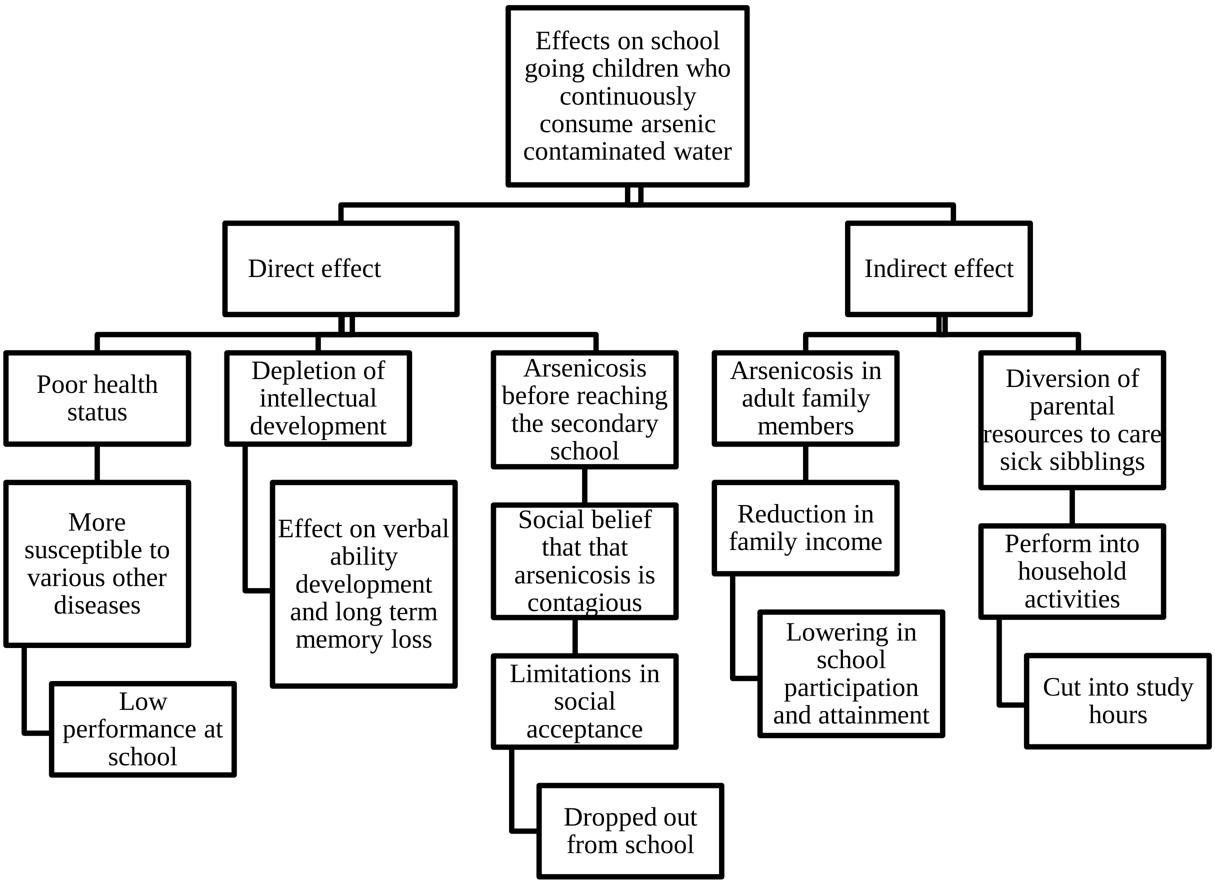


Fig:2.4. Obstruction of educational development of school going children

Vibol, Hashim and Sarmani (2015) divided the study area according to the variation of arsenic concentration in the Kandal Province of Cambodia- Kampong Kong Commune as highly contaminated site (300-500 µg/L), Svay Romiet Commune as moderately contaminated site (50-300 µg/L) and Anlong Romiet Commune as a controlled site. The arsenic concentration found in hair samples from the three study areas were significantly different, the median value of arsenic concentration in highly contaminated region was 0.93 µg/g, moderately contaminated region was 0.22 µg/g and in control site the concentration was 0.08 µg/m. The children whose arsenic level in hair found high, experienced 1.57-4.67 times more risk of experiencing lower neurobehavioral test scores in comparison to the lesser exposed group. The result indicated that the children from the highly contaminated study area, displayed the clear evidence of neurobehavioral effects.

Brahman et al. (2016) calculated the Hazard Quotient (HQ) of arsenic on the basis of arsenic concentration in drinking water and scalp hair of the children who were belonged to two age groups, 5-10 and 11-14 years and consumed arsenic contaminated water with different concentration of arsenic. The water samples were observed to be collected from arsenic contaminated and arsenic safe areas and the areas were differentiated into low exposed (LE), high exposed (HE) and non exposed (NE) areas. Arsenic concentration was observed 2.6-230 fold higher in LE and HE areas established by World Health Organization (2004) and in NE area the concentration was found within the permissible limit (<10 µg/L). A positive correlation was observed between the arsenic concentration in drinking water and hair samples of children from the HE area, compared to the other two areas . The arsenic toxicity risk assessment based on HQ for the NE, LE and HE area, the values were reported <10, ≥10 and >10 respectively. The result concluded that the children drinking the groundwater from the LE (Kharipur Mir's) and HE (Tharparkar) areas of Pakistan were faced a potential risk of chronic arsenic toxicity.

Rodriguez-Barranco et al. (2016) evaluated the association between urinary arsenic (UA) concentration and attention performance and Attention-Deficit/Hyperactivity disorder (ADHD) in children residing in a region with high industrial and mining activities in Southwestern Spain. A dose response relationship was found between UA concentration and inattention and impulsivity scores. The study concluded that UA levels were observed to be connected with impaired attention/ognitive function, even at safe levels.

Rahman et al. (2016) observed that children who are exposed to arsenic may show impaired learning and memory, sleep disturbances, abnormality and hearing problem, impairments of higher neurological functions including learning, memory and attentiveness.

Calatayud et al. (2019) estimated the vulnerability of arsenic exposure through drinking water and food, arsenic concentration in urine and hair and effects of arsenic on the child population living in the provinces of Santiago del Estero and Chaco in Argentina. The increase of arsenic level exposure was observed to modify the metabolites profile, with decrease of dimethylarsinic acid (10%) and increase in monomethylarsonic acid (4%) and inorganic As (6%). The results showed high values of 8-OHdG (3.7-37.8 µg/g creatinine) which was considered as a oxidative DNA damage marker in the two areas where arsenic concentration were high.

Rahman and Hashem (2019) examined the quality of the drinking water supplied to the primary school children at Satkhira district, Bangladesh to secure arsenic free drinking water. The result found that the arsenic concentration exceeded the permissible value set by WHO in 49% of tubewells and the maximum concentration was found 167.9 µg/L. Chronic daily intake (CDI) and

Hazard Quotient (HQ) were found to be estimated from the result dataset and value of HQ was noted as >1 for arsenic concentration in the tubewell water. The result indicated that the consumption of such a high arsenic contaminated water could trigger the development of cancer risk to the human health.

Signes-Pastor et al. (2019) explained the cross-sectional association between the exposure to inorganic arsenic and neurodevelopmental outcomes among children residing in Spain and the major route of arsenic exposure was diet. Consumption of inorganic arsenic from the very early stage of life could adversely impact the health later in life. The neurodevelopment in children were adversely affected who were reported to be exposed to higher level of arsenic concentration.The result suggested that exposure to low inorganic arsenic could lead to neuropsychological developmental impairment in children and sex related differences could be present in susceptibility to arsenic related health diseases.

In table 2.2, the effects of arsenic pollution on child population has been described.

Table: 2.2. Effects of arsenic on child population

Place of study	**Age group (years)**	**As concentration (ppb)**		**Findings**	**Reference**
		Drinking water	**Urine**		
Taiwan	13-14	130-340		Neurobehavioral function in adolescents may be affected by childhood exposure to arsenic in drinking water	**Tsai et al. (2003)**
Bangladesh	13-14			Negative correlation was found between school performance of the children and arsenic contaminated drinking water source at home.	**Asadullah and Chaudhury (2011)**
Kambodia	10-16	50-300		High arsenic exposed school children showed clear evidence of lower neurobehavioral effects	**Vibol et al. (2015)**
Spain	6-9		0.7	Postnatal arsenic exposure was associated with impaired selective and focused atttention and with a delayed reaction time	**Rodriguez-Barranco et al. (2016)**
Uruguay	5-8		2.6-50.1	The academic achievement was not affceted at low level exposure	**Desai et al. (2020)**
Bangladesh	5-10	1-482		Exposure to arsenic is associated with lower cognitive abilities.	**Vahter et al. (2020)**

Desai et al. (2020) estimated the relationship between urinary arsenic concentration (U-As) and educational attainment, modification of outcomes by vitamin B intake, status and range of arsenic methylation in children aged between 5-8 years in Montevideo. Millions of children were reported to be manifestated to lower level of arsenic from water and food and the lower exposure levels were understudied. The result suggested that at low level of arsenic exposure, U-As was not found to affect the academic achievement of the children.

Vahter et al. (2020) studied the exposure of arsenic on child population and its impact on cognitive development at school age. The presence of arsenic in groundwater with different concentrations specified the impact on the verbal cognitive function of a child at 5 years of age. The results inferred that both the early prenatal and childhood arsenic exposure (even at lesser levels) were observed to be inversely connected with cognitive abilities at the school going age. As exposure prenatally or in early childhood seems to affect the developing immune system, impair fetal and childhood growth and increase the risk of later life cancer A modest inverse association was found between the children's concurrent urinary arsenic and their cognitive ability at the age of 5 years. Despite of major mitigation measures over the last 15-20 years, the families residing in As contaminated region are continuously exposed to arsenic through drinking water and food

2.3.2. Socio cultural effect of arsenic on population

Hadi and Parveen (2004) evaluated the prevalence of arsenicosis and its association with socio demographic covariates among a rural community exposed to arsenic contaminated drinking water in Bangladesh. Approximately 2.9% of the studied population was reported with symptoms from arsenic poisoning and the manifestation of arsenicosis was influenced by age, sex, education and economy of the household. Age and economic status was recognized as the notable predictor of arsenicosis controlling for education and gender. The prevalence of arsenic was observed only in 1.63% young population (<19 years) compared to 3.99% in the middle aged (20-39 years)population and 3.46% among the old population (≥40 years). The prevalence increased nearly 2.5 times from the young to middle aged population($p<0.01$) and decreased marginally in the old population. A negative correlation was found between prevalence of arsenicosis and economic status. The result indicated that the socio economic distribution of arsenicosis in different demographic zones would recognize the vulnerable groups from arsenic affected communities.

Paul (2004) investigated the extent of knowledge among rural residents regarding arsenic contamination to determine the association between various socio economic and demographic characteristics of the residents. In the risk zone, nearly 90% of the tubewells were found to be contaminated with arsenic above the WHO guideline. The study recognized the arsenic contaminated region, level of education, gender and age of the participants as the major parameters of arsenic knowledge.

A tendency was observed by **Hasan et al. (2005)** to exclude the arsenic affected people thinking of arsenicosis as a contagious disease and the people were found to be forbidded in social activities and often face rejection within the community. arsenic contamination in groundwater developed an extensive social problems for the arsenic affected people and their families in Bangladesh. Women with significant arsenicosis symptoms were found unable to get married and some affected housewives were reported to be divorced by their husbands. Children with visible arsenicosis symptoms were not sent to school to conceal the problem. The authors found extreme negative social impacts faced by the patients and a distinct difference of perceptions about arsenic and social issues between arsenicosis patients and unaffected people.

Das and Roy (2013) found the effects of arsenicosis to impact on human well being i.e. labour productivity, lowering income earning capacity,loss of lifetime income due to prolonged disease or death, inter- generational poverty and health status. From the study, various social and economic manifestations i.e. instability, sense of marginalization, cause of suicide, problems in marriage, loss of labour power due to amputation, cause for long term indebtness of household, loss of job, increasing poverty, charge of high dowry were found. Social exclusion was also reported to magnify 'social attitude towards arsenic affected health disorders leading to social discontent'.

Rahman et al. (2018) studied the arsenic exposure pathways to human body, outlined the health impact of chronic arsenic poisoning on human body and the socio economic inferences and consequences of arsenicosis with a focus on Bangladesh. The socio-economic consequences of arsenicosis were analysed by considering the factors- food habits, nutritional status, socio economic infrastructure and socio cultural behaviours of the people of the country. The pathways of arsenic exposure in human body was found to include drinking water, food and non dietary sources like soil. The people with visible symptoms of arsenic was found to be abandoned by the society, became jobless, got divorced and were drove to live a sub-standard life. The fragile public health system in Bangladesh was observed as a burden by the management of thousands of arsenicosis patients in Bangladesh.

2.4. Cost related to arsenic contamination in groundwater

2.4.1. Cost of illness of groundwater arsenic contamination on population

50% of the districts in West Bengal are exposed to elevated level of arsenic concentration in groudwater and a large number of population living in those districts have been diagnosed with symptoms of arsenic poisoning. Arsenic concentration in drinking water can develop skin, lung, liver, kidney and bladder cancer. In a developing country, the medical expenditure for arsenic related illness thrusts an additional burden on the already overburdened public provision of medical care. So, there is need for a study regarding the economic dimension to welfare loss and the associated costs and benefits of arsenic contamination and removal.

Ahmed et al. (2002) calculated the willingness to pay (WTP) for piped water supply projects in the arsenic contaminated regions in Bangladesh. The estimated WTP for community water standpost found in Bangladesh Taka (BDT) was 51 per month with an added BDT 960 towards the capital cost. The mean estimation for domestic connection was found BDT 87 per month with BDT 1787 for capital expenses. BDT 68 per month was observed to expense for poor households and BDT 1401 was the capital cost for a home connection.

Maddison, Catala-luque and Pearce (2005) evaluated epidemiological dose response relationship integrated with survey estimates of arsenic levels in groundwater and estimated the annual mortality and morbidity cases due to the consumption of arsenic contaminated drinking water among the households residing in Bangladesh. The estimated health impacts were observed in 6500 case of fatal cancers and 2000 case of non fatal cancers. The gross willingness to pay (WTP) to avoid the health impact was observed $2.7 billion annually by using "purchasing power parity exchange rates".

Roy (2008) estimated the economic cost of arsenic induced health problems in West Bengal.The study is based on the household health production function model including a household health production function and household demand function for mitigating and averting activities to estimate the benefits from a decline in arsenic concentration in groundwater. It was found from the study that the reduction of arsenic concentration to the permissible limit (50 µg/L) then per household would be benefitted by Rs 297 per month. The same benefit was Rs 161 per month if the arsenic concentration was reduced by half of the present concentration. The estimated cost burden in monetary term was found Rs 229 million in North 24 Parganas. The present cost for filtered piped water supplied by the Kolkata Municipal Corporation per household per month was found Rs 127. Thus, investment for safe drinking water was found economically achievable and willingness to pay was observed among the people if they were aware of the effective gain in welfare.

Khan and Haque (2010) evaluated the individual cost of arsenic exposure in Bangladesh. The households were found to spend BDT 1057 per year for arsenic related illness, which was observed approximately 0.73% of the income of the household. The amont was pretty high for poor household considering the fact that most of the population live with less than BDT 175 per day. If 50 million peoplewere at risk, the estimated loss of income was 625 million Taka. The actual cost would rise each year as the occurence of arsenic induced illness increase by nearly 4 for every 1000 population each year.

Khan et al. (2014) studied the willingness to pay (WTP) for arsenic free drinking water across different arsenic contamianted regions of Bangladesh. Health risk awareness levels were found high and households were willing to pay on average 5% of their disposable average annual income for arsenic free drinking water. The factors influencing WTP included the bid amount to build communal deep tubewell for arsenic free water supply, the risk zone, household income, water consumption,social awareness about arsenic contamination, the number of household members were affected by arsenic contamination and if they had mitigation measures to treat arsenic.

Mahanta, Chowdhury and Nath (2016) evaluated the health cost of arsenic contamination in groundwater in Assam where approximate one million people are critically affected. The result was found that the 'average annual health cost of 1 µg increase in arsenic concentration per litre of drinking water' was approximately INR 4 per household. If the average extent of arsenic concentration was lowered down to the permissible limit (50 µg) per litre, the average annual welfare gain for a household was INR 862. By projecting the figure to the total arsenic affected population, the estimated annual health cost was found about 0.76 million. The health cost and welfare gain was found to be differed appreciably across different arsenic concentrations and districts.

The cost of illness due to arsenic pollution in groundwater has been discussed in table 2.3.

Table: 2.3. Cost of illness due to arsenic pollution in groundwater

Study area	**As conc (ppb)**	**Annual cost of 1 ppb increase in arsenic per capita(INR)**	**Year of study**	**Reference**
Matlab and Laksman, Bangladesh	more than 50 ppb	1.51	2005	**Khan (2007)**
North 24 Parganas, West Bengal	51-3370	1.33	2002-2003	**Roy (2008)**
Jorhat, Assam	avg 253.75	1.07	2013	**Chowdhury and Mahanta (2014)**
Jorhat and Nalbari, Assam	62.7-491 and 58.4-621	0.97	2013	**Chowdhury, Mahanta and Nath (2015)**
Patna and Bhojpur, Bihar	0-500	2.09	2013	**Thakur and Gupta (2019)**
North 24 Parganas	51-1600	1.55	2005-06	**Chakraborty and Mukherjee (2020)**

Thakur and Gupta (2019) calculated the health compensation cost due to arsenicosis among the population of Bihar. The wage loss per annum, cost of medical help and cost of illness were observed to be estimated as INR 2437.92, INR 5942.40 and INR 8380.32 respectively. The annual cost of illness for the society was estimated INR 265.97 million. Policy implications for supplying arsenic free water to the arsenic affected regions were found to lower the cases of arsenicosis development in sustainable manner, improve well being and potential productivity.

2.4.2. Alternative source for arsenic free water

Addy (2010) suggested that there are two primary categories in which safe water approach falls- switching to alternative source of water that is arsenic free and remediation of arsenic contaminated sources. The former category is comprised of installation of deep tubewells those are considered to be arsenic free, treatment of surface water by Pond Sand Filters or shallow dugwells and rainwater harvesting. The efforts applied for arsenic remediation was primarily focused on household filters for contaminated wells. arsenic removal technologies are often based on adsorption onto a relatively low cost chemical sorbent added to the water, such as zero valent iron, granular ferric hydroxide or activated alumina. Each safe water option differs in capital and recurring costs, extents of maintenance, water quality, water flow rate, social acceptability and other external factors. The installation of deep tubewell has been considered as the strong preference for arsenic free water source among the users. But the installation of deep tubewell was found expensive and only achievable where the deep aquifer is free from As contamination and the installation should be proper to avoid cross contamination from shallow aquifers. Increased pumping from deep aquifer can withdraw arsenic in from shallow counterparts. So, there is a need to install arsenic removal technology to the contaminated source to get As free water.

Remediation has been considered as the most viable solution, mainly in regions with limited or no access to alternative sources of safe water. Significant investments were made in these kind of treatments, but the total positive impact of the efforts were found difficult to measure. The global population affected by arsenic contamination was found high due to the lack of commercially available removal technologies. The technologies vary widely and their implementations were found dependent on the quality of the water source. It is difficult to understand what are the most cost effective remediation options for low-income settings.

2.4.2.1. Arsenic removal technologies from groundwater

There are different conventional As removal technologies from groundwater under both laboratory and field conditions.

Household based point of use (POU) filters have been plagued by high abandonment rates after a short interval of installation due to difficulties in operation, the quantity of attention required for operation and low cultural accepatibility. The chemical adsorbents utilized in the filters have restricted efficacy in removing As (III), which makes up about 70-90% of the total arsenic calculated in Bangladeshi tubewells.

Shan et al (**2018**) studied As remediation technologies used in laboratory and field and the cost of per litre of treated water. The technologies and costs are listed in table no 2.4

Table: 2.4. Arsenic remediation technologies and the cost of per litre of treated water

Origin of influent water	**Remediation technology**	**Technology type**	**Cost of per litre of treated water (INR)**	**Reference**
Bangladesh	Naturally occuring iron in groundwater	Co precipitation	near zero cost	**Mamtaz and Bache, 2000**
India	Ferruginous manganese ore	Adsorption	not applicable	**Chakravarty et al. 2002**
Bangladesh	Water hyacinth	Bio remediation	near zero cost	**Misbahuddin and Fariduddin, 2002**
Thailand	Immobilized green alga	Bioremediation	near zero cost	**Visoottiviseth and Ahmed, 2008**
India, Bangladesh	Activated alumina metal oxide as adsorbent	Adsorption	90.84	**Visoottviseth and Ahmed, 2008**
India	Ferric hydroxide as adsorbent	Adsorption	45.81	**Sen Gupta et al. 2009**
Vietnam	Treated magnetite waste	Adsorption	not applicable	**Nguyen et al. 2009**
India	Activated alumina or hybrid anion exchanger as adsorbent	Adsorption	57.46	**Sarkar et al. 2010**
Argentina	Hydrogel adsorbent	Coagulation, filtration and adsorption	7212.92	**Bundschuh et al. 2010**
Bangladesh	Mg-Fe based hydrotalcite like compound	Adsorption and ion exchange	0.78	**Kumasaka et al. 2013**
India	Citric acid from lemon, tomato and lime	Oxidation	65.29 (lemon) 50.52 (tomato) 38.08 (lime)	**Majumder et al. 2013**
India	$NaHCO_3$, $KMnO_4$, $FeCl_3$	Oxidation, coagulation, precipitation and filtration	13.20	**Bordoloi et al. 2013**
China	Two bucket system with ferric sulfate and polyferric sulfate	Coagulation and filtration	35.75	**Cui et al. 2015**
India	Aluminium electrode	Coagulation, precipitation and filtration	28.76	**Thakur and Mondal, 2017**
India	Activated laterite	Adsroption	27.95	**Mondal et al. 2017**

Millions of people in the rural part of South Asia are observed to be exposed to elevated level of As concentration through groundwater. Several established arsenic remediation technologies were failed quickly because they were not maintained at all, repaired, accepted or affordable. It is therefore very crucial that the As remediation technologies should be evaluated for their potentiality to perform within a sustainable and scalable business model that addresses the challenge. The efforts made for arsenic removal had focused on the development and dissemination of household filters that often abandoned due to the amount of attention and maintenance that they needed. A community scale clean water center has countless advantages over household filters and has been accepted for both chemical and electricity based technologies to be beneficial to rural areas. Full cost recovery would enable the treatment center to be sustainable over time. Electro Chemical Arsenic Remediation (ECAR) has been considered as compatible with community scale water treatment for rural Bangladesh. The ability of ECAR to lower down arsenic level from >500 ppb to less than 10 ppb in synthetic water and rural ground water of Bangladesh was demonstrated and the influence of several operating parameters on arsenic removal effectiveness was examined. ECAR technology was considered as electricity based technology viable in potentially non electrified rural areas. ECAR technology was found very much compatible with this model due to its low operating cost, low waste output, easy maintenance without strong alkalies or corrosive acids, limited supply chain needs and scalability.

Amrose et al. (2014) presented field trial results of a 600 L Electro-Chemical Arsenic Remediation (ECAR) reactor working over 3.5 months in West Bengal. The capacity of ECAR was found to be consistently reduce As concentration from 266 ppb to 5 ppb in real groundwater. ECAR was proved as a promising technology to help supply a clean water solution in As affected areas of South Asia.

From the above study, it can be concluded that arsenic should be considered truly as “worst mass poisoning in human history”. A complex pattern of spatial distribution of arsenic was found in groundwater with notable differences between neighbouring wells, trends at the regional scale and changes with depth underground. A small insignificant positive correlation was found between observed As concentrations and shallow tubewell density and elevated level of arsenic (137 ppb) was also observed in deep groundwater samples of West Bengal. The temporal variation of arsenic in groundwater is thought to be significant too. Ordinary kriging has been considered as the most utilized interpolatatin method that can estimate As concentration unbiasdely. Worldwide distribution of arsenic in groundwater and associated carcinogenic and non carcinogenic impacts has become a matter of growing concerns during the last thirty years. Besides the public health impacts of arsenicosis, elevated arsenic concentration in groundwater may generate socio-economic consequences for the arsenic affected people and their families.

2.5. Summary of Literature Review

On the basis of this concerning situation, the reviews were made on different aspects of As pollution under sections of global distribution, prediction in groundwater at unsampled locations by using Geostatistics, impact on population and the cost realted to the contamination.

From the literature based on "global distribution of As concentration in groundwater", the following points were noted.

- The natural contamination of As in groundwater has been reported worldwide, the majority of the regions belong to South Asian and South American regions. The severely affected countries include India, Bangladesh, China, Nepal, Cambodia, Vietnam, Myanmar, Laos, Indonesia, The USA. In addition, countries like Argentina, Chile, Hungary, Canada, Pakistan, Mexico and South Africs are also affected.
- Groundwater has been considered as playing the vital role in India to meet the water demands of various sectors, i.e. domestic, industrial and irrigational needs.
- India is one of the fastest urbanizing countries among the world. Due to rapid population growth with rising economic and technological development, utilization of water was increased and severe water scarcity was observed.
- The groundwater fluctuation was reported to be influenced by seasonal movement of groundwater and anthropogenic groundwater withdrawal. Excessive withdrawal of groundwater from shallow tubewell rises the level of arsenic concentration in groundwater.
- Distribution of arsenic concentration in groundwater is geogenic in nature. The hypotheses for geological arsenic mobilization were- Pyrite oxidation over-abstraction and Oxyhydroxide reduction.
- Arsenic concentration in groundwater beyond the maximum stipulated limit of 0.01 mg/L was documented in different zones of the lower delta region of the Ganga-Padma river system. Arsenic concentration was high along the eastern bank and low along the western bank of Hooghly River.
- The arsenic contaminated regions were found to be confined in the shallow aquifer (<150 m below ground level). Arsenic concentration in groundwater was observed to decrease with depth.
- Rice was considered as a potential source of arsenic exposure next to drinking water of the people living in arsenic affected regions
- Positive correlation with arsenic were found between pH, Iron, Molybdenum, Fluoride, Manganese, Sulphate.

- The spatial distribution pattern of arsenic was found patchy with regions holding high arsenic contamination (>200 µg/L) with close vicinity (within 100 m) to low arsenic contaminated groundwater (<50 µg/L).

From the reviews on "prediction in groundwater at unsampled locations by using Geostatistics", the findings were-

- The geostatistical approach is a distribution free method and is dependent on a theory of regionalized variables with the varying values from place to place. Geostatistics represents a proper method of prediction and extensively applied for spatial estimation taking spatial variability into account.
- The objective of Geostatistics is to predict the possible spatial distribution of a property. The property values from locations that are in close proximity, have a tendency to be more similar than the values from locations that are further apart.
- Geostatistical methods were considered as one of the advanced techniques applied for the interpolation of groundwater quality data and the kriging method was considered as more accurate than the traditional interpolation methods.
- The knowledge on spatial distribution of arsenic is important to recognize the complex processes of arsenic concentration variations and spatial predictions in the unsampled regions of the study area
- Geostatistical approaches could be suitable for planners and policy makers to mature the plan of actions for sustainable management of groundwater resources and reduce the polltion.

From the literature survey on "impact of arsenic on population", the following points were found-

- The pathways of arsenic exposure in human body was found to include drinking water, food and non-dietary sources.
- Pigmentation and keratosis was supposed to be specific skin diseases developed by chronic arsenic toxicity. The other effects of chronic arsenic toxicity was observed to give rise different systematic manifestation including chronic lung disease (chronic bronchitis, chronic obstructive or restrictive pulmonary disease, bronchiectasis), liver diseases (non cirrhotic portal fibrosis), polyneuropathy, peripheral vascular diseases, hypertension, nonpitting edema on feet and hands, conjunctival congestion, weakness and anemia. The symptoms developed after the consumption of arsenic contaminated water for a long time. Cancer development in squamous cell, basal skin, lung, uterus, bladder and genitourinary tract is common in later phase of chronic arsenic toxicity
- The Arsenical Skin Lesions (ASL) was found in the people who consumed water with arsenic concentration more than 300 µg/L for a sustained period.

- Four factors were documented to control the appearance of the skin diseases- a) the concentration of arsenic in drinking water b) period of exposure c) volume of daily intake and d) nutritional status
- High concentration of arsenic at early life is considered as a critical period, giving rise to health effects later in life including cancer and overall morbidity and mortality.
- It was observed that arsenical skin lesions were not developed in chidren below 11 years of age, but exceptions occurred where the concentration of arsenic in drinking water was more
  than 1000 µg/L and poor nutrition was associated with more than 500 µg/L arsenic concentration in drinking water.
- The concentration of arsenic in biological samples of the children residing at arsenic affected regions exhibited elevated levels of arsenic in 90% of the cases indicating the manifestation of external symptoms might be a matter of time.
- The development of carcinogenic risk was observed higher in adults than children, while the non-carcinogenic effect was found higher in children than the adult because the child population are exposed to As to a lesser amount of time.
- The children who are exposed to arsenic may show impaired learning and memory, sleep disturbances, abnormality and hearing problem, impairments of higher neurological functions including learning, memory and attentiveness.
- Low amount of calcium, animal protein, folate and fibre had the potential to develop arsenic induced skin lesions and arsenic free drinking water supply could only get rid of the situation.
- The effects of arsenicosis was documented to impact on human wellbeing i.e. labour productivity, lowering income earning capacity, loss of lifetime income due to prolonged disease or death, inter- generational poverty, health status and reduction of school enrolment

From the literature survey on “cost realted to arsenic contamination in groundwater”, the findings are as follows-

- Medical expenses, loss of wages, expenditures to prevent the occurrence of the diseases, changes in life expectancy due to pollution induced diseases are all economically quantifiable aspects of As contamination in groundwater.
- The actual cost would rise each year as the occurrence of arsenic induced illness is also increaseing
- The reduction of arsenic concentration from higher level to the permissible limit is quite beneficial to the households suffering from As induced diseases. Investment for safe drinking water was found economically achievable for them.

- Two primary categories were considered in which safe water approaches fall- switching to alternative As free water source and remediation of As contaminated sources.
- Not so many technologies were found to reduce As concentration from higher concentration to WHO standard of 10 ppb from groundwater.

2.6. Research gap

- Geostatistics can interpolate the distribution of arsenic concentration in groundwater as kriging is considered as one of the most accurate techniques than the traditional interpolation methods.
- There are some other water quality parameters that are correlated with arsenic concentration help to predict the arsenic concentration in groundwater.
- There is a social cost for arsenic affected illness for arsenic affected regions.
- The cost for different arsenic removal technogies are not similar. It is important to find a low cost technology that will help to remediate As from groundwater to meet the permissible limit consistently.
- Due to the exposure of As affected ground water, the study on the vulnerability of the primary school going children who are the future of our society.

2.7. Present Research Context

The As affected districts are found mainly lined up along a linear tract along the river Ganga in Bihar and West Bengal. The occurence of elevated level of As concentration in groundwater was first reported in West Bengal. 79 blocks in 8 districts were found As affected beyond the permissible limit of 10 ppb. The most As affected areas are on the eastern side of the Bhagirathi river in the districts of Malda, Murshidabad, Nadia, North and South 24 Parganas and western side of the districts of Howrah, Hugli and Bardhman. High arsenic contamination is found confined mainly in the aquifers upto 100 m depth, but deeper depth was found also contaminated in some regions.

The present study from parts of Bengal Delta in West Bengal is carried out at district level and designed to explore the spatial distribution pattern of arsenic contamination in groundwater and to estimate the arsenic concentration in groundwater by geostatistical approach at unsampled areas of South 24 Parganas district. South 24 Parganas is one of the highly arsenic contaminated district which is also the second large populated district in West Bengal. The population are forced to drink water with arsenic concentration range of 10-3200 ppb. Spatial heterogeneity in the distribution of arsenic is the most critical part of arsenic contamination, so the prediction of arsenic concentration at a specific location is also diificult. Geostatistical method is a technique that can predict the possible spatial distribution of a property. Most of the earth science data sets are often skewed and show spatial correlation among themselves. The property values from locations that are in close proximity, have a tendency to be more similar than the values from locations that are further apart. In Geostatistical estimation, a property at an unsampled location is estimated on the basis of the spatial correlation characteristics of the property and the values at existing sample location. Geostatistics is used mainly in mining industries, only a few works have been done on arsenic concentration.

Children are the most vulnerable part of a population who are affected by higher arsenic concentration. Education is the basic right for a child, but if a child is going to a primary school located in a high arsenic contaminated region and drinks water, is considered as a health hazard. In Primary schools, children usually come from 1 km radius, so the children are exposed to arsenic both in home and school. The prevalence of the development of arsenic induced illness is found to develop after 11 years of age among the child population. The children who reside in arsenic contaminated region will surely develop the diseases as a result of continuing exposure to arsenic. The impacts of arsenic concentration among them before the age of 10 years are not clearly found.. Apart from causing health issues and death, inadequate safe drinking water gives rise to poverty by increasing health cost, school dropout rate and low work productivity

Recent study predicts arsenic concentration in drinking water source of primary schools located in higher arsenic contaminated blocks by using ordinary kriging. The comparative analysis is to be done between the cost of illness among total population and the cost of arsenic removal technologies in arsenic contaminated blocks of South 24 Parganas.

CHAPTER 3

OBJECTIVE AND SCOPE OF WORK

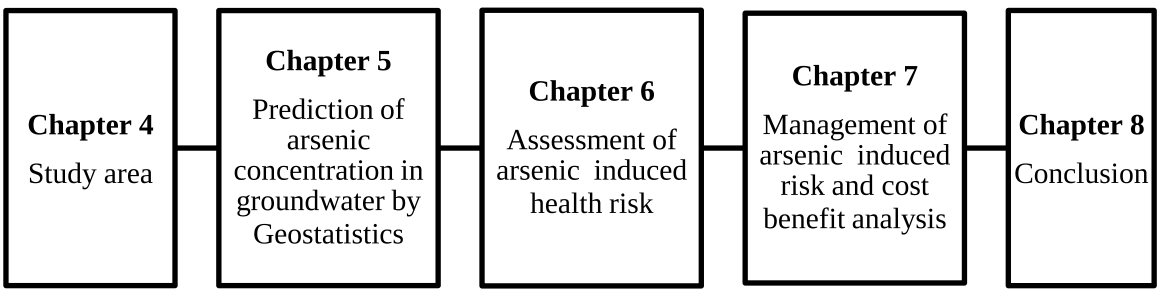
Objective

- Prediction of arsenic concentration in groundwater in an effective and economic way with the help of GIS and Geostatistics.
- Assessment of arsenic induced health and societal risk with the possible mitigation with special reference to primary school going children considering South 24 Parganas as the study area.

Scope of work

- Identification of focus area from South 24 Parganas district on the basis of arsenic concentration in groundwater (more than permissible limit).
- Modeling of the spatial variation of arsenic concentration in the focus area.
- Analysis of the model with hydrogeological characterization of the region towards determination of the cause of arsenic contamination.
- Developing a geostatistical model to estimate arsenic concentration in groundwater in arsenic affected region by using semivariogram and kriging.
- Generation of primary data in the form of site selection, sample collection and sample analysis.
- Estimation of arsenic concentration from tubewells in the focus area through primary and secondary data.
- Determination of the cross correlation among chemical parameters i.e. arsenic, iron and chloride.
- Estimation of arsenic concentration at Government aided Primary Schools in the focus area through secondary data.
- Determination of arsenic risk among the children among different arsenic contaminated zone.
- Determination economic loss due to arsenic induced illnesses on the total population of the focus area.
- Finding out of possible mitigative measures for the minimization of arsenic induced health risks.

Distribution of the chapters in the present study



CHAPTER 4
STUDY AREA

South 24 Parganas district faces difficulties of getting fresh and potable water amidst plenty of water available in a deltaic riverine plain. Most of the population are dependent on groundwater to fulfil their daily drinking water needs. The district suffers from the following groundwater problems (CGWB 2008):

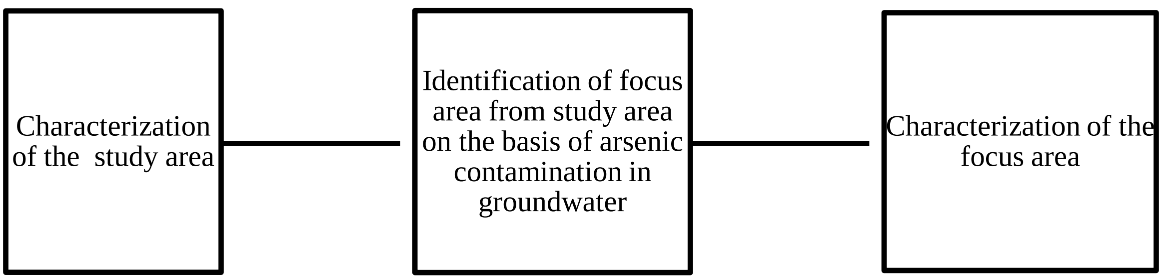
- Arsenic concentration beyond the permissible limit (As concentration ranges from 0 to 3200 ppb)
- Iron concentration more than the permissible limit (Fe concentration ranges from 100 ppb to 7820 ppb)
- Salinity hazards (Cl concentration ranges from 1750 to 6300 ppm)
- Decling trend of groundwater level (in premonsoon 2.5 to 5.4 m and in post monsoon 2.19 to 6.3 m in Baruipur block)

It was found from the literature that the population from the study area consume arsenic contaminated groundwater which cause different types of detrimental illnesses.

4.1. Purpose of the study

South 24 Parganas was selected for the study because the district was considered as one of the most arsenic contaminated district of West Bengal. As the groundwater of the total district is not arsenic contaminated, the first thing done in this study was to identify the focus area on the basis of arsenic concentration reported in the blocks from secondary data. The further study was done in the arsenic contaminated blocks only.

4.2. Scope of the study



4.3. Characterization of the study area

4.3.1. Location and Geographical Extent

South 24 Parganas district is located between 21^{o}29´N and 22^{o}33´45´´N latitude and 88^{o}3´45´´E and 89^{o}4´50´´E longitude. It is the largest and second most densely populated district of West Bengal located at the south east corner of the state covering an area of 9960 sq km. The district is surrounded by Kolkata in the north, Howrah and Purba Medinipur in the west, North 24 Parganas in the east and Bay of Bengal in the south of the district. It is situated in the Gangetic Delta Plain and shares a international border with Bangladesh in the east. Sundarban- the largest mangrove forest ecosystem of the world is situtated in most of the southern and eastern part of the district. The district has 29 Community Development Blocks (C.D. Blocks) and 7 Municipalities under 5 sub divisions- i) Alipore Sadar ii) Baruipur iii) Canning iv) Diamond Harbour and v) Kakdwip (Census, 2011). Each block has various Gram Panchayats (village unions) and each Gram Panchayat is made up of several villages. There are total 111 Census towns (urban units) and 2042 villages are distributed in the 29 CD blocks of the district. The population density of the district is 819 inhabitants per square kilometer and the population growth rate over the decade 2001- 2011 was 18.2%. The climate of the district is hot and humid throughout the year with well distributed rainfall during the monsoon season. The maximum and minimum temperature are 37^{o}C and 9^{o}C respectively recorded during the year 2011 at Diamond Harbour. The soil of the district is classified into two broad categories i.e. non saline soils and coastal soils of tidal origin.

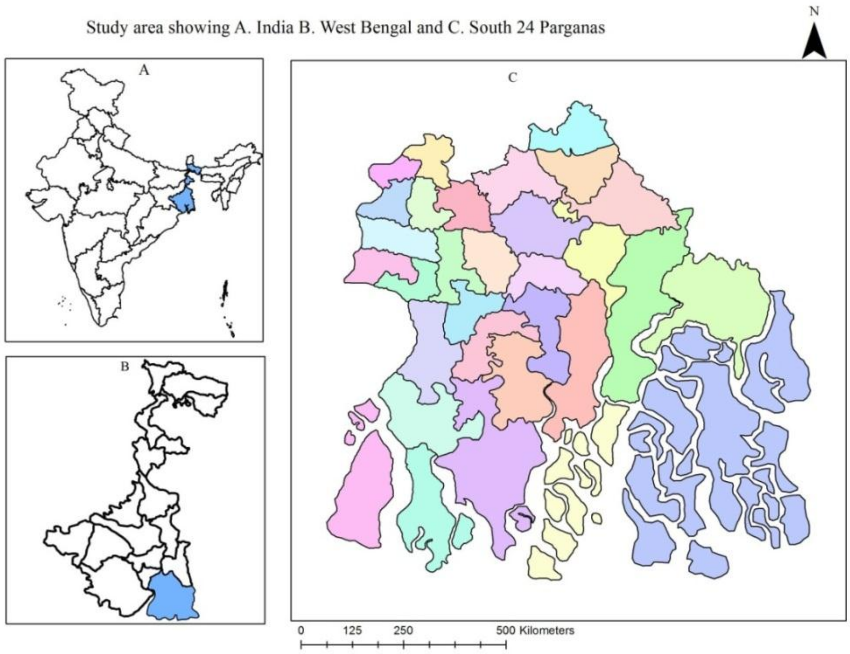


Fig: 4.1. Study area showing India, West Bengal and South 24 Parganas

In fig 4.1, Map of India (collected from Survey of India Web Map Service, n.d.) that shows West Bengal, Map of West Bengal (Egiye Bangla n.d.) showing South 24 Parganas and map of South 24 Parganas (ISGPP, Panchayats and Rural Development Department). The maps were collected for determination of study area. The maps were then digitized by ArcGIS (version 10.2.2) software.

The district is blessed with sufficient amount of surface and groundwater, but the geo hydrological settings, sea water intrusion, soil salinity and high content of soil clay create the major problems. The adopted management strategy for water resource is not good enough for the district. So, the population of the district have to suffer all year round to get the clear potable water. The district is also vulnerable to arsenic contamination through drinking water and the dietary consumption of rice, vegetables and fruits which are produced with arsenic contaminated irrigated ground water.

4.3.2. Population growth

The district of South 24 Parganas had a population of around 81.6 lakh in 2011 which was almost 9% of the state population (Census 2011). According to the Census data from 1971 to 2011, the population growth of the district was found increasing. In the present study the population growth for the last 50 years has been summarised in fig 4.2.

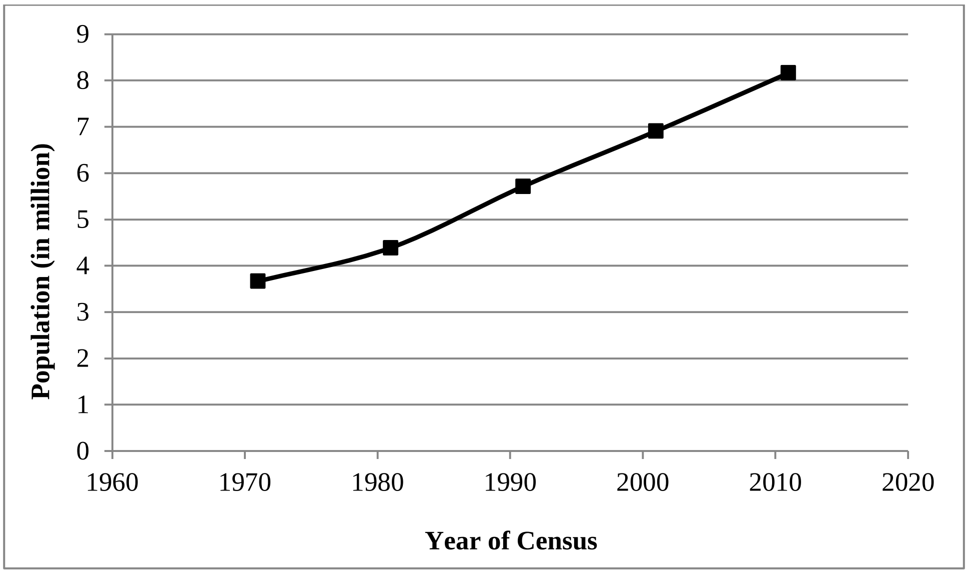


Fig: 4.2. Population growth of South 24 Parganas in last 5 decades (Census data 1971-2011)

From fig 4.2., it was observed that the population has been rising at a more or less steady rate in the last 5 decades. The population of the district was found increasing from 3.66 million to 9.64 million implying a nearly 2.63 fold growth during the last 50 years. The decadal growth rate of population between 1991 and 2001 was 20.85% which was higher than the state average, 17.77% (District Human Development Report, 2009).

4.3.2.1. Rural and urban population growth

South 24 Parganas was considered as the largely rural district. The urbanization is restricted to the regions located close to Kolkata (District Development Report, 2009). In fig 4.3., the growth of urban and rural population in South 24 Parganas has been discussed for the present study.

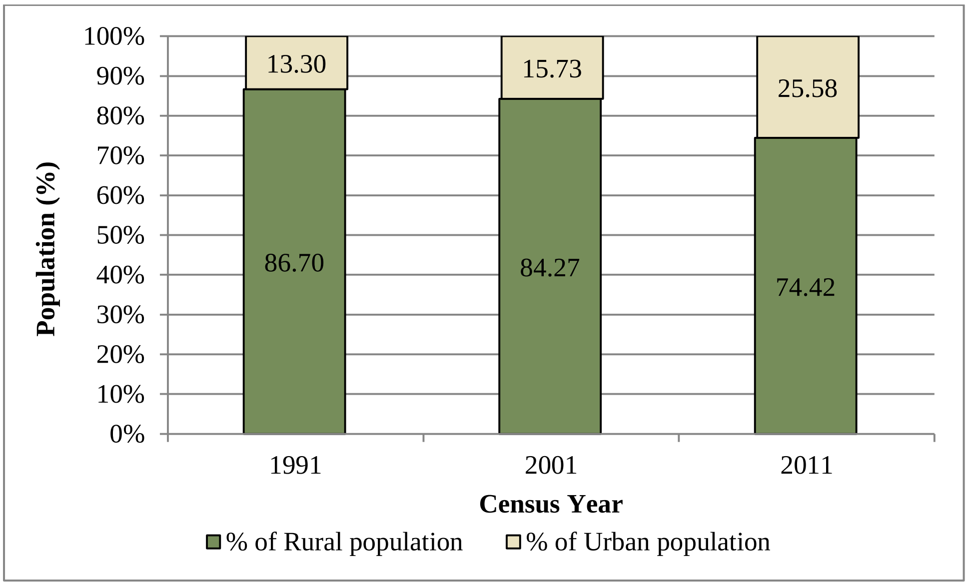


Fig: 4.3. Population growth of rural and urban population of South 24 Parganas (Census 1991-2011)

The major population of South 24 Pargana live in rural areas, but the rate of urbanization is very high. The district met an increasing share of urban population over time. From fig 4.3. it was observed that approximately 25.57% of the population was reported to live in urban areas in 2011 whereas the population share was 13.3% in 1991. The close proximity to Kolkata, the largest metropolitan city of Eastern India is the main reason for the increase of urban population (Human Development Report 2009). The high population pressure puts a gigantic burden on natural resources of the district. As a whole 74% population still are in rural areas. Decresing trend of population was observed in the rural areas due to the unavailability of minimum basic facilities.

4.3.3. Groundwater Resource

South 24 Parganas faces crisis of fresh and drinking water supply though the district is bounded by plenty of water obtainable from the deltaic riverine plain. So, the district has to rely on groundwater for drinking purposes.

4.3.3.1. Aquifers

In South 24 Parganas two broad group of aquifers were found**-** The upper group of aquifers contain saline water where the lower group of water were identified as fresh water. The potential freshwater bearing aquifers were found within 20-160 m bgl in the northern part and within 160-

360 m bgl in the central and southern part of the district. The thickness of individual fresh groundwater bearing aquifers varies between 5-30 m bgl and thick clay layers differentiate each aquifers. The fresh water bearing aquifers from northern part of the region is affected by arsenic contamination (Misra and Nag, 2009).

In the present study, the aquifer characteristics was found different for both arsenic contaminated and arsenic safe blocks. The aquifer zonation data was found from PHED (Public Health Engineering Department) (2003) portal and it was observed that 9 blocks were arsenic contaminated and the other 20 blocks were arsenic free in South 24 Parganas.

A. Aquifer characteristics of arsenic contaminated blocks

Almost same pattern of arsenic zonation was observed among the arsenic contaminated blocks. In fig 4.4. aquifer zonation of arsenic contaminated blocks were summarized.

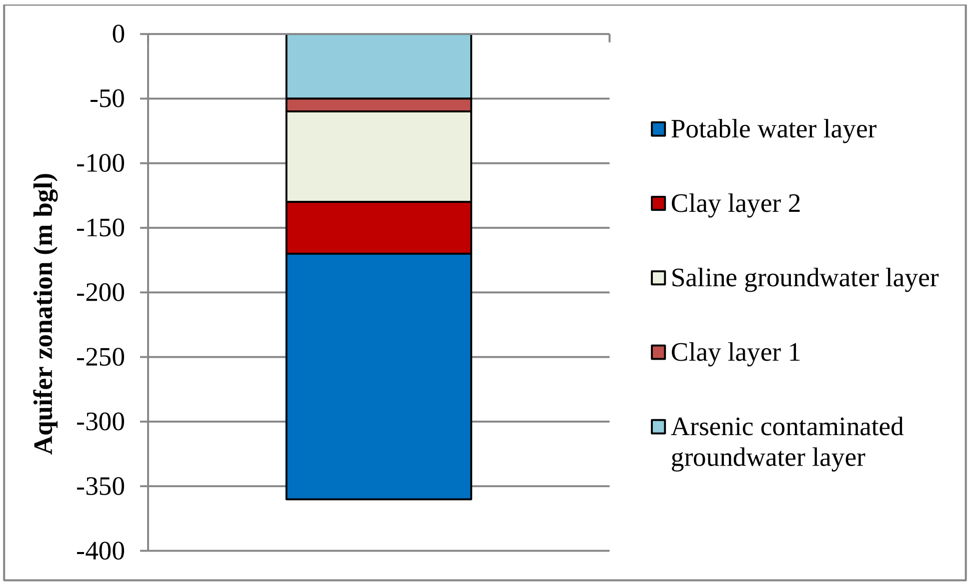


Fig: 4.4. Aquifer zonation of arsenic contaminated blocks in South 24 Parganas

From fig 4.4. it was observed that arsenic contaminated groundwater was present mostly within the depth of 50 m below the ground level. The saline water is present below the arsenic contaminated water present in between 50-130 m bgl. There is a clay layer separating the arsenic contaminated water and saline water in each block. The potable water is present below 150 m and there is also a clay band separating the saline water and potable water. It was found from the literature that approximately 3 million tubewells in Bangladesh with a depth of 10 to 50 m contain arsenic concentration more than 50 ppb. Only 1-5% of deep tubewells was observed to exceed the safe level for arsenic, while the value was 27-46% for the shallow depth tubewells. The bounding depth between the shallow and deep aquifers were noticed to be controlled by the local geology that contained the aquifer characteristics and confining clay units. The regional depth variance of arsenic concentration in groundwater was observed to follow a bell shaped curve with the maximum concentration at the depth of 15-30 m in Bangladesh. The rise of arsenic concentration was observed up to a depth of 10-20 m and then decreased from 50 to 150 m (Chakraborty et al, 2015**)**

B. Aquifer characteristics of arsenic free blocks

In fig 4.5. aquifer zonation in arsenic free blocks were summarized.

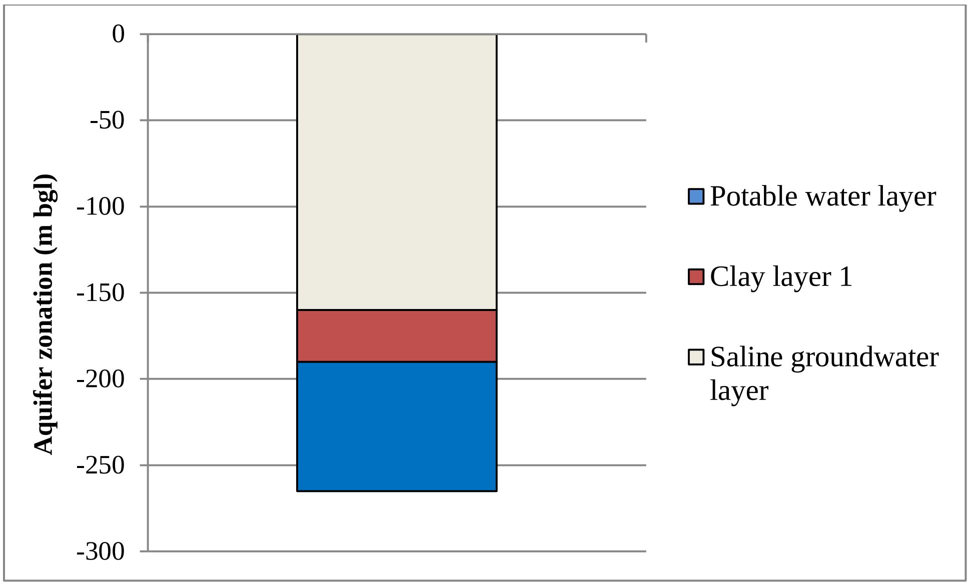


Fig: 4.5. Aquifer zonation of arsenic free blocks present in South 24 Parganas

From fig 4.5. it was found that the saline water layer is present within 150 m below ground level in the arsenic safe blocks. The potable water layer is present from 200 m down from ground level. The saline water layer and potable water layer are separated by a thick clay layer. The characteristics of the aquifers were mentioned in a study done by Bhattacharya, Chatterjee and Jack in 1997. From that study it was observed that the characteristics of aquifer differs from north to south part of the Bengal Delta from open to semi confined type towards the south. The groundwater aquifers of Malda, Murshidabad and Nadia are of unconfined in nature whereas the aquifers from Bardhaman, North and South 24 Parganas are semi confined.

The aquifer zonation was done in the study area because arsenic concentration was estimated in shallow and deep depth aquifer both.

4.3.4. Arsenic contamination scenario in the arsenic contaminated blocks

For the present study, the groundwater arsenic contamination data was collected from NRDWP-IMIS (National Rural Drinking Water Programme- Integrated Management Information System) portal governed by Jal Jeevan Mission in the year of 2017-18. It was a large dataset, only the data suitable for the present study was kept and that data was used for rest of the study.

4.3.4.1. Descriptive statistics of arsenic concentration in groundwater

The number of tubewells with different level of arsenic concentration was summarized in table 4.1.

Table: 4.1. Descriptive statistics of arsenic in the blocks

Block	No. of tubewells	Arsenic concentration in ppb						
		% of As affected tubewells					Max	Mean
		0-10	11-50	51-150	151-350	more than 350		
Baruipur	330	11.82	12.73	24.55	30.91	20.00	2320	222.1
Bhangar I	120	20.00	9.17	33.33	20.83	16.67	818	169.2
Bhangar II	135	3.70	18.52	51.11	22.22	4.44	762	125.4
Bishnupur I	78	82.05	15.38	1.28	1.28	0.00	240	11.2
Jaynagar I	63	50.79	9.52	25.40	11.11	3.17	610	66.8
Jaynagar II	65	41.54	18.46	23.08	16.92	0.00	570	71.2
Magrahat II	84	90.48	8.33	1.19	1.19	0.00	220	7.28
Sonarpur	83	32.53	34.94	20.48	3.61	8.43	2400	120.2
Mathurapur I	11	72.73	27.27	0.00	0.00	0.00	71	6.5

From the table 4.1, it was found that maximum arsenic concentration was reported in Sonarpur and Baruipur block. The mean arsenic concentration was observed highest in Baruipur block followed by Bhangar I, Bhangar II and Soanrpur. In a study done by Chakraborty et al. (2015) in Bangladesh, the observed mean and median arsenic concentration was found 55-60 ppb and 4 ppb respectively considering the arsenic concentration of the tubewells below detection limit to be half of the detection limit.

4.3.4.2. Percentage of tubewells that contain arsenic more than permissible limit

In fig 4.6. the percentage distribution of tubewells containing arsenic more than 10 ppb was mentioned.

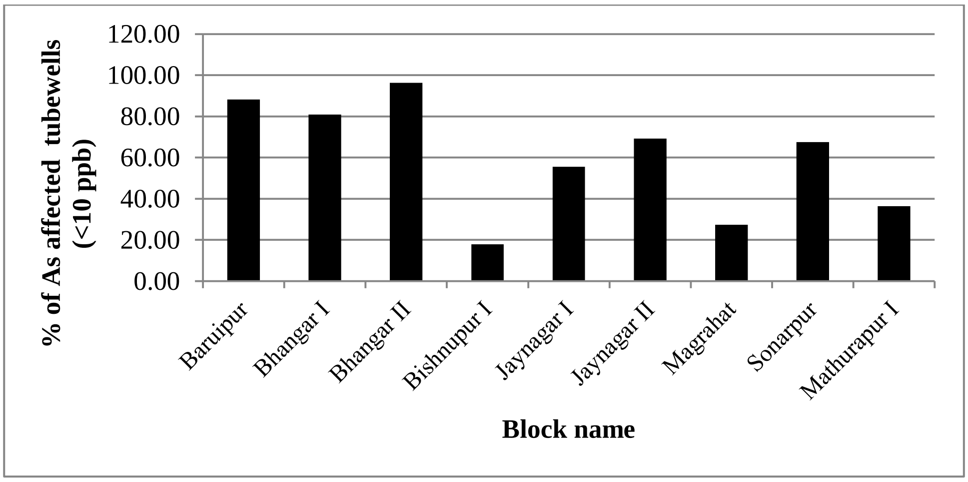


Fig:4.6. Percentage of tubewells containing arsenic more than the permissible limit

In fig 4.6. the diagram showed the percentage of tubewells that contained arsenic more than 10 ppb. In Baruipur, Bhangar I, Bhangar II, Sonarpur and Jaynagar II block, more than 70% of tubewells were found that contained arsenic more than the permissible limit.

4.3.4.3. Distribution of arsenic concentration in different depth

The distribution of arsenic concentration was observed heterogeneous showing several anomalies concerning spatial and vertical distribution pattern. The groundwater from the shallow aquifer was found enriched with inorganic arsenic in West Bengal. In fig 4.7. distribution of arsenic concentration among different depth was summarized for the present study.

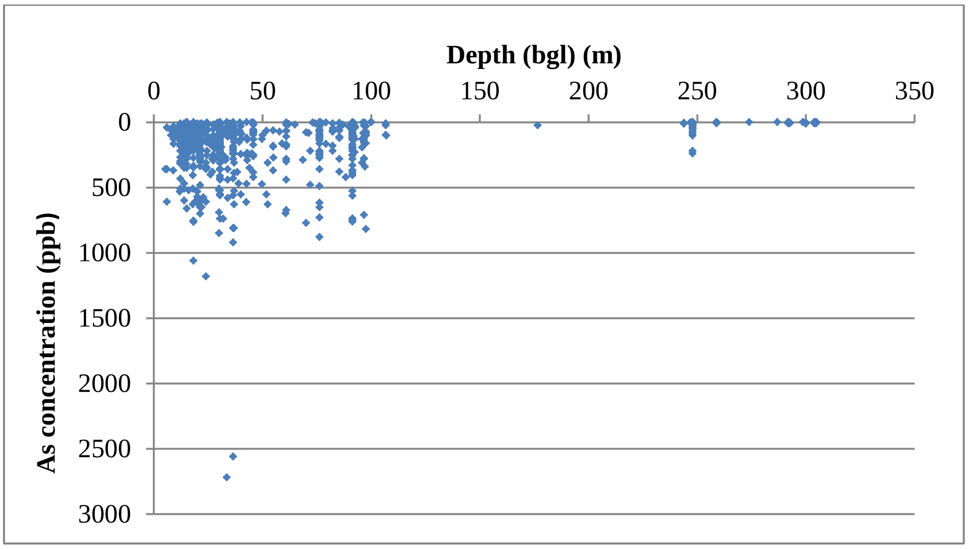


Fig: 4.7. Distribution of arsenic concentration at different depth in South 24 Parganas

From fig. 4.7. it was observed that high arsenic concentration (more than 10- 1000 ppb) was generally found in shallow aquifer with depth less than 100 m below ground level and average depth of the tubewells were 42 m. The concentration of arsenic increased upto depth of 100 m and decreased with higher depth, more than 150 m below ground level. Arsenic concentration more than 1000 ppb was found in 4 points. 89.64% of arsenic concentration ranges from 0-500 ppm and 10.51% of arsenic ranges from 501-3000 ppb are present within 100 m below ground level. 100 m depth as shallow depth and 101- 300 m as deep depth was considered for the present study. The similar studies were done in the Bengal basin region and the results showed that the highest arsenic concentration was found to be restricted within 6-70 m bgl in the western part of the basin formed by the late Pleistocene-Holocene sedimentary settings and the zone was called as the 'arseniferous unit' of the Bengal Basin. (Kinniburgh et al 2003). An depthwise increase in the number of arsenic contaminated tubewells was reported in Bangladesh, from 25% at 8-10 m to 75% between 15 and 30 m and 10% at 90 m (Van Geen et al, 2003). The higher Arsenic concentration are mainly found in the shallow, Holocene aquifers, while lower concentrations are observed in deeper aquifers (50-100 m). (Charlet and Polya, 2006) . Approximately 60% of wells located in the Ganges Brahmaputra Delta plain are contaminated with arsenic, within the shallow aquifers in the Meghna river system and coastal plains 80% of the wells are highly contamianted (Chakraborty et al, 2015).

In present study, shallow and deeper depth both were considered. The range of spatial variability of arsenic concentration was much higher in shallow depth.

4.3.4.4. Spatial distribution of arsenic

The spatial distribution map was prepared with the help of ArcGIS (Version 10.2.2) from the arsenic concentration data (mentioned in 4.3.4) in shallow tubewell for the present study. In fig 4.8. the spatial distribution of arsenic concentration in shallow tubewell has been described.

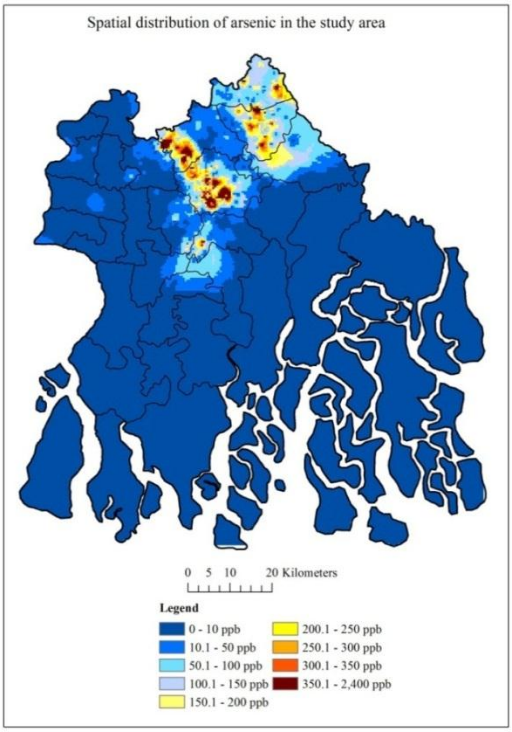


Fig: 4.8. Spatial distribution of arsenic concentration in shallow tubewell in South 24 Parganas

In fig. 4.8, arsenic concentration below 10 ppb and above 10 ppb was found in distinct clusters and no systematic pattern was apparently noticed in shallow tubewell. Spatial distribution of arsenic was found widely varying in all the blocks. The blocks in close proximity to Kolkata were found affected by higher arsenic concentration other than the blocks located far away from Kolkata. Higher arsenic contaminated zones were surrounded by lower arsenic contaminated zone and vice versa. The arsenic affected blocks were located in the northern part of the study area. The blocks from the southern part of the study area were arsenic free. Only the arsenic contaminated blocks were kept for the further study and identified as the focus area of the study. There are very small patches of arsenic concentration (10-50 ppb) was observed outside the focus area. These areas were not considered in the present study. From a study on spatial variability of arsenic done by Chakraborty et al. (2015), it was found that a wide range of arsenic concentration was noticed to the arsenic concentration at a local scale (well to well variability), which made the prediction of arsenic concentration from the unsampled wells very difficult, even the arsenic concentration from the neighbouring tested wells were known. The pattern of arsenic distribution was found to follow the depth and geological setting of the region.

4.4. Identification of the focus area

The focus area was identified on the basis of distribution of arsenic concentration in shallow tubewell in the district for the present study. In fig 4.9 the focus area was identified for the present study.

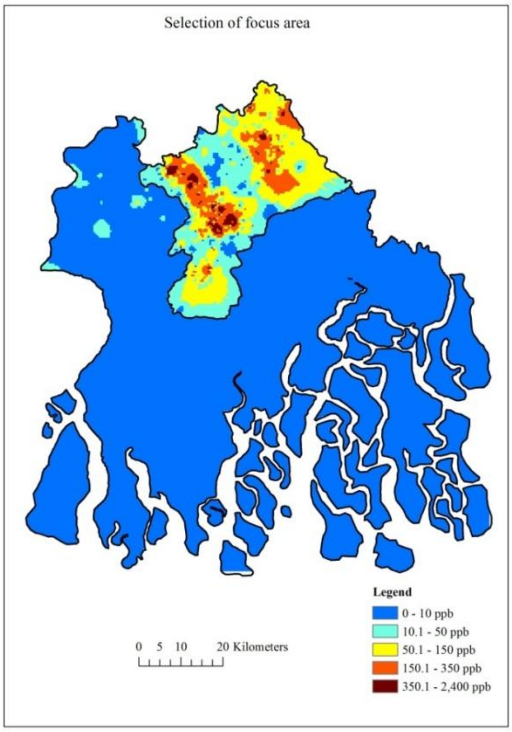


Fig:4.9. Identification of focus area in South 24 Parganas

In fig. 4.9. only the regions with more than 10 ppb arsenic concentration was selected for the study. The map was drawn in ArcGIS (Version 10.2.2) with the help of Inverse Distance Weighting (IDW) interpolation method. Arsenic contamination in groundwater is a natural phenomenon, any boundary couldn't be set up for the spatial distribution. In the present study total Baruipur, Bhangar I, Bhangar II and Sonarpur blocks and part of Bishnupur I, Canning II, Jaynagar I, Jaynagar II, Magrahat II, Mandiarbazar and Mathurapur I were considered to be located in the focus area where arsenic concentration was found more than permissible level. Bishnupur II and Budge budge II were not included in the focus area because they formed small clusters outside the main arsenic contaminated region. The range of arsenic concentration was observed 0-2400 ppb in the focus area. In the focus area, the light blue portion denotes arsenic concentration 10-50 ppb, the yellow portion contained arsenic concentration 51-150 ppb, the orange part denotes arsenic concentration 150.1 to 350 ppb and the red points denotes arsenic concentration 350.1-2400 ppb. The almost identical patterns are observed in the Nadia district in West Bengal and Faridpur Municipality of Bangladesh (Pal et al, 2002). It indicated the consistency found in widely separated areas with the similar pattern of small clusters of arsenic contaminated region surrounded by safe water zone for the total arsenic affected region of the delta.

4.5. Characterization of the focus area

The occurrence of arsenic in groundwater was found dependent on the local geology, hydrology, geochemical characters, land use pattern, fresh organic matter in sediments and different anthropological activities (Chatterjee et al. 2005). In present study, geological, geomorphological, geohydrological and groundwater fluctuation maps were prepared to characterize the study area, The District Resource map was collected from Survey of India and Water Table Fluctuation map was collected from Central Ground Water Board (CGWB). The Geological, Geomorphological and Geohydrological maps were prepared from the District Resource map. The Pre and Post monsoon groundwater fluctuation map was prepared from Water Table Fluctuation map. The maps were prepared with the help of ArcGIS (Version 10.2.2).

The focus area is located in the northern part of the district comprising of high arsenic contaminated region of the district. Concerning the source of arsenic, Mandal et al. (1996) studied that a single rural Water Supply Scheme (RWSS) of PHED supplying groundwater to some villages of Maldah, alone was found withdrawing 147 kg of arsenic from groundwater in 1 years that means the source of arsenic may be geological.

The focus area is made up of 608 villages and 3 municipalities. Due to increasing population, the demand for water mainly for domestic purposes was found to be risen up by many folds. Groundwater is the main source of water in this region. John and Das (2020) studied that continuous withdrawal of groundwater from aquifers has created a trough due to depletion of groundwater. In rural areas, people are completely dependent on groundwater collected from tubewells. Extensive use of groundwater causes unintended exposure of a significant proportion of the population to elevated level of arsenic in groundwater, leading to widespread incidents of arsenic induced diseases.

4.5.1. Geological characters

The geological map of the focus has been mentioned in fig no. 4.10.

In fig 4.10. it was seen that the focus area is located mostly in the Arambagh formation, a small part is situated in the Present Day Deposit. A small belt of active estuarine deposit was found in between Arambagh formation and present day deposit. The detail of the map has been discussed in table 4.2.

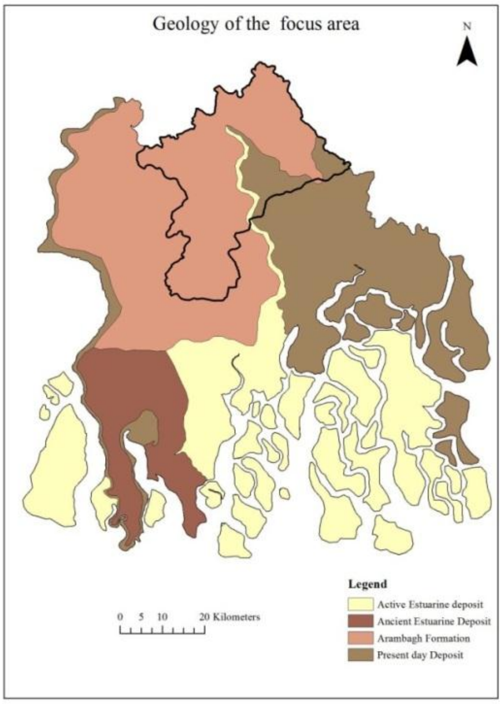


Fig: 4.10. Geological map of the focus area (District Resource Map, Geological Survey of India, 2007)

From table 4.2. it was observed that the focus area is located at the Gangetic Delta Plain and formed by the late Holocene to Recent sediment deposition from the River Ganges. The Ganges Delta are made up of multilayered unconfined to locally confined aquifers in the shallow alluvial deposits and confined in the deeper alluvial deposits. The groundwater level has been observed to lie within a few meters of the surface and fluctuated with the annual dry and wet season conditions. A similar study was done by Neidhardt et al. (2013) and observed that higher arsenic concentration was found in young Holocene sediments at 20-40 m bls, whereas Pleistocene aquifers are considered as primarily arsenic free.

From the literature survey, it was found that the western part of Hooghly river is free from arsenic contamination and it is made up of early Holocene older alluvial plane deposition overlain by alluvial fans of Damodar River. The aquifer sediments are made up of different stack of finning upward cycles of different thickness, the components from top to downward are clay with occasional intercalatery thin peat bands, silty clay, silty sand, fine and minor medium sand. (Pal et al, 2002)

Table: 4.2. Geological composition of the focus area (District Resource Map, Geological Survey of India, 2007, SWID, 2016)

Deposition type	Sedimatary deposit	Geological characters	Time period	Lithology	Aquifer
Arambagh formation	Fluvial	alternate layers of sands, silts and dark grey clays with geomorphic features like natural levee and flood basin zone	Middle Holocene	Flood plane of river basin with levee, flood basin zone etc	Aquifer with primary intergranular porosity
Present day deposit	Fluvial	very fine sands and silts with geomorphic features like channel bars, point bars and meander scrolls	Upper Holocene	Lower active tide dominated deltaic plane with interbanded layers of sand and silts	Deeper aquifers with under flowing condition and shallow brackish aquifer
Active Estuarine deposit	Marine	Interdistributory supratidal flat with thin layer of greyish black clay blanketting horizons of different tidal regime	Upper holocene	The dominated delatic plane with greyish black clay	Fresh water overlaying by saline groundwater

In the present study, arsenic contamination in the focus area has been considered as a geological problem. The shallow subsurface sediments are rich in arsenic and the shallow groundwater exhibits arsenic pollution at several small patches. There are safe zones of groundwater in the shallow aquifer. The safe zones always contain a thick clay cap which should be used as a deciding parameter for locating future shallow tubewells in those areas. New incidences of arsenic concentration has been found in the adjacent areas due to emergence of new data, increased mass awareness on arsenic and more wells being tested.

4.5.2. Geomorphological and geohydrological characters

The focus area is present in the Bengal Delta, the largest Delta in the world (Akter et al. 2016). It drains the most sediment producing mountains in the world through the three main river systems: the Ganges, Brahmaputra and Meghna and the rivers carry the largest sediment load to the delta. In the present study, the geomorphological and geohydrological maps (fig 4.11) were prepared with the help of ArcGIS (Version 10.2.2) to understand the nature of the focus area.

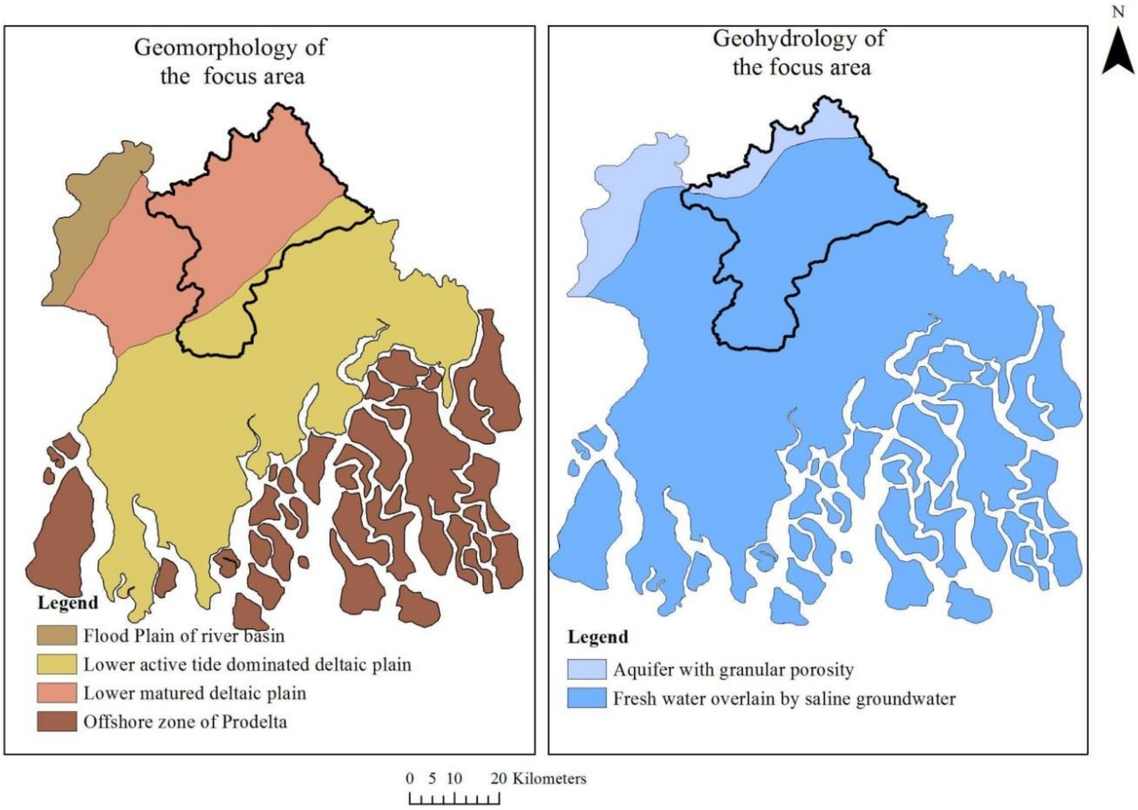


Fig: 4.11. Geomorphological and Geohydrological map of focus area (District Resource Map, Geological Survey of India, 2007)

In Geomophological map (fig. 4.11), the major part of the study area is present in the Lower matured deltaic plain, only a small portion of south and east part is located in the Lower active tide dominated deltaic plain.

In Geohydrological map (fig. 4.11), the prominent part of the focus area is occupied by fresh water overlain by saline groundwater, only the upper part consist of the aquifer with granular porocity. Bhattacharya, Chatterjee and Jacks (1995) reported that in South 24 Parganas, the aquifer was found semi confined. The characteristics of the aquifer change gradually from open to semi confined character towards the southern part of the study area.

4.5.3. Groundwater table fluctuation in pre monsoon and post monsoon period

Withdrawal of groundwater for irrigation purposes was observed from the time of India's green revolution to overcome the annual dry season to expand the agricultural productivity. Approximately 10 million irrigation and tap well were installed in Bengal Basin during last four decades which supply groundwater to more than 100 million people and the hydrology has been affected at the regional scale. The sediments of the Bengal Delta Plain is considered as one huge hydraulically interconnected aquifer system, extensive withdrawal of groundwater can provoke drawdown of arsenic enriched shallow groundwater into deeper aquifer sections. Massive extraction of groundwater can cause a local depression cone in the surface near shallow aquifer, occuring subsequent attraction of a nearby arsenic plume and drawdown of arsenic rich groundwater in direction of the deep pumping well.

The fluctuation of groundwater table during pre monsoon and post monsoon was done in the present study and it was summarized in fig. 4.12.

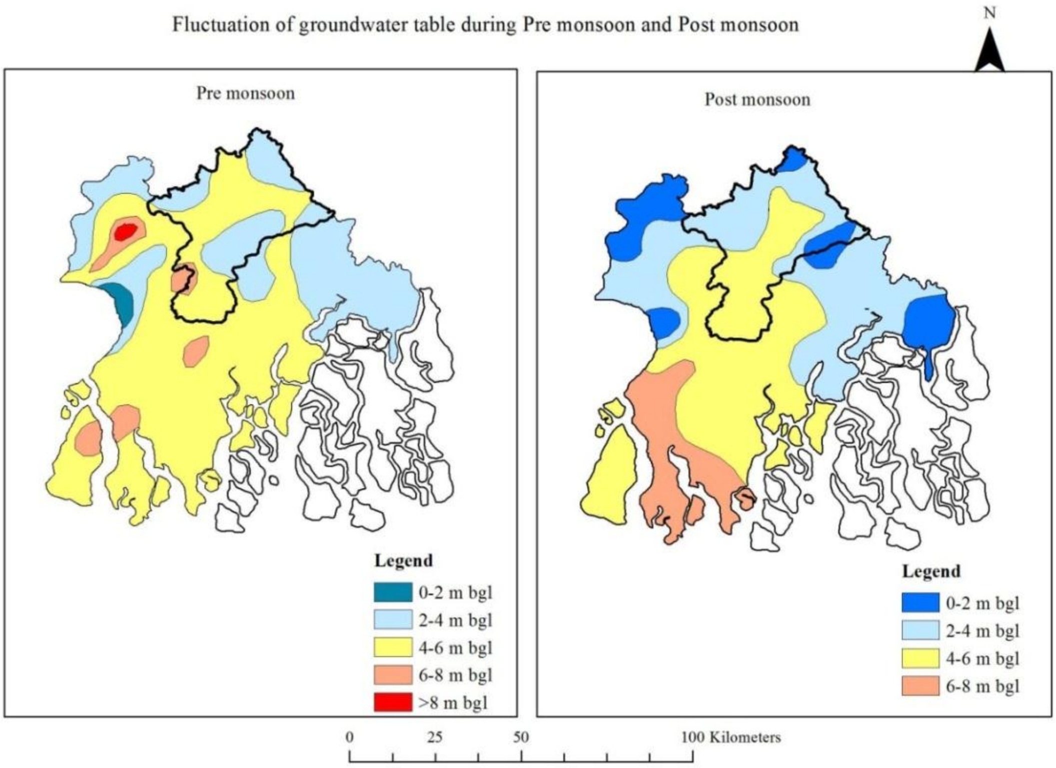


Fig: 4.12. Groundwater table fluctuation map in Pre monsoon and Post monsoon period in focus area

From fig no 4.12 it was observed that being a monsoon fed district, the variation in seasonal water level in South 24 Parganas depends upon the amount of rainfall. In pre monsoon period the maximum fluctuation is 4-6 m bgl in most of the focus area, only a small part has groundwater level 2-4 m bgl. In post monsoon time the groundwater table is present in 2-4 m bgl and 4-6 m bgl. The maximum groundwater fluctuation is 6 m bgl in both pre monsoon and post monsoon period.

The raise and fall of groundwater table may develop different chemical reactions and successive changes in the chemistry of groundwater.

4.5.4. Spatial distribution of Iron and Chloride in groundwater

The groundwater of the focus area also contain iron and chloride. The spatial distribution of arsenic, iron and chloride are mentioned in fig no. 4.13 in the present study.

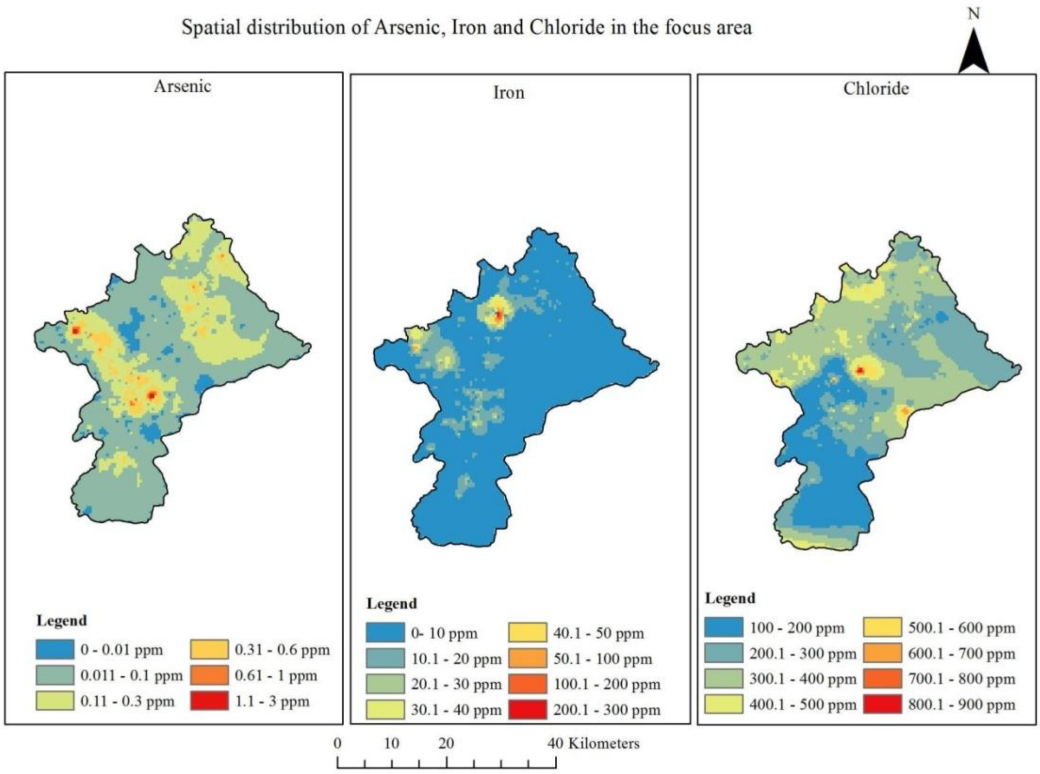


Fig: 4.13. Spatial distribution of arsenic, iron and chloride in groundwater of focus area

From fig 4.13, it was observed that the distribution of iron concentration in the focus area is also patchy in nature like arsenic. The maximum concentration (200-300 ppm) was found in the upper part of the focus area. The rest of the part has iron concentration within 10 ppm. Chloride concentration is very high along the total focus area. Most of the parts have chloride concentration more than 400 ppm. In the central part of focus area the concentration reaches almost 900 ppm.

Bhattacharya, Chatterjee and Jack (1997) observed that the arsenic mobilization process works better in presence of iron in groundwater. Most of the arseniferous groundwater contain higher level of ferrous iron and phosphate. Groundwater quality can be degraded by unplanned groundwater extraction and land-use pattern. The experiences of the pumping from the deeper aquifer when arsenic concentration increased with time specify that the quality of water is influenced by the pumping rate.

4.5.5. Occurrence of arsenic concentration in the focus area

The focus area was selected on the basis of arsenic concentration more than 10 ppb. The occurrence of arsenic concentration in groundwater was classified initially into 12 classes- 10-50 ppb, 51-100 ppb, 101-200 ppb, 201-300 ppb, 301-400 ppb, 401-500 ppb, 501-600 ppb, 601-700 ppb, 701-800 ppb, 801-900 ppb, 901-1000 ppb and 1001-3000 ppb in present study. In fig. 4.14. the occurrence of arsenic concentration in groundwater was summarized.

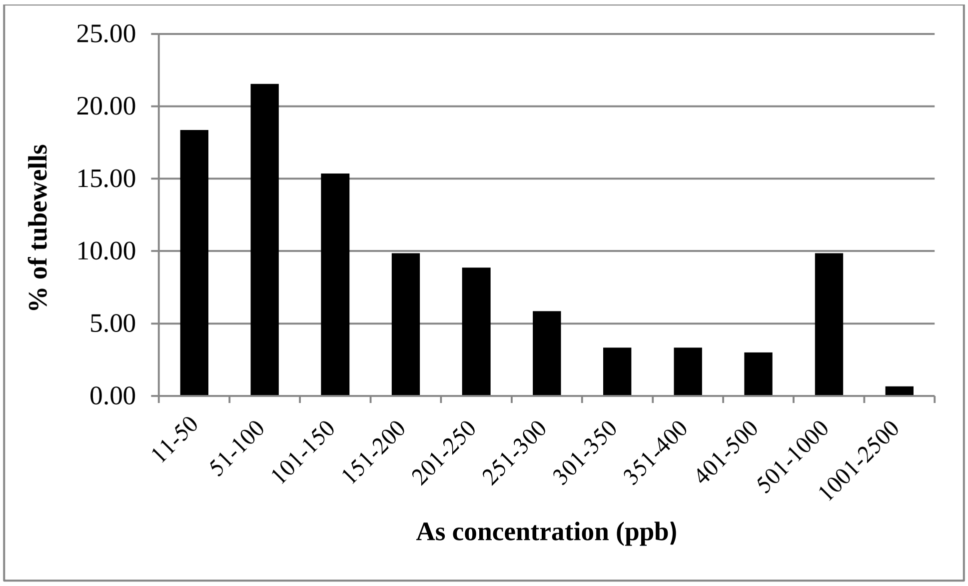


Fig: 4.14. Occurrence of arsenic concentration in groundwater of focus area

The occurrence of arsenic concentreation was mainly found maximum in 10 to 300 ppb, after 300 ppb, the occurrence was found decreasing. 10 to 50 ppb and 51 to 100 ppb arsenic concentration was observed among 18% and 22% of tubewells respectively.101-150 ppm among 15%, 151-200 ppb among 10%, 201-250 ppb in 9%, 251-300 ppb among 6%, 301-350 ppb among 3%, 351-400 ppm among 3%, 401-500 ppm among 3%, 501-1000 ppb among 10% and 1001-2500 ppm among 1% tubewells were observed.

4.5.6. Classification of the focus area

On the basis of the occurrence of groundwater arsenic in the present study, the focus area has been classified into different zones (fig 4.15) because the impact of arsenic concentration was found different in different arsenic concentration level. The focus area was classified into 4 wider regions on the basis of occurences of arsenic concentration in the focus area. The zones were- zone I (0-10 ppb), zone II (10.1- 100 ppb arsenic concentration among 40% of tubewells), zone III (100.1-300 ppb arsenic concentration in 40% of tubewell) and zone IV (more than 300 ppb to 2500 ppb arsenic concentration among 20% of tubewell). The zone II was found as the most sensitive zone and the concentration was found predominant in the focus area. In safe zone (zone I), the arsenic concentration is within permissible limit stipulated by BIS (2015) and WHO (2012). The differences between arsenic related health costs with different arsenic concentration zone were found in a study done by Mohanta et al. (2016).The different health cost was estimated in low (less than 100 ppb), medium (between 100-300 ppb) and high (above 300 ppb) arsenic contaminated zone. The health cost was considered to be based on the cost related to increase of 1 μg of arsenic concentration per litre of water.

Chakraborti et al (2009) made this type of zone classification of arsenic contaminated region in West Bengal (<10 ppb, 10-19 ppb, 20-29 ppb, 30-39 ppb, 40-49 ppb, 50-99 ppb, 100-299 ppb, 300-499 ppb and 500-1000 ppb).

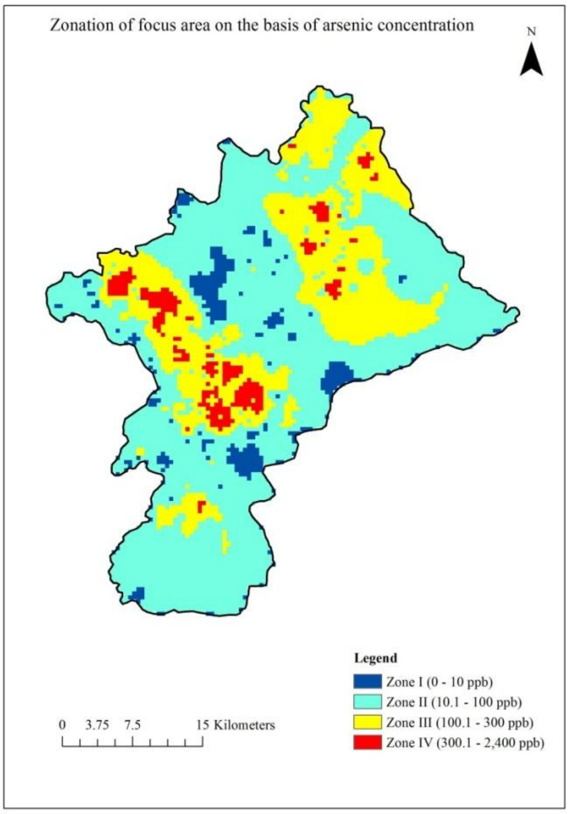


Fig: 4.15. Classification of focus area on the basis of arsenic concentration in groundwater

From the fig no 4.15 it can be discussed that a very small region was found arsenic safe in the focus area. Arsenic concentration in most of the part of the focus area was found in zone II followed by zone III. The zone IV were surrounded by zone III. The higher concentrations were observed in Baruipur, Sonarpur and Bhangar I and II blocks. Only rural areas have been considered in present study because there are no alternative sources of arsenic safe water in the villages in comparison to the municipal areas.

4.6. Observations from the present study

From the present study it can be understood that arsenic contamination in groundwater and the health hazards related to arsenic has been considered as a "high profile problem" throughout the globe. The aquifers containing arsenic are identified and measures are taken to remediate the problem.

South 24 Parganas has been considered as the one of the most arsenic contaminated district of West Bengal. In last 20 years the percentage of urban population increases almost 2 times more and percentage of rural population was found decreasing. Kolkata, being the main city of the eastern part of the country, it played a critical role to attract the massive population from the surrounding districts. So, the urban agglomeration was found to develop due to adjacency of Kolkata. From the literature it was found that people from South 24 Parganas migrates because of economic reasons, unsustainable agriculture, lack of oppurtunities, environmental reasons like cyclones and floodings and social reasons. The urbanisation causes an extensive pressure on the groundwater resource of the study area.

In Baruipur, Bhangar I, Bhangar II, Jaynagar II and Sonarpur blocks, the percentage of tubewells that contained arsenic more than 10 ppb was found in more than 70% tubewells. Shallow aquifer is the most contaminated aquifer in South 24 Parganas. Higher level of arsenic concentration was confined in shallow aquifer (within 100 m bgl). From 101 to 300 m depth was considered as the deeper depth in the study. No significant pattern of spatial distribution of arsenic concentration in groundwater from shallow aquifer was observed. Separate clusters of higher arsenic concentration was observed. The largest cluster was observed in western part of Sonarpur and Baruipur block with epicenters of arsenic hotspots. The wide range of variabilty of arsenic concentration was found between two neighboring wells as well. So, prediction of arsenic concentration at unsampled locations was found very difficult. The arsenic contaminated part of South 24 Parganas has been considered as focus area and further study was done only on the basis of the focus area. The focus area was located in fluvial sedimentary deposition formed in Holocene period. The presence of arsenic in groundwater depends on the geological settings of the region. The fluctuation of groundwater table was observed 2-6 m bgl in both pre and post monsoon period. Groundwater from the focus area also contain elevated level of iron and chloride concentration.

The focus area was then classified into four zones according to arsenic concentration- Zone I (0-10 ppb), Zone II (10.1-100 ppb), Zone III (100.1-300 ppb) and Zone IV (more than 300 ppb). Only rural areas have been considered in the present study.

CHAPTER 5

PREDICTION OF ARSENIC CONCENTRATION IN GROUNDWATER BY GEOSTATISTICS

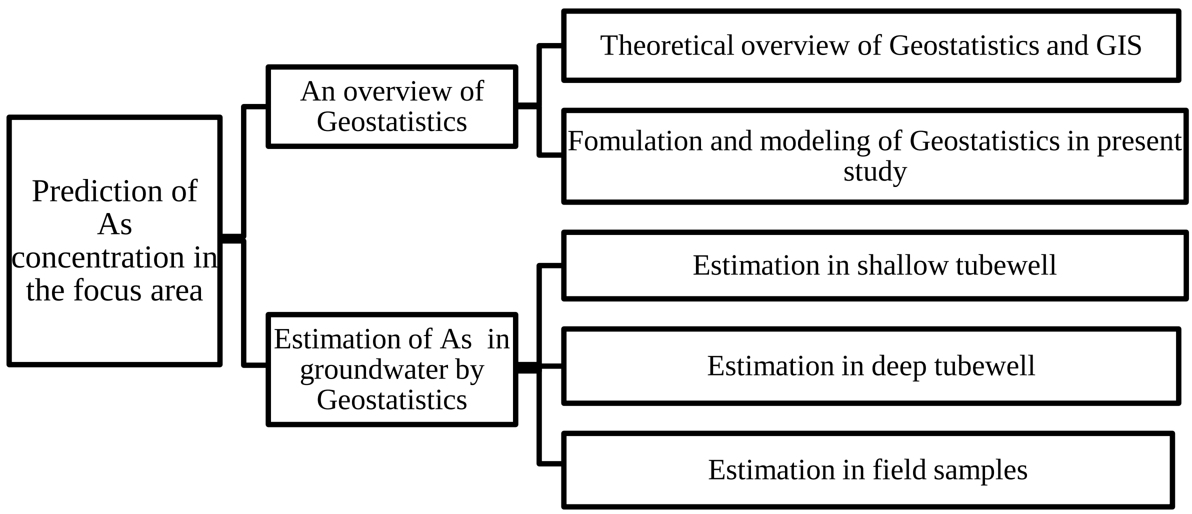
Geostatistics is a well established and widely applied approach in environmental reasearch and technology. It has been considered as a ‘subdiscipline of spatial statistics’. It incorporates a set of statistical methods that cover random variables with spatial variability at random fields. The statistical measures such as mean, variance, standard deviation etc. were found to extract convenient information from the available data. The primary characteristics of Geostatistics deals with the dependency on the spatial distribution. The objective of Geostatistical analysis was to estimate the statistical parameters that calculate the spatial distribution and dependence of the relevant variables. The parameters were found to interpolate the variables at unknown spatiotemporal locations where no measurements were done (Varouchakis 2019). The data those are close enough are usually more correlated than those are far apart. Prediction of arsenic at a particular location where there is no datum, estimated from the observed nearby data is the subject of this study.

5.1. Purpose of the study

This study gave the basic mathematical background of Geostatistics and methodological guide for Geostatistical analysis of arsenic contamination in groundwater.

5.2. Scope of the study

The study has been divided into two parts- i) An overview of Geostatistics and GIS and ii) Estimation of arsenic concentration in groundwater by Geostatistics.



Measurement of data from tubewells clearly suggests the significant spatial variability of arsenic concentration in the study area means that the arsenic related health risks will also vary from location to location corresponding to the variation of arsenic concentration in ground water. So, there is a serious need to study the variability of arsenic concentration from region to region to improve health risk assessment due to arsenic. Regular monitoring of spatial distribution of arsenic in groundwater is both expensive and time consuming. Using of Geostatistical kriging interpolation method including semivariogram, are extensively applied for determination of arsenic concentration as well as assessment of arsenic related health effects. (Liang et al, 2018).

5.3. An overview of Geostatistics

5.3.1. Theoretical overview of Geostatistics and GIS

5.3.1.1. Statistical methods

The basic statistical methods of modeling and estimation are principally based upon the distribution and correlation of data values. The data can either be one variable or bivariate or multivariate. The data of a single property is modelled and estimated on the basis of its common representative values based upon measures of central tendency and dispersion. At the same time the distribution of the variables, mainly the probability distribution based upon the discrete or continuous characteristics of the data, are used as the primary modeling parameter. The statistical methods that are used for this study includes-

- Frequency Distribution and Measures of central tendency
- Measures of Dispersion
- Probability Distribution of the variable

In case of analysis of data of two or more properties simultaneously, the statistical methods for bivariate or multivariate data anaysis is used. These processes include

- Analysis of correation among two or more variables using the correlation coeeficient in two dimensional or multi dimensional field.
- Using the theories of correlation finding out the relationship among the variables following the methods of regression analysis and curve fitting to model and estimate an unknown quantity from known values of other quantities and
- Using bivariate or multivariate probability distribution to estimate the probable value along with the reliability studies.

But in these forms of basic statistical analysis if a single variable or multiple variables are properties of a natural substance or phenomena spreading across an area or distributed over a space then only the values of these variables are considered but their distribution and concentration over an area or space was not considered.

5.3.1.2. Geostatistical methods

Geostatistical methods are based on

- Spatial description
- Data posting
- Contour maps
- Symbol maps
- Indicator map:
- Spatial analysis

Only *symbol maps* and *spatial analysis* has been used in this study.

- **Symbol maps**

The individual posting of all the data values may become difficult for many very large regularly gridded data sets and a contour map can mask most of the important local details due to global scaling of the system. An alternative that is often applied in the situation is a symbol map. A symbol map is close to a data posting with each location replaced by a symbol that indicates the class to which the data value belongs. These symbols are mainly selected so that they convey the relative ordering of classes by their visual density. This type of representation on the basis of the variation in colour density of a symbol gives a broad based idea regarding variation of the characteristics in a global system. (Isaaks and Srivastava 1989).

A symbol map was prepared with the help of ArcGIS (Version 10.2.2) and the datasets those were used in section 4.3.4. were utilized here for the making of the symbol map in present study. The symbol map was represented in fig no. 5.1.

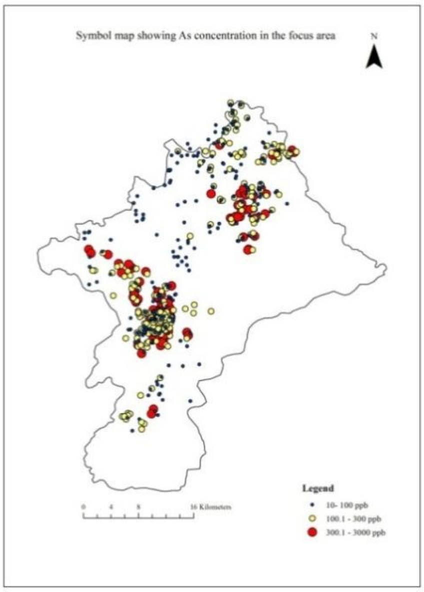


Fig: 5.1. Symbol map showing arsenic concentration in focus area

In fig 5.1., the small black points denote the location of arsenic concentration ranges from 10 to 100 ppb, the yellow points denote 100.1 to 300 ppb and the red points are the symbol for arsenic concentration more than 300 ppb.

- **Spatial analysis**

Spatial description methods as described are the fundamental form of representation of spatial variability of a geo data and is very useful in first hand characterization of the same. The principles of GIS are initially based upon this kind of spatial desription. But the description is more qualitative in nature and thus for a proper analytical solution of the same problems certain kind of analysis techniques are needed to be studied and adopted. The major types of analysis tools for description, modeling and estimation of spatially varied data are described here under (Isaaks and Srivastava 1989). They are-

i) Moving Window Statistics

ii) Proportional Effect of characteristics

iii) Spatial continuity

iv) h-Scatterplots

v) Cross h-Scatterplots

Only *h-scatterplots* has been used in this study for geostatistical modeling.

➢ **h- Scatterplots**

An h-scatterplot shows all possible pairs of data values whose locations are separated by a certain distance in a particular direction. This is one of the major and fundamental basis of the process of Geostatistics and is also the foundation of the model on which the thesis stands. The idea and the notation for this h scatterplot were presented herein following an example. The example was based upon a 10 × 10 square grid of data values that were spaced over a field of east coordinate of 10 unit and north coordinate of 10 units. The location of any point can be described by a vector, as can the separation between any two points. When describing pairs of values separated by a certain distance in a particular direction, it is convenient to use vector notations thus the point at (X_i,Y_i) can be written as $\mathbf{t_i}$, where t is a vector. Similarly, the location of the point at (X_j, Y_j) can be written as $\mathbf{t_j}$. The separation between point i and point j is $\mathbf{t_j}$-$\mathbf{t_i}$, which can also be expressed as the coordinate pair (X_j-X_i, Y_j-Y_i) and is referred as the separation vector $\mathbf{h_{ij}}$. This separation vector $\mathbf{h_{ij}}$ indicated to the vector going from point i to point j and it is different from the separation vector $\mathbf{h_{ji}}$ referring to the vector from point j to i . In fig 5.2, the vector notation was mentioned.

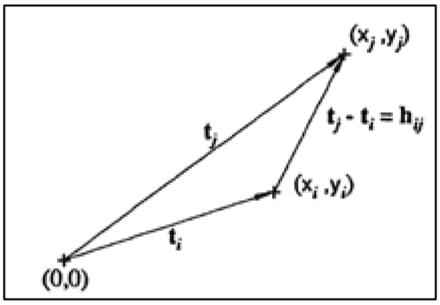


Fig: 5.2. An illustration of the vector notation (Isaaks and Srivastava, 1989)

From fig 5.2. it was observed that for a h scatterplot of a particular property V, the x axis is labelled V(**t**) and the y axis is labeled at V**(t+h).** The X coordinate of a point corresponds to the V value at a particular location and the y coordinate to the V value a distance and direction h away. For example, a h scatterplot of a specific value for **h**=(0,1) means that each data taken and paired with the data location whose easting is the same and whose northing is 1 m larger. In fig 5.3 the data pairing of h scatterplot was mentioned.

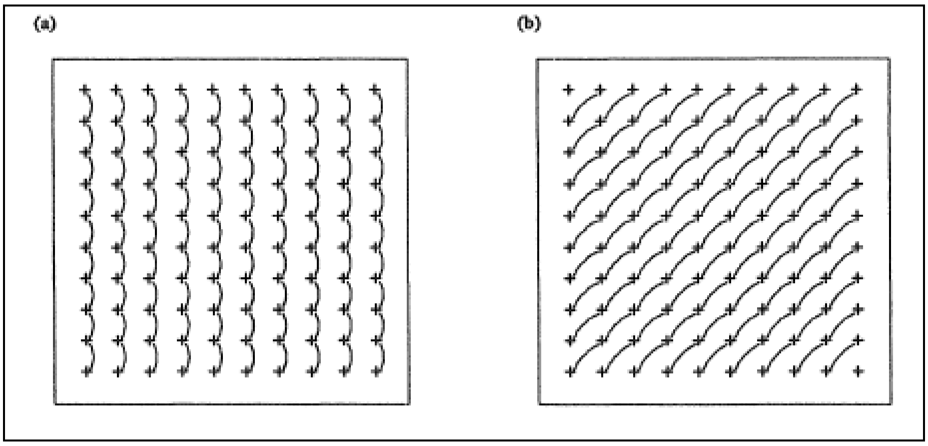


Fig: 5.3. Example of data Pairing for h scatterplot (Isaaks and Srivastava, 1989)

From fig 5.3. it was observed that the shape of the cloud points on an h scatterplot tells about how continuous the data values are over a certain distance in a particular direction. If the data values at locations separated by **h** are very similar then the pairs will plot close to the line x=y, a 45^{o} line passing through the origin. As the data values become less similar, the cloud of points on the h-scatterplot becomes fatter and more diffuse. Generally it can be observed that for the same property value the similarity decreases with the increase in separation vector.

Fig 5.4. (Fig a to d) indicate the h- scatterplot for four typical cases of separation vector being (0,1), (0,2), (0,3) and (0,4) showing the diffused scatterplot with increase of h.

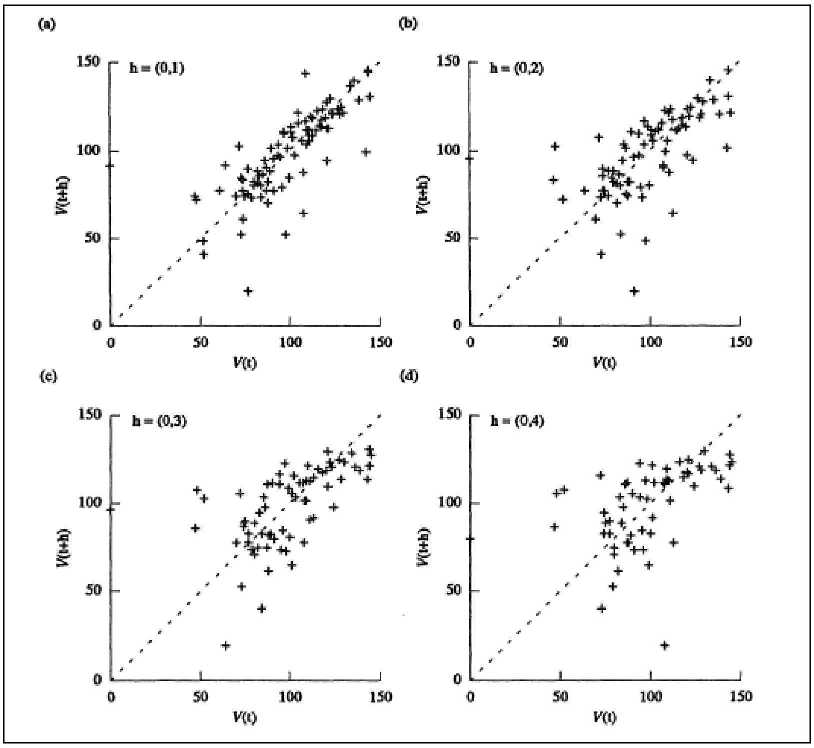


Fig:5.4. h scatterplots for varying separation distances showing the change in scattering (Isaaks and Srivastava, 1989)

But similar to the limitations of contouring process the h scatterplot also depends upon the regularity of the data grid and thus for not so regular grids some other analytical solutions based upon the same principle are normally preferred over this kind of graphical representation. There are three major types of analytical process that are used to express the character of an h scatterplot. They are-

a) Correlation function

b) Covariance function

c) Moments of Inertia and Variogram

Only *Moments of Inertia* and *Variogram* has been used in this study.

- ✓ **Moment of Inertia and Variograms**

The plausible index for the fatness of the cloud is the moment of inertia about the line x=y, which can be calculated from the following expression-

Moment of inertia= $\frac{1}{2n}\sum_{i=1}^{n} (x_i - y_i)^2$ (Equation 5.1)

It is half of the average squared difference between the x and y coordinates of each pair of points on the h-scatterplot, the factor $\frac{1}{2}$ being a consequence of interest in the perpendicular distance of the points from the 45° line. Though the moment of inertia about the line x=y can be calculated for any scatterplot, it usually has no particular releveance since there is usually no special significance to the 45^{o} line. On an h-scatterplot, this line has special significance because the pairing of the values of the same variable is done with each other. All the points on the h scatterplot for **h** = (0,0) will fall exactly on the line x=y since each value will be paired with itself. As **h** increases, the points will drift away from this line and the moment of inertia about the 45^{0} line is therefore a natural measure of the fatness of the cloud. Unlike the other two indices of spatial continuity, the moment of inertia increases as the cloud gets fatter.

The relationship between the moment of inertia of an h scatterplot and h is traditionally called the semivariogram (Isaaks and Srivastava 1989)

Mathematical Expressions for Variogram

Although the h scatterplots contain much more information than any of the three summary statistics, it is quite common to bypass the actual **h** scatterplots and go directly to variogram [$\gamma(\mathbf{h})$] to describe spatial continuity. The formula can be summarized as related with spatial statistics as follows:

The variogram, $\gamma(\mathbf{h})$ is the half the average squared difference between the paired data values

$$\gamma(\mathbf{h})= \frac{1}{2N(h)} \sum_{(i,j)|h_{ij}=\boldsymbol{h}} \left[(v_i - v_j)^2 \right] \qquad \text{(Equation 5.2)}$$

The values of $\gamma(\mathbf{h})$ are unaffected if all the i and j subscripts in the preceeding equation are switched. Instead of summing over all (j,i) pairs that are separated by **h**, one could sum over all (i,j) pairs that are separated by **–h** and the same values will be obtained. The result entails that the variogram calculated for any particular direction will be identical to the variogram calculated in the opposite direction. For this reason commonly the opposite directions are combined while describing spatial continuity. For example, rather than speaking of the spatial continuity in the northerly direction, it is common to speak of spatial continuity in the north-south direction. Since for calculating this distribution of moment of inertia calculation is done only on the basis of one half of the direction vector, so it is termed as Semivariogram. As seen in majority of the presentations of the researchers in this field, use of the semivariogram for spatial continuity mapping is found to be the most suitable technique.

I. Semivariogram analysis

The variogram is found as one of the best model to work with geo-data. In most of the data related to earth science, variables of the h- scatterplots are estimated through moment of inertia and semivariogram plot. The plot of moment of inertia γ(h) vs the separation vector h in a standard graph generally show a particular trend.

For an unbiased statistically homogeneous sample the variogram graph starts from the origin and shows an increasing trend upto a certain maximum, which is reached for a specific separation vector h_c and this vector is termed as range (r). Beyond this point the curve becomes almost parallel to the horizontal axis. The maximum Semivariance value corresponding to the separation vector 'range' is termed as 'Sill' and is denoted by γ_r. Normally the variation of γ(h) vs h is found to follow a typical mathematical model as given by the following equations-

i) Power $\gamma(h)=bh^c$

ii) Logarithmic $\gamma(h)=b.\ln(h)$

iii) Exponential $\gamma(h)= \gamma_c\,(1- e^{-\frac{h}{r}})$

iv) Spherical $\gamma(h)= \gamma_c$ for h>r

$$\gamma(h)= \gamma_c\,(\frac{3h}{2r} - \frac{h^3}{2r^3}) \text{ for } h>r$$

The sample values separated by a distance less than the range of the semivariogram are strongly correlated. The presence of any extreme data sometimes led to multiple sills of a semivariogram or early pick followed by reduction of the value of γ(h) with increasing h. This extremity of data may be due to extreme value of certain property or may be due to gross irregularity in sampling.

II. Determination of the influencing points

In case the points are spread over a 2D field the semivariogram changes with different separation direction. For each direction separate range will be obtained unless the system is made of pure homogeneous and isotropic condition, which is not at all a practical condition. So, considering the anisotropy, for the variogram the critical range is the maximum range value among the ranges of all the directions and the corresponding direction for which the range is maximum, is considered as the major direction of continuity. The range in the direction perpendicular to the major direction is the minor range. Normally the variations of range values in different direction are found to follow an elliptical model and the anisotropy ratio is defined as the ratio between the minor range and major range (a value between 0 and 1). In this case the major direction is considered as the direction of separation vector and the range in that direction is considered as limiting distance of separation vector. Thus the points within the separation vector from the point of estimation are considered as the influencing points.

III. Estimation methods

In real world, it is impossible to get exhaustive values of data at every desired point because of practical constraints. Thus, interpolation is important and fundamental to graphing, analysing and understanding of data related with two dimensional field. The estimation problem starts with identification of the samples which influence the estimation. The estimation may be done either by using the principles of basic statistics or considering the spatial effect and using different methods that takes into consideration the spatial separation.

It was already established that for variability in data related with earth using normal statistical methods without using the idea of spatial variabilty. Most of these methods actually estimate the property at unknown location as weighted sum of the properties of the surrounding influencing points using the equation-

$V_e = \sum_{i=1}^{n} w_i V_i$ (Equation 5.3)

Where V_e is the property value at the point of estimation and V_i is the property value at the i^{th} data point.

Thus the estimation problem actually is a two step process consisting of

Determination of the influencing points ⟶ Determination of the weights for estimation

The reliable methods that are used for determination of the weights are-

i) Inverse Distance Estimate

ii) Inverse Distance Squared Estimate

iii) Kriging

Only *Inverse Distance Estimate* and *kriging* have been used for the present study.

- **Inverse Distance Estimate**

In this method, the weightage factor for each data point is considered to be proportional to inverse of the distance of the said data point from the point of estimation.

$w_i = \frac{\frac{1}{d_i}}{\sum_{i=1}^{n} \frac{1}{d_i}}$ (Equation 5.4)

where w_i= weightage factor of the i^{th} data point

d_i=distance of the i^{th} data point from the point of estimation

n= number of data points influencing the estimate or total data points

As the distance between points of estimation and a data point increases, so in this method the weight factor automatically decreases and thus beyond a certain point, irrespective of the range of the semivariogram, the influence of the data on estimate vanishes.

- **Kriging**

The word “kriging” is synonymous with ‘optimal prediction’. It is a method of interpolation which predicts unkown values from data observed at known locations. This method uses variogram to express the spatial variation, and it minimizes the error of predicted values which are estimated by spatial distribution of the predicted values. The samples may be of three types-

i) Point (where the sample is a single point)

ii) Vector (where the sample is a set of points)

iii) Line (where the sample is average over a linear field)

The estimated field may also be of three types-

i) Point (estimation of a point is requirred)

ii) Line (estimation of average over a linear field is requirred)

iii) Field (estimation over a two dimensional field is requiired)

The process of Kriging estimate is explained as follows- Denoting the sample field as 'S' and the estimating field as 'Y', the distance between the estimate and sample points are denoted by h(S,Y), the distance between the samples are h(S,S) and distance between estimates (for linear or field estimate) are h(Y,Y). From the theoretical model that best suits the semivariograms of the sample, the semivariance values between samples (S,S), between estimates (S,Y) are found out. They are denoted as γ(S,S), γ(Y,Y) and γ(S,Y) respectively.

For a point estimate γ(Y,Y)will be zero as there is only one point to be estimated and for a point sample γ(S,S) will be zero.

The error in the estimate will occur due to the different types of uncertainties associated with natural resource data and this error is denoted as the 'Standard Error of Estimate' and is obtained from the following expression-

$S_e^2 = 2.\ \gamma(S,Y) - \gamma(Y,Y) - \gamma(S,S)$ (Equation 5.5)

where γ is the weighted average of the Semivariance value. These weights are also used in predicting the unknown value by the method of Kriging. The weights for each data point are such that the standard error is minimised.

Thus to determine the weight factors the principle of least error with conditional extreme is used. In this method by minimizing the standard error function with the condition that sum of the weights is unity, the weights for each sample data point is determined.

From the minimisation function under the specific condition (n+1) no of equations are developed for solution of unknown Lagrangian coefficient, λ, and 'n' number of unknown weight factors. The equations derived are

$\lambda + \sum_{j=1}^{n} w_i\, \gamma(S_i, S_j) = \gamma(S_i, Y)$ for i= 1 to n (Equation 5.6)

$\sum_{j=1}^{n} w_i = 1$ (Equation 5.7)

By solving the (n+1) simultaneous equations the weights (w_1 to w_n) and the Lagrangian parameter (λ) are obtained and the estimated value is obtained using equation as given in previous section. Along with this the Standard Error of Estimate can also be determined that gives the idea of the level of quality of estimate.

Apart from this normal Kriging process certain other methods of Kriging are also available and those methods are also used in various problems relating to geoscinece data estimate. But this thesis is primarily aimed at finding the suitability of Semivariogram and Kriging in arsenic concentration determination modeling and Estimation.

5.3.1.3. GIS methods

The acronym of GIS stands for Geographical Information System. GIS is used as a tool to work with geographic information (Huisman and de By, 2009). GIS is based on computer based system that produces the following sets of potentiality to manage the georeferenced data

a. Data capture and preparation

b. Data management, including storage and maintenance

c. Data manipulation and analysis

d. Data presentation

In a general sense, the term describes any information system that integrates, stores, edits, analyses, shares and displays geographic information for informing decision making. GIS applications are tools that allow users to create interactive queries, analyse spatial information, edit data in maps and present the results of all these operations. Geographic information science is the science underlying geographic concepts, application and systems. This works on the principle of Database management where at least one data is Geosptially marked.

5.3.1.4. Geostatistics and GIS

Geostatistics is a branch of statistics that deals with field data, spatial data with a continuous index and it provides methods to model spatial correlation and predict values at arbitrary locations. One of the main aims of Geostatistics is to assess and model the uncertainty of geospatial data and to develop suitable estimation and interpolation technique.

As it is being seen that both the methods of Geostatistics and GIS actually work on the same principle with the same objective, thus with time this two fields started interacting closely and now are almost synonymous. The theoretical methods of Geostatistics and the estimation processes as discussed in the chapter are regularly represented and mapped by GIS and also the GIS methods, some of which have been discussed briefly, work on the background theory and logic of Geostatistics. So, now a days both these two are intertwined and as such the thesis uses the combined term Geostatistics and GIS for giving solution to the problem of characterization of geological properties through modeling and estimation.

Hence, Semivariogram and Kriging has been utilized to estimate arsenic concentration in groundwater and the formulation and modeling are described in the following parts.

5.3.2. Formulation and modeling of the problem

5.3.2.1. Specification of the sampling characteristics

On the basis of the theoretical variability models of arsenic concentration and the optimisation theories of sampling for Geostatistical modeling as proposed by various researchers a generalized guideline regarding sampling scheme for arsenic concentration has been proposed in this thesis.

A. Spatial Field Problem

Arsenic concentration was found spatially distributed throughout the world. The fig 5.5 below shows the distribution of the sample data points in a field spread over an area

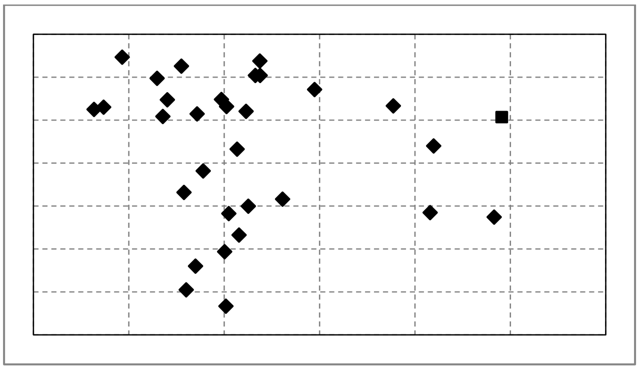


Fig: 5.5. Sample position for a spatially distributed arsenic concentration testing field

B. Field Conditions

In order to solve the aforesaid problem certain field conditions and associated assumptions were made

1. The solution for a field with sample data points are spread across an area.

2. The concentration of arsenic within a specific aquifer as measured from groundwater samples is considered to vary smoothly and arithmetic mean is assumed as the representative value .

3. The estimation is to be made at certain points indepedently so the problem was a vector point estimation problem.

C. Assumptions for formulation

1. The field is assumed to be spatial if the sample locations are not along a line or the formation of the field is not linear.

2. The analysis can be done only upto the depth of samping i.e. extrapolation of the result in the vertical direction is not possible.

3. The statistical distributions are assumed to follow a perfect theoretical model.

5.3.2.2. Geostatistical Methods

This problem is to be solved in-

A. Spatial Analysis using the semivariance function

B. Rose diagram and modeling of spatial distribution

C. Estimation by using the method of ordinary Kriging

D. Comparing the estimated value and checking the acceptability

A. Spatial analysis of arsenic by using the semivariance function

The spatial analysis problem is to be solved by the semivariance modeling using the general theory and methodology as discussed earlier. In this case, the sample field consists of points spread across an area and separated by distances in different direction. The sample data points are paired on their separation vector so that each pair is separated by a specific separation distance or less than that in a particular direction which is known as the separation vector h for that data set. For all such values the semivariance that is moment of inertia about the central line is caculated using the equation as already stated.

As mentioned earlier, with these values of semivariance and corresponding separation vector in one particular direction the semivariogram is plotted and a curve best fitting the semivariogram is obtained using the principle of regression analysis (Goon et al, 1975).

From the trend line of the semivariogram as obtained the values for sill (γ_r) and range (r) in that particular direction is determined. So, in the spatial sample data field problem, a set of sill and range values are obtained for each direction. In order to continue the next stage of work, that is the estimation of the property values at certain points, a specific value of the critical range in one particular direction is required. It was reported that the influence zone in a 2D field for geo data normally follows an elliptical region around the point for estimation (Isaaks and Srivastava, 1989).

In this thesis the following procedure involving rose diagram has been proposed for getting the model.

B. Rose Diagram and modeling of spatial distribution

The numbers of critical range values and corresponding direction of separation vector depend upon the number of directions chosen. In this thesis, the separation vectors are taken at a radial interval of 15°. The points which are separated by a distance 'h' in a particular direction within an angular tolerance of ±15° from a specific radial line are considered for each semivariogram. In the following figure (Fig 5.6) showing the separation vectors each of length 'h' in dashed lines at a spacing of 20° and the shaded portion is the region with a ±10° tolerance from a vector line. The sample points within this zone are considered to form the set of points for calculation of Semivariance corresponding to the separation vector **h**. (Aitch 2012).

In fig 5.6, the zonation of Sample Points for Semivariance for a separation vector was summarized. A set of critical range values along the directions of separation vector at approximately 20° spacing are obtained, which are plotted in a rose diagram.

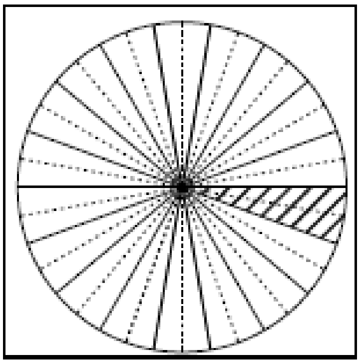


Fig: 5.6. Zonation of Sample Points for Semivariance for a separation vector (Aitch 2012)

A Rose Diagram is defined as a circular histogram (Aitch, 2012) where the bars are extended to different direction from a central point where the length of each bar corresponds to the frequency in that particular direction (Aitch, 2012). This idea is used to display correlation models for angles ranging from 1^0 through 360° simultaneously. In spatial data analysis, the spatial variability is represented by a continuous line of proportional length along the direction in which the variability is measured. Rather than viewing only along one angle at a time, the rose diagram allows the users to view the variabilty in all directions for a spatially distributed data field at once.

In the figure 5.7, a representative rose diagram is presented for better understanding-

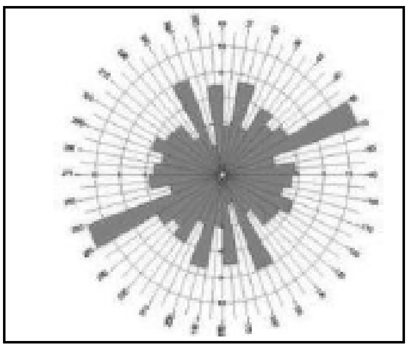


Fig: 5.7. A typical 10° Rose diagram (Aitch 2012)

In this problem the rose diagram of range values of semivariogram along each direction is drawn as lines, whose lengths are proportional to the value of the range, in that particular direction (fig. 5.7). As the Semivariance function is a symmetric function, i.e. γ(h)= γ(-h), so the maximum range value in a particular direction when plotted symmetrically in the rose diagram indicates the critical profile direction along which the range is maximum. The rose diagram for critical semivariance model of arsenic concentration shows the distribution in such a way that, the tip of the rose lines when joined shaped almost like an ellipse or circle with the major axis along the critical profile diection. A typical figure indicates the feature in Fig 5.8.

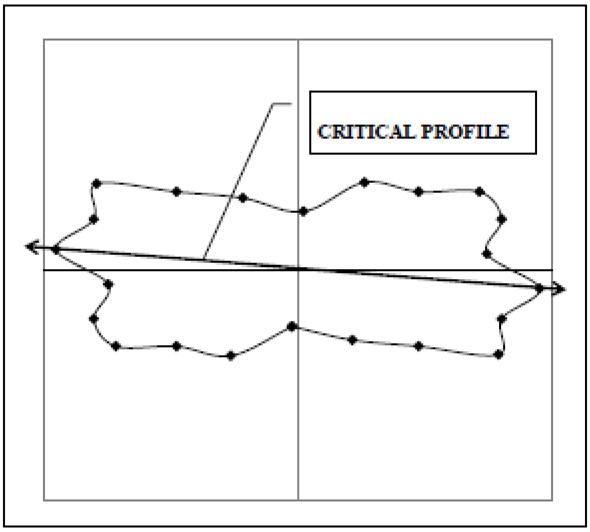


Fig: 5.8. A Typical Rose Diagram of Semivariogram Distribution (Aitch 2012)

This maximum value of range along the critical profile direction is considered as the Critical Range value of the spatially distributed sample data set and the direction as the Critical Direction (fig 5.8).

Those sample data points whose separation vector measured from the point of estimation is along the critical direction and is less than the critical range actually influence in the estimation of the specific property value at that point for the spatially distributed sample data.

C.Estimation by using the method of ordinary Kriging

Ordinary kriging is an established technique for geostatistical estimation. Cross validation is an important method in geological study in the field of ordinary kriging. In a cross validation practice, the estimation method is evaluated at the locations of existing samples. The value at a specific sample location was dropped out for the time being from the sample data set. The value at the same location was estimated by the remaining samples. The estimated value was then compared with the original sample value from the dataset. This procedure was applied for all available sample data sets. (Aitch, 2012)

The estimation process is to be done by using the Kriging method. The estimation process using this Kriging method of Geostatistics and GIS starts with fixing the points that influence the estimation process. For the estimation process using the kriging method of Geostatistics and GIS, the first step is to identify the points that influence the estimation process. The separation distances for the entire sample data points from the point of estimation are calculated and the influencing points are identified by comparing with the range of the semivariogram of the specific property. Once the data set is ready, the sample points in this data set are termed as influencing sample data and they are separated along with their positional and property values. For any two influencing sample points S_i and S_j the separation distance between them h_{ij} is determined and the corresponding semivariance value $\gamma(S_i, S_j)$ is to be determined for all (i,j)pair. Along with this for each influencing sample point S_i the separation distance of the point with the point of estimation (E), h_i is determined and the corresponding semivariance value $\gamma(S_i, E)$ is to be determined for all (i).

Using these values of γ in the Kriging equation, the weight factors, w_i corresponding to each influencing sample point S_i, are solved and these weight factors are used to estimate the unknown arsenic concentration at the point of estimation.

The separation vector i.e., the distances and position of all the sample data points from the point of estimation are calculated. As already mentioned the critical separation vector ($\mathbf{h_r}$) is the maximum range along the critical direction. For estimation process a critical zone is marked with the centre at the point of estimation and bounded by the radial lines at $\pm 45^o$ from the critical direction (Isaaks and Srivastava 1989). The sampling points whose relative position with respect to the point of estimation falls within this critical zone and the separation distance from the point of estimation is less than the critical value of the range is considered to influence the estimation of the specific geotechnical property.

Once this influencing sample data set is ready then for all these points the calculation is done using the semivariance model as earlier computed along the critical direction. Then similar to linear field estimate the weight factors, w_i corresponding to each influencing sample point S_i, are determined by the method of Kriging and using these weight factors the unknown arsenic concentration value at the point of estimation is estimated.

D. Comparing the estimated value and checking the acceptability

The property value so estimated is cross checked with the property value at the point of estimation similarly like the earlier case-

i) For certain point of estimation, water quality tests are carried out at a later period of time and the quality of estimates are checked and

ii) For certain other cases one or some of the sample data points are left out during modeling and are estimated and then compared with the previously sampled data to determine the quality of estimate.

Along with these, certain other water contaminants are estimated at a series of points

- **Cross correlation**

Similar to the spatial sample data set, cross relationship among various water contaminants are made in spatial distribution also to check whether the spatial distribution pattern of semivariance distribution (as obtained by the semivariogram rose) for different contaminants follow the same pattern or not. This is very much relevant towards planning the sampling and testing plan in future. If the spatial semivariogram distributions for different properties are found to be similar then detail study of any one of them, normally the simpler and cheaper one is sufficient for finding the influencing zone for all other properties for a specific point of estimate. For reaching to this conclusion the semivariance rose diagram of different water contaminants values prepared by the process described in section 5.3.2.1. B are compared.

- **Process of Computation**

The computational part of the whole process was carried out by a series of three computer programmes.

1. Calculation of semivariance values of arsenic for different separation distance

   - The best fit curve into the semivariogram was prepared on the basis of semivariance. The rose diagram at different directions (0-360^{o} with 15^{o} interval) and determination of the critical direction was made on the basis of the semivance.

2. Estimation of the arsenic concentration at a point or series of points by Kriging.

   - Influencing points and their weight factors of the point of estimation were determined.

3. Estimation of cross correlation between arsenic, iron and chloride.

Estimation of arsenic concentration by using ordinary kriging was based on the previous overviews in the present study.

5.4. Estimation of arsenic concentration in groundwater by Geostatistics in focus area of present study

5.4.1. Methodology

5.4.1.1. Data collection

The study is based on both primary and secondary data. The semivariogram model and estimation were made by secondary data and estimated data validation was made with the help of primary data. A dataset (290 secondary data) of arsenic containing tubewells was collected from NRDWP-

IMIS (2017-18) at Baruipur block for validation of the nature of the semivariogram model. The secondary data that was mentioned in section 4.3.4 was used for the semivariogram modeling and estimation study. Arsenic data was used for semivariogram and estimation purposes and Iron and Chloride data was used for cross correlation study. The study was done in shallow (10-100 m bgl) and deep (101-300 m bgl) depth tubewell. For semivariogram modeling of arsenic at shallow depth tubewell, 599 tubewell data with arsenic concentration and locations and for deep tubewell 159 tubewell data with arsenic concentration and locations was collected. For cross correlation study, co-located arsenic, iron and chloride data from shallow tubewell with location was collected. The name of the gram panchayats (GPs) and villages were mentioned in the secondary data source. The location of the villages were determined from various sources- the georeferenced toposheet of the study area in ArcGIS (Version 10.2.2), Bhuvan Panchayat (ISRO) portal and the prepared village map from the focus area with the help of ArcGIS (Version 10.2.2) (data collected from Institutional Strengthening of Gram Panchayats (ISGP) Programme-II, Panchayats and Rural Development Department, Government of West Bengal). All the data were summarized in annexure I.

For primary data, 45 samples were collected from the tubewells present in focus area. The depth of the tubewells were recorded from the local people living nearby the tubewells. The samples were collected in 100 ml polyethylene bottle washed with 1:1 nitric acid water and after collection, 1 ml of nitric acid was added to preserve the samples in a refrigerator keeping the temperature below $4^{o}C$. The samples were filtered through Whatman 42 filter paper before analysis. Analysis of arsenic concentration in ground water was performed in Atomic Absorption Spectrophotometer (AAS) (Perkin Elmer) at Department of Civil Engineering, Jadavpur University. This data was mentioned in table 5.9 in estimation part.

5.4.1.2. Formulation of the model

A vast toolbox of algorithms were available to generate the sptial distribution and estimation at unknown locations (Goovaerts, 2001). The formulation of Geostatistical Modeling in this study was done with the help of Microsoft Visual Basic for Applications (VBA) (Microsoft's programming language for Excel) that run on Excel environment. The programming was done in VBA because of the ease of the data input as no additional user training was requirred. Total three computer programs were made for prediction- the variability modeling of arsenic for spatial field, estimation modeling of arsenic concentration at unknown locations with the equations generated with the help of the influencing points and their weightage factors and cross correlation for arsenic, iron and chloride. All the algorithms are summarized in the annexure I .

5.4.1.3. Preparation of Rose diagram

The rose diagram was made in Autocad software (Autocad 2021). To make the rose diagram, 15^o interval from 0^o to 360^o was taken. The average angle 7.5^o was considered for the study and each average angle has an individual range. So, length of the lines varies with the range of the angle. The maximum length shows the influencing zone.

5.4.1.4. Cross correlation study

Cross correlation study was done with three variables- arsenic- iron and arsenic-chloride as the study area was found affected by arsenic, iron and chloride.

The present study was divided into three parts on the basis of the methodology.

i) Validation of the semivariogram model- A dataset of Baruipur block was taken to observe the nature of the semivariogram model.

ii) Semivariogram modeling and estimation of arsenic in groundwater- In the focus area the shallow aquifer is highly arsenic contaminated than deep aquifer. The two aquifers were considered as two layers and tubewell locations were also different for each aquifer. There were total 599 tubewell locations were found in shallow aquifer and 159 tubewell locations were found in deep aquifers. Semivariogram modeling and estimation was done with the data set for both aquifers.

iii) Cross correlation study- the study was done to check the correlation between co-located arsenic, iron and chloride concentration. The study was done with the data from shallow aquifers used in the semivariogram modeling and estimation method of arsenic concentration.

5.4.2. Validation of the semivariogram model in Baruipur block

The modeling was first carried out with sets of secondary data from Baruipur block. The study was conducted for the following solutions-

a) Semivariance values for diffrent separation distance in one specific direction was estimated and on the basis of this for each direction the critical semivariance vector (the Range value in that direction) was obtained. The rose diagram of distribution of semivariogram ranges was prepared and the orientation of the spatial variability was modelled. The equation was generated with the nature of the graph.

5.4.2.1. Location of spatially distributed sampling points in Baruipur block

Baruipur is one of the most arsenic contaminated blocks and the population is also high in the focus area. The tubewells present in this block was selected for the validation of the model. 290 tubewell data from shallow aquifer located in Baruipur block were selected for the study (described in 5.4.1.1). The small dataset was selected to observe if the nature of the curve follows the theoretical nature of the curve of semivariogram. Location of spatially distributed data in Baruipur block in shallow tubewell is mentioned in fig no. 5. 9.

290 tubewells were spatially distributed in Baruipur block (fig 5.9). The distribution is dense in the central part of the block. From the field survey it was observed that the population was dependent on groundwater for drinking purposes and the number of tubewells were found higher than the other blocks from the study area. The data was then used for semivariogram modeling.

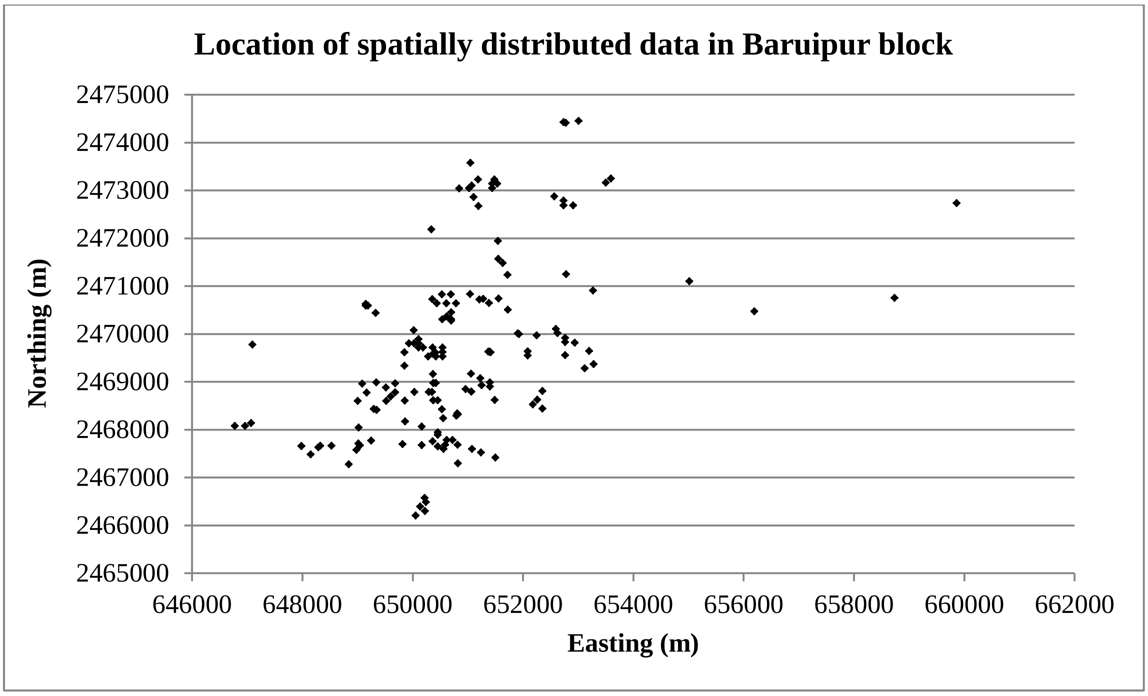


Fig: 5.9. Distribution of tubewell points (shallow depth) in Baruipur block

The formula used for semivariogram was $\gamma(\mathbf{h}) = \frac{1}{2N(h)} \sum_{(i,j)|h_{ij}=\boldsymbol{h}} [(v_i - v_j)^2]$ (Equation 5.2)

Some important terminology are used here to describe the important features of the semivariogram (fig. 5.10)-

Range- As the separation distance between the pairs increases, the corresponding semivariogram value will also generally increase. Eventually an increase in the separation distance no longer causes a corresponding increase in the average squared differnce between pairs of values and the semivariogram reaches a plain. The distance at which the semivariogram reaches this plain is called the range.

Sill- the plain where the semivariogram reaches at the range is called the sill.

Nugget effect- though the value of the variogram for h=0 is strictly 0, several factors such as sampling errors and small scale variability may cause sample values separated by extremely small distances to be quite dissimilar. This causes a discontinuity at the origins of the variogram. The vertical jump from the value of 0 at the origin to the value of the variogram at extremely small separation distances is called the nugget effect.

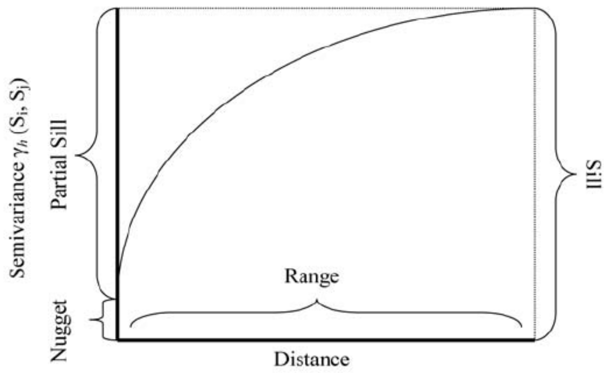


Fig: 5.10. Components of a semivariogram (Wagner, Mielbrecht and Van Woesik, 2008)

γ(h) is assumed to be dependent on the separation vector, h. The function γ is called variogram by some authors (Wackernagel (2003), Worboys 1995; Gneiting et al. 2001), some call it semivariogram (Journel and Huijbregts 1978; Cressie 1991; Goovaerts 1997; Burrough and McDonnell 1998; Olea 1999; Stein 1999; Gringarten and Deutsch 2001) stating that a semivariogram is half of a variogram, the others use the term variogram and semivariogram synonymously ((Isaaks and Srivastava 1989; Webster and Oliver 2007) (Bachmaier and Backes, 2008). In this study, the term 'semivariogram' will be utilized for the function of γ.

5.4.2.2. Semivariogram modeling

In Geostatistics, there is no accepted universal algorithm for determining a variogram. To create the Semivariogram modeling, a computer programming was made with the help of Microsoft Visual Basic for Applications (VBA) that run on Excel environment. The structure of the basic programing language is very simple, particularly as to the executable code. The algorithm is summarized in the annexure I.

The excel worksheets are discussed as follows:

There are three worksheets (Data, Calculated Data and Semivariance data) in the excel workbook named Semivariance for spatial relationship.

In the first worksheet means Data worksheet, the location name was renamed with numbers. Then the X and Y coordinate and the respective arsenic concentration in ppb was recorded. Two buttons- one was named as "Get Semivariance Data" and the other was "Clear All Data" was incorporated in the page. "Get Semivariance Data" button will give the semivariance value in third worksheet named Semivariance data and "Clear All Data" will delete all the data from calculated data and Semivariance data. The Data worksheet is showed in fig no. 5.11.

- **Data worksheet**

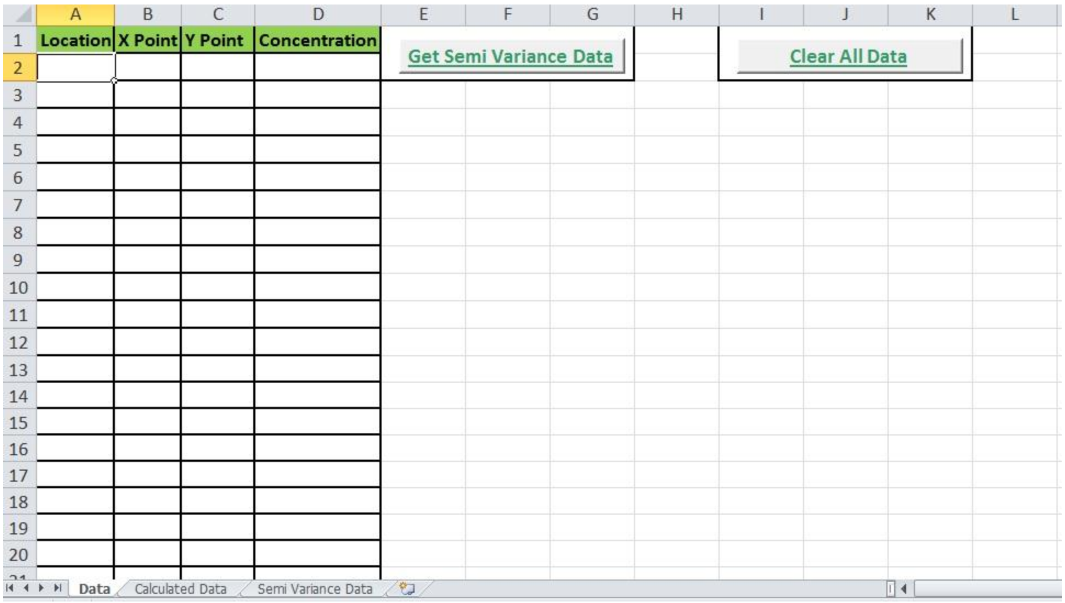
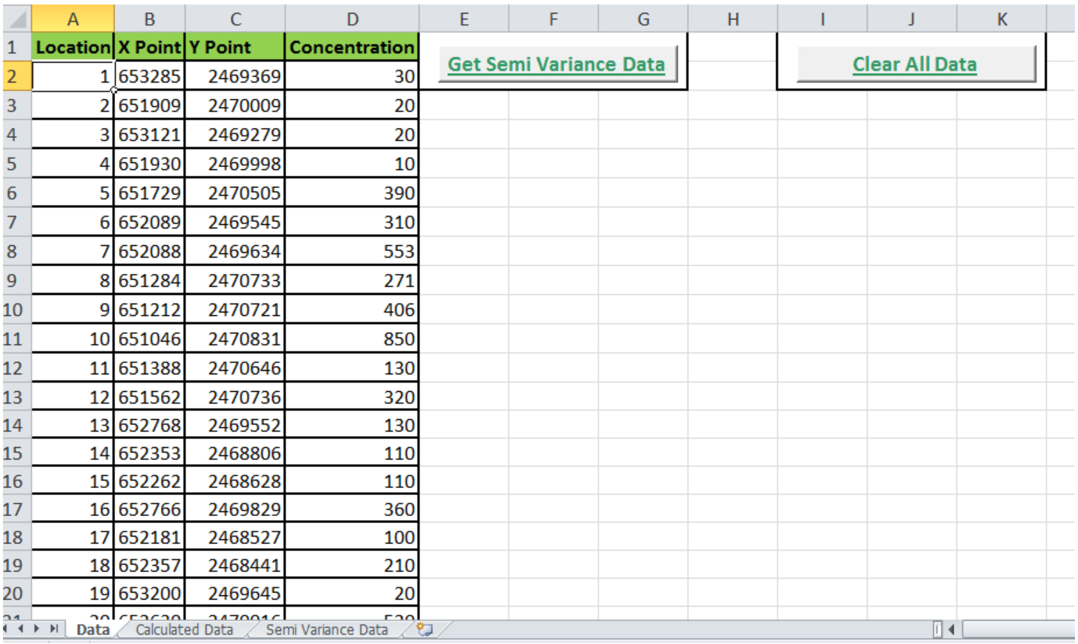


Fig:5.11. Data worksheet of semivariogram modeling

As per the structure of the table, a village named Ramnagar in Dhapdhapi I Gram Panchayat was selected for the example. Ramnagar was labelled as no. 1 and X and Y coordinate was 653285 and 2469369. At this location the arsenic concentration in the tubewell was 30 ppb.

In fig 5.12, the village locations and their associated arsenic concentration was recorded.



Location	X Point	Y Point	Concentration
1	653285	2469369	30
2	651909	2470009	20
3	653121	2469279	20
4	651930	2469998	10
5	651729	2470505	390
6	652089	2469545	310
7	652088	2469634	553
8	651284	2470733	271
9	651212	2470721	406
10	651046	2470831	850
11	651388	2470646	130
12	651562	2470736	320
13	652768	2469552	130
14	652353	2468806	110
15	652262	2468628	110
16	652766	2469829	360
17	652181	2468527	100
18	652357	2468441	210
19	653200	2469645	20

Fig: 5.12. Data worksheet with location, X and Y coordinates and arsenic concentration

Thus, all the 290 village locations were numbered from 1 to 290 and the coordinates and arsenic concentration was placed in the table respectively (fig. 5.12). After that "Get Semivariance Data" button was clicked and third worksheet was opened. The semivarinace data was calculated in that sheet. The background calculation for semivariance was done in Calculated data worksheet in fig 5.13.

- **Calculated data worksheet**

	A	B	C	D	E	F
1	Seperation Distance	Pairs		Concentration Difference	Theta (Degree)	Lag Sep Distance
2	0	1	1	0	0	0
3	0	2	2	0	0	0
4	0	3	3	0	0	0
5	0	4	4	0	0	0
6	0	5	5	0	0	0
7	0	6	6	0	0	0
8	0	7	7	0	0	0
9	0	8	8	0	0	0
10	0	9	9	0	0	0
11	0	10	10	0	0	0
12	0	11	11	0	0	0
13	0	12	12	0	0	0
14	0	13	13	0	0	0
15	0	14	14	0	0	0
16	0	15	15	0	0	0
17	0	16	16	0	0	0
18	0	17	17	0	0	0
19	0	18	18	0	0	0
20	0	19	19	0	0	0

Data | Calculated Data | Semi Variance Data

Fig: 5.13. Calculated data worksheet of semivariogram modeling

In the second worksheet (Calculated data), 5 columns were added named separation distance, pairs, concentration difference, Theta (angle) and lag separation distance. Separation distance was calculated from each location including the same location. For same location, the separation distance, concentration diffrence and angle all were found 0. Pairing was done with each of the location including the same location. Lag separation distance was considered as the closest integer value of the separation distance (the lag separation distance for 22.83 will be 23) (fig.5.13).

In the third worksheet (Semivariance Data) (fig. 5.14), 5 columns were inserted- group, angle (degree), separation distance, semivariance and lag separation distance. Here each group signifies a specific angle. For example, here group 1 means 0^o and group 2 means 0.1^o to 15^o. Semivariogram modeling was done with 15^o angle interval from 0^o to 360^o, 24 semivariogram models were obtained, the second one ($0\text{-}15^o$) interval was taken to interpret for the study. 15^o interval was considered because it was assumed that all the points are lying on a straight line, so, a small interval was taken. The angle of the first one was found 0. So, it was not considered for the study. The second one was assumed as the first one. The average interval angle was taken assuming the points were present along a straight line. The average angle data was found by averaging the maximum and minimum angle data. For example- For $0\text{-}15^0$ angle, the average angle will be 7.5^0. Semivariogram modeling was made for each group with the help of semivariance and lag separation distance data. Total 24 semivariogram models were made for the study at different directions.

- **Semivariance data worksheet**

The third worksheet was semivariance data worksheet (fig 5.14).

	A	B	C	D	E	F
1	Group	Theta (Degree)	Seperation Distance	Semi Variance	Lag Sep Distance	
2	1	0	0	486.4269663	0	
3	1	0	21	641.5777778	21	
4	1	0	33	1767.094737	33	
5	1	0	41	1742.081633	41	
6	1	0	51	1915.25	51	
7	1	0	55	2245.196262	55	
8	1	0	62	2642.216216	62	
9	1	0	83	3263.320833	83	
10	1	0	89	4470.719512	89	
11	1	0	92	5379.248062	92	
12	1	0	1019	37341.82199	1019	
13	2	0.127678406	7180.02	43352.54414	7181	
14	2	0.145966406	7458.02	43329.34752	7459	
15	2	0.191326877	8385.05	43127.95524	8386	
16	2	0.235877707	7530.06	43304.93657	7531	
17	2	0.291854888	6871.09	43417.4397	6872	
18	2	0.325540699	176	19391.12113	176	
19	2	0.347242897	165	18215.51676	165	
20	2	0.40195622	7127.18	43272.61394	7128	
21	2	0.427572507	134	11148.92683	134	
22	2	0.429446025	8672.24	43030.63327	8673	
23	2	0.441407134	5841.17	43632.30573	5842	
24	2	0.504795569	227.01	20858.70185	228	

Data | Calculated Data | Semi Variance Data

Fig: 5.14. Semivariance data worksheet of semivariogram modeling

5.4.2.3. Semivariogram modeling at 0^o-15^o interval (Group 1)

For Semivariogram modeling, separation distance and semivariance value was placed in x and y axis respectively (fig.5.15). The unit of separation distance was in meter and semivariance in square of concentration.

In fig 5.15 , the semivariance is increasing with separation distance. The red point indicates the value from where the model starts to flatten out and after that point the curve becomes a straight line that implies that there is no relationship exists between the sample points after that point. If a vertical line is drawn from the red point to the separation distance axis (x axis), the distance from the origin to where the line cuts the axis is called range (X). A horizontal line drawn from the red point to the semivariance axis (y axis), the distance from origin to the line cuts the axis is called sill (Y). The range (X) and sill (Y) value of the semivariogram are 2059.1 m and 42916.63 sq ppb respectively. The sample values are spatially correlated within 2059.1 m in this model, after 2059.1 m the values are independent. Thus 24 different ranges were obtained by drawing the models at different angles. The angles and range values are tabulated in table. 5.1. The average angle was taken for the study considering all the points are located on the straight line.

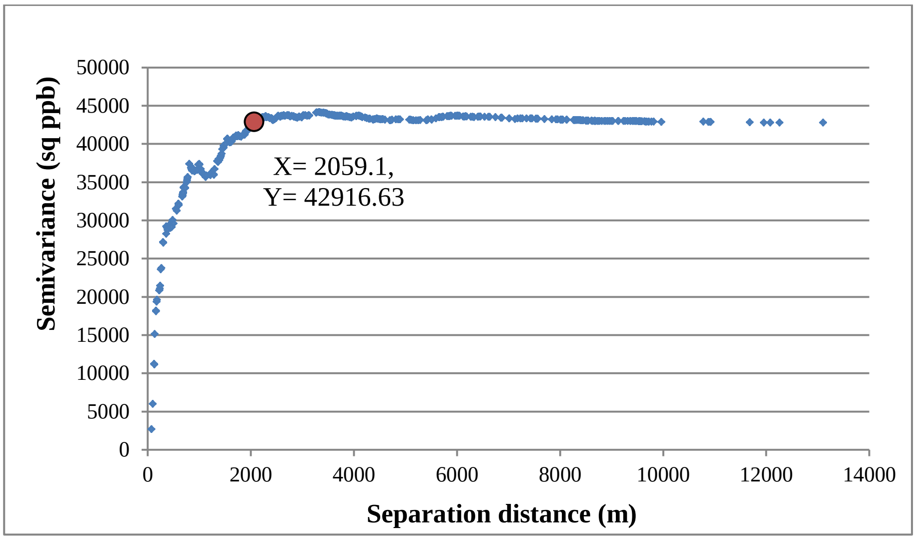


Fig: 5.15. Semivariogram of arsenic concentration in groundwater of Baruipur block

From 24 ranges, 2 values were observed same at each opposite directions (table 5.1). They all are located in a 360° angle with 15° distance from each other. The maximum range was found 2249 m. For maximum range, 2249 m was present both in 30° to 45° (average 37.5°) and 210° to 225° (average 217.5°). Rose diagram was drawn to know about the direction of the values.

Table: 5.1. The angle and range for the semivariogram of different directions at Baruipur

Group	**Initial angle (degree)**	**Final angle (degree)**	**Average Angle (degree)**	**Range (m)**	**Group**	**Initial angle (degree)**	**Final angle (degree)**	**Average Angle (degree)**	**Range (m)**
1	0	15	7.5	2059	13	180	195	187.5	2059
2	15	30	22.5	1949	14	195	210	202.5	1949
3	30	45	37.5	2249	15	210	225	217.5	2249
4	45	60	52.5	2165	16	225	240	232.5	2165
5	60	75	67.5	2244	17	240	255	247.5	2244
6	75	90	82.5	2090	18	255	270	262.5	2090
7	90	105	97.5	2114	19	270	285	277.5	2114
8	105	120	112.5	2125	20	285	300	292.5	2125
9	120	135	127.5	1921	21	300	315	307.5	1921
10	135	150	142.5	2148	22	315	330	322.5	2148
11	150	165	157.5	2186	23	330	345	337.5	2186
12	165	180	172.5	2133	24	345	360	352.5	2133

5.4.2.4. Rose diagram of semivariogram of 24 angles

For arsenic determination, there may be geologic information about the contaminated aquifer could be helpful in choosing directions for semivariogram calculations. A rose diagram has been plotted to calculate several directional variograms which shows the variogram range at the origin as a function of direction (fig.5.16).

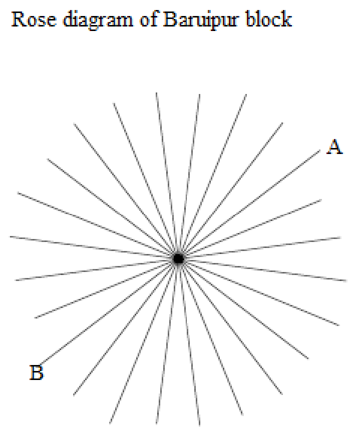


Fig: 5.16. Rose diagram of semivariogram of arsenic concentration at 24 different angles of Baruipur block

The above figure (fig. 5.16) shows the distribution of critical separation vector along different directions. From this Rose Diagram it can be concluded that arsenic distribution is almost symmetrical in Baruipur block. The orientation of the critical direction for analysis of groundwater arsenic is along the line AB (major axis) at angle of about 37.5^{o} and 217.5^{o} measured from east towards north with a critical range of 2249.89 m. The longest range was displayed in the NE-SW direction.

Once the direction of maximum continuity has been established, there is need to choose a directional occurrence that is large enough to allow sufficient pairs for a clear variogram.

5.4.2.5. Semivariogram modeling of arsenic concentration at 30^{o} -45^{o} and 210^{o} -225^{o} angle:

The angle was considered for further study as the maximum range was found at that angle. So, the angle was named influential zone. In this zone the correlation is maximum between the points. For estimation, all the data will be taken from influential zone. In fig 5.17 the semivariogram of arsenic in influential zone was drawn.

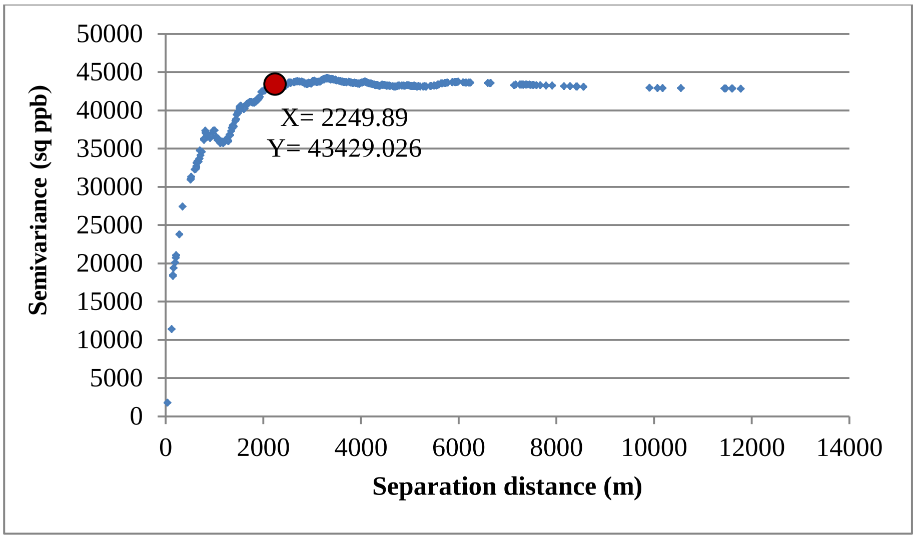


Fig: 5.17. Semivariogram of arsenic at influential zone of Baruipur block

From the fig. 5.17, it was observed that the nature of the curve is similar as the curve drawn for 0-15° angle, but the range and sill values are different. At 37.5° and 217.5° angle, the range value of the semivariogram is maximum. The range and sill of the model are 2249.89 m and 43429.026 sq ppb.

5.4.2.6. Determination of Bearing of Major Zone of Influence

Influential angle was determined as 30 ° -45° and 210 ° -225° and range was 2249.89 m. It means that for estimation of arsenic in groundwater at a location will be influenced only by the points that are located within the separation distance of 2250 m at 30 ° -45° and 210 ° -225° angle. The other points will not influence the estimating properties.

5.4.2.7. Equation generation for prediction

In the semivariogram model of Baruipur, the variation of γ(h) vs h is found to follow a typical mathematical model followed by Power equation. So, the equation will be-

Power equation : $\gamma(\mathbf{h}) = b\mathbf{h}^c$, b is a constant and the value of b was unknown.

For present study, the equation was written as

$D = A(S)^2$

D= separation distance (range value)= 2250 m

S= semivariance= 43429 sq ppb

$A = 2250/(43429)^2 = 1.1\times10^{-6}$

$$S = \frac{1}{\sqrt{1.1\times10^{-6}}} \times D^{0.5}$$

S= 953.46

The S value will act as a multiplier to estimate arsenic concentration at an unsampled location.

The study with data sets of Baruipur blocks was done to check if the computed semivariogram model was working properly. As the data set of Baruipur block were smaller than the data sets of focus area, accurate results were found. Prediction was not done in Baruipur block because the validation of semivariogram modeling was done here only. The semivariogram modeling, equation generation and estimation was done with the shallow and deep tubewell data at the focus area.

The prediction of arsenic in groundwater was estimated by ordinary kriging. The study was done with the secondary data for the semivariogram modeling and estimation of arsenic concentration in the focus area and primary data for validation of the estimated value. 599 arsenic data with tubewell locations for shallow aquifer and 159 arsenic data with tubewell locations at deep aquifer were utilised (described in 5.4.1.1). Same methodology was used for all of the estimations.

5.4.3. Prediction of arsenic in shallow tubewell from the focus area

The study was conducted for the following solutions-

1. Semivariance values for diffrent separation distance in one specific direction was estimated and on the basis of this for each direction the critical semivariance vector (the Range value in that direction) was obtained. The rose diagram of distribution of semivariogram ranges was prepared and the orientation of the spatial variability was modelled. The equation was generated with the nature of the graph.

2. Estimation of arsenic concentration was done with determination of influencing sample points and there weightage factors. Comparison was done with the actual and estimated value.

3. In case of the erroneous results, the cause of the errors of the estimated values was determined.

5.4.3.1. Location of spatially distributed sampling points in focus area

The location of the sample points in the focus area was mentioned in fig 5.18.

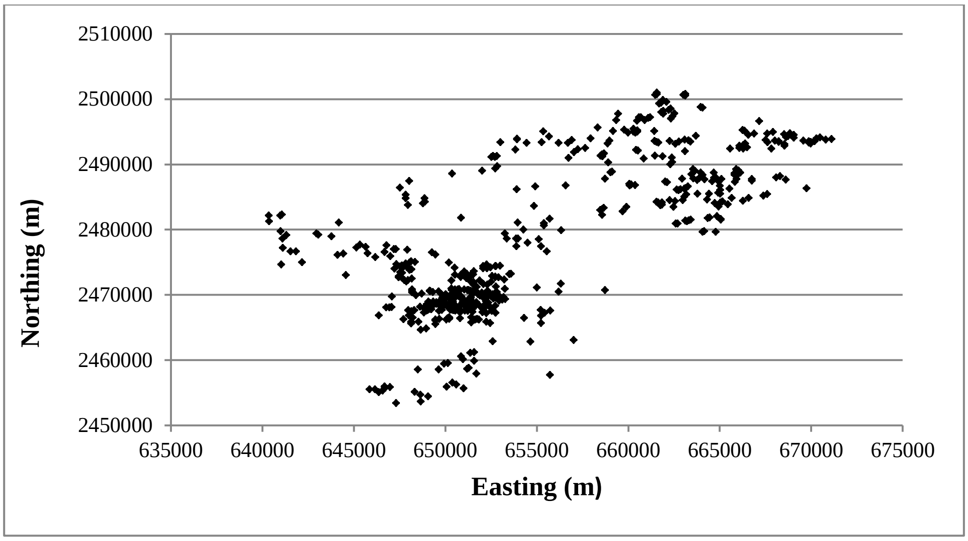


Fig: 5.18. Arsenic distribution in shallow tubewells in focus area

From fig 5.18 it was observed that arsenic distribution in shallow tubewell is spatially distributed throughout the focus area. The samples were very close in the middle part of the focus area.

5.4.3.2. Semivariogram modeling of arsenic at 0 ° -15° interval (Group I)

Semivariogram modeling was done with the help of the programming that was mentioned in Baruipur block. The same procedure was used to make the semivariogram modeling at the focus area. The semivariogram model was drawn for 0 ° -15° interval in fig no. 5.19.

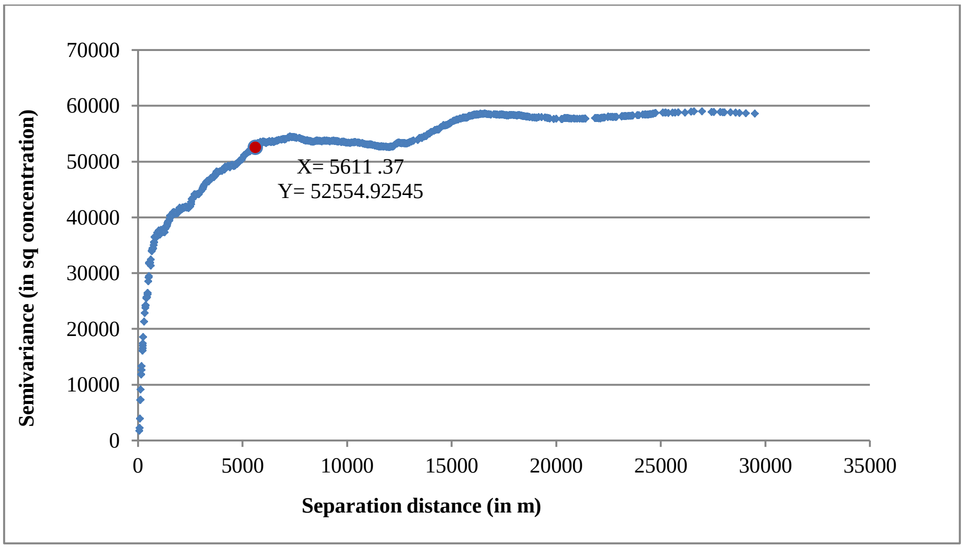


Fig: 5.19. Semivariogram modeling of arsenic in shallow tubewells in focus area

The range and sill value of the semivariogram are 5611.37 and 52554.92 respectively was observed in fig no 5.19. The sample points present within 5611.37 m are considered as spatially correlated. Thus 24 different angles and range values were preapared. The angles and range values for 24 different angles are tabulated in table no. 5.2

From the table 5.2 it was observed that the range values from group no 1 to group no 12, were repeated in range values from group no 13 to group no 24. The same range values were present in the same straight line at opposite directions. The maximum range was observed along 45 ^{o} -60^{o} and 225 ^{o} -240^{o} angle and the average angle was 52.5^{o} and 232.5^{o} measured from east. The maximum range was 6592 m.

Table: 5.2. The angle and range for the semivariogram of different directions at focus area

Group	**Initial angle (degree)**	**Final angle (degree)**	**Average angle (degree)**	**Range (m)**	**Group**	**Initial angle (degree)**	**Final angle (degree)**	**Average angle (degree)**	**Range (m)**
1	0	15	7.5	5611	13	180	195	187.5	5611
2	15	30	22.5	5463	14	195	210	202.5	5463
3	30	45	37.5	5579	15	210	225	217.5	5579
4	45	60	52.5	6592	16	225	240	232.5	6592
5	60	75	67.5	6336	17	240	255	247.5	6336
6	75	90	82.5	5560	18	255	270	262.5	5560
7	90	105	97.5	6281	19	270	285	277.5	6281
8	105	120	112.5	6062	20	285	300	292.5	6062
9	120	135	127.5	5494	21	300	315	307.5	5494
10	135	150	142.5	5441	22	315	330	322.5	5441
11	150	165	157.5	6095	23	330	345	337.5	6095
12	165	180	172.5	5921	24	345	360	352.5	5921

5.4.3.3. Rose diagram of semivariogram of 24 angles

The rose diagram was made with 24 angles with different ranges obtained from table 5.2. In fig 5.20, the rose diagram was summarized.

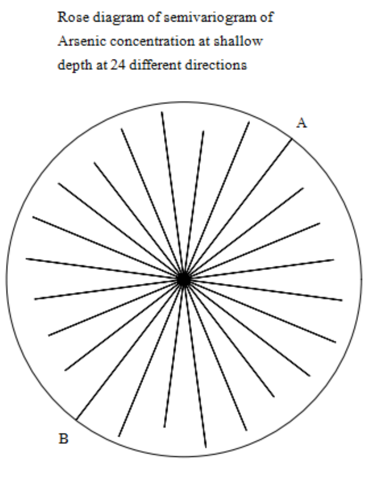


Fig: 5.20. A rose diagram of the 24 ranges in focus area

The rose diagram of the 24 ranges is shown in fig 5.20. The major and minor axes represent the axes of a geometric anisotropy. Distribution of arsenic in shallow depth was found symmetrical in focus area. The orientation of the critical direction for analysis was along the line AB at an angle of 52.5^{o} and 232.5^{o} measured from east with a critical range of 6592 m.

The distribution of arsenic was homogeneous with the longest range displayed in the NE-SW direction.

5.4.3.4. Semivariogram modeling of arsenic concentration at 45^{o}-60^{o} and 225^{o}-240^{o} angle

The range and sill at influential angle (52.5^{o} and 232.5^{o}) was determined from the fig no. 5.21.

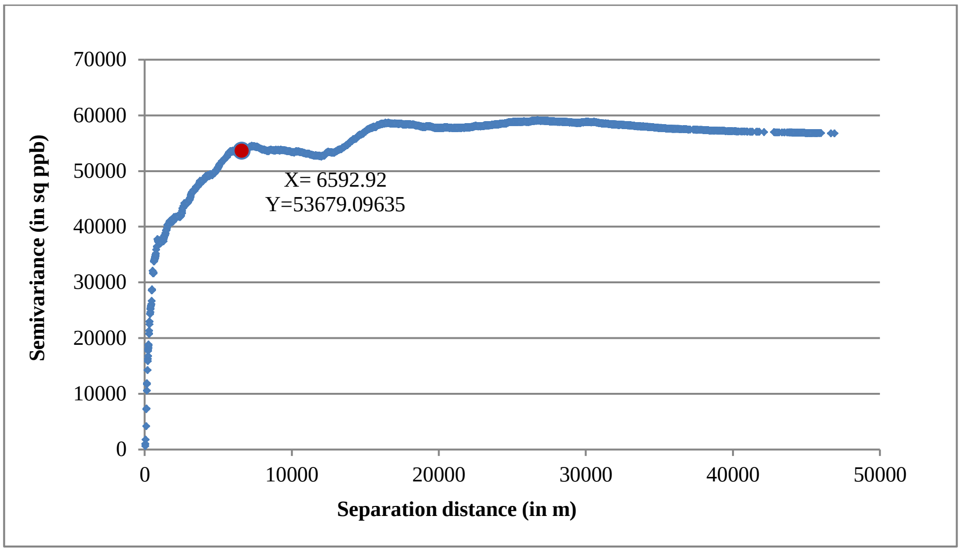


Fig:5.21. Semivariogram of arsenic in influential zone of the focus area

From the fig 5.21, it was observed that the range and sill of the model are 6592.92 m and 53679.09 sq ppb. From a study done by Marinoni (2003), it was found that semivariogram calculated the range at which the samples become uncorrelated from each other and they gave an idea of the direction of the best and worst spatial correlation.

5.4.3.5. Determination of Gradient/Bearing of Major Zone of Influence

Influential angle for the focus area was found 52.5^{o} and 232.5^{o} measured from east. For estimation of arsenic in groundwater at a specific location in the focus area will be influenced by the points those are located within the separation distance of 6592.92 m and close bearing of 52.5^{o} to 232.5^{0} from the east.

5.4.3.6. Equation generation for prediction

In the semivariogram model of focus area, the variation of $\gamma(h)$ vs h is found to follow a typical mathematical model followed by Power equation. So, the equation will be-

Power equation : $\gamma(h)= bh^{c}$, b is a constant and the value of b was unknown

For the present study, the equation can be rewrite as

Here, $D= A(S)^2$

D= separation distance (range value)

S= semivariance

By putting D and S value in the equation, the A value was 2×10^{-5}

$S = \frac{1}{\sqrt{2\times10^{-5}}} * D^{0.5} = 661.145$

The value was kept for the prediction of arsenic concentration at a sample point.

5.4.3.7.Determination of influencing points

Influencing sample points are those points which help to take decision about the weight of the nearby samples and make the estimates unbiased. The sample points lies within 6592.92 m and the angles 45^o-60^o and 225^o-240^o measured from the east are considered as influencing sample points. Arsenic concentrations from these points influence to predict the concentration of estimation point.

5.4.3.8. Estimation of arsenic

Estimation was done in 30 shallow tubewells, the estimated tubewells were enlisted in the 599 tubewells. At the time of estimation, the arsenic concentration at that location which is to be estimated was omitted from the list. A programing was made to generate equations from which the weighted points were got. The name of the programing workbook was Estimating Point Location. In Estimating Point Location workbook, there are 6 worksheets named Data, Distance and angle, Influencing points, Calculated Data, Separation distance-final and equations were incorporated.

For example, the arsenic concentration at sample location 1 would be predicted. The point to be estimated was placed at the first row with name EP (estimating point). The other 598 locations were placed in the table. The Get distance and Angle button was clicked. In fig. 5.22, the data worksheet for determination of distance and angle were summarised.

- **Data worksheet:**

Location	X Point	Y Point	Concentration
EP	652508	2471985	
2	650390	2456574	610
3	650087	2455907	360
4	655740	2457733	42
5	650600	2456244	40
6	650389	2488574	40
7	650542	2469718	100
8	649194	2470591	60
9	651538	2473138	370
10	650060	2466204	80
11	649473	2466198	167
12	655706	2481651	130
13	652031	2489033	32
14	650867	2481824	50
15	651377	2469627	110
16	651075	2473101	90
17	651554	2471566	530
18	650618	2470361	50
19	647653	2473378	315
20	647973	2472274	166
21	647872	2472051	433
22	652315	2470655	220
23	651377	2461123	170
24	648516	2458549	143

Get Distance & Angle | Clear All Data

Fig: 5.22. Data worksheet for determination of distance and angle

Then the Distance and Angle worksheet was opened and was mentioned in fig 5.23.

- **Distance and angle worksheet**

Seperation Distance	Pairs		Theta (Degree)	Lag Sep Distance
488.7	EP	27	65.585154	489
529.32	EP	135	39.40364793	530
657.49	EP	295	340.820992	658
736.82	EP	153	71.8109543	737
788.51	EP	375	290.4114666	789
793.53	EP	313	25.37021661	794
810.45	EP	202	60.01836063	811
832.13	EP	246	74.02623049	833
889.23	EP	247	85.93733642	890
958.92	EP	196	2.510316023	959
1007.31	EP	195	30.15407951	1008
1041.96	EP	17	23.71124228	1042
1085.72	EP	519	43.61919647	1086
1138.4	EP	213	354.9604981	1139
1319.31	EP	404	305.2802044	1320
1343.93	EP	22	81.74328401	1344
1449.73	EP	525	338.0885053	1450
1482.72	EP	200	332.4844273	1483
1495.6	EP	283	334.154535	1496
1502.6	EP	245	314.9191119	1503
1506.75	EP	9	310.0733519	1507

Bearing Low	Bearing High	Range
51.5	53.5	6592
231.5	233.5	6592

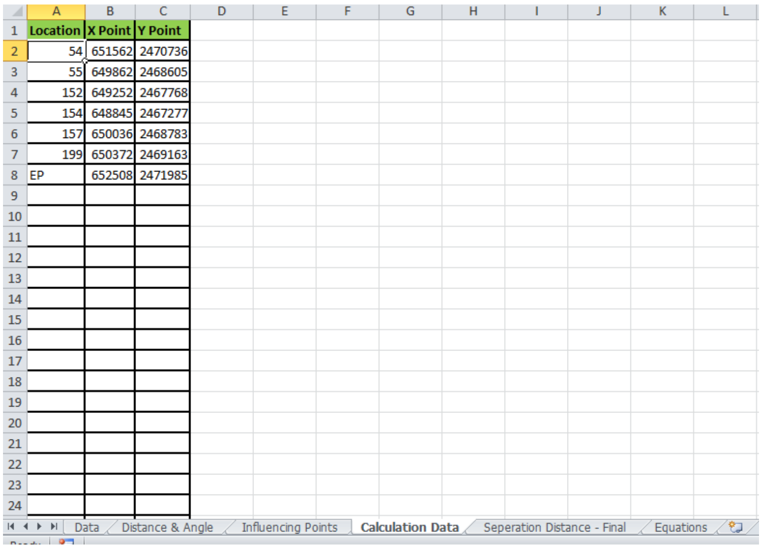
Get Influencing Points

Fig: 5.23. Distance and angle worksheet for determination of influencing points

In fig 5.23, separation distance, pairing with estimating point to other 598 points, the angle and lag separation distance all were calculated. Here, the angle and range were mentioned to calculate the influencing points. 6-10 influencing points were considered for each estimating point. The Bearing low and Bearing high were mentioned for influential angles. The interval of angle was changed according to the presence of the influential points. For point number 1, the angle interval was kept 2^o. The Get Influencing points button was clicked to get the influencing points.

The calculation data worksheet was mentioned in fig 5.24.

- **Calculation data worksheet**



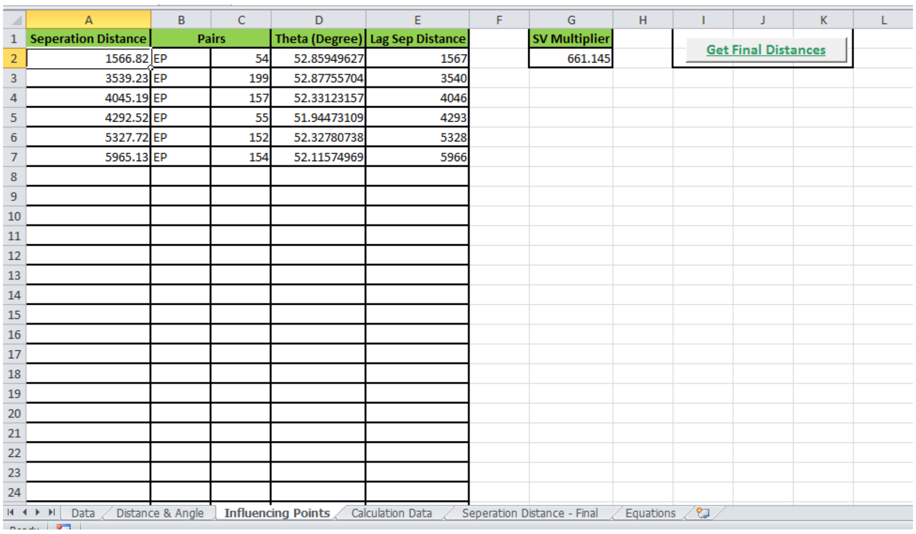
Location	X Point	Y Point
54	651562	2470736
55	649862	2468605
152	649252	2467768
154	648845	2467277
157	650036	2468783
199	650372	2469163
EP	652508	2471985

Fig: 5.24. Calculation data worksheet

In the Calculation data worksheet (fig 5.24), the location of influencing points were estimated. In case of location no of 1, there are 6 influencing points- 54, 55, 152, 154, 157 and 199.

In fig 5.25. the influencing points were determined.

- **Influencing points worksheet:**



Seperation Distance	Pairs		Theta (Degree)	Lag Sep Distance		SV Multiplier
1566.82	EP	54	52.85949627	1567		661.145
3539.23	EP	199	52.87755704	3540		
4045.19	EP	157	52.33123157	4046		
4292.52	EP	55	51.94473109	4293		
5327.72	EP	152	52.32780738	5328		
5965.13	EP	154	52.11574969	5966		

Fig: 5.25. Influencing points worksheet to determine final distance

From fig 5.25 it was observed that the separation distance, angle and lag separation distance was calculated from estimating point to each of the influencing points. SV (semivariance) multiplier 661.145 was obtained from equation generation. After that Get final distances button was clicked and Separation distance-final worksheet was opened.

- **Separation distance-final worksheet**

  In fig 5.26, separation distance-final worksheet was summarized.

	A	B	C	D	E	F	G	H	I	J	K
1	Seperation Distance	Pairs		Semi variogram				Generate Equations			
2	0	54	54	0							
3	2726.02	54	55	34519.241							
4	3761	54	152	40546.034							
5	4398.5	54	154	43847.922							
6	2478.48	54	157	32914.664							
7	1972.42	54	199	29362.729							
8	1566.82	54	EP	26170.154							
9	2726.02	55	54	34519.241							
10	0	55	55	0							
11	1035.7	55	152	21277.162							
12	1672.68	55	154	27039.78							
13	248.92	55	157	10431.016							
14	755.95	55	199	18177.881							
15	4292.52	55	EP	43316.452							
16	3761	152	54	40546.034							
17	1035.7	152	55	21277.162							
18	0	152	152	0							
19	637.75	152	154	16696.366							
20	1282.53	152	157	23677.208							
21	1788.97	152	199	27963.933							
22	5327.72	152	EP	48257.788							
23	4398.5	154	54	43847.922							
24	1672.68	154	55	27039.78							

Data / Distance & Angle / Influencing Points / Calculation Data / Seperation Distance - Final / Equations

Fig: 5.26. Separation distance worksheet to generate equations

From fig 5.26, it was observed that the pairing was done with all the influencing points and estimating point. The separation distance and semivariogram of each pair also calculated in the page. Generate equations button was clicked for equation generation.

- **Equation worksheet**

The equation for Estimation was=v=$\sum_{i=1}^{n} w_i \times v_i$

Here v_1 to v_n are the n number of available data values and w_i is a weight assigned to the value v_i. These weights are usually standardized so that they sum to one.

In fig 5.27, the equations were summarized in the worksheet

	Equations	A	B
1	Equations	A	B
2	Lambda + 0W1 + 34519.241W2 + 40546.034W3 + 43847.922W4 + 32914.664W5 + 29362.729W6 = 26170.154	1 0 34519.241 40546.034 43847.922 32914.664 29362.729;1 34519.241 0 21277.162 27039.78 10431.016 18177.881;1 40546.034 21277.162 0 16696.366 23677.208 27963.933;1 43847.922 27039.78 16696.366 0 28970.149 32568.824;1 32914.664 10431.016 23677.208 28970.149 0 14890.301;1 29362.729 18177.881 27963.933 32568.824 14890.301 0;0 1 1 1 1 1 1	26170.154;43316.452;48257.78 .017;39332.46;1
3	Lambda + 34519.241W1 + 0W2 + 21277.162W3 + 27039.78W4 + 10431.016W5 + 18177.881W6 = 43316.452		
4	Lambda + 40546.034W1 + 21277.162W2 + 0W3 + 16696.366W4 + 23677.208W5 + 27963.933W6 = 48257.788		
5	Lambda + 43847.922W1 + 27039.78W2 + 16696.366W3 + 0W4 + 28970.149W5 + 32568.824W6 = 51063.041		
6	Lambda + 32914.664W1 + 10431.016W2 + 23677.208W3 + 28970.149W4 + 0W5 + 14890.301W6 = 42050.017		
7	Lambda + 29362.729W1 + 18177.881W2 + 27963.933W3 + 32568.824W4 + 14890.301W5 + 0W6 = 39332.46		
8			
9			
10			
11			
12			
13			
14			
15			
16			
17			
18			

Data / Distance & Angle / Influencing Points / Calculation Data / Seperation Distance - Final / Equations

Fig: 5.27. Equation worksheet

In fig 5.27 it was observed that 6 equations were generated from the programing and one equation was mentioned in equation no. 5.7 (W1+W2+W3+W4+W5+W6=1). They were solved at online equation solver and the value of W1, W2, W3, W4, W5 and W6 was obtained. Then the concentration of the influencing points were multiplied with the weightage of the influencing points.

The set of weights is allowed to change as the estimation of unknown values at different locations. The estimation at an unknown location with influencing points and their weightage factors were mentioned in table 5.3.

In table 5.3, the estimation of arsenic concentration at a sample point was calculated with the help of weightage and concentration of influencing points. The sample locations who were closer to the estimation point, the weightage factor of those location determine the estimated concentration of that point. In a hot spot region, where higher concentrations lies between lower concentrations or vice versa, the estimation process will not give the accurate results.

Table: 5.3. Estimation of arsenic concentration at sample point 1

Influencing points	**Weightage of the influencing points**	**Concentration of the influencing points (ppb)**	**Weighted concentration (ppb)**
54	0.6696	320	214.272
55	0.0413	220	9.086
152	0.0473	50	2.365
154	0.0741	20	1.482
157	0.046	210	9.66
199	0.1217	140	17.038
Estimated concentration (ppb)			253.9
Actual concentration (ppb)			360

5.4.3.9. Location of sample and estimated points in the geological map

The location of sample points and estimating points were plotted in fig no 5.28

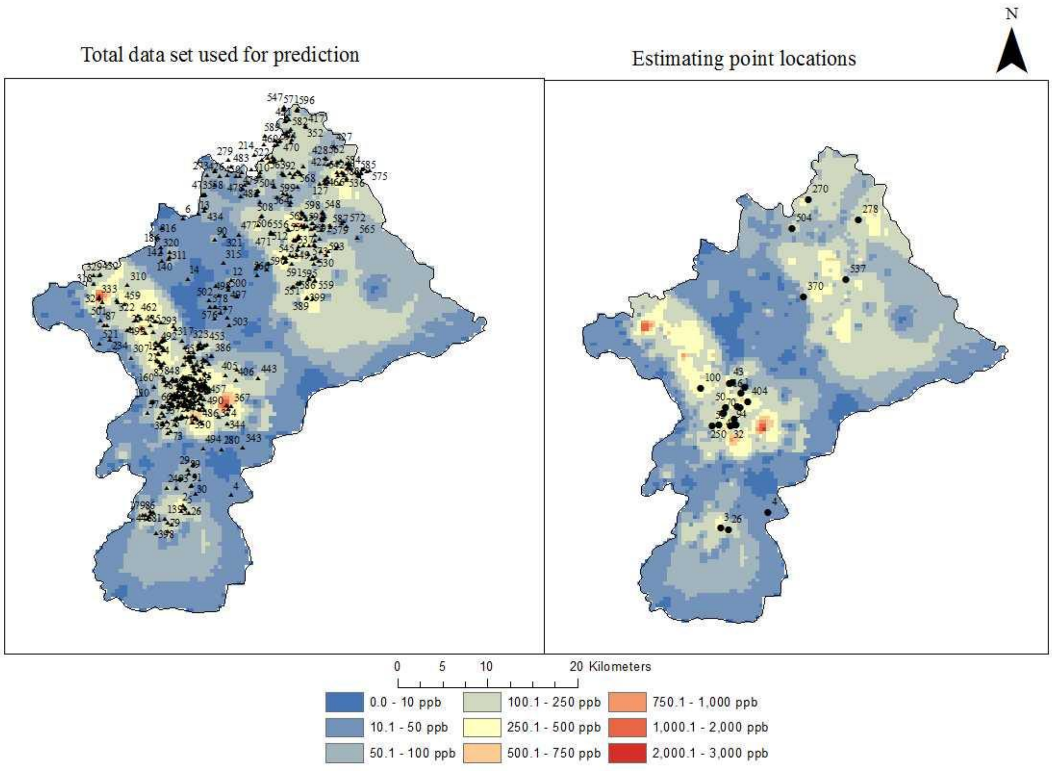


Fig: 5.28. Location of the data set used for the prediction and location of estimating points in focus area

The location for total data set of estimation (599 locations) and estimating point locations (30 locations) were shown in fig no.5.28 . In total data set location some data location were found lying outside the focus area. Those data were taken to estimate the concentration which were present in the edge of the focus area. Point no 270, 278 and 504 are present at almost the edge of the focus area.

In table 5.4, the list of estimating points, their locations, influencing points, actual value and estimated values were summarized.From table 5.4 it was observed that the estimated values were found different from actual values in some locations. In the present study, the depth range of the tubewells were 10-100 m bgl. Here the total depth range is considered for the study instead of a specific depth. For example, it was assumed that the depth of sample no 1 tubewell was 20 m bgl, but the influencing points are present in 30 m bgl. Then the model will give the predicted concentration at this location at 30 m bgl depth, the concentration will become different.

Table: 5.4. List of estimating points, their locations, no of influencing points, actual and estimated value:

Point no	X	Y	No of Influencing points	Actual Value (ppb)	Estimated value (ppb)
1	652508	2471985	6	360	253.9
3	650087	2455907	7	360	382.28
4	655740	2457733	6	42	64.32
16	651075	2473101	6	90	121.076
26	651017	2455694	7	100	101.1
32	651206	2468097	6	299	358.26
43	651486	2473227	6	250	283.4
47	650420	2469529	6	110	103.47
50	650701	2470307	6	90	76.26
53	649023	2468043	8	20	27.33
70	650368	2469584	6	70	103.74
94	651617	2468212	6	117	181.39
100	647661	2472603	6	225	257.42
123	650884	2469423	7	335	315.83
192	651926	2468215	8	575	101
202	652913	2472687	6	30	38
205	652422	2470213	6	255	312.08
221	652009	2470320	6	152	134.45
223	651714	2468877	6	293	321.21
250	649866	2468173	6	20	30.71
270	660509	2494988	6	91	75.79
278	666500	2492615	7	54	213.15
306	648151	2475154	6	132	155.73
329	640982	2482174	6	72	57.9
370	659908	2483465	6	53	510.97
404	653270	2470908	6	240	295.43
412	668535	2494631	8	250	213.256
504	658590	2491535	7	89	78.46
537	665033	2485512	6	220	248.32
546	666024	2489067	7	120	136.25

5.4.3.10. Estimation of occurrence level

As the actual and estimated value are not same in all the prediction points, the occurrence level of estimated value are discussed in fig no. 5.29.

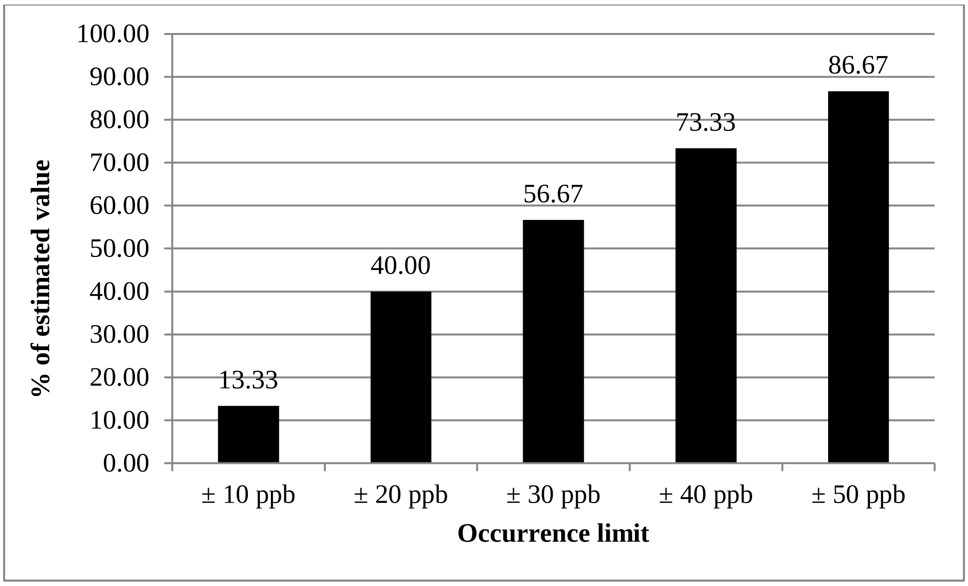


Fig: 5.29. Occurrence level of estimated arsenic concentration

Occurrence level of the estimated value has been considered as the measurement of error in present study. From fig 5.29, it was observed that 13.3% of estimated values are present in ±10 ppb and 56.67% estimated values are observed in ±30 ppb occurrence level. 86.67% of the estimated values were observed to be present in ±50 ppb occurrence level.

5.4.3.11. Distribution of errors

At every location where estimation was done, there are two values, one is actual value and the other is the estimated value. The error can be defined at each location as the difference between the estimated value and true value. If r is positive, then the true value is underestimated and if r is negative, then the true value is overestimated. In fig 5.30, the distribution of error between actual and predicted value was summarized.

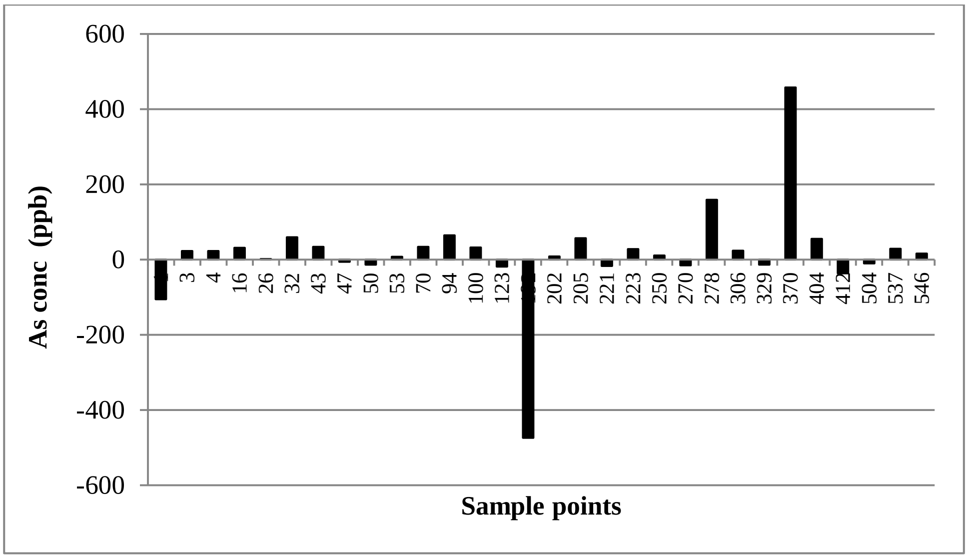


Fig: 5.30. Distribution of error of arsenic concentration in predicted values of shallow tubewell

Among 30 estimated points, r value of 20 sample points were found positive and 10 sample points were negative (fig. 5.30). According to Isaaks and Srivastava (1989), most estimation methods, even those are globally unbiased, are guilty of overestimation and underestimation for some range of values.

5.4.3.12. Study of deviation between actual and estimated value of arsenic concentration

If there is a set of estimates at several locations, it is natural to compare their distribution to the distribution of the true values at the same locations. It feels better when the distribution of estimated values are similar to the distribution of true values. But the deviation occurs between the estimated and actual due to sampling error, measurement error, geological settings of the study area. The deviation of actual and estimated value of arsenic concentration is summarized in fig no. 5.31

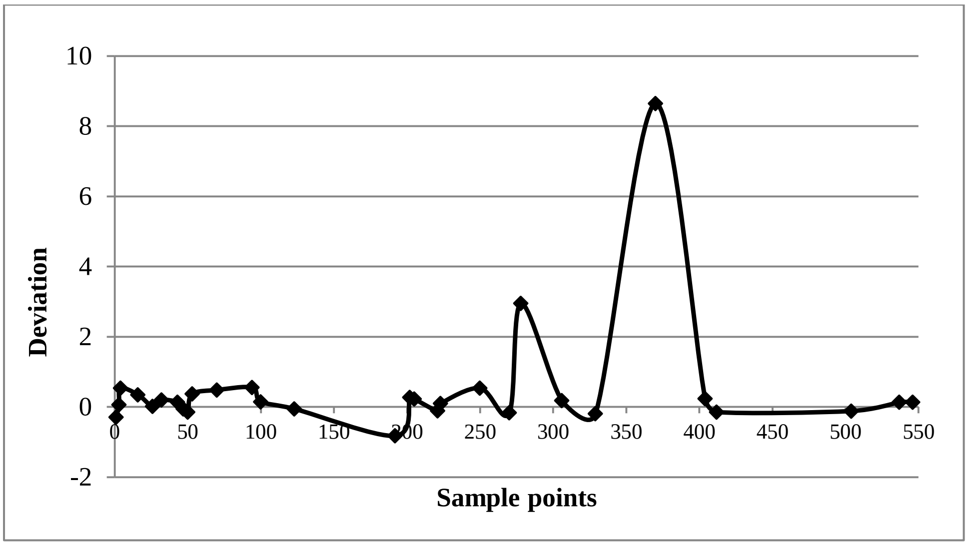


Fig: 5.31. Deviation of arsenic concentration among actual and estimated value of shallow tubewell

The deviation between estimated and actual values was observed as 20% samples at 0.01 to 0.1, 60% in 0.1 to 0.5, 13.3% in 0.5 to 1 and 6.6% was present in more than 1. From the fig 5.31, it was found that the maximum deviation was observed in point no 192, 278 and 370. These are the most erroneous points of estimation. Point number 192 and 370 were selected to determine the cause for erroneous determination.

5.4.3.13. Cause of erroneous estimation at two sample points

Estimation needs to account for the distance from the point to be estimated to the individual sample locations. Some samples get much closer than others and the values at these closer locations should be given more weight than the values that are further away. The concentration varies with the geological settings of the study area. In focus area, higher arsenic concentration was observed to be surrounded by low arsenic contaminated zone. If a sample is located in the pocket of the high arsenic contaminted zone and the influencing points are located in low arsenic contaminted zone, the predicted value will be erroneous.

Two sample points (192 and 370) were selected to estimate arsenic concentration. The influencing points of the respective estimation points were located within 45^o-60^o and 225^o-240^o angles from the points in the focus area. The total weightage value for all points was 1. Only the number of influencing points differ from 6-10. In sample no 192, the estimated value was almost 5 times lower than the actual value and sample no 370 the estimated value is approximately 10 times higher than actual value.

For point no 192, the total number of influencing points were 8. The influenceing points, weightage value, arsenic concentration at influenting points and theit weightage concentration was mentioned in table 5.5.

Table: 5.5. Estimation of arsenic concentration in point no 192

Influencing Point	Weightage value	Arsenic conc at sample points (ppb)	Weightage concentration (ppb)
71	0.1212	70	8.484
73	0.0152	40	0.608
75	0.0175	350	6.125
339	0.1162	110	12.782
340	0.1659	110	18.249
355	0.0328	218	7.1504
384	0.4623	100	46.23
429	0.0689	20	1.378
Estimated arsenic concentration (ppb)			101
Actual arsenic concentration (ppb)			575

Estimated concentration was 101 ppb whereas actual concentration 575 ppb was found for sample no 192 in table 5.5. The value was underestimated.

For point 370, the number of influencing points were 6. The influenceing points, weightage value, arsenic concentration at influenting points and their weightage concentration was mentioned in table 5.6.

From the table 5.6, the estimated and actual concentrations were found 510.97 ppb and 53 ppb respectively. The value was overestimated. The complexity in relation to the distribution of arsenic seems to follow a pattern if both the depth and geological settings are taking into consideration (Kinniburgh et al, 2003 and Van Geen et al, 2003).

Table: 5.6. Estimation of arsenic concentration in point no 370

Influencing points	**Weightage value (ppb)**	**arsenic conc at sample points**	**Weightage concentration (ppb)**
435	0.1368	630	86.184
523	0.3716	747	277.5852
524	0.0674	737	49.6738
527	0.2094	407	85.2258
569	0.078	14	1.092
597	0.1368	82	11.2176
Estimated arsenic concentration (ppb)			510.97
Actual arsenic concentration (ppb)			53

According to Marinoni (2003) OK can overestimate the lower value and underestimate the higher value. It is called 'smoothing' effects. In this study the cause for over and underestimation was discussed by the geological formation of the study area.

The deviation of actual and estimated value mainly depends on the geological settings of the study area**.** The location of estimating points and the estimating points with influencing points were summarized in fig no. 5.32.

From fig 5.32, it was found that the estimating points were located in the isolated arsenic patches. Point no 192 was located in higher arsenic concentration zone, but the influencing points those lie between 45^o-60^o angle, were present in less than 100 ppb arsenic concentration region. The influencing points were observed between 225^o-240^o are present in 100-250 ppb arsenic concentration zone, only 2 points in this zone have arsenic concentration more than 200 ppb. The most weighted points were 384 (0.4623), 340 (0.1659) and 339 (0.1162) and their concentrations are 100 ppb, 110 ppb and 110 ppb respectively. So, the estimated point is influenced by those points and the value is near 101 ppb. But the point is located in high arsenic containing mineral belt. So, the deviation occured between actual (575 ppb) and estimated (101 ppb) point.

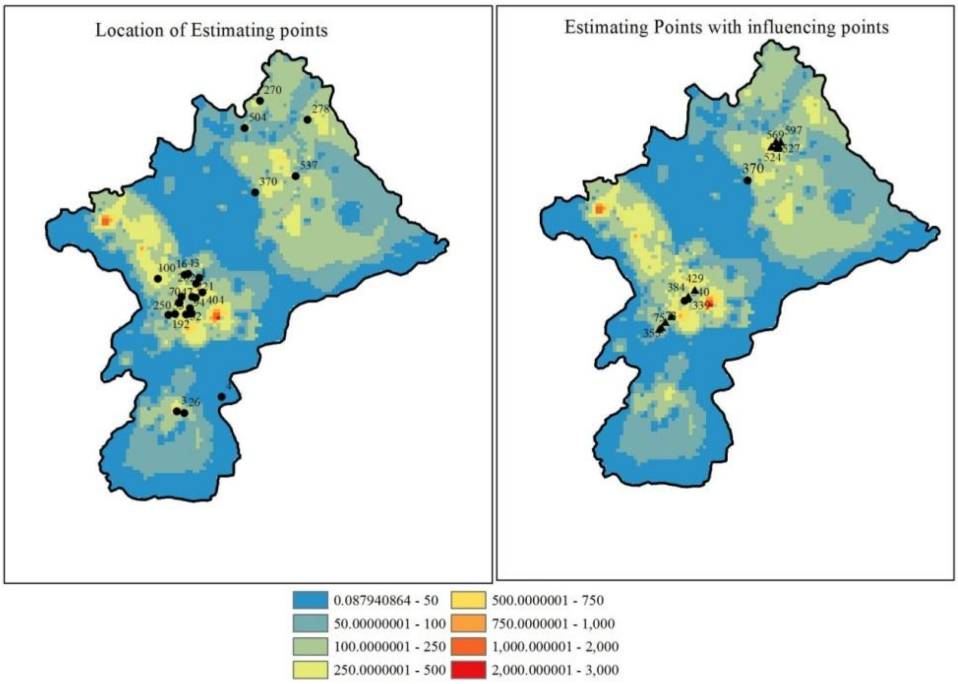


Fig: 5.32. Location of estimating and influencing points in shallow tubewell

In case of point no 340, the most weighted points are 523 (weightage factor 0.3716), 527(weightage factor 0.2094) and 597 (weightage factor 0.1368) and the concentrations of the points are 747 ppb, 407 ppb and 82 ppb. The points lie in 45^o-60^o angle. As the influencing points are located in high arsenic concentration zone, the estimated point is also higher though the estimating point is located in low concentration zone. The estimated and actual concentrations were 510.97 ppb and 53 ppb respectively. Most of the points were found locating in the Arambagh formation in lower matured deltaic plain, only some points were found in Present day deposit. The fluctuation of water table was reported from 2-6 m bgl.

5.4.4. Prediction of arsenic in deep tubewell in focus area

5.4.4.1. Location of spatially distributed sampling points in focus area

159 secondary data was selected for the study of semivariogram model in deep depth tubewell. The numbers of sample location points were less than shallow tubewell data because arsenic concentration was not found everywhere in deeper aquifer in the focus area. Distribution of arsenic concentration is summarized in fig no. 5.33.

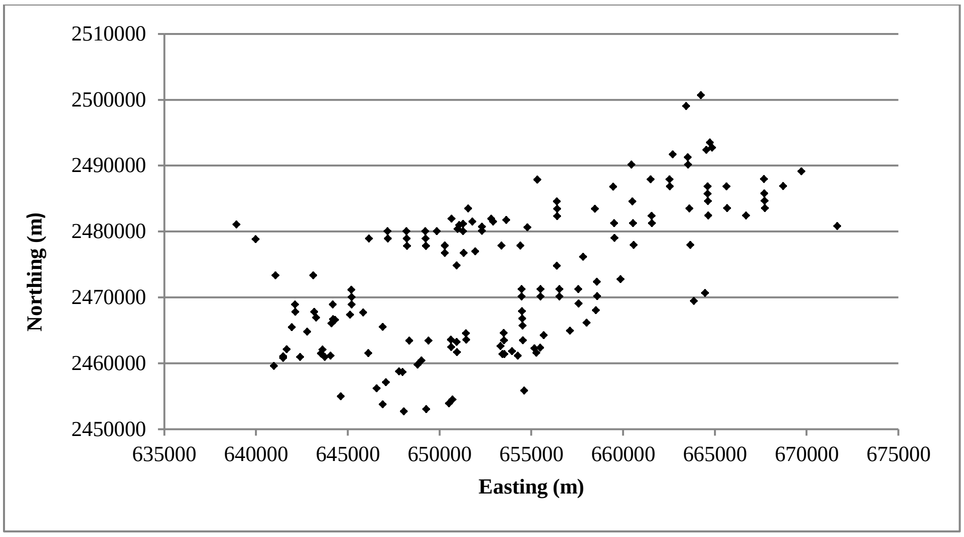


Fig: 5.33. Distribution of arsenic in deep tubewell in focus area

The sample points containing arsenic distribution in deep tubewells were spatially distributed over the focus area (fig 5.33).

5.4.4.2. Semivariogram modeling of arsenic at 0-15° interval (Group I)

The same programming that was used for Baruipur block and shallow depth tubewell in focus area, also used here to make semivariogram modeling. Semivariogram modeling was done with 15° angle interval from 0° to 360°, 24 semivariogram models were obtained, the first one (0° -15°) interval was taken for the study. The average interval angle was taken assuming the points were present along a straight line. The semivariogram for 0° -15° angle were summarized in fig no. 5.34.

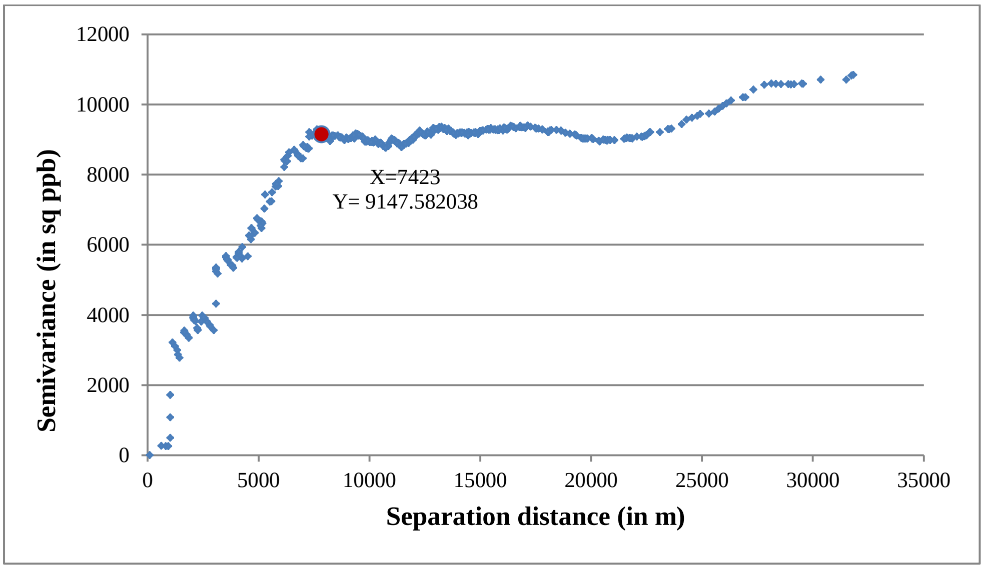


Fig: 5.34. Semivariogram of arsenic in deep tubewell

In fig 5.34, the range and sill value of the semivariogram were found 7423 m and 9147.58 sq ppb respectively. The sample values are spatially correlated within 7423 m in this model. Thus 24 different ranges were obtained by drawing the models at different angles. The angles and range values are tabulated in table 5.7. The average angle was taken for the study.

From the table 5.7 it was observed that the range values from group no 1 to group no 12, were repeated in range values from group no 13 to group no 24. The same range values were present in the same straight line at opposite directions. The range was maximum at 7859 m. The maximum range was observed along 45-60^o and 225-240^o angle and the average angle was 52.5^o and 232.5^o.

Table: 5.7. The angle and range for the semivariogram of different directions at focus area

Group	**Initial angle (degree)**	**Final angle (degree)**	**Average angle (degree)**	**Range (m)**	**Group**	**Initial angle (degree)**	**Final angle (degree)**	**Average angle (degree)**	**Range (m)**
1	0	15	7.5	7207	13	180	195	187.5	7207
2	15	30	22.5	7188	14	195	210	202.5	7188
3	30	45	37.5	7738	15	210	225	217.5	7738
4	45	60	52.5	7859	16	225	240	232.5	7859
5	60	75	67.5	7408	17	240	255	247.5	7408
6	75	90	82.5	7352	18	255	270	262.5	7352
7	90	105	97.5	7641	19	270	285	277.5	7641
8	105	120	112.5	7299	20	285	300	292.5	7299
9	120	135	127.5	7713	21	300	315	307.5	7713
10	135	150	142.5	7152	22	315	330	322.5	7152
11	150	165	157.5	7217	23	330	345	337.5	7217
12	165	180	172.5	7158	24	345	360	352.5	7158

5.4.4.3. Rose Diagram of semivariogram of 24 angles

The rose diagram of 24 directions was made to observe the orientation of critical direction. The rose diagra of semivariogram at deep tubewell was mentioned in fig 5.35.

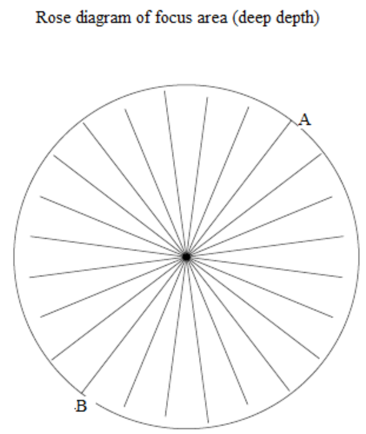


Fig: 5.35. Rose diagram of arsenic concentration in deep tubewell

In fig 5.36, the rose diagram for arsenic concentration was found symmetrical in the deep tubewell water of the focus area. The orientation of the critical direction for analysis of groundwater arsenic is along the line AB at an angle of about 52.5^o measured from north towards east with a critical range of 7859 m. The longest range was displayed in the NE-SW direction.

5.4.4.4. Semivariogram modeling of arsenic concentration at 45^o-60^o and 225^o-240^o angle

Semivariogram modeling of arsenic concentration at influential zone was summarized in fig 5.36.

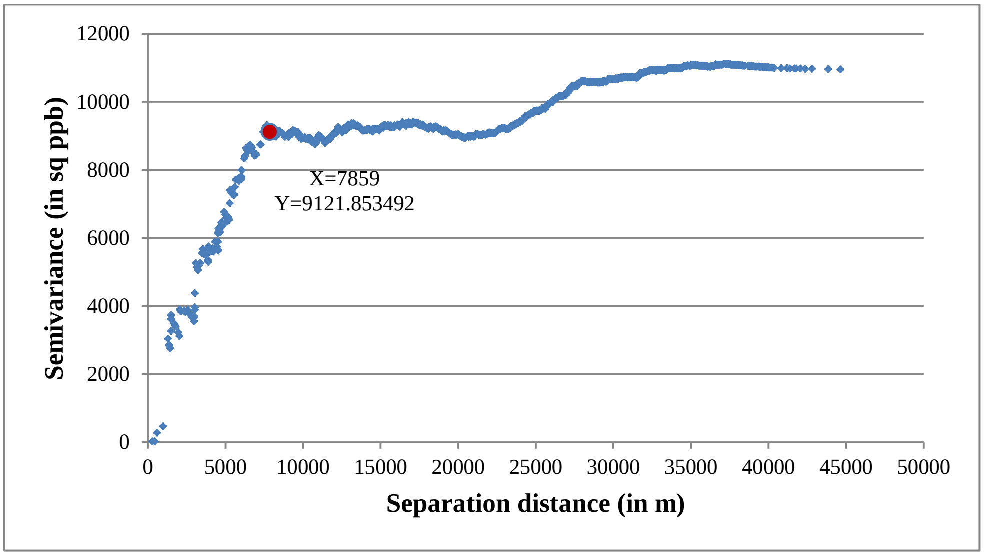


Fig: 5.36. Semivariogram of arsenic at influential zone in deep tubewell

From fig 5.36, it was found that at 52.5^o and 232.5^o angle, the range of the model is maximum. The range and sill of the model are 7859 m and 9121.85 sq ppb.

5.4.4.5. Determination of Gradient/Bearing of Major Zone of Influence

Influential angle was determined at 45-60^o and 225-240^o angle. For estimation of arsenic in groundwater at a point that will influence the estimate should be within the separation distance of 7859 m

5.4.4.6. Equation generation for prediction

In the model the variation of γ(h) vs h is found to follow a typical mathematical model followed by Power equation

Power : $\gamma(h)= bh^c$

Here, $D= A(S)^2$

D= separation distance (range value)

S= semivariance

By putting D and S value in the equation, the A value was $9*10^{-4}$

$$S = \frac{1}{\sqrt{9*10^{-4}}} * D^{0.5}$$

S= 102.937

5.4.4.7. Estimation of arsenic concentration

30 points were selected from the semivariogram data set used for focus area (deep tubewell) for estimation. The same procedure was used for the estimation that was utilized in shallow depth tubewell in focus area. In table 5.8 the point location, number of influencing points, actual and estimated value.

Table: 5.8. List of point no, location, number of influencing points and actual and estimated value

Point no	X	Y	No of Influencing points	Actual value (ppb)	Estimated value (ppb)
12	662703	2491689	7	98	96.84
14	664853	2492708	6	25	25.05
15	664742	2493482	7	12	11.89
23	647792	2458763	7	10	10.123
34	650945	2463223	6	10	7.25
44	641485	2460809	7	50	50.117
49	644117	2466037	7	70	27.45
53	649013	2460436	8	20	22.78
57	640981	2459586	7	10	9.38
66	651571	2483492	6	0	1.52
74	643173	2467800	8	5	5.82
79	645213	2470030	6	5	3.02
81	658603	2470160	6	4	1.29
88	654483	2470120	6	10	7.92
92	653519	2463470	8	50	48.76
98	644214	2466700	8	10	22.35
102	655335	2487850	6	2	6.27
105	660583	2477940	7	3	1.49
113	665636	2486850	6	12	35.48
114	659519	2481250	8	26	22.41
118	664631	2484620	6	40	43.74
120	659542	2479030	7	90	87.25
122	664654	2482410	7	16	24.4
124	665672	2483530	7	17	15.2
129	660549	2481260	8	52	50.76
138	651285	2481160	7	13	18.52
139	651328	2476740	6	31	40.5
144	643122	2473340	6	11	9.02
150	649258	2477820	6	34	29.87
158	651296	2480060	7	19	15.62

The actual and estimated values were found almost similar in deep tubewell because the range of spatial variability was found less in the deep tubewell.

5.4.4.8. Location of sample and estimating points in map:

The location of sample data and estimating point location was mentioned in fig 5.37.

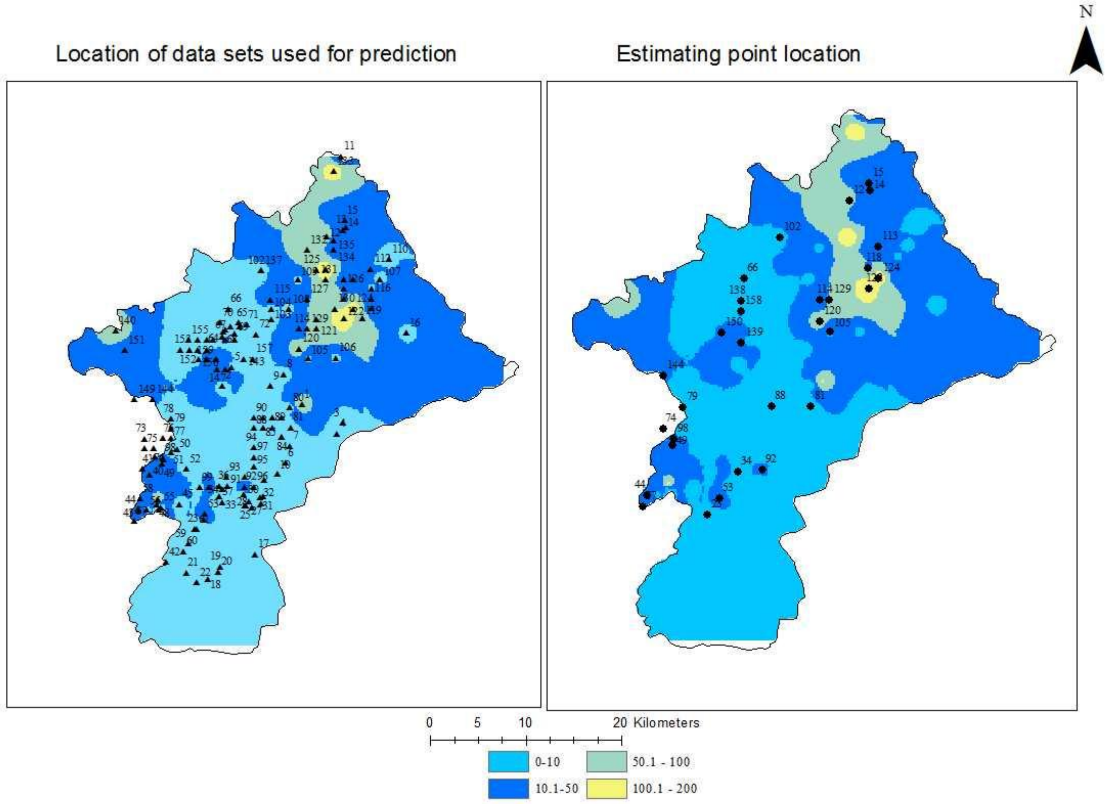


Fig: 5.37. Location of data sets for prediction and estimating points in deep tubewell

The locations of arsenic contaminated tubewells in deep aquifer is spatially distributed (fig 5.37). The tubewell locations were taken almost all the zones of the study area. The estimation was also done in all the zones of the focus area.

5.4.4.9. Estimation of occurrence level

The occurrence level of estimated value was summarized in fig 5.38

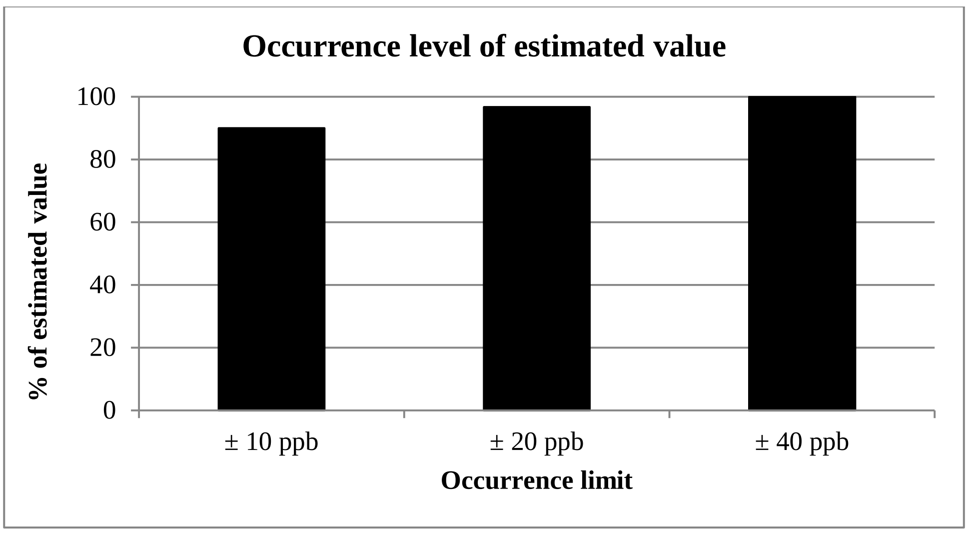


Fig: 5.38. Occurrence level of estimated value in deep tubewell

From fig 5.38, it was found that the occurrence level of estimation in deep tubewell was observed 90% for ±10 ppb. So, the estimated values was almost similar to the actual value.

5.4.4.10. Distribution of errors

Distribution of errorrs between actual and estimated concentration was measured in fig 5.39.

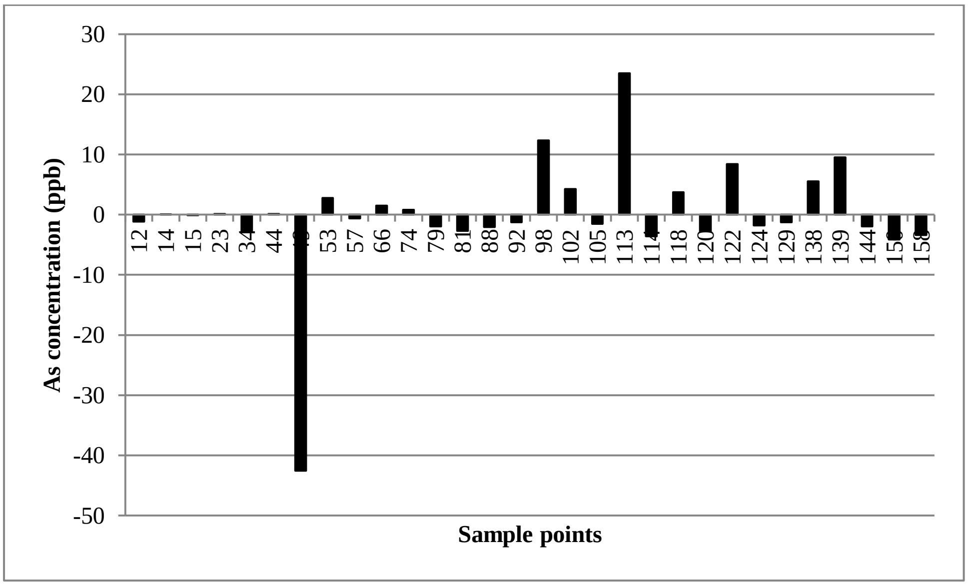


Fig: 5.39. Distribution of error of arsenic concentration in predicted values of deep tubewell

Positive error was observed in 10 sample points and negative error was observed in 20 sample points (fig 5.39). The estimated value of point no 49 was found lower than the actual value because the estimation point exists in higher concentration zone (50-100 ppb) and the influential points were present in low arsenic concentration zone (10-50 ppb). The estimated value at point no 98 and 113 was higher than the actual value. Both the points are located in lower arsenic contaminated zone (10.1-50 ppb) and the influential points are present in higher arsenic contaminated zone (50.1-100 ppb)

5.4.4.11. Study of deviation between estimated and actual arsenic concentration

The deviation was observed between estimated value and actual value in fig 5.40.

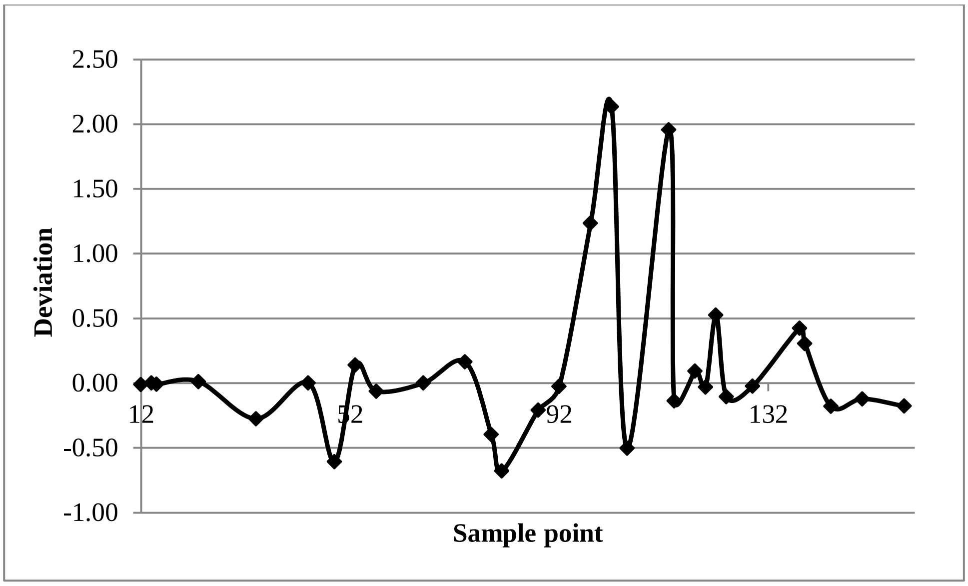


Fig: 5.40. Deviation of arsenic concentration among actual and estimated value of deep tubewell

From fig 5.40, maximum deviation between estimated and actual concentration was observed in point number 81. The deviation observed between the actual and estimated values were 33.3% in 0.01 to 0.1, 46.7% in 0.1 to 0.5, 10% in both 0.5 to 1 and more than 1.

5.4.5. Prediction of arsenic in field samples in focus area

45 water samples were collected from tubewells of the focus area. The point numbers mentioned here was the GPS location point. The tubewell depths were collected from the local people who were using the water for drinking purposes. According to the local people all the depth of the tubewells were 1000 feet or 304.8 m.

5.4.5.1. Location of field sampling points

Field sampling points were identified by the GPS and the water samples were collected from different tubewells from the focus area. In fig 5.41, the location of field sampling points were mentioned.

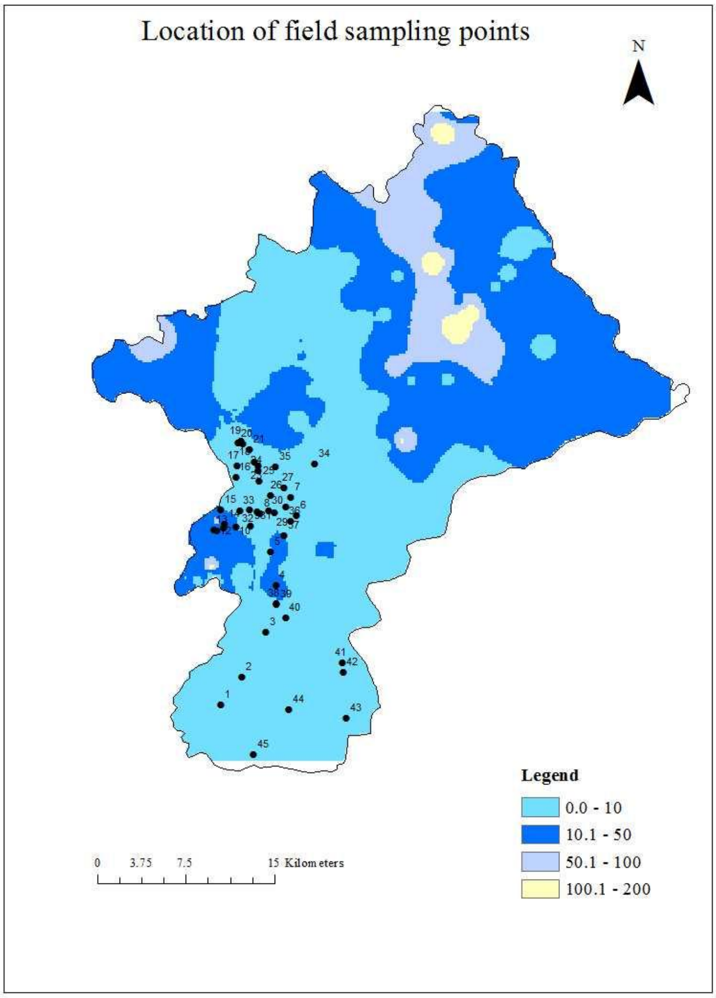


Fig: 5.41. Location of field sampling points in the focus area

Samples were collected from the southern part of the focus area. The collected water samples were further tested in Civil Engineering Department lab, Jadavpur University to obtain the actual data. Then the estimation was done with the deep tubewell data set as the depth of tubewells were more than 300 m bgl with ordinary kriging interpolation method.

Table: 5.9. Location of sampling points and comparison between actual and estimated value

Srl no	Point no	Place	X	Y	Actual (ppb)	Estimated (ppb)
1	65	Mouzpur settlement area	644537	2450375	59.91	62.65
2	66	Opposite Jaynagar Institution	646291	2452742	29.68	35.978
3	68	Hachimpur FPS Kulpi Baruipur Road	648310	2456563	30.54	19.83
4	69	Padmer hat FPS	649182	2460540	26.81	13.2
5	70	Sarberia Satadal School	648747	2463345	26.43	20.48
6	71	Surjapur Nachangacha FPS	650931	2466458	13.27	12.72

Srl no	Point no	Place	X	Y	Actual (ppb)	Estimated (ppb)
7	72	Dhapdhapi Surjapur FPS	650415	2467966	12.56	9.47
8	143	Shankarpur	647822	2466588	12.53	16.25
9	145	Balbalia	647021	2465543	11.42	15.29
10	146	Narayanpur SSK	645773	2465474	32.83	12.57
11	147	Multi Anganwari	644761	2465393	28.21	27.7
12	148	Multi Sahapara Battala	644144	2465153	41.46	58.31
13	149	Multi Dhamua	643914	2465276	13.62	5.59
14	150	Dhamua Girls High School	644818	2465765	24.15	34.67
15	151	Badurtala Dhamua	644510	2466956	9.2	11.25
16	154	Durgapur	645808	2469718	12.13	15.49
17	155	Indrapala FPS	645911	2470653	18.52	13.8
18	157	Kalyanpur High School	645971	2472659	9.61	14.5
19	159	Nihata	646203	2472810	21.78	11.92
20	160	Kalyanpur FPS	646391	2472524	35.25	10.97
21	161	Baruipur Byepass	646930	2472089	15.72	9.13
22	162	Shasan	647355	2470997	16.59	10.21
23	163	Sikharbali II	647669	2470664	8.25	10.9
24	164	Shikharbali II near GP	647681	2470301	9.17	11.86
25	165	Shikharbali II Bancharamer bagan	647751	2469412	12.74	5.29
26	166	Banberia Junior School	648752	2468151	8.26	9.8
27	167	Mirpur FPS	649845	2468822	10.82	13.57
28	168	Kumorhat FPS	650011	2467196	12.46	10.39
29	169	Teka FPS	649006	2466692	15.5	9.84
30	170	Alampur	648531	2466835	12.93	7.25
31	171	Gazirhat Ratanpur FPS	647559	2466796	8.63	10.85
32	172	Shankarpur FPS	646894	2466947	15.49	8.51
33	173	Dadpur FPS	646092	2466860	12.41	15.73
34	174	Kathalberia Primary School	652434	2470824	8.71	11.35
35	294	Ramnagar, Canning Rd	649145	2470580	18.72	15.53
36	296	Keyatala high School	650458	2465975	13.37	15.31
37	297	Paschim Panchgachia FPS	649880	2464777	15.41	24.19
38	298	Jinatullah FPS	649216	2458987	8.62	17.53
39	299	Beliadanga FPS	649209	2458921	9.2	16.25
40	300	D. Barasat Raynagar	649977	2457794	17.63	9.27
41	302	D. Barasat Padmapukur	654800	2453958	5.24	8.39
42	303	Beledurganagar FPS	654843	2453152	10.7	12.38
43	305	Beside State Highway	655148	2449299	13.91	5.64
44	335	Purba Raghunathpur FPS	650270	2450001	8.26	10.47
45	340	Nimpith, Bakultala	647243	2446160	9.32	2.35

Here FPS means Free Primary schools

5.4.5.2. Occurrence level of estimated arsenic concentration

The estimated values were not differed very much from the actual value. The occurrence level of estimated value was summerized in fig no. 5.42.

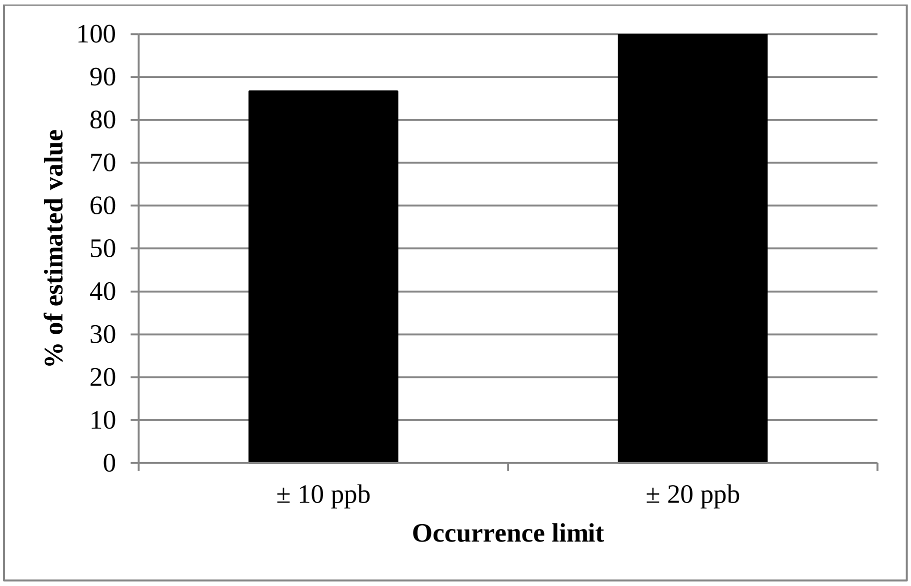


Fig: 5.42. Occurrence level of estimated value from the field samples

Occurrence level ±10 ppb concentration was found in 85% of the sampled value and 100% of the sample values were found in ±20 ppb concentration in fig 5.42.

5.4.5.3. Distribution of errors

The estimated and actual values were not same at all the locations. So, distribution of errors were measured in fig 5.43.

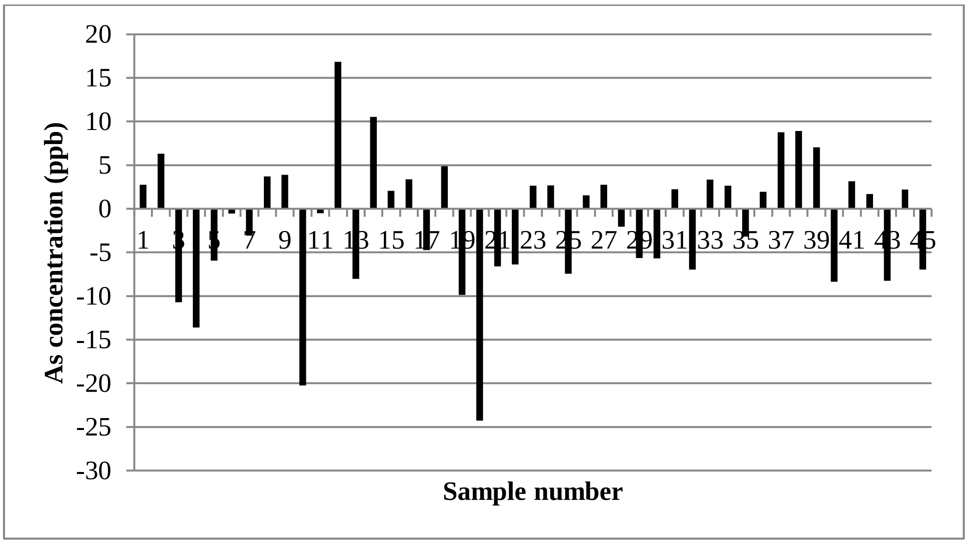


Fig: 5.43. Distribution of error of arsenic concentration in predicted values in field samples

From fig 5.43, it was found that positive error (over estimated) was found in 22 sample locations and negative error (under estimated) was found in 23 sample locations. Maximum positive error was found in point no 12 (16 ppb) and negative error was found in point no 20 (-25 ppb).

5.4.5.4. Study of deviation between estimated and actual value of arsenic concentration

The deviation of estimated and actual arsenic concentration was observed in fig no 5.44 in field samples.

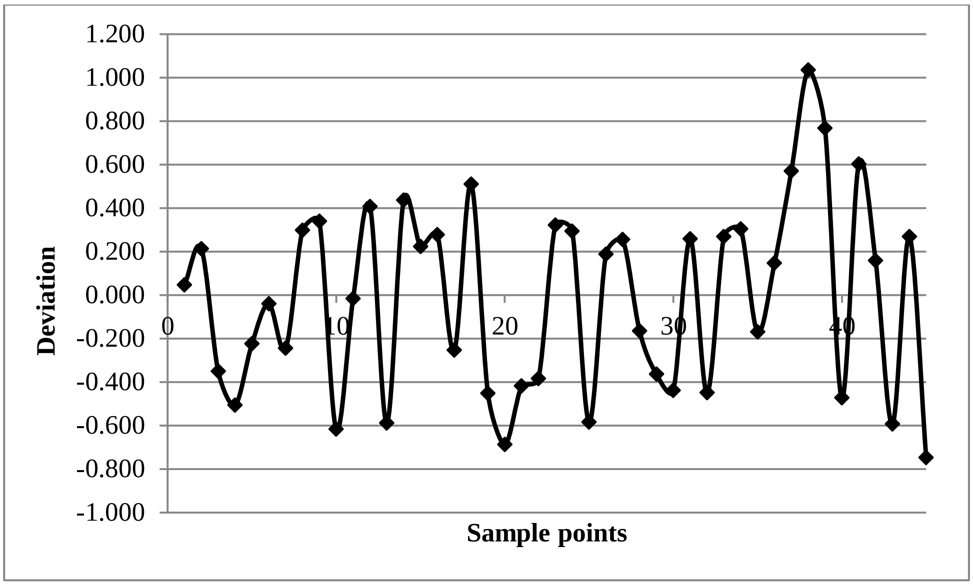


Fig: 5.44. Deviation of arsenic concentration between actual and estimated value from the field samples

Maximum deviation was observed in point number 20 and 45. The deviation of arsenic concentration between actual and estimated values in field samples was 6.7% in 0.01 to 0.1, 66.7% in 0.1 to 0.5, 24.4% in 0.5 to 1 and 2.2% in more than 1. The deviation was occured due to error in data collection, measurement error and geological settings of the focus area (fig 5.44).

5.4.6. Cross correlation

The correlation found between the primary and secondary variable was expressed by cross correlation model (Xu et al 2020). In this study arsenic was considered as primary variable and iron and chloride were secondary variables. The experimental cross correlation can only be determined when the measurements of the primary and secondary variable are co-located.

5.4.6.1. Correlation between arsenic, Iron and Chloride at shallow tubewell

The major cations and anions in natural water system usually have inteaction among themselves. Pearson correlation study revealed the actual interdependence among various water parameters (Chattopadhyay et al, 2020). In the present study, the presence of arsenic, iron and chloride was found more than permissible limit in the aquifer of the focus area. The concentration of iron was found increasing with arsenic concentration. The aquifer within the depth range of 150 m bgl is generally marked by brackishness where chloride value ranges from 1750 to 6300 ppm. In deeper depth, the chloride value ranges from 14 to 596 ppm (CGWB, 2015). The descriptive statistics was done by using Pearson correlation in statistical package of SPSS version 25.0 (SPSS Inc., USA) and was mentioned in table 5.10.

Table: 5.10. Correlation between arsenic, Iron and Chloride

		Arsenic	Iron	Chloride
Arsenic	Pearson Correlation	1	.564**	-.036
	Sig. (2-tailed)		.000	.374
	N	599	599	599
Iron	Pearson Correlation	.564**	1	.063
	Sig. (2-tailed)	.000		.123
	N	599	599	599
Chloride	Pearson Correlation	-.036	.063	1
	Sig. (2-tailed)	.374	.123	
	N	599	599	599
**. Correlation is significant at the 0.01 level (2-tailed).				

From table 5.10, it was observed that Pearson correlation study exhibited the actual interdependency among different water quality parameters. A degree of positive correlation (r= +0.564) was found between arsenic and iron and negative correlation (r= -0.036) was found in between arsenic and chloride. Chattopadhyay et al (2000), Bhattacharya et al (2003) observed a positive correlation (r=+0.207 and +0.77) between arsenic and iron concentration in groundwater.

Like the variogram for spatial continuity of a single variable, the cross correlation has been used to describe the cross continuity between two variables. Iron and chloride are considered as two secondary variables in the study. To study the cross correlation between arsenic and iron and between arsenic and chloride, semivariogram modeling was done for iron and chloride.

A. Iron

- **Rose diagram of iron**

The rose diagram of iron concentration was made in fig 5.45.

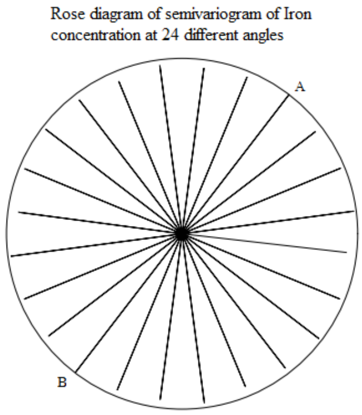


Fig: 5.45. Rose diagram of semivariogram of Iron concentration in shallow tubewell

The orientation of the critical direction for analysis is along the line AB at an angle of 52.5° and 232.5° with a critical range of 6592 m (fig 5.45).

- **Semivariogram of iron in influencing zone:**

The influencial zone of semivariogram of iron was found 45-60° and 225-240° angle. The semivariogram of iron in influencing zone was measured in fig 5.46.

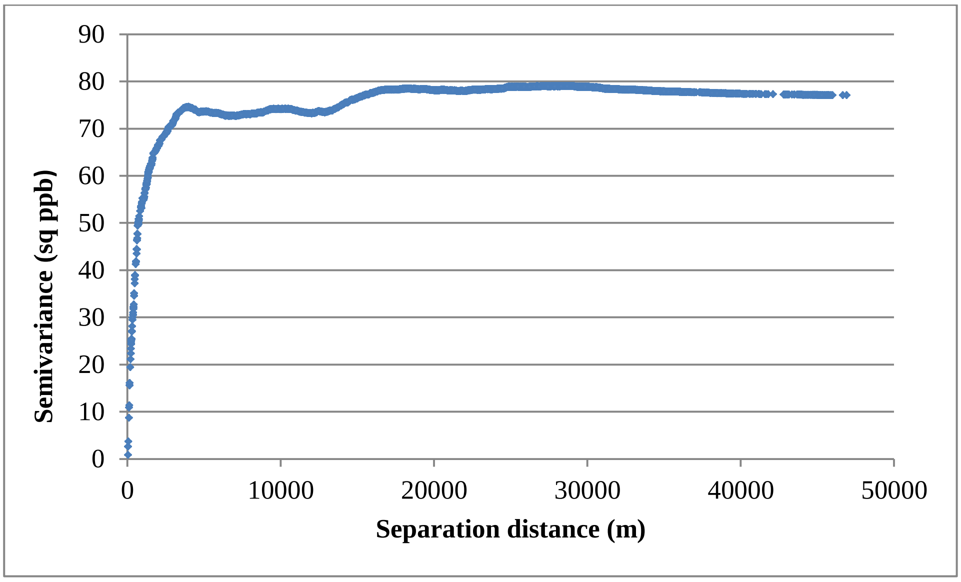


Fig: 5.46. Semivariogram of Iron in influencing zone in shallow tubewell

At 52.5° and 232.5° angle the range was maximum (fig 5.46). Here the semivariance is low because ppm is used for the unit of concentration of iron. As the iron concentration is very high in the study area, if ppb was used the number of semivariance will be very large. So ppm was used here. The range is 3677.96 m, it means the correlation will exist in between the points that are present within 3677.96 m.

The programming was done for the cross variogram study for arsenic with iron and arsenic and chloride as both are present in groundwater from the study area.

- **Data worksheet**

The data worksheet was discussed in fig 5.47.

Location	X Point	Y Point	Concentration - As	Concentration - Xx
1	652508	2471985	0.36	30.06
2	650390	2456574	0.61	33
3	650087	2455907	0.36	25.8
4	655740	2457733	0.042	4.9
5	650600	2456244	0.04	4.8
6	650389	2488574	0.04	12.37
7	650542	2469718	0.1	2
8	649194	2470591	0.06	1.9
9	651538	2473138	0.37	12
10	650060	2466204	0.08	4
11	649473	2466198	0.167	13.6
12	655706	2481651	0.13	16.4
13	652031	2489033	0.032	11.55
14	650867	2481824	0.05	19.2
15	651377	2469627	0.11	2.6
16	651075	2473101	0.09	1.6
17	651554	2471566	0.53	19
18	650618	2470361	0.05	1.1
19	647653	2473378	0.315	3.29
20	647973	2472274	0.166	5.59
21	647872	2472051	0.433	10.21
22	652315	2470655	0.22	30.56
23	651377	2461123	0.17	16.5
24	[illegible]	458549	0.143	11.4

Get Semi Variance Data | Clear All Data

Data | Calculated Data | Semi Variance Data

Fig: 5.47. Data worksheet for cross correlation

From fig 5.47, it was observed that the concentration of arsenic and iron data was observed from the same point, so arsenic and Fe are co located here. In this study, the pairing was done in between the locations of arsenic and iron concentration instead of arsenic and arsenic concentration. All the concentrations are converted into ppm.

The calculated data worksheet was mentioned in fig 5.48

Seperation Distan	Pairs		Concentration Differen	Theta (Degre	Lag Sep Distan
244.81	20	21	-10.044	65.63352425	245
244.81	21	20	-5.157	65.63352425	245
391.15	2	5	-4.19	302.4711923	392
391.15	5	2	-32.96	302.4711923	392
464.48	9	16	-1.23	4.569002745	465
464.48	16	9	-11.91	4.569002745	465
587.03	10	11	-13.52	0.585626415	588
587.03	11	10	-3.833	0.585626415	588
613.79	3	5	-4.44	33.30171528	614
613.79	5	3	-25.76	33.30171528	614
647.48	7	18	-1	83.259145	648
647.48	18	7	-1.95	83.259145	648
732.6	2	3	-25.19	65.56899049	733
732.6	3	2	-32.64	65.56899049	733
839.94	7	15	-2.5	353.7803356	840
839.94	15	7	-1.89	353.7803356	840
1041.96	1	17	-18.64	23.71124228	1042
1041.96	17	1	-29.53	23.71124228	1042
1055.86	15	18	-0.99	315.9593172	1056
1055.86	18	15	-2.55	315.9593172	1056
1149.44	19	20	-5.275	286.1644992	1150
1149.44	20	19	-3.124	286.1644992	1150
1187.03	17	22	-30.03	309.8735522	1188

Data | Calculated Data | Semi Variance Data

Fig: 5.48. Calculated data worksheet for cross correlation

In the calculated data page, the calculated columns are separation distance, pairs between arsenic and Fe, concentration difference, angle and lag separation distance (fig 5.48)

- **Semivariance data**

The semivariance data worksheet for iron was summarized in fig 5.49.

1	Group	Theta (Degree)	Seperation Distance	Semi Variance	Lag Sep Distance
2	1	0	8504	105.7691302	8504
3	2	0.585626415	587.03	98.26484838	588
4	2	1.174756818	3121.66	141.2087856	3122
5	2	4.569002745	464.48	114.5629404	465
6	2	9.828756428	1722.28	138.8274445	1723
7	2	12.22341778	5474.1	111.2973959	5475
8	2	13.62331489	3668.2	106.9809372	3669
9	2	14.92796826	3210.35	132.0776398	3211
10	3	15.61765211	1704.95	134.5510272	1705
11	3	16.15570597	5351.33	106.7676523	5352
12	3	16.51553554	3823.76	105.3047482	3824
13	3	17.90120001	5940.6	111.534717	5941
14	3	18.150058	3370.71	125.0676349	3371
15	3	22.44726183	2553.47	130.7304487	2554
16	3	22.81355528	3595.25	111.8453834	3596
17	3	23.71124228	1041.96	144.1535993	1042
18	3	27.85568132	2005.37	139.5290276	2006
19	4	33.30171528	613.79	112.7764387	614
20	4	40.67112493	2491.88	132.0394914	2492
21	4	41.97725302	3848.48	105.1987688	3849
22	5	45.77203899	11545.27	113.6342553	11546
23	5	47.37668604	3461.44	118.5082339	3462
24	5	47.62106944	1391.63	155.5082075	1392

Data | Calculated Data | Semi Variance Data

Fig: 5.49. Semivariance data worksheet for cross correlation

At semivariogram data page the lag separation distance and semivariance data was found (fig 5.49). The rose diagram was drawn with the 24 ranges at different directions.

- **Rose Diagram of Cross correlation among arsenic and Iron**

The rose diagram of cross correlation between arsenic and iron was mentioned in fig 5.50.

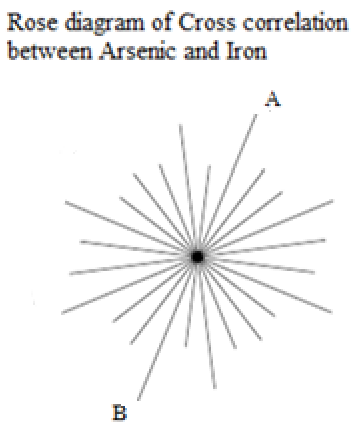


Fig: 5.50. Rose diagram of cross correlation between arsenic and iron in shallow tubewell

The rose diagram is elliptical in nature (fig 5.50). The AB line was supposed to be the critical axis for cross correlation of arsenic and Fe. The maximum correlation between arsenic and iron was observed along this line. If we can estimate iron concentration along this straight line and it was high, we can assume that the arsenic concentration will also be high at that direction.

- **Cross Correlation between arsenic and Iron at influential zone:**

The influencial zone of semivariogram of iron was found 45-60^o and 225-240^o angle and it was drawn in fig 5.51.

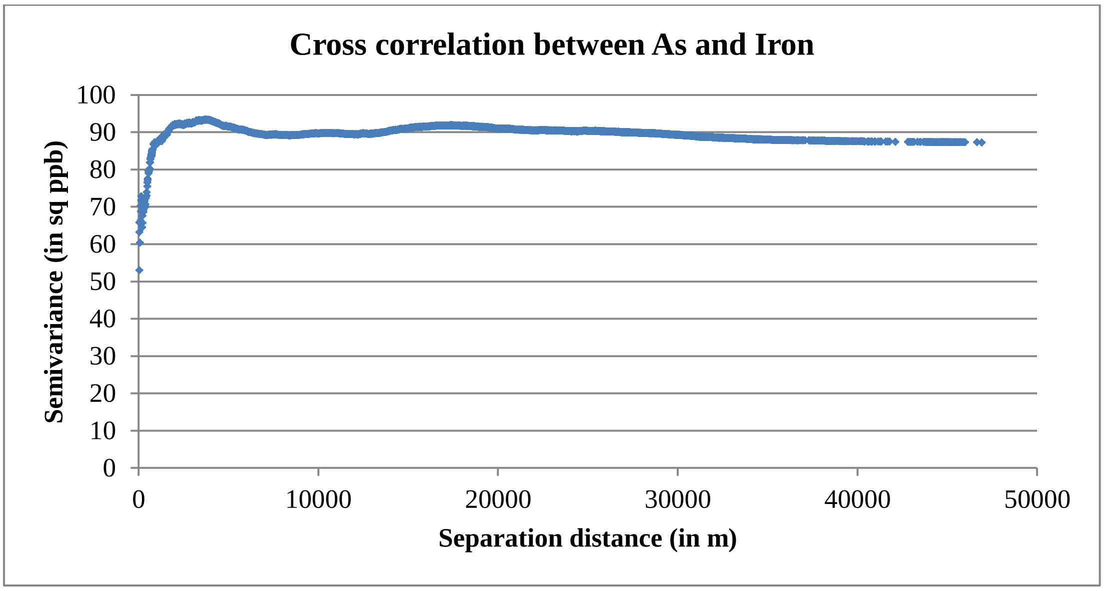


Fig: 5.51. Semivariogram of cross correlation between arsenic and Iron in shallow tubewell

The fig 5.51 shows the cross variogram calculated along the directions of maximum continuity. Cross variogram is reasonably well behaved. The maximum range at 52.5^o and 232.5^o angle observed was 1983 m that means the correlation of arsenic and Fe can be observed within 1983 m of the focus area. From the cross correlation study, it can be concluded if the measurement of arsenic concentration is not possible in the study area, iron concentration should be measured to get the picture of arsenic concentration. If the concentration of iron was found high in the influencing zone, it can be assumed that the arsenic concentration would also be high in this zone. If arsenic concentration can't be measured at all the locations, the iron concentration should be measured. If the concentration of Iron was found higher at that location, then there is chances to get higher arsenic concentration. Thus, if we measure the Iron concentration from all locations, where the Iron concentration was found higher, arsenic concentration was measured only at that point.

B. Chloride

Semivariogram modeling of chloride was done with the shallow tubewell data sets. 24 semivariogram modeling was done at different directions and they are plotted in the rose diagram.

- **Rose diagram of semivariogram of chloride**

Rose diagram of semivariogram of chloride was summarized in fig 5.52.

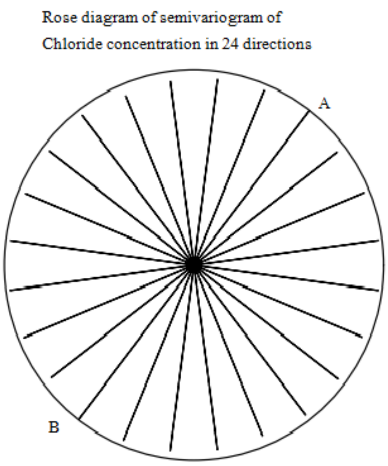


Fig:5.52. Rose diagram of chloride in shallow tubewell

The orientation of the critical direction for analysis is along the line AB at an angle of 52.5° and 232.5° with a critical range of 6592 m (fig 5.52).

- **Semivariogram modeling of chloride at influential zone**

At 52.5° and 232.5° angle the range was found maximum and semivariogram modeling was summarized in fig 5.53.

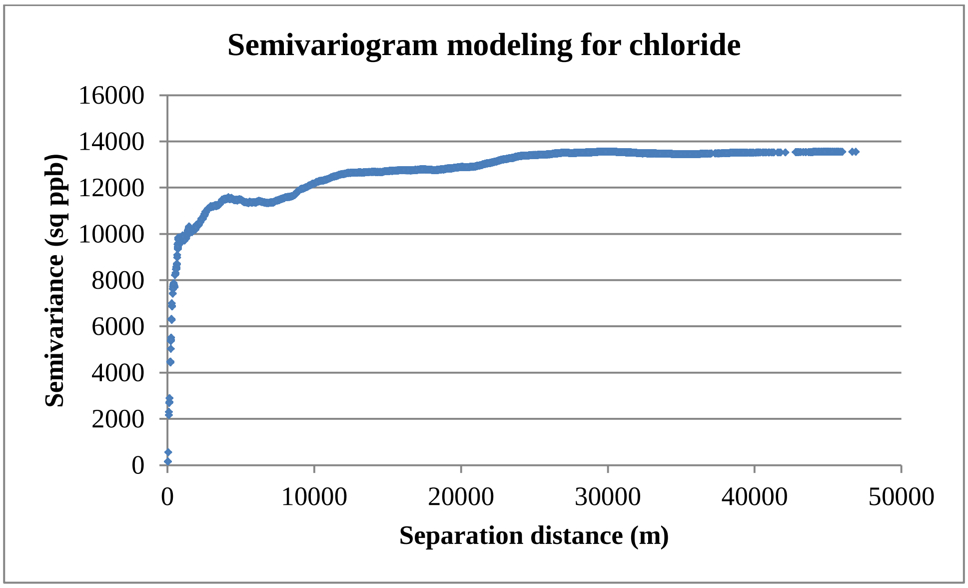


Fig: 5.53. Semivariogram modeling for chloride in shallow tubewell

The range was found 3677 m. from fig no 5.53. All the chloride values those are present within 3677 m are correlated.

- **Rose diagram of Cross Correlation among arsenic and chloride**

Rose diagram of cross correlation between arsenic and chloride was drawn in fig 5.54.

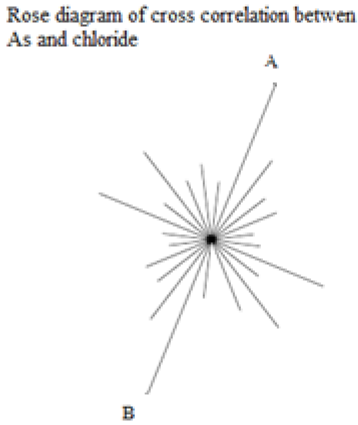


Fig: 5.54. Rose diagram of cross correlation between arsenic and chloride in shallow tubewell

The rose diagram found in fig 5.54 was elliptical in nature. The AB line was supposed to be the critical axis for cross correlation of arsenic and Cl. The maximum correlation between arsenic and chloride was observed along this line.

- **Cross Correlation between arsenic and Chloride at influential zone**

The cross correaltion between arsenic and chloride at influential zone was mentioned in fig 5.55.

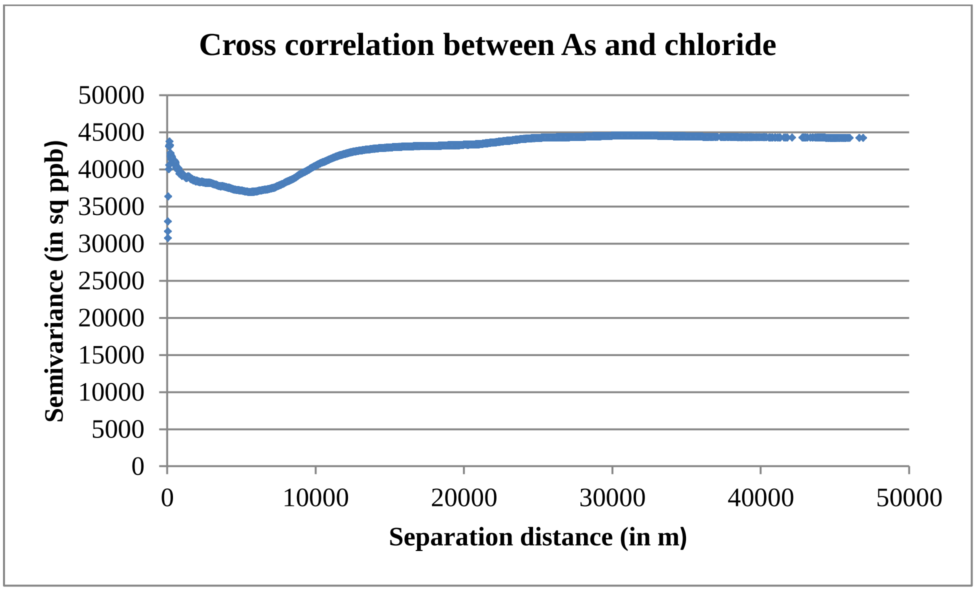


Fig: 5.55. Semivariogram of cross correlation between arsenic and chloride in shallow tubewell

No cross correlation was observed between arsenic and chloride in the focus area (fig 5.55). So, determination of chloride will not be helpful for the estimation of arsenic concentration.

5.5. Observations from the present study

Ordinary kriging has been established as the best interpolation method to estimate the variable. So, ordinary kriging was used to estimate arsenic concentration in shallow and deep depth aquifers in the focus area. The wide range of variability in arsenic concentration was observed in the shallow depth tubewell. The data set of Baruipur block was used to validate the nature of the semivariogram model. From the spatial distribution model (semivariogram model) of Baruipur block, the orientation of the critical direction for analysis of arsenic concentration of Baruipur block (in shallow tubewells) was found at angle of about 30-45^o angle (average 37.5^o) and 210-225^o angle (average 217.5^o) measured from east towards north and from west towards south with a critical range of 2249 m. Then the prediction of arsenic concentration was done with the shallow (10-100 m bgl) and deep (101-300 m bgl) depth tubewell data from the focus area. 12 different range values were obtained at 24 different directions at 15^o angle interval (360/15= 24). A similar range value was observed in opposite directions, so, only 12 range values were obtained. The orientation of the critical directions were found at angle of 45-60^o and 225-240^o angle and the average angles were 52.5^o and 232.5^o measured from east towards north with a critical range of 6592 m. The critical angle was considered as the gradient of major zone of influence. For estimation of arsenic in groundwater at a specific location, the prediction will be influenced by the points those are located within the separation distance of 6592 m and close bearing of 52.5^o and 232.5^o from the point of estimation. In the semivariogram model of focus area, the variation of $\gamma(h)$ vs h is found to follow a typical mathematical model followed by Power equation. The location points those are present within the critical range and critical angle are called the influencing points and total 6-10 influencing points were considered for the determination of arsenic concentration. The estimation at a certain point mainly depends on the arsenic concentration of the influencing points. The sample locations who are more closer to the estimation point, the weightage factor of those location determine the estimated concentration of that point. There is a limitation of the model, in a hot spot region, where higher concentrations lies between lower concentrations or vice versa, the estimation process will not give the accurate results. Spatial distribution of arsenic concentration mainly depends on the geological settings of a region. So, estimation is also dependent on the geological settings of an region. The deviation between estimated and actual values was observed as 20% samples at 0.01 to 0.1, 60% in 0.1 to 0.5, 13.4% in 0.5 to 1 and 6.6% was present in more than 1. The error was found positive (over estimation) in 20 sample points and negative (under estimation) in 10 sample points. Maximum errors were observed at three locations. For the first error, the estimated concentration was calculated 101 ppb and actual concentration was 575 ppb because the estimated point was located in higher arsenic contaminated zone whereas the 8 influencing points were present in low arsenic contaminated zone. For the third error, the estimated point was located in low arsenic contaminated zone whereas the 6 influencing points were located in high arsenic contaminated zone. The second error was in medium point of the two errors. To estimate arsenic concentration at a specific location along a deep tubewell, the range was maximum at 7859 m and the maximum range was observed along 45-60^o and 225-240^o angle and the average angle was found 52.5^o and 232.5^o. The deviation observed between the actual and estimated values were 33.3% in 0.01 to 0.1, 46.7% in 0.1 to 0.5 and 10% in both 0.5 to 1 and more than 1. So, the model will work better for deep tubewell as less variation of arsenic concentration was observed at that depth. Groundwater samples were collected from deep depth tubewells at different locations of the focus area and arsenic concentration were measured from those samples. The estimated values were calculated by using ordinary kriging at those sampling points. The measured values were compared to the estimated values. The deviation of arsenic concentration between actual and estimated values in field samples were 6.7% in 0.01 to 0.1, 66.7% in 0.1 to 0.5, 24.4% in 0.5 to 1 and 2.2% in more than 1. Semivariogram modeling was also done for Iron and chloride concentration at shallow aquifer and the zone of influence was also found at 52.5^o and 232.5^o angle. As the analysis of arsenic concentration in groundwater was found expensive and time consuming. Cross correlation method was applied to determine if arsenic concentration can be predicted by measuring Fe and chloride from a specific location where arsenic, iron and chloride are co located. A positive correlation (0.564) was found between arsenic and iron, but no correlation (-0.036) was found between arsenic and chloride. Determination of iron concentration in groundwater is less expensive and we can easily measure it. After determination of Iron concentration in the lab if the result is found higher, there is chances to get elevated level of arsenic concentration. So, instead of random sampling for arsenic concentration, we can determine iron concentration at first and after getting the result, the decision for testing of arsenic concentration can be taken. Thus the time and money both can be saved.

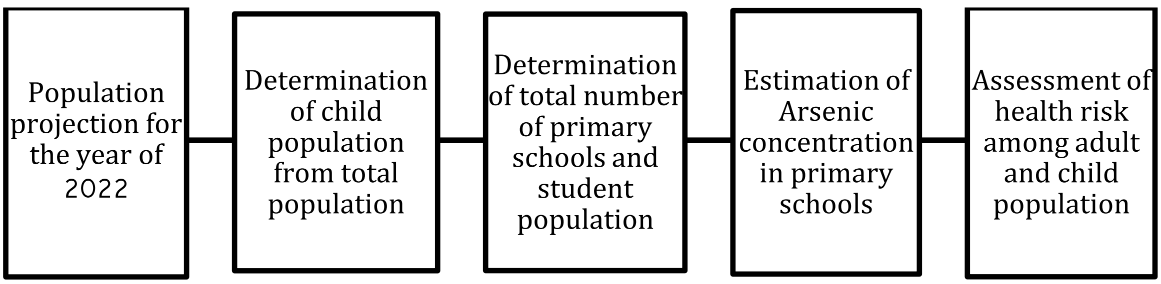
CHAPTER 6
ASSESSMENT OF ARSENIC INDUCED HEALTH RISK

The consequences of drinking arsenic contaminated water can take years to health impairment of an individual by developing diseases like various forms of cancer, mainly skin cancer and numerous noncancer effects including diabetes, chronic cough and toxic effects on liver, kidney, cardiovascular system and peripheral and central nervous system (Vahter 2007). According to WHO, consumption of 1 mg of inorganic arsenic per day may develop skin lesions within a few years after the first exposure (Mahanta et al. 2016). The US EPA calculated that 1.3 persons per 100 population can be at life risk from arsenicosis if arsenic concentration in the drinking water was 50 ppb (µg/L) (Smith et al. 1992) and when the concentration is 10 µg/L, risk for cancer development was 0.7 person per 100 population (Smith et al. 2002). Thus, arsenic has a cumulative toxic effects that can impact the human being leading to assured death (Chakraborty and Mukherjee 2020). The impact of arsenic induced illness are quite high for the health and welfare of both the affected individuals and their families. The source of arsenic in groundwater of focus area is geogenic and the mobilization of arsenic is dependent on naturally occurring aquifer conditions. The shallow aquifer (within 10-100 m bgl) of the focus area is highly arsenic contaminated and higher concentrations occur in patches. The deeper aquifer (100-300m bgl) is also arsenic contaminated but not as much severe like the shallow aquifers.

6.1. Purpose of the study

The estimation of arsenic concentration by Ordinary Kriging interpolation method in groundwater with special reference to the primary school and the impact of arsenic concentration among the adult and child population including the primary school going children who are the future of our nation is needed to develop the management strategies to mitigate arsenic concentration from groundwater.

6.2. Scope of the study



6.3. Population projection for the year of 2022

In the present study, the population of 2022 was projected by the suitable population projection methods because of the unavailability of the population data for the year of 2022. The population data was collected from Census population records and future population was predicted by using different population projection methods that are appropriate for the region considering the growth pattern followed by the area.

In focus area, 608 villages and 3 municipal areas were reported and the population was known for each village and municipal area from the year of 1971 to 2011 from Census data. The population projection was made for the year of 2022.

The methods adopted for estimating future populations in this study were-

1. Arithmetic Increase Method- This method is suitable for large and old cities with considerable development. The average increase in population per decade is calculated from the past census reports. The increase is added to the present population to find out the population of the next decade. Thus it is assumed that the population is increasing at a constant rate.

2. Geometric Increase Method- In this method the percent increase of population from decade to decade is assumed to be constant. The Geometric mean increase is utilized to observe the future increment in population. Since this method gives higher values and should be applied for a new industrial town at the beginning of development for only few decades.

3. Incremental Increase Method- The method is based on arithmetic increase method and is applicable for an average size of a town or village where the growth rate is found to be in increasing order. The incremental increase is determined for each decade from the past population and the average value is added to the present population along with the average rate of increase.

The population forecasting methods (Arithmetic, Geometric and Incremental increase method) were calculated by using the population data from a village named Harimul in Baruipur block to show a sample calculation using all the above mentioned methods. Harimul village was taken for the calculation because the increase of population was constant. The population of Harimul village is mentioned in table 6.1.

Table: 6.1. Population of Harimul village from 1971 to 2011

Block	**GP**	**Village**	**Population**				
			1971	**1981**	**1991**	**2001**	**2011**
Baruipur	Belegachi	Harimul	1445	1540	1924	2282	2999

6.3.1. Arithmetic increase method

The arithmetic increase method was applied to assume that the population is increasing at a constant rate.

The population at the end of n^{th} decade can be estimated as:

$P_n = P_o + n.x$

where P_n= population after n^{th} decade

P_0= present population

n= no. of decades

x= average increment per decade

For Harimul village, the population forecasting of 2022 will be

P_n= number of projected population of 2022

P_0= number of population of 2011= 2999

n= 1.1

n (no of decades) was taken 1.1 because each year was considered 0.1 (1/10). It is 11 years from 2011 to 2022, so n= 11×0.1= 1.1

Determination of the average increment per decade was calculated in table 6.2.

Table: 6.2. Determination of average increment per decade (x)

Year	**Population**	**Increment of population per decade**
1971	1445	-
1981	1540	1540-1445= 95
1991	1924	1924-1540= 384
2001	2282	2282-1924= 358
2011	2999	2999-2282= 717
Total increment in all decade		1554
Average (x) increment per decade		1554/4= 389

Assuming that the future growth follows the arithmetic average 389 per decade for the period of 2011 to 2022, the number of population in 2022 is,

P_{2022}=2999+1.1×389 = 3426

6.3.2. Geometric increase method

The geometric increase rate was applied to assume that the percent increase of population from decade to decade is assumed to be constant in the village.

The population at the end of n^{th} decade can be estimated as:

$P_n = P_0\left(1 + \frac{r}{100}\right)^n$

Where P_n= projected population after n decades

P_0= initial population (at the end of the last census)

n=number of decades between now and future

r= geometric mean rate of increase in population per decade= $\sqrt[m]{r_1\, r_2\, r_3 \ldots r_m}$

m= n-1

r_1, r_2, r_3,... r_m= growth rate for different decades= $\frac{Increase\ in\ population}{Original\ population} \times 100$

For Harimul village, the population forecasting of 2022 will be

P_n= Number of Population in 2022

P_0= Number of Population in 2011= 2999

n= 1.1

Determination of geometric mean rate of increase in population per decade (r) has been calculated in table 6.3

Table: 6.3. Determination of geometric mean rate of increase in population per decade (r)

Year	**Population**	**Increment of population per decade**	**Increase of population**	**% increase**
1971	1445	-	-	-
1981	1540	95	95/1445= 0.0657	6.5%
1991	1924	384	384/1540= 0.249	24.9%
2001	2282	358	358/1924=0.186	18.6%
2011	2999	717	717/2282= 0.314	31.4%

Geometric mean, r= $\sqrt[4]{0.0657 \times 0.249 \times 0.186 \times 0.314}$ = $\sqrt[4]{0.00096}$ = 0.175= 17.5% per decade

Geometric mean= 17.5% per decade

Assuming that the future growth follows the geometric mean of 17.5% per decade for the period of 2011 to 2022, the number of population in 2022 is

P_{2022}= $2999\times \left(1+\frac{17.5}{100}\right)^{1.1}$ = 3581

6.3.3. Incremental increase method

Incremental increase method was applied assuming that Harimul is an average size of a town or village where the growth rate is found to be in increasing order.

The population at the end of n^{th} decade can be estimated as:

P_n= $P_0 + n \times x + \left(\frac{n(n+1)}{2}\right) \times y$

Where P_n= number of population after n^{th} decade x= average increase

y= incremental increase

For Harimul village, the population forecasting of 2022 will be

Where P_n= Number of Population in 2022

The calculation for average (x) and incremental increase (y) was discussed in table 6.4.

Table: 6.4. Calculation for average (x) and incremental increase (y)

	Population	**Increment of population per decade**	**Incremental increase per decade**
1971	1445	-	-
1981	1540	1540-1445= 95	-
1991	1924	1924-1540= 384	384-95= 289
2001	2282	2282-1924= 358	358-384= -26
2011	2999	2999-2282= 717	717-358= 359
Total increment in all decade		1554	622
Average increment per decade		1554/4= 389	622/3= 207

x= 389 per decade

y= 207 per decade

n=1.1

Assuming that the future growth follows the average increase of 389 per decade and incremental increase of 207 per decade for the period of 2011 to 2022, the number of population in 2022 is

P_{2022}= $2999+1.1 \times 389 + \left(\frac{1.1 \times (1.1+1)}{2}\right) \times 207$= 3666

If we assume three different conditions for the population growth, the observed population of Harimul village was discussed in table. 6.5

Table. 6.5. Population determination in Harimul village with three population increase method

Arithmetic increase	**Geometric increase**	**Incremental increase**
3426	3581	3666

The projected growth rate was calculated for each villages from the focus area with the means of Arithmetic Increase method, Geometric Increase method and Incremental Increase method.

6.3.4. Graphical representation of the existing population growth

In the present study, the graphical representation of population growth was made by using the population data from 1971 to 2011 for each villages. The forecasting of type of population growth was selected according to the nature of growth of population in last 5 decades for the villages. The growth curves were prepared for each 608 villages and 3 municipal areas and the pattern of the growth curves were recorded. After getting the pattern of the individual population curve, the projected population were documented from the initially calculated Arithmetic, Geometric and Incremental increase method.

6.3.4.1. Population growth in rural areas

To understand the calculation, 5 villages were selected as the sample villages to study the pattern of the growth curves to select the method of population forecasting from that the population growth will be calculated. The villages and the population from 1971 to 2011 are discussed in table 6.6

Table: 6.6. Population growth in the villages from 1971 to 2011

Block	**GP**	**Village**	**Population**				
			1971	**1981**	**1991**	**2001**	**2011**
Baruipur	Belegachi	Harimul	1445	1540	1924	2282	2999
Baruipur	Sikharbali II	Kundarali	1384	1921	2725	3521	3756
Jaynagar I	Narayanitala	Sarberia	1598	2253	2737	2944	3154
Bhangar II	Shanpukur	Chandihat	1427	1843	2283	4427	5272
Canning II	Sarangabad	Miagheri	72	1321	1642	1813	4134

The population growth curves were made with the population for last 5 decades. The growth patterns were observed and the projected population was recorded from the initially calculated Arithmetic, Geometric and Incremental increase method. The pattern of the curves of the villages are mentioned below:

- **Harimul village**

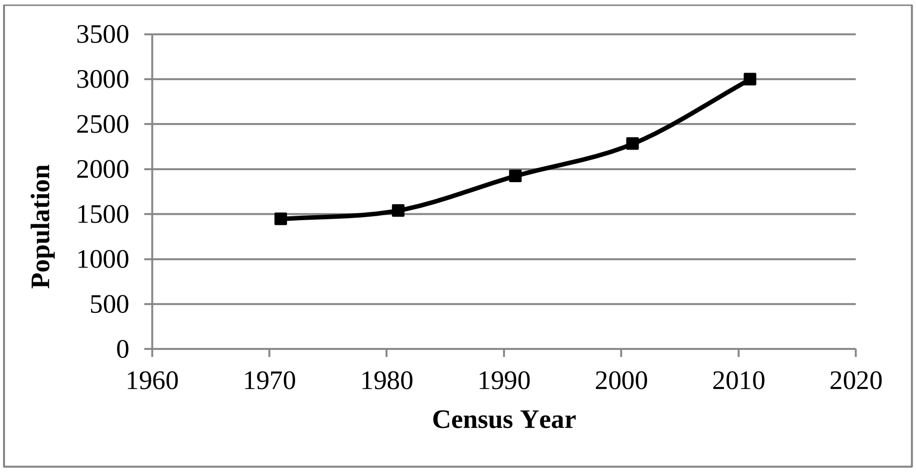


Fig: 6.1. Population growth in Harimul village

The nature of the curve was Geometric Increase method (fig 6.1). So, the population forecasting of the village will be predicted with the help of Geometric Increase method.

- **Kundarali**

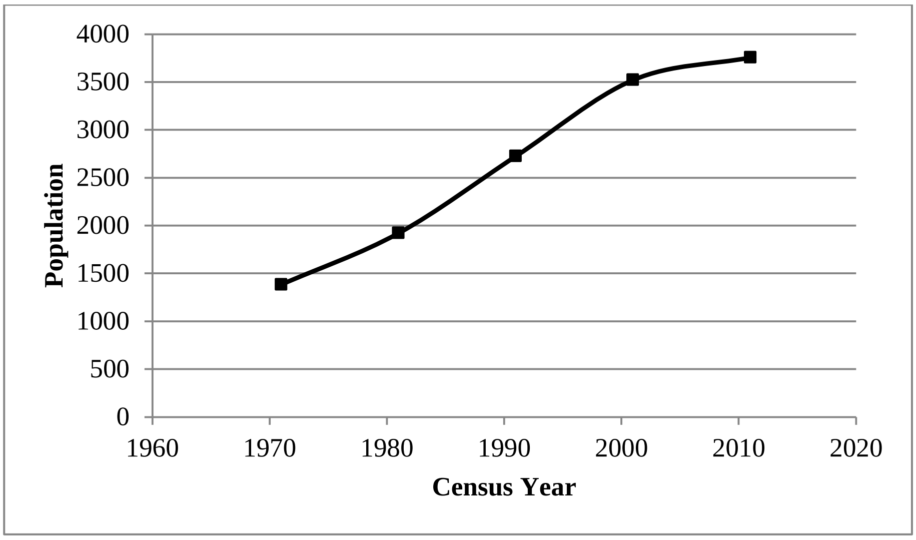


Fig: 6.2. Population growth in Kundarali village

The nature of the curve was Incremental Increase method (fig 6.2). So, the population forecasting of the village will be predicted with the help of Incremental Increase method.

- **Sarberia**

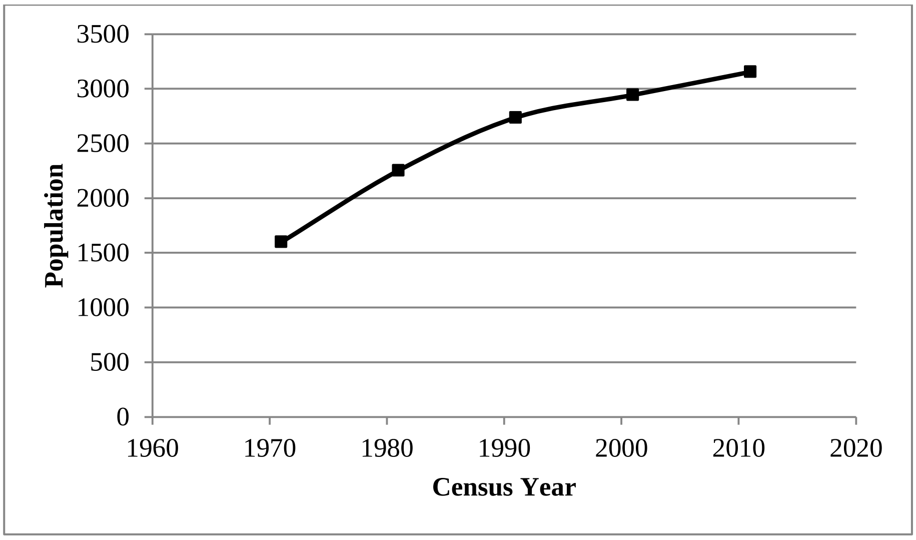


Fig: 6.3. Population growth in Sarberia village

The nature of the curve was Arithmetic Increase method (fig.6.3). So, the population forecasting of the village will be predicted with the help of Arithmetic Increase method.

- **Chandihat**

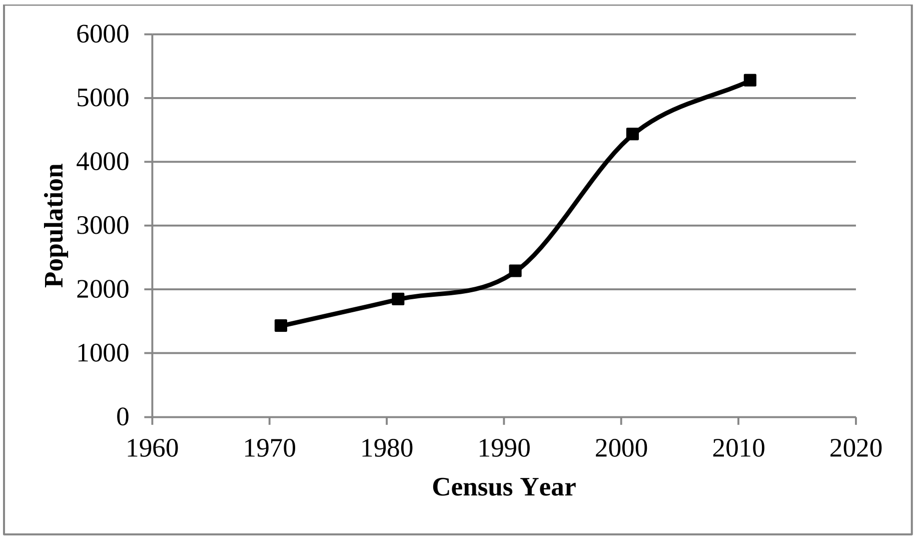


Fig: 6.4. Population growth in Chandihat village

The nature of the curve is Combination of Geometric (40%) and Incremental method (60%) (fig 6.4). So, the population forecasting of the village will be predicted with the help of Geometric and Incremental Increase method.

- **Miagheri**

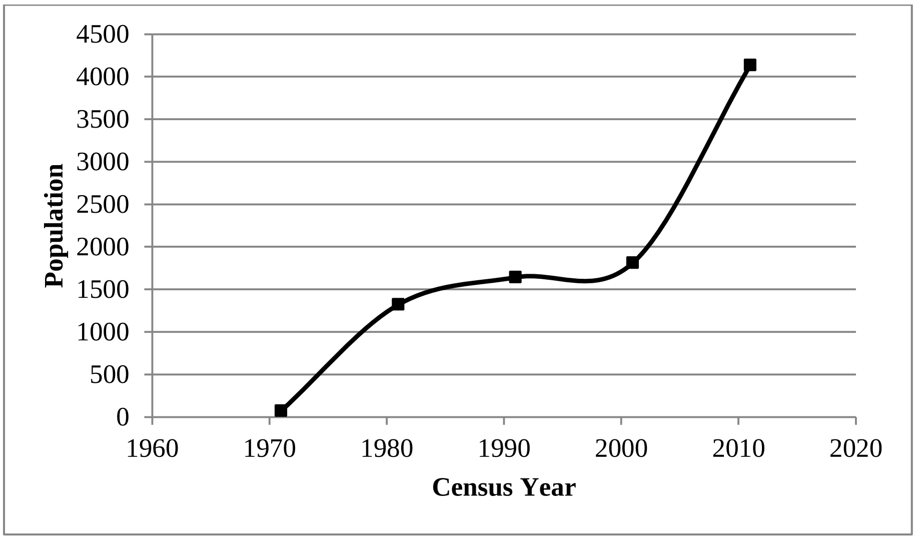


Fig: 6.5. Population growth in Miagheri village

Nature of the curve- Combination of Arithmetic (40%) and Geometric (60%) method (fig 6.5). So, the population forecasting of the village will be predicted with the help of Arithmetic and Geometric Increase method.

For population projection in 2022, combined graphical method was used and the graphs were prepared with the help of Arithmetic, Geometric and Incremental method.

After preparation of the graphical representation of the growth pattern for all the villages and municipal areas, a pie chart was prepared showing different types of increase of population growth in fig 6.6.

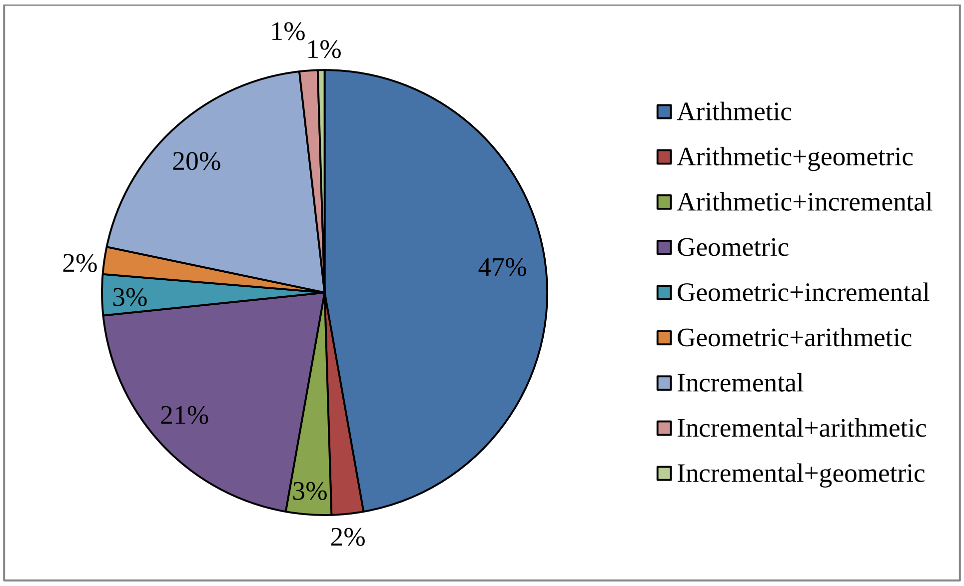


Fig: 6.6. Different types of population growth in villages from focus area

From the pie chart (fig 6.6) it was found that almost half of the population growth followed the Arithmetic increase pattern (47%) followed by Geometric (21%) and Incremental (20%) increase method. The rest 12% was comprised of Composite increase. In Composite increase method, the graph follows two methods simultaneously. For example, in Arithmetic+ Geometric method, a certain distance of following Arithmetic increase method, the growth pattern starts following Geometric mean. Both Arithmetic+ Geometric, Arithmetic+ Incremental, Geometric+ Incremental, Geometric+ Arithmetic, Incremental+ Arithmetic and Incremental+ Geometric increased method were observed in the composite increase. The Arithmetic+ Geometric increase and Arithmetic+ Incremental increase method was found villages near urban and municipal areas . In case of some villages, it was found that the growth rate was very high following Geometric increase method, after that the growth rate became almost constant and followed Arithmetic increase method.

6.3.5. Projected population of 2022 in the focus area

In the present study, the projected population of 2022 was determined for the rural and urban areas.

6.3.5.1. Projected population in rural areas

In the focus area, the total population of all the blocks were not determined because only some villages of the blocks were found present. The percentage of total population was calculated as the complete blocks were not included in the focus area. The blockwise projected population of 2022 was mentioned in table 6.7 and village wise projected population has been has been summarized in annexure II.

Table: 6.7. Projected population of 2022 in rural areas

Block	Total projected Population of 2022 present in the focus area	% of total population present in the focus area
Baruipur	514926	100
Bhangar I	294082	100
Bhangar II	291175	100
Bishnupur I	92663	39.36
Canning II	266911	65.37
Jaynagar I	242643	74.05
Jaynagar II	203067	76.29
Magrahat II	174347	44.65
Mandirbazar	69398	31.36
Sonarpur	264228	100
Mathurapur I	21112	10.35
Total	2434552	100

From table 6.7 it was observed that the highest population was found in Baruipur followed by Bhangar I, Bhangar II and Sonarpur block. The total population from Baruipur, Bhangar I, Bhangar II and Sonarpur blocks are present in the focus area. For the other 7 blocks, some parts of the blocks are present in the focus area. The total projected population in rural areas was observed 2434552.

From the focus area map, it was observed that the pockets of high arsenic concentration zones were formed near the municipal areas signifying that the withdrawal of excessive amount of groundwater occurred due to rapid population growth in municipal areas. In municipal areas the arsenic affected population can get arsenic safe water sources, they are economically in better condition than the rural people. 78.85% population share comes from rural areas in focus area, so more emphasis were done on the rural population.

6.3.5.2. Projected population in urban areas

The projected population in urban areas has been summarized in table 6.8.

Table: 6.8. Projected population of 2022 in municipal areas

Municipality	Projected Population of 2022	% of total population present in the blocks
Rajpur Sonarpur	561668	100
Baruipur	62100	100
Jaynagar Mazilpur	29436	100
Total	653204	100

From table 6.8, it was observed that in Rajpur Sonarpur Municipal area, the population from 2022, is maximum among the three municipal areas. The total projected population in 2022 was 653204. The total population of the municipal areas live in As contaminated region.

6.4. Determination of number of arsenic affected villages and total population

Tubewells were considered as the single most important source of drinking water in Bangladesh. According to the 2001 population census, 88% of the rural households were found to use tubewells as the principal source for drinking water (Asadullah and Chaudhury 2011).

In the present study, the determination of the number of arsenic affected villages and total population was done on the basis of the arsenic concentration in shallow aquifer**.**

6.4.1. Rural areas

According to the arsenic distribution map, 11 blocks were found to be arsenic affected. Among the 11 blocks, 4 blocks namely Baruipur, Bhangar I, Bhangar II and Sonarpur, all the villages were affected by different level of arsenic concentration. The 7 remaining blocks- Bishnupur I, Canning II, Jaynagar I, Jaynagar II, Mandirbazar, Magrahat II and Mathurapur I are partially affected by arsenic. The classification of the focus area according to arsenic concentration was discussed in section 4.5.6. In table 6.9, the number of arsenic affected villages and population were discussed.

Table**:** 6.9. Classification of villages according to arsenic concentration in groundwater

Blocks	**Classification of villages into zones according to arsenic concentration**				**Total arsenic affected villages**	**% of arsenic affected villages**	**Total arsenic affected population**	**% of arsenic affected population**
	I	**II**	**III**	**IV**				
Baruipur	39	47	36	16	99	71.74	3,45,297	67.06
Bhangar I	24	27	14	15	56	70	2,00,703	68.25
Bhangar II	7	31	20	2	53	88.33	2,72,879	93.72
Bishnupur I	9	23	2	0	25	29.76	76,080	32.32
Canning II	0	39	18	0	57	93.44	2,66,911	65.37
Jaynagar I	0	42	16	1	59	90.77	2,42,643	74.06
Joynagar II	0	26	2	0	28	59.57	2,03,067	67.3
Mandirbazar	0	35	0	0	35	31.82	69,398	31.37
Magrahat II	0	40	0	0	40	51.28	1,74,347	44.66
Sonarpur	16	37	4	8	49	75.38	1,95,822	74.11
Mathurapur I	0	6	0	0	6	6.59	21,112	10.35
Total	95	353	112	42	507	83.39	2068259	84.95

From table 6.9, it was observed that more than 50% of population of the blocks named Baruipur, Bhangar I, Bhangar II, Sonarpur, Canning II, Jaynagar I and II were affected by different levels of arsenic concentration. Bishnupur I, Mandirbazar, Magrahat II and Mathurapur I blocks, less than 50% population were found to be affected by arsenic concentration considering 10 ppb as the permissible limit.

6.4.2. Municipal areas

Table: 6.10. Classification of wards according to As concentration in groundwater

Municipality	**Classification of wards into zones according to As concentration**				**Total As affected wards**	**% of As affected wards**	**Total As affected population**	**% of affected population**
	I	**II**	**III**	**IV**				
Rajpur Sonarpur	0	0	35	0	35	100	561668	100
Baruipur	0	0	17	0	17	100	63058	100
Jaynagar Mazilpur	0	14	0	0	14	100	29436	100

From table 6.10, it was observed that the the total population from the three municipal areas were found to be affected by arsenic contamination in groundwater.

The rest of the study was done with the population from the rural areas because in municipal areas, the people may have an alternative source for safe drinking water i.e. treated surface water, Public Water Supply Scheme (PWSS) by PHED,. But in rural areas, the population don't have any alternative. They do have to rely on groundwater.

6.5. Total arsenic affected adult and child population in the focus area

The total population consist of adult and child population in the present study. According to Census data (2011), the child population (6-10 years) comprises of 9.65% share of the total population in South 24 Parganas. Distribution of arsenic affected adult and child population was discussed in table 6.11.

Table. 6.11. Blockwise distribution of arsenic affected population

Blocks	**Arsenic affected population in focus area**		
	Total	**Adult**	**Child (6-10 years)**
Baruipur	3,45,297	3,11,976	33321
Bhangar I	2,00,703	1,81,335	19368
Bhangar II	2,72,879	2,46,546	26333
Bishnupur I	76,080	68,738	7342
Canning II	2,66,911	2,41,154	25757
Jaynagar I	2,42,643	2,19,228	23415
Joynagar II	2,03,067	1,83,471	19596
Mandirbazar	69,398	62,701	6697
Magrahat II	1,74,347	1,57,523	16824
Sonarpur	1,95,822	1,76,925	18897
Mathurapur I	21,112	19,075	2037

From table 6.11, it was observed that Baruipur contains the maximum number of child population among all the blocks followed by Bhangar II and Jaynagar I.

6.6. Arsenic contamination and its effects on primary school going children

Primary education is the foremost and fundamental right of every child. The main objective of Primary education is to ensure broad based learning among child population from 6-10 years. A successful primary education system can create a strong foundation and directions for future success that elevates social changes and minimizes poverty. The learning includes development of social, cognitive, cultural, emotional and physical skills .The entire Primary school education in West Bengal can be classified into government run schools, government aided schools, madrasas, private schools, schools run by local bodies, religious organizations, NGOs and schools for the physically challenged children (Ghosh 2008). Mid Day Meal is served to the children from Primary schools to meet the demand of nutrition.

Mid day meal is considered as a freshly cooked lunch served to the Primary school going children in government and government aided schools in India and was introduced in 2003. The objective of the Mid day meal scheme (MDMS) was to reduce classroom hunger and malnutrition. After the implementation of MDMS, the school enrolment and attendence was increased, school dropout rates were reduced, simultaneously the nutritional level of the primary school children was improved (Mid Day Meal Programme Annual Work Plan and Budget 2018-19).

From extensive literature survey, it was found that exposure to arsenic in early life can cause carcinogenic effects. There are evidences that chronic arsenic toxicity can significantly increase the rate of morbidity and mortality in person with probable exposure to elevated concentration of arsenic in drinking water in early childhood. The educational development of children can be hampered by elevated arsenic concentration in drinking water (Asadullah and Chowdhury 2011). The reasons are-

- The children who are continuously forced to drink arsenic contaminated water are likely to have poor health status and can not show good performance in schools compared to the children who have grown up in arsenic free region. In case of early life exposure the adverse health effects are more severe.
- Drinking of arsenic contaminated water could develop arsenicosis among the adult members of the family which in turn may affect income adversely- labour productivity of wage earner is likely to be reduced due to declining health condition.
- The direct impact of arsenic exposure was observed on the intellectual development of child population between 5 to 15 years. It was included the deficiency in verbal and school performance domains with memory being affected to a lesser extent.
- Arsenical skin lesions can be developed in child population by the time they reach secondary school age if a child is exposed to higher level of arsenic at early ages. Children with keratosis may become socially obstracised at school on the basis of common belief that arsenicosis is contagious.

According to the Right to Education (RTE) Act, it was instructed that all the children should have access to Primary schools within 1 km distance from their habitation (Halder 2016). In arsenic contaminated region, the children are exposed to arsenic contamination both in home and school. The Mid Day Meal cooked in the schools are made up of arsenic contaminated water. The ingestion route of arsenic is by drinking arsenic contaminated water and eating food that was prepared by arsenic contaminated water. Thus, they are affected severely by arsenic induced illnesses. Arsenic exposure is considered as a public health concern for child population. Knowledge of arsenic concentration in drinking water in Primary schools is important to determine the health effects of child population. Estimation is the best method to monitor regularly the arsenic concentration as sampling and lab testing of the water samples from the schools tubewells are not always possible.

6.6.1. Determination of total number of primary schools and student population from each of the primary school

In the present study, students from grades 1 to 5 (6-10 years) are considered to spend most of the day time in their schools (Kaiser et al. 2001). The study was done with the FPs (Free primary school), JBs (Junior Basic) and SSKs (Sishu Sikha Kendra) from the focus area managed by Department of Education. In FPs, JBs and SSKs, the children come from poor community, they get free meal from the schools and are dependent on the tubewells those are present in the school premises for drinking water sources. If the school is located in a arsenic contaminated zone, the children are exposed to arsenic by drinking arsenic contaminated water and eating mid day meal that are cooked with arsenic contaminated water. So, intake of arsenic is high among those children and they will be highly impacted by arsenic contamination. The children from middle and upper class, attend the Private schools which have their own treated water source. So, they are safe from arsenic related health hazards.

The details of the Primary schools were collected from UDISE (Unified District Information System for Education) Data and School report card portal (DISE 2018) (developed by National University of Educational Planning and Administration) . The total number of schools were determined from the block level data. The primary schools those were managed by Department of Education were kept for the study only. The total number of students from each school from class I-V from the year of 2011-2018 was found from the portal (http://www.schoolreportcards.in/). The student population of 2022 from each school was projected with the help of Arithmetic increase method. The student population was found decreasing in some schools and became negative in projected population from 2022. The population from the year of 2018 were considered for those schools.

The total 1044 (530 FPs, 106 JBs and 408 SSKs) Primary school data was collected for the study. Nearly 108465 students aged between 6 to 10 years were recorded studying in those schools. About 3650 teachers were employed in those schools. The range of student population was found 20 to 961 in schools in 2022. Blockwise distribution of schools and population was presented in fig no. 6.7.

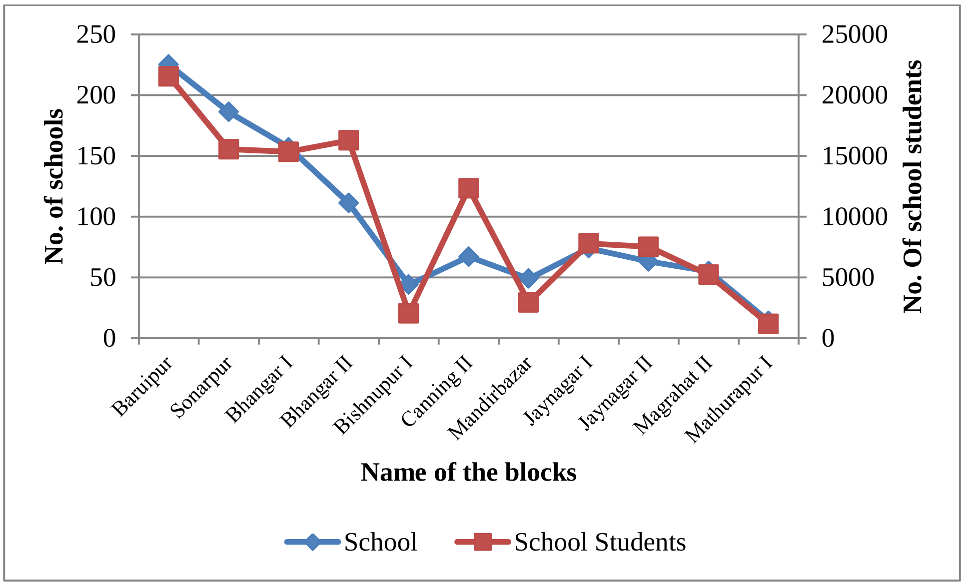


Fig: 6.7. Blockwise distribution of school and school student

From fig 6.7 it was observed that in Baruipur, Sonarpur, Bhangar I, Bhangar II blocks, the number of schools are observed more than 150 because the total blocks are located in the focus area and all the schools from those blocks are listed. So,the school population are high in the blocks. In Bishnupur I, Canning II, Mandirbazar, Jaynagar I and II, Magrahat II and Mathurapur I blocks, the number of schools are less than 100 because some parts of the blocks are located in the focus area.

6.6.1.1. Percentage of child population in Government aided primary schools from arsenic affected blocks

In table 6.12, total arsenic affected child population and percentage of arsenic affected child population in Govt. aided schools were mentioned

From table 6.12, it was observed that in Baruipur block, the total number of child population is high, but the percentage of child population going to Govt aided primary schools is 59.28%. In Sonarpur, 90.5% of child population followed by Bhangar I attend primary schools those are Govt aided. The main source of the schools were found groundwater lifted by shallow or deep tubewell.

Table. 6.12. Blockwise distribution of arsenic affected child population in primary schools

Blocks	**Arsenic affected child population in focus area**		
	Total population	**Population in Govt. aided primary schools**	**% of population in Govt aided Primary school**
Baruipur	33321	19753	59.28
Bhangar I	19368	13772	70.45
Bhangar II	26333	13852	52.29
Bishnupur I	7342	1965	26.76
Canning II	25757	12745	49.48
Jaynagar I	23415	13144	56.13
Joynagar II	19596	7324	37.37
Mandirbazar	6697	2848	42.53
Magrahat II	16824	5214	30.99
Sonarpur	18897	17116	90.58
Mathurapur I	2037	1149	56.41

The vast majority of the wells was not tested before and the students from the schools did not know the status of the wells with respect to arsenic. According to Jamil et al (2019) in Bangladesh, the cost for testing arsenic concentration was previously determined at US$2.50 per well (at an exchange rate of BDT80/$1) including the cost of the field kit, labour and supervision. In India, the cost for testing per tubewell will be ≈INR 198 ($2.50 × INR 78.95). If there are 1044 tubewells are present in the focus area, total INR 2,06,712(1044 × INR 198) were requirred for determination of arsenic concentration in all the tubewells. But in field kit, the determination of arsenic concentration under 10 ppb is not detectable and we can get only a range of values. If arsenic concentration in groundwater is measured by Atomic Absorbtion Spectrophotometer (AAS), the average cost per sample will be INR 475 including the cost of gas, reagents etc. So, for 1044 schools, the cost will be INR 4,95,900 (1044× INR 475). So, there is a need to predict arsenic concentration with ordinary kriging from the drinking water sources in the schools to save the money and time.

6.6.1.2. Locations of primary schools at different arsenic contaminated zone

The locations of the primary schools data were collected from Schools Geo Portal (2015) managed by Ministry of Human Resource Development (MHRD). For data validation, the locations of some of the schools were determined by using a handheld GPS (Garmin E-Trex 10). The locations of the schools were plotted on the arsenic concentration map prepared in ArcGIS (Version 10.2.2). The arsenic concentration map was prepared on the basis of shallow (l0- 100 m bgl) and deep tubewells (100-300 m bgl). Shallow and deep tubewell data both were selected for the study because the concentration at both level were different. In fig 6.8, the locations of primary schools were discussed. The locations of the schools were mentioned in both shallow and deep depth as the concentration were diffrent in those two different depths.

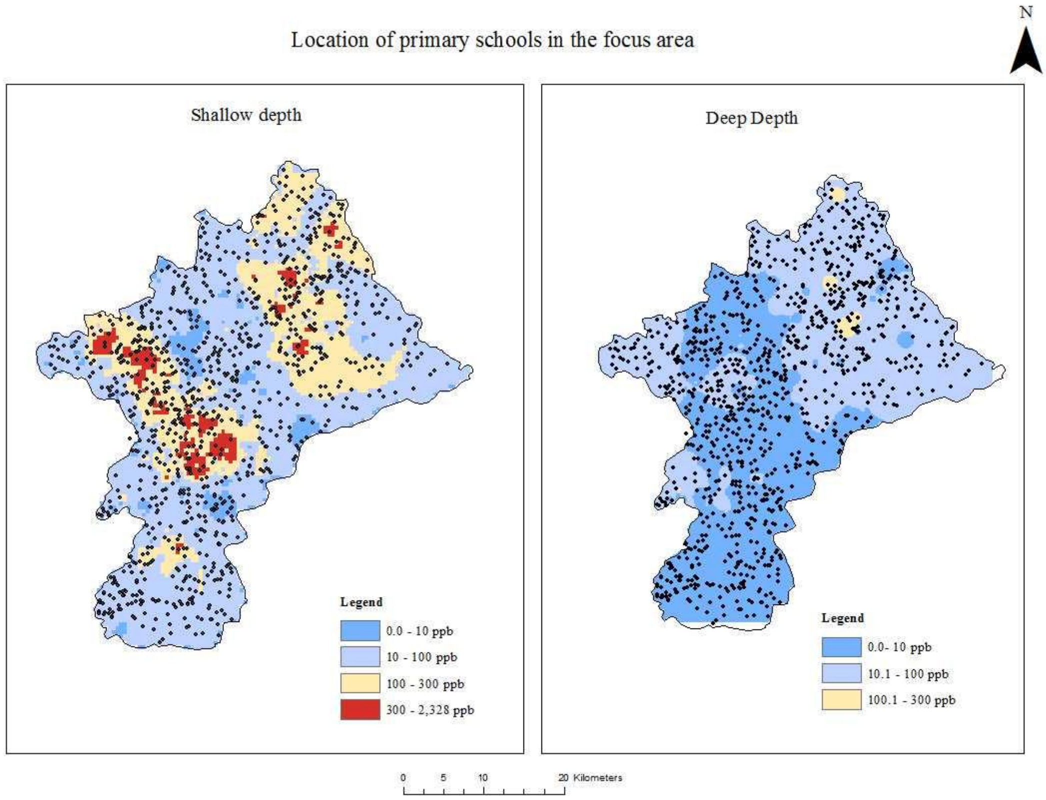


Fig: 6.8. Location of primary schools in the focus area when the water sources are shallow and deep depth

From fig 6.8 it was observed that primary schools were equally distributed within the focus area. The shallow and deep depth map was prepared on the basis of arsenic concentration of the tubewell. In the focus area the shallow aquifer is contaminated with high concentration of arsenic and deeper aquifers are less contaminated. The arsenic concentration was estimated for both shallow and deep depth aquifer for each tubewell present in those school premises. So, each tubewell got two values, one is for arsenic concentration present in shallow depth and the other is for arsenic at deeper depth. In shallow depth map, most of the schools were found to be present in the regions where arsenic concentration was more than the permissible limit, in those schools the primary school children consume water which were not suitable for their health. Very small numbers of schools were present in arsenic safe zone. In deep depth map almost half of the schools contain safe water sources.

6.6.1.3. Validation of estimation of arsenic concentration in primary schools

Estimation was done in two steps- one is to validate the model with sample data sets and the second one is to predict arsenic concentration in all schools present in the focus area. The estimation was done with the data set that were used to predict arsenic concentration in shallow and deep depth mentioned in section 5.4.1.1.

30 primary schools were selected for the validation of the model (Annexure II).The location of the schools were collected by using the GPS by field survey and arsenic concentration were calculated from spatial distribution of arsenic concentration map (shallow and deep both). The schools were well distributed in the focus area. The depth of the tubewell was divided into shallow depth (10-100 m bgl) and deep depth (more than 100 m -300 m bgl). Arsenic concentration in both shallow and deep depth from each tubewell were estimated. The actual arsenic concentration was determined from the prepared map (fig 4.15) and the estimated concentration were calculated with the help of ordinary kriging. The kriging interpolation was done to estimate the arsenic concentration in both the shallow and deep depth tubewell.

A. Shallow depth tubewell

The actual and estimated values of arsenic in 30 schools at shallow depth were summarized in fig 6.9.

In shallow depth tubewell, most of the actual and estimated values are found almost similar, only in some schools the actual and estimated value was found different due to the geological characterization of the focus area. (fig 6.9). In Nalmuri FP, Shaurandaria FP and Gorkhara FP the estimated values are much higher than the actual value because of higher arsenic contaminated patches are present beside the region where the schools are located. Arsenic concentration in most of the schools is more than 100 ppb. In Chilatala FP, Naora Lalit Mohan FP, Alipur Suryapur JB and Chohati JB, arsenic concentration is observed more than 300 ppb. The cause of deviation among actual and estimated concentration was discussed in section 5.4.3.13.

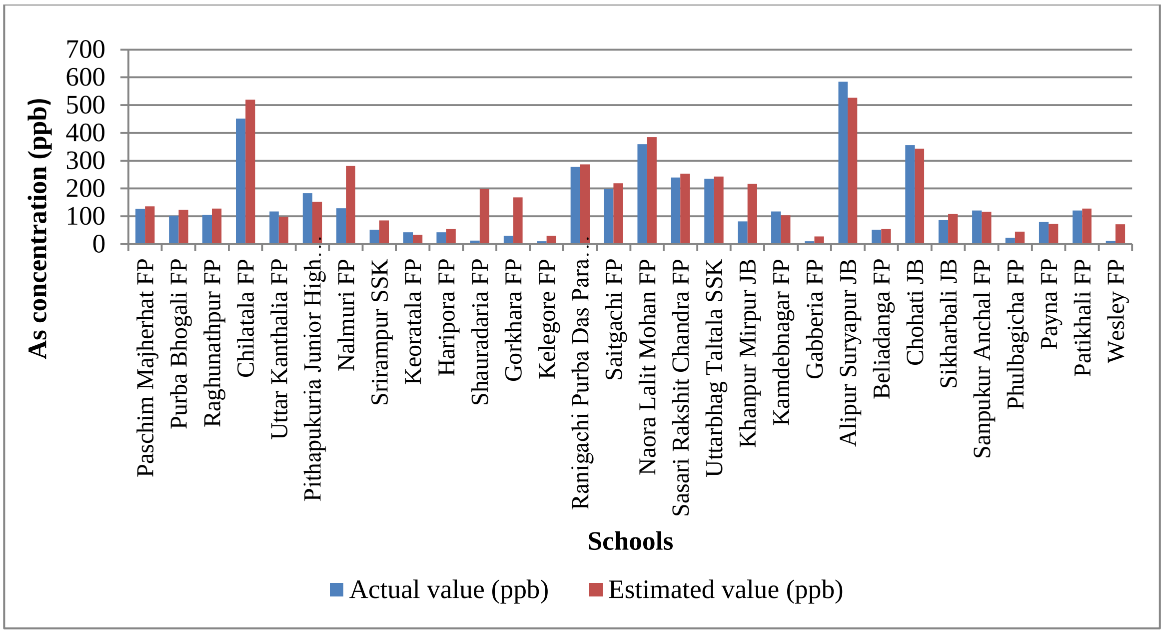


Fig: 6.9. Comparison between actual and estimated value of arsenic in shallow tubewell

B. Deep depth tubewell

The actual and estimated arsenic concentration in 30 tubewells from deep aquifers were summarized in fig 6.10.

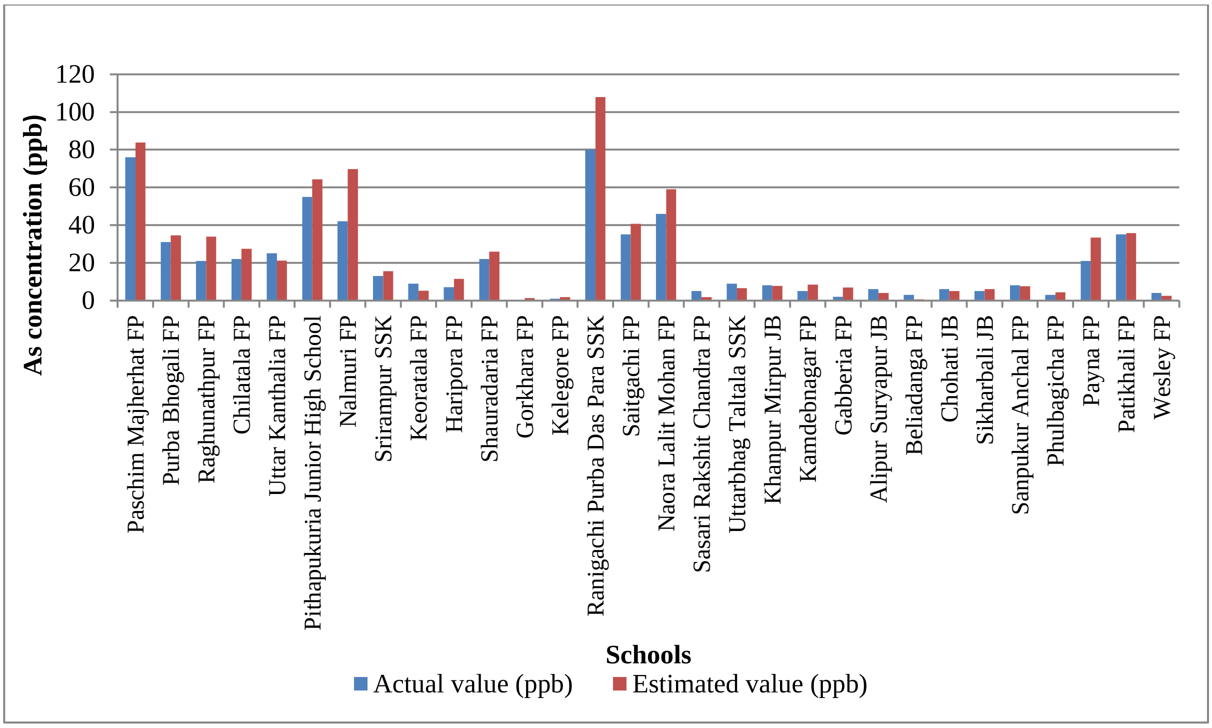


Fig: 6.10. Comparison between actual and estimated value of arsenic in deep tubewell

From fig 6.10, it was observed that in deep depth tubewell, the maximum arsenic concentration was observed 105 ppb in Ranigacchi Purba Das Para SSK. Half of the tubewells contain arsenic concentration less than permissible limit (10 ppb). No variation of arsenic in deep tubewell due to the geological settings of the aquifer. The estimated results were found better in deeper depth than the shallow depth.

6.6.1.4. Estimation of arsenic concentration in all primary schools

The estimation of arsenic in the groundwater of the schools was done with the kriging interpolation method both in shallow and deep depth from each tubewell. No actual values were calculated here. Only estimated values got from Kriging Interpolation method was considered for the study. Further work was carried out with the estimated values of arsenic concentration.The estimation was done with kriging with the total school data set in shallow and deep tubewell.

A. Shallow depth tubewell

- **Descriptive statistics of arsenic**

The descriptive statistical analysis was done for the arsenic concentration for total number of schools in shallow tubewell. The result is tabulated in table no. 6.13

Table: 6.13. Descriptive statistics of arsenic in tubewell

Number of schools	1044
Minimum arsenic concentration (ppb)	2
Maximum arsenic concentration (ppb)	1024
Mean arsenic concentration (ppb)	107.2
Median arsenic concentration (ppb)	72

Among 1044 tubewells, the minimum and maximum arsenic concentration were 2 and 1024 ppb respectively (table 6.13). The mean was 107.2 ppb and median 72 ppb.

- **Percentage of primary schools at diiferent arsenic concentration level**

Percentage of primary schools at different arsenic concentration level was summarized in fig 6.11.

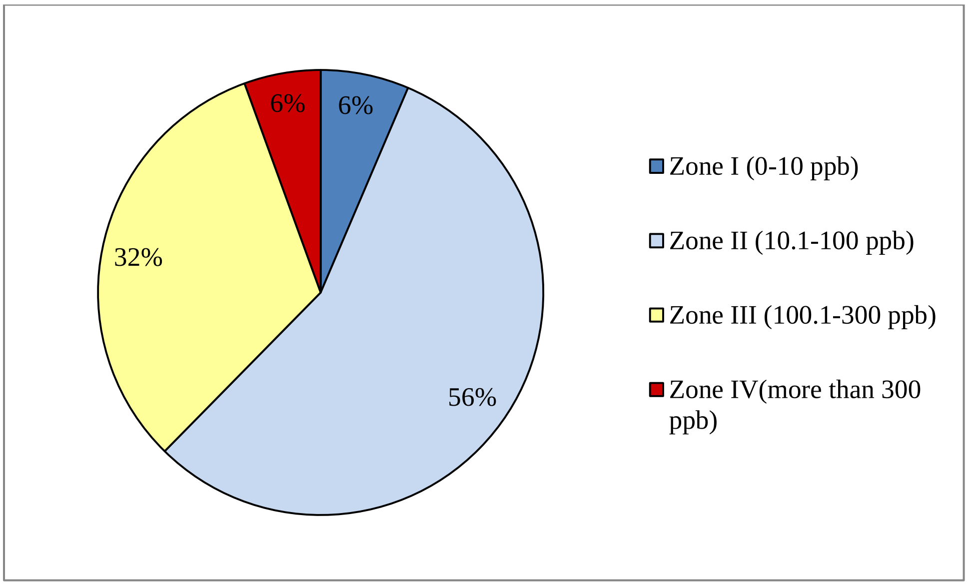


Fig: 6.11. Percentage of primary schools at different arsenic concentration level at shallow depth

The total number of schools were divided on the basis of arsenic concentration in groundwater (table 6.11). Among them, only 6% schools were present in zone I, 56% in zone II, 32% in zone III and 6% in zone IV.

- **Total percentage of population at different arsenic concentration level**

The total percentage of population at different arsenic concentration level was summarized in fig 6.12.

From fig 6.12, it was found that 6% of student population was found to be present in safe zone, 55% in zone II, 33% in zone III and 6% in zone IV. The population in the schools are evenly distributed.

It was observed from the study by Asadullah and and Chaudhury (2011) that 59% of the sample children (n=7710) attended school in affected region, 12% of the total sample had been reported having arsenic contaminated wells at home too.

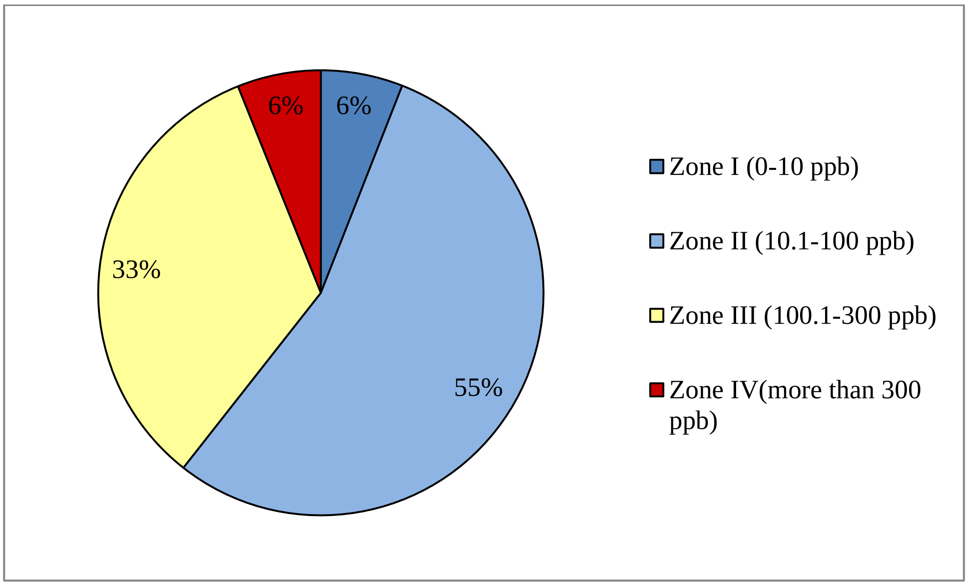


Fig: 6.12. Total percentage of population at different arsenic concentration level at shallow depth

- **Blockwise minimum and maximum arsenic concentration of the tubewells from the schools**

Blockwise distribution of total number of schools, population and arsenic concentrations are tabulated in table no. 6.14.

Table. 6.14. Number of schools, student population and arsenic concentration in the blocks

Block	Total number of schools	Total student population	arsenic concentration (ppb)		
			Minimum	Maximum	Mean
Baruipur	208	19753	2	962	141.8
Bhangar I	141	13645	11	453	142.9
Bhangar II	101	13772	18	519	121.9
Bishnupur I	34	1965	5	262	36.2
Canning II	66	12745	12	178	83.9
Jaynagar I	113	13144	10	490	86.8
Jaynagar II	62	7324	8	102	52.5
Magrahat II	53	5214	8	184	45.01
Mandirbazar	48	2848	12	88	40.8
Sonarpur	204	17116	6	1024	123.5
Mathurapur I	14	1149	10	65	39.92

From table 6.14, it was observed that the maximum arsenic concentration was found 1024 ppb in Sonarpur block followed by 962 ppb in Baruipur block. The mean arsenic concentration is maximum in Bhangar I followed by Baruipur, Sonarpur and Bhangar II. The arsenifeous belt can be present in shallow depth (within 100 m bgl) for those blocks.

- **Blockwise distribution of percentage of student population**

The percentage of student population in different arsenic contaminated blocks was summarized in fig 6.13.

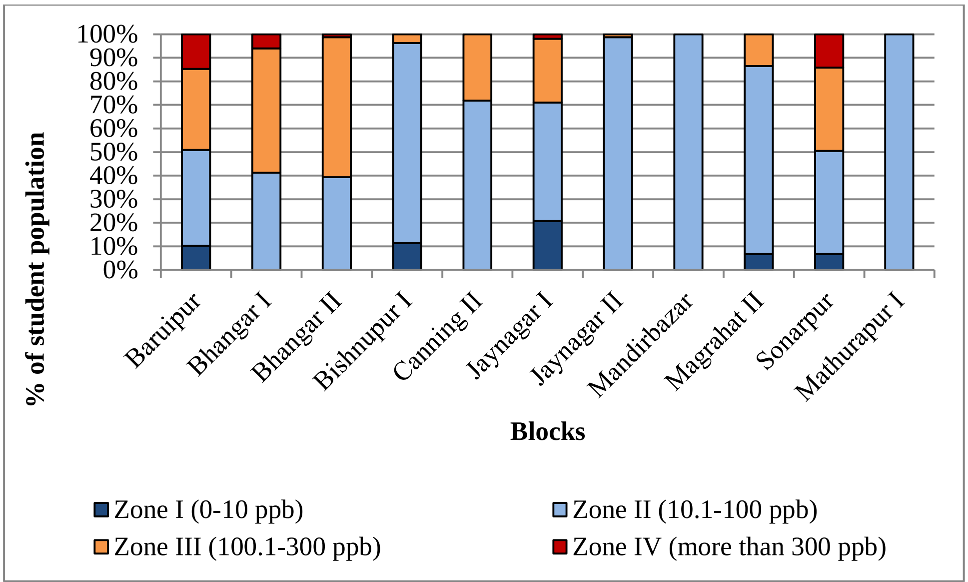


Fig: 6.13. Blockwise percentage of student population in different arsenic concentration zone at shallow depth

From fig 6.13, it was observed that most of the schools are situated in zone II followed by zone III. In Baruipur, Bhangar I and II, Jaynagar I and II and Sonarpur block, more or less 10% schools are present in zone IV. In Jaynagar II, Mandirbazar and Mathurapur I, all the schools were located in zone II.

It was found from the study by Mandal et al. (1998) that the symptoms of arsenical skin diseases developed insidiously after 6 months to 3 years or more depending on the quantity of arsenic intake.

B. Deep depth tubewell

- **Descriptive statistics of arsenic**

The statistical analysis done for the estimated arsenic data for all of the primary schools located in the focus area was described in table 6.15.

Table: 6.15. Descriptive statistics of arsenic in deep tubewell

Number of schools	1044
Minimum arsenic concentration	1 ppb
Maximum arsenic concentration	157 ppb
Mean arsenic concentration	20.42 ppb
Median arsenic concentration	9 ppb

From table 6.15, it was observed that the minimum arsenic concentration was 1 ppb and maximum was 157 ppb. The mean concentration was 20.42 ppb.

- **Percentage of primary schools at diiferent arsenic concentration level**

The percentage of schools at different arsenic concentration level was summarized in a pie chart in fig no 6.14.

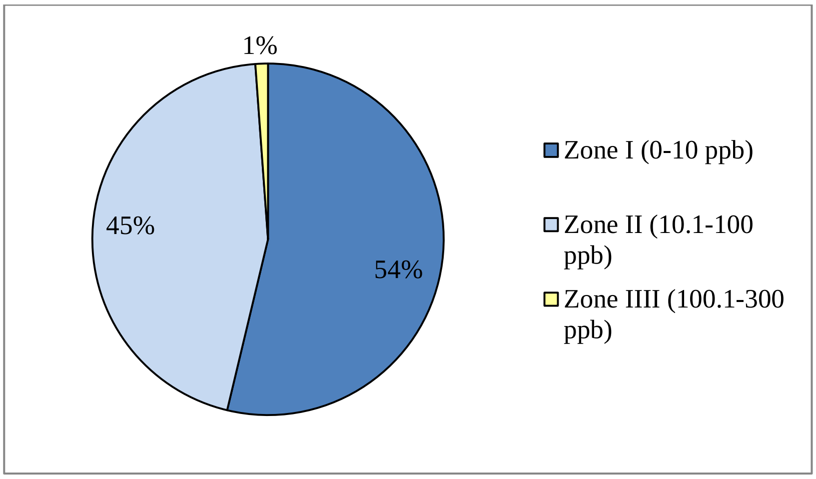


Fig: 6.14. Percentage of schools at different level of arsenic concentration at deep depth

If the tubewells are considered to be installed at deep depth, 54% schools will be present in safe zone, 45% in zone II and only 1% in zone III (fig 6.14).

- **Percentage of population at different arsenic concentration level**

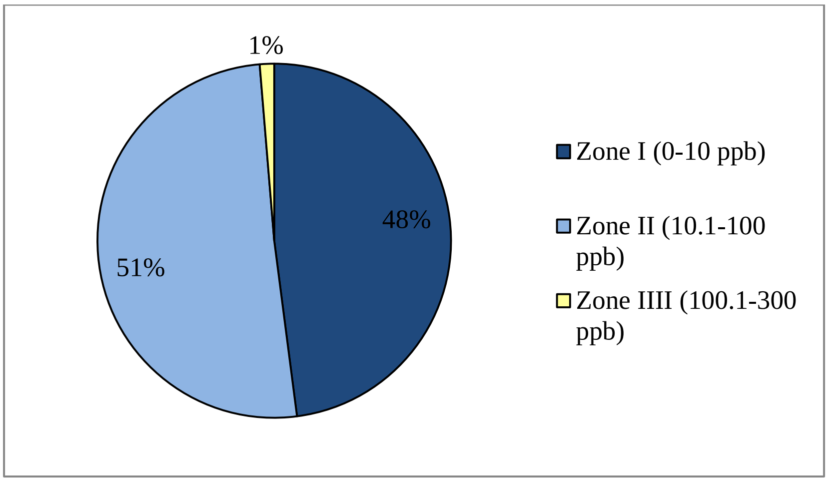


Fig: 6.15. Percentage of population at different arsenic concentration level at deep depth

From fig 6.15, it was observed that in deep depth tubewells, 48% population was found in safe zone while 51% was from zone II and only 1% in zone III.

- **Minimum and maximum concentration of arsenic in tubewells present in primary schools**

Blockwise distribution of total schools, population and arsenic concentration in deep tubewell was determined and tabulated in table no 6.16.

Table: 6.16. Number of schools, student population and arsenic concentration in the blocks

Block	Total schools	Total Population	Arsenic concentration in ppb		
			Minimum	Maximum	Mean
Baruipur	208	19753	1	29	9.3
Bhangar I	141	13645	5	157	40.3
Bhangar II	101	13772	7	104	40.5
Bishnupur I	34	1965	5	82	31.6
Canning II	66	12745	5	45	28.3
Jaynagar I	113	13144	1	136	24.7
Jaynagar II	62	7324	3	67	6.8
Magrahat II	53	5214	3	75	11.9
Mandirbazar	48	2848	3	10	6.1
Sonarpur	204	17116	1	62	11.7
Mathurapur I	14	1149	4	9	6.7

The maximum arsenic concentration was found in Bhangar I and Jaynagar I block (from table 6.16). Mean value of arsenic in deep aquifer is lower in Baruipur, Jaynagar II, Magrahat II, Mandirbazar, Sonarpur and Mathurapur I. The mean value of arsenic is lower in Baruipur block than Bishnupur I, that means the arsenifeous aquifer is present in deep depth in Bhangar I and II, Bishnupur I, Canning II and Jaynagar I.

- **Blockwise distribution of percentage of student population**

The percent of student population from the focus area at different arsenic contaminated zone was determined and summarized in table 6.16.

In Baruipur, Jaynagar I, Magrahat II and Sonarpur blocks, more than 50% of schools were present in zone I (fig 6.16). Only Bhangar I and II, safe, zone II and III are present. Zone IV is absent in deep tubewell.

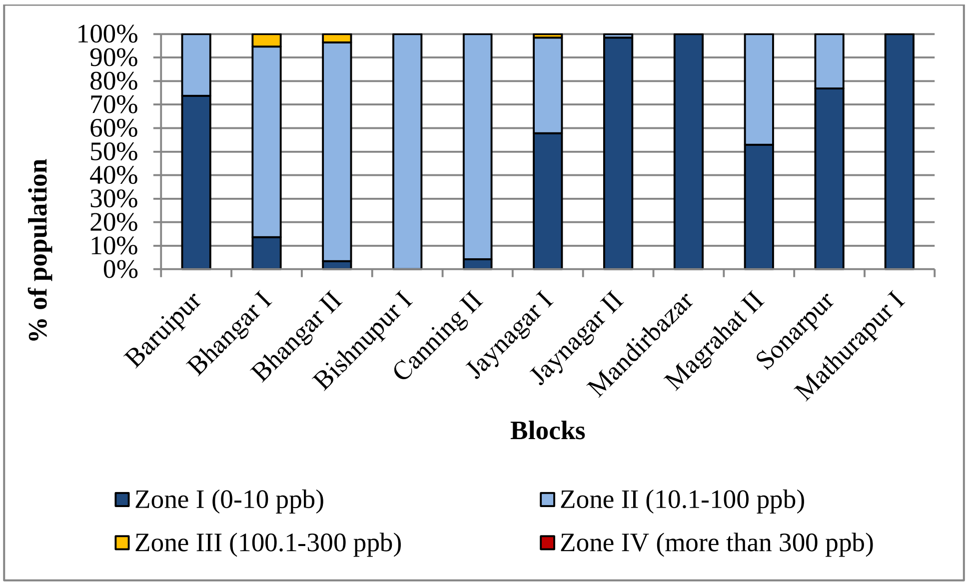


Fig: 6.16. Percentage of student population in different arsenic concentration zone in deep depth

The distribution of percentage of schools at different arsenic concentration zones in shallow and deep depth are summarized in fig 6.17.

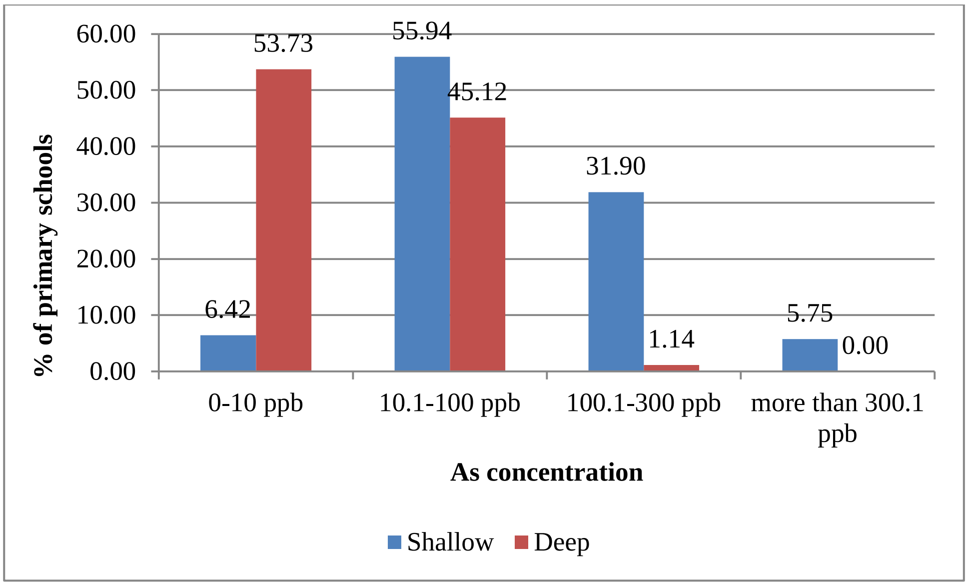


Fig: 6.17. Percent distribution of primary schools in different arsenic contaminated zone in both shallow and deep aquifer

From fig 6.17, it was observed that for shallow depth, 55.94% schools are located in zone II (10.1- 100 ppb) and 31.9% are located in zone III (100.1-300 ppb). For deep depth, 53.73% are present in zone I (0-10 ppb), 45.115% in zone II (10.1-100 ppb) and 1.14 in zone III (100-300 ppb) zone. The number of schools, student population and arsenic concentration in shallow and deep depth tubewells were mentioned in annexure II.

According to Chakraborty and Saha (1987), the lowest arsenic concentration was found 0.2 mg/L (200 ppb) that could produce dermatosis, that didn't mean that all the people drinking 200 ppb arsenic contaminated water would show arsenical skin lesions. The governing factors for developing arsenical skin lesions described by Mandal et al. (1998) were i) the amount and duration of year of arsenic contaminated water drunk ii) nutritional status iii) the higher the concentration of arsenic in drinking water, the greater the percentage of prevalence among the population and iv) genetic basis of human. Tseng et al. (1961) determined an association of skin cancer after consumption of water containing more than 0.5 mg/L (500 ppb) arsenic. WHO (1981) reported that the consumption of approximately 1 mg/L (1000 ppb) of arsenic contaminated water daily may develop skin problems within a few years of exposure.

6.6.2. Assessment of Human health risk developed by arsenic concentration among adult and child population

Health risk assessment is a process to evaluate the probability of adverse health effects in humans who are manifested by different environmental contaminants now and near future (EPA 2021).

The source of drinking water is tubewells present in school premises. The children spend almost half of the day in these schools. The mid day meal is prepared with the water from tubewells. The weather of the focus area can be considered as hot and humid summer with a very short span of winter. The daily recommended intake for water is dependent on age, sex, weight, activity status, temperature and humidity (Faizan and Rouster 2021). A 10 years old child is assumed to be more involved in physical activities like running, playing with friends. So, water requirement is higher for a child who is physically active in a hot and humid area. The risk calculation was done with adult and child population both. The local adult residents are considered as adult population.

6.6.2.1. Exposure risk assessment

In the present study, exposure risk assessment was done to estimate the magnitude of the impact of arsenic contamination on the population (Huy et al. 2014)

The TDI (Tolerable Daily Intake) of the study population was calculated as follows:

$$TDI = C \times \frac{IR \times EF \times ED}{BW \times AT}$$

C=arsenic concentration in ppm

IR= Ingestion rate in L/day

EF= Exposure frequency (days/years of use of arsenic contaminated source)

ED= Average Exposure duration (years of using arsenic contaminated source)

BW =Average body weight (Kg)

AT = Average Life expectancy (days)

Hossain et al. (2013) found that the pattern of daily water consumption can be classified as direct and indirect intake. The direct intake means ingestion of drinking water only and indirect intake means consumption of water combined with food and beverages, that two makes the total intake of water daily. The direct water intake for an adult (male) was considered as 3.95±0.79 lpcd and for a child (boy) was 2.15±0.75 lpcd. The indirect water intake was found 1.21±0.48 lpcd for adult population and 0.62±0.37 lpcd for child population.

In the present study, the total intake of water is taken 10 lpcd for adults and 6 lpcd for children. The direct intake for adult was taken 5 lpcd and indirect intake was 5 lpcd (CPHEEO, 1999). For child population, the value is 2 lpcd for direct and 4 lpcd for indirect intake. The indirect intake was considered more than Hossain et al. (2013) because cooking are done with the arsenic contaminated water. Absorbtion of arsenic into rice and vegetables during cooking is a notable contribution to water intake. Arsenic concentration from rice was not considered in present study because the source of rice was unknown. The rice either cultivated with arsenic contaminated water or not was not known. According to Mandal et al. (1998), it was studied that apart from drinking, cooking and washing, the population was found to use the contaminated water for face washing, washing their mouth after eating which also contributed some arsenic.

Exposure frequency means the number of days per year a person is exposed to arsenic contaminated water. In this study, the population are supposed to expose to arsenic concentration since their birth. So, they are exposed to arsenic throughout the year assuming no alternative source of water was available.

Exposure duration means the years of arsenic contaminated source are being used. The age of the primary school going children are considered 10 years and for adult population, it was 35 years. Average 35 years age for adult population was assumed because if a person consumes higher level of arsenic contaminated water for 35 years, the signs of arsenic induced illnesses will be prominent at this stage of life (Huy et al. 2014).

The average body weight was considered as 28 kg for child population and 60 kg for adult population. According to Khadilkar et al. (2015), the average weight for a 10 years old child in India is 31 kg. But in this study it is considered 28 kg because the student population in the FPs and SSKs come mainly from poor community and they are supposed to be suffered from malnutrition.

Average life expectancy in India is considered 70 years (World Bank Data 2020).

6.6.2.2. Risk assessment

Risk of arsenic can be divided into non carcinogenic risk and carcinogenic risk.

- **Non carcinogenic risk characterization**

Hazard Quotient (HQ)

Hazard quotient is the index of non carcinogenic toxicity of a substance (arsenic in drinking water in the present study). The calculation for non carcinogenic risk has been done through a standard quantification method 'Hazard Quotient' which is the ratio between 'Tolerable Daily Intake' and 'Reference Dose' (USEPA 1993). It can be calculated by the following equation-

HQ= TDI/ RfD

RfD= Reference dose for Arsenic (mg/Kg d)= 0.0003 mg/Kg d) (USEPA 2005)

RfD indicates "the daily exposure to which the human population could be continually exposed over a lifetime without an appreciable risk of deleterious effects" (Alidadi et al. 2019).

When the calculated value of HQ is <1, no adverse non carcinogenic effects are visible, otherwise an adverse non carcinogenic risk has been considered as possible.

- **Carcinogenic risk characterization**

The quantification of Cancer Risk (CR) for arsenic contamination has been applied to determine the potential risk associated with the exposure throughout the lifetime. Cancer Slope Factor (SF) and Age Dependent Adjustment Factor (ADAF) was used to estimate the cancer risk among the child and adult population.

Cancer Risk (CR)= TDI × SF × ADAF (Huy et al. 2014)

EPA defined carcinogenic or cancer risks (CR) as "the incremental probability of an individual to develop cancer, over a lifetime, as a result of exposure to a potential carcinogen" (Alidadi et al. 2019)

The SF= Cancer Slope Factor index (1.5 mg/kg day^{-1}). Only skin cancer risk was considered in the study as the availability of SF.

ADAF= Age-dependent adjustment factor. ADAF was found different for different age groups, for adult (>16 years) and child(6-16 years) population it was 1 and 3 respectively. (Huy et al. 2014)

The range of risks borderline by the EPA is 1×10^{-4} to 1×10^{-6} and unacceptable if the risks are surpassing 1×10^{-4} . A carcinogenic risk of 1×10^{-4} gives rise to potential health hazard (Alidadi et al. 2019)

The factors considered for present study for adult and child population are mentioned in the table. 6.17. All the factors except arsenic concentration was same for the study.

Table: 6.17. The factors associated for risk assessment

Factors	Adult (35 years)	Child (6-10 years)
IR [Average Ingestion rate (L/Day)]	10	6
EF [Exposure frequency (days/year of use of arsenic contaminated source)]	365	365
ED [Average Exposure duration (years of using arsenic contaminated source)]	35	10
BW [Average body weight (Kg)]	60	28
AT [Average Life expectency (days)]	70×365= 25550	70×365= 25550
RfD [Reference dose for arsenic (mg/Kg d)	3×10^{-4}	3×10^{-4}
SF [Cancer slope factor index (mg/kg day^{-1})]	1.5	1.5
ADAF [Age-dependent adjustment factor]	1	3

6.6.2.3. Calculation of exposure risk and assessment

In the present study, risk assessment was done in all schools located in the focus area. Three schools were selected from the list for the sample calculation of health risk assessment. The schools belong to different arsenic concentration zone. The zoning was done for both the shallow and deep depth as the distribution pattern of arsenic is completely different in shallow and deep depth. One school was taken from arsenic safe zone where the concentration of arsenic was found within permissible limit both in shallow and deep tubewell.

A. Risk assessment calculation in 3 sample schools

3 sample schools were sorted for the study to calculate the risk assessment in table 6.18.

Table 6.18. Arsenic concentration in both shallow depth and deeper depth

Block	Village	School	Shallow depth		Deeper depth	
			Zone	Estimated As value (ppb)	Zone	Estimated As value (ppb)
Bhangar II	Bodra	Srirampur SSK	Zone II	84.7	Zone II	15.51
Bhangar I	Pranganj	Saitgachi FP	Zone III	219.04	Zone II	27.46
Bhangar II	Bhogali I	Chilatala FP	Zone IV	519.83	Zone II	40.62

From table 6.18, it was observed that the schools were located in different villages of Bhangar I and II blocks. Bhangar I and II blocks are the most arsenic affected blocks where shallow and deep depth aquifer both are arsenic contaminated. In shallow depth aquifer, the location of the schools can be classified as zone II, III and IV, but in deep depth aquifer, the schools are present within zone II.

Srirampur SSK is present in zone II for both shallow and deep depth. But Saitgachi FP lies in zone III for shallow depth and zone II for deep depth. Chilatala FP lies in zone III for shallow depth and zone II for deep depth. So, the zoning is completely different for both depth.

For arsenic concentration, the estimated values were taken for the following calculations. The risk was calculated for both adult and child population in Srirampur SSK, Saitgachi Fp and Chilatala FP in table 6.17, 6.18, 6.19, 6.20, 6.21 and 6.22. The calculation was done among adult and child population both to compare the effects on the population. The child population was considered the student population studying in those schools present in focus area and the adult population was considered residing the neighbouring regions of those schools.

- **Srirampur SSK**

Table 6.19. The risk calculation for an individual adult in Srirampur SSK

Assessment	Formula and parameters that will remain same	Depth	Parameters that will change	Results
Exposure [Tolerable Daily Intake (TDI)]	TDI= C× $\frac{IR \times EF \times ED}{BW \times AT}$ IR= 10 L/day EF=365 days ED= 35 years BW= 60 kg AT= 25550	Shallow	As conc= 0.0847 ppm	70.5 $\times 10^{-4}$ mg/kg.day
		Deep	As conc= 0.0155 ppm	12.9×10^{-4} mg/kg.day
Health risk (HQ)	HQ= TDI/RfD RfD= 3×10^{-4} mg/kg.day	Shallow	TDI= 70.5 $\times10^{-4}$ mg/kg.day	23.52
		Deep	TDI= 12.9 $\times10^{-4}$ mg/kg.day	4.31
Cancer risk (CR)	CR=TDI×SF× ADAF SF= 1.5 mg/kg.day ADAF= 1	Shallow	TDI= 70.5 $\times10^{-4}$ mg/kg.day	105.75 $\times10^{-4}$
		Deep	TDI= 12.9 $\times10^{-4}$ mg/kg.day	19.35×10^{-4}

Table 6.20. The risk calculation for an individual child in Srirampur SSK

Assessment	Formula and parameters that will remain same	Depth	Parameters that will change	Results
Exposure [Tolerable Daily Intake (TDI)]	TDI= C× $\frac{IR \times EF \times ED}{BW \times AT}$ IR= 6 L/day EF=365 days ED=10 years BW= 28 kg AT= 25550	Shallow	As conc=0.0847 ppm	25.93×10^{-4} mg/kg.day
		Deep	As conc= 0.0155 ppm	4.76×10^{-4} mg/kg.day
Health risk (HQ)	HQ= TDI/RfD RfD= 3×10^{-4} mg/kg.day	Shallow	TDI= 25.93 $\times10^{-4}$ mg/kg.day	8.64
		Deep	TDI= 4.76 $\times10^{-4}$ mg/kg.day	1.58
Cancer risk (CR)	CR=TDI×SF× ADAF SF= 1.5 mg/kg.day ADAF= 3	Shallow	TDI= 25.93 $\times10^{-4}$ mg/kg.day	116.68×10^{-4}
		Deep	TDI= 4.76×10^{-4} mg/kg.day	21.42×10^{-4}

- **Saitgachi FP**

Table. 6.21. The risk calculation for an individual adult in Saitgachi FP

Assessment	Formula and parameters that will remain same	Depth	Parameters that will change	Results
Exposure [Tolerable Daily Intake (TDI)]	$TDI = C \times \frac{IR \times EF \times ED}{BW \times AT}$ IR= 10 L/day EF=365 days ED= 35 years BW= 60 kg AT= 25550	Shallow	As conc= 0.219 ppm	182.53×10^{-4} mg/kg.day
		Deep	As conc= 0.04062 ppm	33.85×10^{-4} mg/kg.day
Health risk (HQ)	HQ= TDI/RfD RfD= 3×10^{-4} mg/kg.day	Shallow	TDI= 182.53×10^{-4} mg/kg.day	60.84
		Deep	TDI= 33.85×10^{-4} mg/kg.day	11.28
Cancer risk (CR)	CR=TDI×SF× ADAF SF= 1.5 mg/kg.day ADAF= 1	Shallow	TDI= 182.53×10^{-4} mg/kg.day	273.8×10^{-4}
		Deep	TDI= 33.85×10^{-4} mg/kg.day	50.77

Table. 6.22. The risk calculation for an individual child in Saitgachi FP

Assessment	Formula and parameters that will remain same	Depth	Parameters that will change	Results
Exposure [Tolerable Daily Intake (TDI)]	$TDI = C \times \frac{IR \times EF \times ED}{BW \times AT}$ IR= 6 L/day EF=365 days ED=10 years BW= 28 kg AT= 25550	Shallow	As conc= 0.219 ppm	67.053×10^{-4} mg/kg.day
		Deep	As conc= 0.04062 ppm	12.435×10^{-4} mg/kg.day
Health risk (HQ)	HQ= TDI/RfD RfD= 3×10^{-4} mg/kg.day	Shallow	TDI= 67.053×10^{-4} mg/kg.day	22.351
		Deep	TDI= 12.435×10^{-4} mg/kg.day	4.14
Cancer risk (CR)	CR=TDI×SF× ADAF SF= 1.5 mg/kg.day ADAF= 3	Shallow	TDI= 67.053×10^{-4} mg/kg.day	301.74×10^{-4}
		Deep	TDI= 12.43×10^{-4} mg/kg.day	55.95×10^{-4}

- **Chilatala FP**

Table. 6.23. The risk calculation for an individual adult in Chilatala FP

Assessment	Formula and parameters that will remain same	Depth	Parameters that will change	Results
Exposure [Tolerable Daily Intake (TDI)]	$TDI = C \times \frac{IR \times EF \times ED}{BW \times AT}$ IR= 10 L/day EF=365 days ED= 35 years BW= 60 kg AT= 25550	Shallow	Arsenic conc=0.5198 ppm	433.19×10^{-4} mg/kg.day
		Deep	Arsenic conc= 0.0275 ppm	22.88×10^{-4} mg/kg.day
Health risk (HQ)	HQ= TDI/RfD RfD= 3×10^{-4} mg/kg.day	Shallow	TDI= 433.19×10^{-4} mg/kg.day	144.4
		Deep	TDI= 22.88×10^{-4} mg/kg.day	7.62
Cancer risk (CR)	CR=TDI×SF× ADAF SF= 1.5 mg/kg.day ADAF= 1	Shallow	TDI= 433.19×10^{-4} mg/kg.day	649.69×10^{-4}
		Deep	TDI= 22.88×10^{-4} mg/kg.day	34.325×10^{-4}

Table. 6.24. The risk calculation for an individual child in Chilatala FP

Assessment	Formula and parameters that will remain same	Depth	Parameters that will change	Results
Exposure [Tolerable Daily Intake (TDI)]	TDI= C× $\frac{IR \times EF \times ED}{BW \times AT}$ IR= 6 L/day EF=365 days ED=10 years BW= 28 kg AT= 25550	Shallow	C= 0.5198 ppm	159.13 $\times 10^{-4}$ mg/kg.day
		Deep	C= 0.0275 ppm	8.4×10^{-4} mg/kg.day
Health risk (HQ)	HQ= TDI/RfD RfD= 3×10^{-4} mg/kg.day	Shallow	TDI= 159.13 $\times 10^{-4}$ mg/kg.day	53.044
		Deep	TDI= 8.4 $\times 10^{-4}$ mg/kg.day	2.8
Cancer risk (CR)	CR=TDI×SF× ADAF SF= 1.5 mg/kg.day ADAF= 3	Shallow	TDI= 159.13 $\times 10^{-4}$ mg/kg.day	716.09 $\times 10^{-4}$
		Deep	TDI= 8.4 $\times 10^{-4}$ mg/kg.day	37.82×10^{-4}

From the above calculations it was observed that the estimated TDI, HQ and CR values were found higher than the stipulated limit.

B. Comparison of risk assessment at different arsenic concentration among individual adult and child

A comparison of risk assessment was done between different arsenic concentration zone was done from the above study. The arsenic concentration of Khakurdaha Jangalia FP is below 10 ppb for both shallow and deep tubewell. It was considered as controlled school. The risk assessment was measured in individual population from 4 different arsenic contaminated schools (table 6.25). Shallow and deep both depths were considered for the study.

Table: 6.25. Exposure and health risk assessment of individual adult and child

School	Depth	Arsenic Conc (ppm)	Exposure risk assessment		Health risk assessment			
			Adult	Child	HQ		CR	
					Adult	Child	Adult	Child
Khakurdaha Jangalia FP	Shallow	0.01	8.33	3.06	2.77	1.02	12.5	13.77
	Deep	0.008	6.66	2.44	2.22	0.81	10	11.02
Srirampur SSK	Shallow	0.0847	70.5	25.93	23.52	8.64	105.75	116.68
	Deep	0.0155	12.9	4.76	4.31	1.58	19.35	21.42
Saitgachi FP	Shallow	0.219	182.53	67.05	60.84	22.35	273.8	301.74
	Deep	0.0406	33.85	12.43	11.28	4.14	50.77	55.95
Chilatala FP	Shallow	0.5198	433.19	159.13	144.4	53.04	649.79	716.09
	Deep	0.0275	22.88	8.4	7.62	2.8	34.32	37.82

From the table 6.25, it was observed that the higher TDI values may be recognized as the state of health risk among school children. In Khakurdaha Jangalia FP, the arsenic concentration in shallow and deep tubewell was 0.01 ppm (10 ppb) and 0.08 ppm (8 ppb) respectively, both are present within permissible limit (10 ppb). But the HQ value were 2.72 and 2.22. Both are greater than 1. In this chart all the values of HQ are higher than 1. If the value of HQ>1, it is considered that there are chances to develop adverse health effects on the population who are consuming that much of arsenic contaminated water. In Srirampur SSK, Saitgachi FP and Chilatala FP, arsenic concentration in shallow tubewell are 8.4, 21.9 and 51.9 times more than the permissible limit. So, the population of the schools are very much vulnerable to develop different kinds of illnesses. A carcinogenic risk of 1×10^{-4} gives rise to potential health hazard. Here the carcinogenic risk lies between 10×10^{-4}- 649×10^{-4}. So, the population from Chilatala FP is 649 times more prone to hazard than the population living in arsenic safe zone.

For the risk assessment among child population, the arsenic concentration was same. Only the daily ingestion rate of water, duration of consumption of arsenic contaminated water and body weight were different.

Exposure to arsenic in adult and child population is different. The children are more vulnerable to arsenic contamination than the adult population, as they are in developing stage, they have low metabolism potential and less detoxification power. So, the arsenic which is not able to be excreted from the body, accumulates within different organs that causes cancer in future life. The TDI is lower in child population than adult population but carcinogenic risk is approximately 1.1 times higher in child population. The adult and child population are using the same source of water with that much of arsenic concentration, so, the impact will be very high among the child population. According to Hossain et al. (2013), the establishment of the guideline values for drinking water contaminants, the WHO and some national agencies use 2 L of consumption of water per day for 60 kg adults.

6.6.2.4. Exposure risk and risk assessment among all schools

The predicted arsenic concentration among the primary schools were taken for the present study and risk assessment was done on the basis of the predicted arsenic concentration. The risk assessment was done in adult population too to compare the risk between adult and child population.

A. Risk assessment when arsenic concentration increases 1 ppb

The risk for different types of diseases increases when aresenic concentration increases 1 ppb. In table 6.26, the risk assessment was determined.

Table: 6.26. Risk assessment when arsenic concentration increases 1 ppb among adult and child population

	TDI	**HQ**	**Cancer risk($\times10^{-4}$)**
Adult	0.833	0.2778	1.25
Child	0.3061	0.102	1.37

The risk for development of arsenic induced illnesses are different for adult and child population (table 6.26). The tolerable daily intake level and hazard quotient are higher in adult population than child population. But the development of cancer risk is higher among child population than adult population. So,we should take more care precautionary measurement against arsenic exposure of child population. So, one of our prime study criteria was based primary school going children.

B. Tolerable daily intake (TDI)

A graph (fig 6.18) was made by plotting arsenic concentration on x axis and tolerable daily intake (TDI) on y axis. The TDI of adult and child population was compared in the fig 6.18.

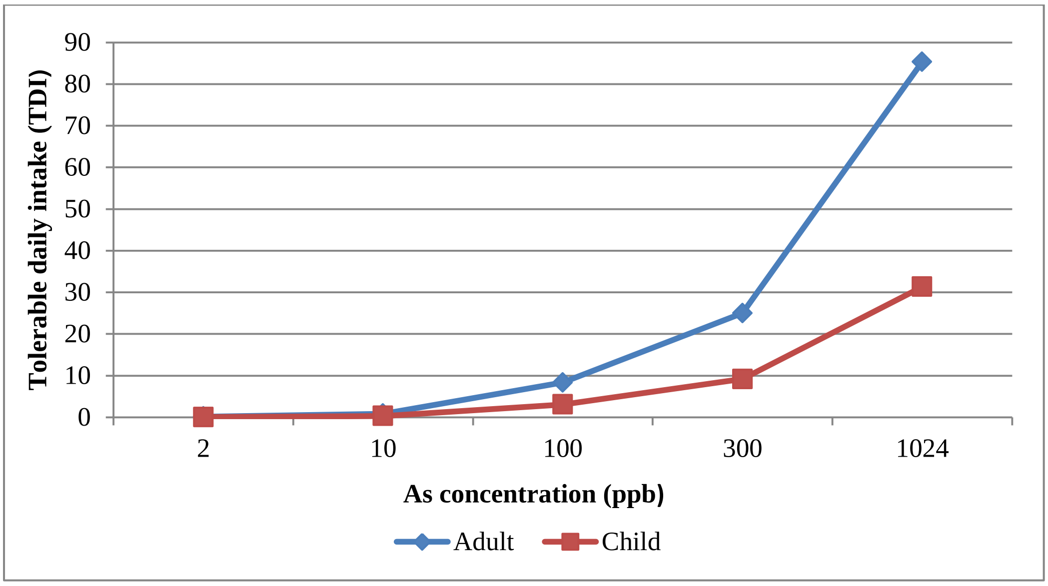


Fig: 6.18. Estimation of TDI at different arsenic concentration among adult and child population

From fig 6.18, it was observed that the daily intake of arsenic from drinking water was found ranging from 0.17 to 85.33 µg/kg body weight by the adult population and 0.06 to 31.34 µg/kg body weight by the child population while the arsenic concentration ranges from 2 to 1024 ppb. The daily intake of arsenic was estimated on the basis of water consumption rate as 10 l per adult and 6 l per child daily. According to Joint FAO/WHO (1989), The provisional tolerable daily intake value of inorganic arsenic 2.1 µg/kg body weight. For 10- 100 ppb arsenic concentration, the daily intake was observed 3 µg/kg body weight for child and 8 µg/kg body weight for adult population. If a child consumes 6 litre of water with 100 ppb arsenic concentration, the daily intake will be 1.5 fold more than the provisional daily intake value (2.1 µg/kg body weight). The value will be 4 fold more for the adult population when the consumption rate was 10 L/day.When the concentration was 300 ppb, the daily intake was almost 5 fold in child and 12 fold in adult population. When the concentration was high, the total daily intake was also high. The average daily intake of arsenic by adult and child population in the study is much higher than the intakes estimated previously in other part of West Bengal. A study done by Roychowdhury et al. (2003) in Murshidabad district (Jalangi and Domkal blocks), the tolerable daily intake values of inorganic arsenic for adult population were 11.8 and 9.4 µg/kg body weight and for child population (10 years) the values were 15.3 and 12 µg/kg body weight when mean arsenic concentration in groundwater was 110 ppb justified the obtained result. Intake of 1 mg of inorganic arsenic per day may give rise to skin lesions with a few years (WHO 1981).

C. Hazard quotient:

The Hazard Quotient graph (fig 6.19) was made by plotting arsenic concentration on x axis and Hazard Quotient on y axis.

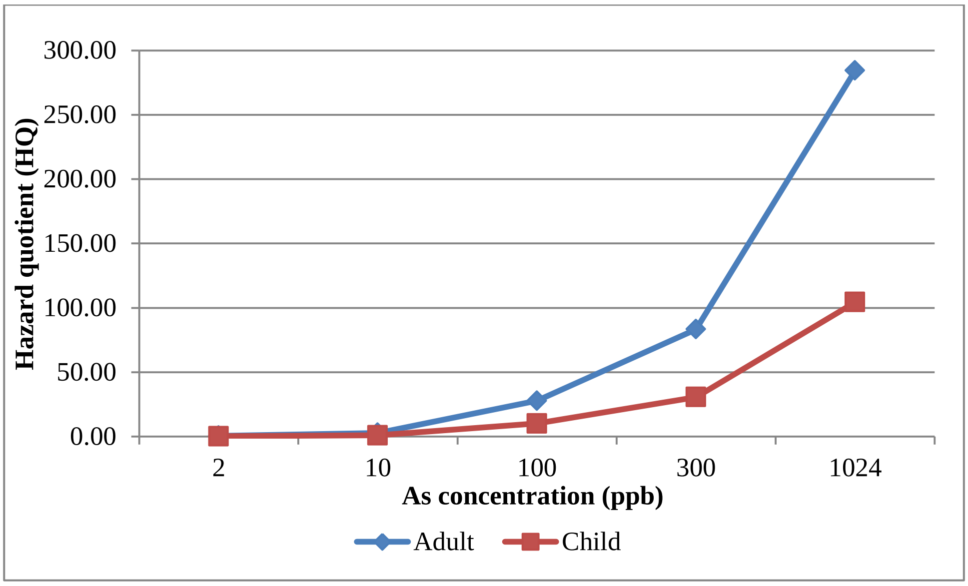


Fig:6.19. Estimation of Hazard Quotient at different arsenic concentration among adult and child population

From fig 6.19, it was observed that the range of HQ for adult population was 0.58 to 284.4 and for child population it was 0.21 to 104.5. When the concentration range was 10 to 100 ppb, the range of HQ was found varying from 1 to 10 for child population and 1 to 28 for adult population which means. It means the HQ was 10 folds higher for child and 28 folds higher for adult population when they consume 100 ppb arsenic contaminated water. Similarly, when the arsenic concentration was 300 ppb, the HQ for child was found 31 and 83 for adult population. The HQ was found increasing with higher arsenic concentration. High HQ denotes that there are high chances to develop arsenic contaminated diseases.

Among the total 1044 schools, the HQ was found less than 1 for child in ten schools. A school named Madanpur N Vidyapith FP, the estimated arsenic concentration was 2 ppb, the HQ was less than 1 for both adult and child population in that school. Only 0.77% school population from the focus area go to schools where HQ is less than 1. The HQ value was found exceeding the threshold value (HQ<1) and several times higher than the threshold values in all the schools. HQ was done to understand the cumulative health risk due to ingestion of arsenic contaminated water.

So, the school children from the focus area are exposed to a level of health concern. The range of HQ for adult and child population was found higher in the present study than the other studies done previously in other part of the world. According to Navoni et al. (2014), 68% of population from Argentina exposed to elevated level of arsenic concentration in drinking water with an HQ of >1.

D. Cancer risk

The graph for estimation of cancer was prepared in fig 6.20.

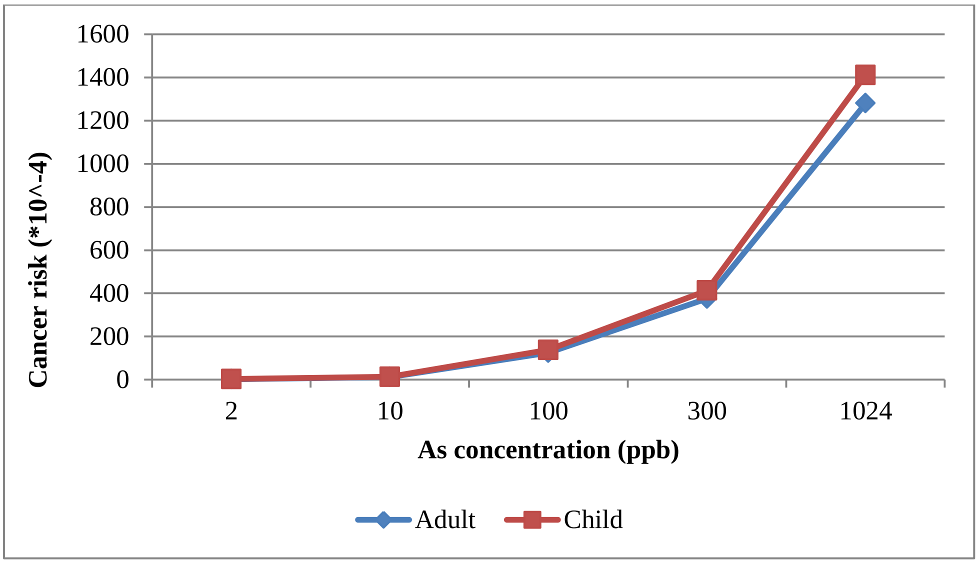


Fig: 6.20. Cancer risk assessment at different level of arsenic concentration among adult and child population

According to USEPA (2015), the standard Cancer risk (CR) value of arsenic was 1×10^{-6}, but the estimated CR is higher than the standard CR value in present study (fig 6.20), that may cause lifetime cancer risk to the primary school children. Risk of cancer development increases with the increase of arsenic concentration in groundwater. When arsenic concentration is 100 ppb, the risk of cancer development is 125×10^{-4} for adult population and 137.76×10^{-4} for child population which is 125 and around 138 fold higher than the standard value. It means there is a chance to develop skin cancer in 125 adults among 10000 populations if they consume 100 ppb arsenic contaminated water daily for 70 years. In child population the number is slightly higher, 138 children among 10000 population for 70 years for 100 ppb arsenic contamination considering the same concentration of arsenic contaminated water they consumed at their home in future. When the concentration was 300 ppb, the cancer risk was around 400 times higher in child population. The cancer risk in this study was found elevated above the estimates derived in other studies. Huy et al. (2014) studied that arsenic concentration in tubewell water was found 8- 579 ppb and the daily consumption of 40% of the adults exceeded the level of TDI. As a result, the average skin cancer risk was found 25.3×10^{-5} among the adult population.

E. Blockwise range of cancer risk at different arsenic concentration zone

Cancer risk was determined in schools blockwise for both shallow and deep depth tubewells.

- **Shallow tubewell**

Table: 6.27. Blockwise cancer risk at different arsenic concentration level among adult and child population in shallow tubewell

Block	Range of arsenic concentration (ppb)	Range of Cancer risk ($\times10^{-4}$)	
		Adult	**Child**
Baruipur	2 to 962	2.62 to 1202.5	2.89 to 1325.2
Bhangar I	11 to 453	13.75 to 566.26	15.15 to 624.03
Bhangar II	18 to 519.53	22.5 to 649.79	24.79 to 716.09
Bishnupur I	5 to 262	6.25 to 327.5	6.88 to 360.9
Canning II	12 to 178	15 to 222.5	16.5 to 245.2
Jaynagar I	10 to 490	12.5 to 612.5	13.78 to 675
Jaynagar II	8 to 102	10 to 127.5	11.02 to 140.5
Magrahat II	8 to 184	10 to 230	11.02 to 253.5
Mandirbazar	12 to 88	15 to 110	16.53 to 121.2
Sonarpur	6 to 1024	7.5 to 1280	8.26 to 1411
Mathurapur I	10 to 65	12.5 to 81.25	13.78 to 89.54

The risk for cancer development in children is very much higher than negligible risk level (1×10^{-6}). So, the children are very much prone to develop arsenic induced cancers due to ingestion of arsenic contaminated groundwater. From table 6.27 it was observed that the risk of cancer development is found higher in Baruipur and Sonarpur block as the arsenic concentration was highest in these two blocks. In Sonarpur block the risk of cancer risk in child population is 1411×10^{-4} that means 1411 children will be at risk to develop skin cancer among 10000 children if they consume 1024 ppb of arsenic contaminated water daily for 70 years

- **Deep tubewell**

Table: 6.28. Blockwise cancer risk at different arsenic concentration level among adult and child population in deep tubewell

Block	Range of Arsenic concentration (ppb)	Range of Cancer risk ($\times10^{-4}$)	
		Adult	**Child**
Baruipur	1 to 29	2.15 to 36.25	2.36 to 39.94
Bhangar I	5 to 157	6.25 to 196.25	6.88 to 216.28
Bhangar II	7 to 104	9.46 to 130	10.48 to 143.27
Bishnupur I	16 to 82	20 to 102.5	22.04 to 112.96
Canning II	9 to 45	11.25 to 56.25	12.39 to 61.99
Jaynagar I	1 to 136	2.15 to 170	2.36 to 187.35
Jaynagar II	3 to 67	3.75 to 83.75	4.13 to 92.29
Magrahat II	3 to 75	3.75 to 93.75	4.13 to 103.32
Mandirbazar	3 to 10	3.75 to 12.5	4.13 to 13.77
Sonarpur	1 to 62	2.15 to 75	2.36 to 85.65
Mathurapur I	4 to 9	5 to 11.25	5.5 to 12.39

The water from deeper depth is also not safe for children. The risk is higher than the negligible risk level. In deep depth, the risk of cancer development is highest in Bhangar I block followed by Jaynagar I and Bhangar II blocks (from table 6.28).

F. Assessment of exposure risk of a person from 0-35 years:

The children after come out from the primary schools are assumed to be lived in the same area for the rest of the life. So, the child is exposed to arsenic from the early childhood to rest of the life. The arsenic exposure risk was calculated for a child of 6-16 years and 16-35 years. The two age group was selected because the ADAF (Age-dependent adjustment factor) were found different for 6-16 years and >16 years. 35 years was taken because the child would be at mature age and consumed arsenic contaminated water for a long time.

In this study it was assumed that a person is living beside Srirampur SSK for 35 years. In his/her childhood, he/she studied in Srirampur SSK. He/she is supposed to consume arsenic contaminated water for same as the school for 35 long years. The cumulative effect of arsenic was calculated in that person. The temporal changes of arsenic was not considered, the arsenic concentration was assumed to remain same as from the very first year of the person.

For Srirampur SSK, the arsenic concentration for shallow Tubewell =84.7 ppb (0.0847 ppm) and deep Tubewell= 15.51 ppb (0.0155 ppm). Arsenic induced risk assessment was calculated at different ages in table 6.29.

Table: 6.29. Arsenic exposure risk of an individual person at different age when arsenic concentration 84.7 ppb (shallow) and 15.5 ppb (deep)

Assessment	**Depth**	**0-10 years**	**10.1-16 years**	**16.1-35 years**	**Total**
Exposure [Tolerable Daily Intake (TDI)]	Shallow	25.93×10^{-4}	12.81×10^{-4}	38.31×10^{-4}	77.05×10^{-4}
	Deep	4.76×10^{-4}	2.34×10^{-4}	7.01×10^{-4}	14.11×10^{-4}
Health risk (HQ)	Shallow	8.64	4.27	12.77	25.68
	Deep	1.58	0.78	2.33	4.69
Cancer risk (CR)	Shallow	116.68×10^{-4}	57.65×10^{-4}	57.47×10^{-4}	231.8×10^{-4}
	Deep	21.36×10^{-4}	10.55×10^{-4}	10.52×10^{-4}	42.43×10^{-4}

If a 35 years old man stays in a arsenic contaminated region where the arsenic concentration in shallow tubewell was 84.7 ppb and 15.5 ppb in deep tubewell since his birth, the hazards are found different at different age. After 35 years, the risk of cancer development is 231.8×10^{-4} (table 6.29).

6.6.2.5. Impact of arsenic on Intelligence Quotient (IQ) among child population

Arsenic is neurotoxic too. Early exposure to arsenic can reduce the Intelligence Quotient (IQ) which results the reduction of cognitive development and neurobehavioral function over the life time of a child. Intelligence has been considered as the potentiality to learn from experience, capacity to adapt, personality development, rational thinking and solve the daily life issues (Bearce 2009). Intelligence Quotient (IQ) is the measure of intelligence that provides the mental and actual age of a child. The mental age is considered as the typical intelligence level found for people a definite actual age (Bearce 2009). There are different intelligence scale to measue IQ. Wechsler Intelligence Scale for Children, Third Edition (WISC-III) is the most popular technique used for the children from 6 to 16 years. The classification of IQ score derived by Wechsler was mentioned in table 6.30.

In the present study, the impact of arsenic on Intelligence Quotient (IQ) was measured among the child population only.

Table: 6.30. Classification of IQ in Educational use (WISC-III) (Wechsler 1997)

IQ score	**Descriptive level**
≤69	extremely low
70-79	borderline
80-89	low average
90-109	average
110-119	high average
120-129	superior
≥130	very superior

The decrease in IQ level among the school children from the focus area due to arsenic was measured in the study. Chronic exposure to arsenic was reported to be responsible for irreversible decrease in intelligence quotient (IQ) and could increase school failure (Hasanvand et al. 2020).

A. Determination of decrease in IQ score among child population among sample schools

According to Wasserman et al. (2011), arsenic concentration in drinking water as low as 10 ppb were observed to cause reductions in the intellectual function in 10 year old children. According to Rodriguez et al. (2003), arsenic concentration of 14.2 ppb in drinking water can reduce the verbal IQ of children for a whole life exposure. The IQ score in maximum number of population was considered in the 90-109 (average) level. Ghosh, Chakraborty and Mondal (2017) considered the mean IQ 108.7 score for the arsenic safe zone.

The decrease in IQ score was measured in all the schools. Calculation was done in 3 sample schools where the risk assessment was measured.

The present study was done with 0.08 IQ scale decrease when arsenic concentration increases by 1 ppb (Hasanvand et al. 2020). The mean IQ score was considered 99.5 as it was the average of 90-109 descriptive level. The sample calculations for determination of IQ loss was summarized in table no 6.31.

Table 6.31. Determination of IQ loss due to arsenic contamination among child population

Name of the school	Tubewell depth	As conc (ppb)	Decrease in IQ score	Present IQ score
Khakurdaha Jangalia FP	Shallow	10	10×0.08= 0.8	99.5- 0.8= 98.7
	Deep	8	8×0.08= 0.64	99.5-0.64= 98.86
Srirampur SSK	Shallow	84.7	84.7×0.08= 6.77	99.5-6.776= 92.72
	Deep	15.51	15.51×0.08= 1.24	99.5-1.24= 98.25
Saitgachi FP	Shallow	219.04	219.04×0.08= 17.52	99.5-17.52= 81.97
	Deep	40.62	40.62×0.08= 3.24	99.5-3.24= 96.25
Chilatala FP	Shallow	519.83	519.83×0.08= 41.58	99.5-41.58= 57.91
	Deep	27.46	27.46×0.08= 2.19	99.5-2.19= 97.3

When arsenic concentration is within permissible limit, there is chances to decrease the IQ level in the child population. If the concentrations become higher, the decrease will be also higher and reaches to the extremely low level of IQ scale. When the concentration is more than 500 ppb, the IQ level will be 57.91, which is less than 69 that stands for extremely low level of IQ scale (table 6.31).

A study by Tsai et al. (2003) in Taiwan also showed that the children from adolescent period from a high arsenic contaminated area could show lower neurobehavioral test scores. According to Vibol et al. (2015), the median neurobehavioral test scores of the school children from highly arsenic contaminated region were observed significantly lower than the modertaely contaminated and controlled study sites in Cambodia. The results justified results obtained from the present study.

B. Determination of IQ among the child population in the blocks

- **Shallow tubewell**

Blockwise determination of IQ loss due to arsenic concentration in shallow tubewell among the child population was shown in table 6.32.

Table: 6.32. Blockwise distribution of estimated IQ In shallow tubewell

Block	Range of arsenic con (ppb)	Range of estimated IQ	% of population at different IQ score			
			90-109 (average)	80-89 (low average)	70-79 (borderline)	≤69 (extremely low)
Baruipur	2 to 962	99.33 to 22.54	59.67	22.77	9.67	7.89
Bhangar I	11 to 453	98.62 to 63.26	51.34	38.14	6.27	4.25
Bhangar II	18 to 519	98.06 to 57.91	57.67	38.77	2.80	0.76
Bishnupur I	5 to 262	98.7 to 78.54	97.51	1.07	1.42	0.00
Canning II	12 to 178	98.54 to 85.26	76.68	23.32	0.00	0.00
Jaynagar I	10 to 490	98.7 to 60.3	78.14	15.31	5.73	0.81
Jaynagar II	8 to 102	98.62 to 91.34	100.00	0.00	0.00	0.00
Magrahat II	8 to 184	98.7 to 84.78	90.03	9.97	0.00	0.00
Mandirbazar	12 to 88	98.54 to 92.46	100.00	0.00	0.00	0.00
Sonarpur	6 to 1024	99.02 to 17.58	53.36	25.17	16.33	5.14
Mathurapur I	10 to 65	98.3 to 94.3	100.00	0.00	0.00	0.00

From table 6.32, it was found that the arsenic concentration in Baruipur and Sonarpur block is very high, so, the IQ level was found decreasing among the primary school in those two blocks. In shallow aquifer when the range of arsenic concentration was 2 to 900 ppb, around 60% of population were found to be present in average (90-109 IQ score), 23% in low average (80-89 IQ score), 10% in borderline (70-79 IQ score) and 7% in extremely low (≤69 IQ score) scale.

- **Deep tubewell**

Blockwise determination of IQ loss due to arsenic concentration in deep tubewell among the child population was shown in table 6.33.

When As concentration is more than 100 ppb, the IQ level decreases from average level (90-109) to low level (80-89). In deep tubewell, 98% of school students were found to be present in 90-109 IQ score and 2% in 80-89 IQ score when the range of arsenic concentration was 1 to 150 ppb (table 6.33).

Table: 6.33. Blockwise distribution of estimated IQ in deep tubewell

Block	**Range of Arsenic conc (ppb)**	**Range of estimated IQ**	**% of population at different IQ score**			
			90-109 (average)	**80-89 (low average)**	**70-79 (border line)**	**≤69 (extremely low)**
Baruipur	1 to 29	99.36 to 97.18	100	0	0	0
Bhangar I	5 to 157	99.1 to 86.94	100	0	0	0
Bhangar II	7 to 104	98.89 to 91.18	97.86	2.14	0	0
Bishnupur I	5 to 82	99.1 to 92.94	100	0	0	0
Canning II	5 to 45	99.1 to 95.9	100	0	0	0
Jaynagar I	1 to 136	99.45 to 88.62	99	1	0	0
Jaynagar II	3 to 67	99.26 to 94.14	100	0	0	0
Magrahat II	3 to 75	99.26 to 93.5	100	0	0	0
Mandirbazar	3 to 10	99.26 to 98.7	100	0	0	0
Sonarpur	1 to 62	99.39 to 94.54	100	0	0	0
Mathurapur I	4 to 9	99.18 to 98.78	100	0	0	0

6.6.2.6. The total impact of arsenic on a 10 years old child

From the present study it was found that a 10 years old child was highly affected by drinking arsenic conatmianted water. The effects were mentioned in table 6.34 and 6.35.

Table: 6.34. The total impact of arsenic on a 10 years old child (shallow tubewell):

Zone	**School**	**arsenic conc (ppb)**	**IQ scale**	**HQ**	**Cancer risk**
Zone I	Khakurdaha Jangalia FP	10	98.7	1.02	13.77×10^{-4}
Zone II	Srirampur SSK	84.7	92.734	8.64	116.7×10^{-4}
Zone III	Saitgachi FP	219.04	81.97	22.35	301.7×10^{-4}
Zone IV	Chilatala FP	519.83	57.91	53.04	716.1×10^{-4}

Table: 6.35. The total impact of arsenic on a 10 years old child in deep tubewell

Zone	School	arsenic conc (ppb)	IQ scale	HQ	Cancer risk
Zone I	Khakurdaha Jangalia FP	8	98.86	0.81	11.02×10^{-4}
Zone II	Srirampur SSK	15.51	98.25	1.58	21.37×10^{-4}
Zone III	Chilatala FP	27.46	97.3	2.8	37.83×10^{-4}
Zone IV	Saitgachi FP	40.62	96.25	4.14	55.96×10^{-4}

When a child is exposed to 10 ppb arsenic concentration for prolonged period, there will be chances to be affected by decreased IQ level, development of carcinogenic and non carcinogenic effects. When the concentrations become higher, the risks of IQ decrease and development of cancer risk also gets higher. If the concentration is more than 500 ppb, then the IQ level of the child will be 57.91, that lies in extremely low IQ class classified by Wechsler (1997), chances of getting non carcinogenic effects is 53 times more than arsenic safe water and if 1000 children consume that water, there is chances to develop cancer among 716 of them. So, a small amount of arsenic is drinking water can cause deleterious effects on the child population.

6.7. Observations from the present study

The spatial health risk analysis is found to be associated with the ingestion of arsenic through drinking water from arsenic contaminated tubewells from the schools of focus area is requirred for better health risk management due to the heterogeneity of the arsenic concentration. The study executes the health risk assessments for arsenic exposure through drinking water of arsenic affected tubewells in South 24 Parganas.

There are 608 villages and 3 municipal areas were found in the focus area. The population of the villages of the focus area was calculated with the help of individual methods like Arithmetic increase method, Incremental increase mothod or Geometric increase moethod etc. and also with combinaton of this method. The nature of the population growth (Arithmetic increase, geometric increase and incremental increase) was recorded from 1971 to 2011 from each village and municipal areas and the forecasted population of 2022 was calculated with the pattern of growth followed by each village and municipal areas. The maximum population growth was observed in municipal areas. In Rajpur Sonarpur municipal area, the population increase was found 7 folds in last 50 years. It was found from the study that from Baruipur, Bhangar I and II and Sonarpur blocks, 100% of total population, in Canning II and Jaynagar I and II blocks, more than 50% of the total population and in Magrahat II, Bishnupur I, Mandirbazar and Mathurapur I, less than 50% population live in the villages of focus area. Among the 608 villages from the focus area, it was found that 83% of total villages and 85% of total population live in arsenic affected region with different level of arsenic concentration of the focus area. 10 to 100 ppb is the predominant concentration in the focus area and 57% population are forced to use arsenic contaminated water at this level followed by 100.1-300 ppb and more than 300 ppb. Only 15% population of the focus area are safe from arsenic concentration.

The exposure to arsenic in early life can cause carcinogenic effects. There are many primary schools those are located in high arsenic contaminated region. There will be some children in the school who are exposed to arsenic only in the schools and the other children were exposed to arsenic both in school and home. Thus, a children from arsenic safe region is affected by arsenic concentration from school as they spend most of the time of the day in the schools. In primary schools, the children get mid day meal and the meal is prepared with the water from the tubewell present in school premises. So, there are two pathways by which arsenic enters to their body- one is drinking water and the other is mid day meal. Total 1044 primary schools were present in the focus area and the range of student population was found 20 to 961 in 2022. The As concentration was predicted from the schools at both shallow and deep depth. If it was considered that the source of water in those primary schools was from shallow depth tubewell, then 56% of the schools contained water with arsenic concentration from 10 to 100 ppb, 32% with concentration from 100 to 300 ppb and 6% with arsenic concentration more than 300 ppb. Only 6% of the schools was found water sources those were free from arsenic contamination. In Sonarpur and Baruipur, maximum number of schools were found and the concentration was also found higher than the other blocks. The maximum arsenic concentration in shallow tubewell of Baruipur block was 962 ppb and in Sonarpur block it was 1024 ppb. If the source of water was considered deep tubewell, then 54% of schools have water sources containing arsenic less than 10 ppb, 45% have water sources in 10 to 100 ppb and only 1% of schools have arsenic concentration from 100-300 ppb. The maximum concentration in deep tubewell was found 157 ppb in Bhangar I block and 136 ppb in Jaynagar I block. Two separate arsenic contaminated zone were found at shallow and deep depth aquifer. For shallow depth, the arseniferous belt was present within 100 m bgl depth in Baruipur, Bhangar I and II and Sonarpur block. In Bhangar I and II, Bishnupur I, Canning II and Jaynagar I blocks, the arseniferous belt is present in deep aquifer (100-300 m bgl).

Ingestion of arsenic contaminated water for a prolonged period, chronic health effects including cancer (skin cancer in present study) and non cancer end points are observed. The study was done on adult and child population both to compare the ill effects of arsenic on child population. The consumption of water was 10 lpcd for adult and 6 lpcd for child population considering the contribution of arsenic affected cooking water. It was observed from the literature that when the calculated value for (HQ) is less than 1, no adverse non carcinogenic effects were visible, otherwise an adverse non carcinogenic risk has been considered as possible. In present study, the hazard quotient (HQ) was found less than 1 in 10 numbers of schools only, the rest 1033 schools has the HQ more than 1. A carcinogenic risk of 1×10^{-4} gives rise to potential health hazard. In present study, only skin cancer risk was considered for assessment of Cancer. Cancer risk was found in the range of 2.1×10^{-4} to 1400×10^{-4} among child population and 2.62×10^{-4} to 1280×10^{-4} among adult population in the primary schools when the water source is shallow tubewell. In deep well, the range for children are 2.36×10^{-4} to 216.28×10^{-4} and for adult it was 2.15×10^{-4} to 36.25×10^{-4} . When the concentration is 10 ppb (permissible limit), the HQ is 1.02 and cancer risk 13.77×10^{-4} in child population. It was found from the study that with the increase of 1 ppb arsenic concentration in drinking water, the hazard quotient (HQ) increases by 0.27 in an adult and 0.102 in a child and the chances of developing cancer in adult was 1.25×10^{-4} and 1.37×10^{-4} in child. So, the development of cancer risk is higher in child population than adult population if they consume the same concentration of arsenic contamintaed water.

In shallow aquifer when the range of arsenic concentration was 2 to 900 ppb, around 60% of population were found to be present in average (90-109 IQ score), 23% in low average (80-89 IQ score), 10% in borderline (70-79 IQ score) and 7% in extremely low (≤69 IQ score) scale. In deep tubewell, 98% of school students were found to be present in 90-109 IQ score and 2% in 80-89 IQ score when the range of arsenic concentration was 1 to 150 ppb. The average IQ score was considered 99.5 for the present study.

Early exposure to arsenic can reduce the Intelligence Quotient (IQ), cognitive development and neurobehavioral function over the life time of a child. If a child consumes water with 10 ppb arsenic concentration, the estimated IQ will be 98.7 whereas the concentration is 84.7 ppb, the estimated IQ will be 92.72. Thus, IQ decreases with the increase of arsenic concentration in groundwater.

So, it can be concluded from the study that arsenic can cause severe health hazard among the population, mostly child population. The guideline value for arsenic in groundwater is 10 ppb for both adult and child population. If a child consumes water with 10 ppb arsenic, the HQ will be greater than 1 which poses various non carcinogenic effects among the child population. So, there is a need to lower down the permissible limit for child population as 10 ppb arsenic in drinking water is hazardous for child population. The risks of cancer development was also found higher. An increase of arsenic concentration in drinking water causes loss of Intelligence Quotient. When the children consume water with very high arsenic contaminated water, there is chances to develop different skin diseases. Thus, arsenic in drinking water will give rise a children with different types of skin diseases which may be turned into skin cancer and less IQ. So, supply of arsenic free water is the primary and foremost task for the school children.

The study has provided the arsenic contamination scenario in drinking water at specific area that are used for the primary school going children. The regular monitoring can help the service authorities to identify the areas where improvement of water quality is needed. Consumption of arsenic contaminated water may cause lifetime cancer risk to the primary school children. The arsenic contaminated water sources should be marked as unsafe. Knowledge of the relative effect of arsenic at school is important as policy makers may seek to target all the places where children potentially drink water and target schools in reducing exposure.

CHAPTER 7

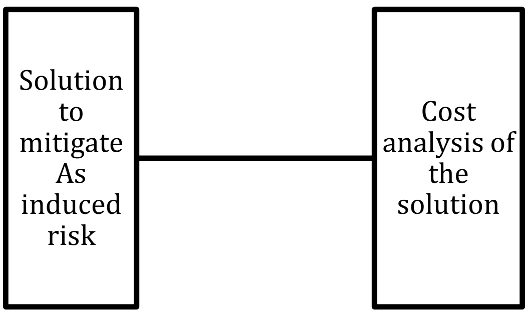
MANAGEMENT OF ARSENIC INDUCED HEALTH RISK AND COST BENEFIT ANALYSIS

Consumption of arsenic contaminated water has been considered as one of the leading global health risk with children being disproportionately affected by associated chronic and acute health issues. Arsenic has the high potential to cause adverse health effects among the exposed population. So, management of arsenic concentration in groundwater must be the foremost action to overcome the problem. The arsenic induced illness can be prevented by measures taken to provide safe drinking water to the community, promotion of nutrition and adequate knowledge on arsenic pollution. Arsenic poisoning can reduce the potentiality to work by gradual loss of energy, physical weakness, gastrointestinal distress etc. that causes loss in income. A person who is affected by arsenic induced illness can work for 2.73 h compared to a healthy person who works beyond 8 h per day (Roy, 2008). Apart from health effects, a huge cost is related due to the exposure of arsenic contaminated groundwater. The cost is associated with medical expenses with treatment costs of arsenic induced diseases, loss of wages, expenditure to prevent the arsenic induced diseases and changes in life expectancy.

7.1. Purpose of the study

Mitigative suggestions and analysis of some of the mitigation costs is an important feature to value the benefits of the improvement of human health.

7.2. Scope of the study



7.3. Solution to mitigate arsenic induced risk from primary school going children

The mitigative measures include different types of options ranging from arsenic removal from groundwater, searching for alternative arsenic free aquifer, supply of surface water after proper treatment, rain water harvesting etc. Evaluation of risk has been considered as the primary factor for determination of the mitigative measures. From the previous chapter it was found that consumption of arsenic contaminated water for a prolong period can develop skin cancers among the child population. So a cancer risk assessment matrix was prepared. The main objective of risk matrix is to develop mitigation strategies.

7.3.1. Cancer Risk Assessment Matrix for child population

The International Agency for Research on Cancer (IARC) is a part of World Health Organization (WHO) and the major objective of the agency is to identify the causes of cancer (American Cancer Society, 2020). IARC categorized arsenic as "carcinogenic to humans" and adequate evidences of skin, lung and bladder cancer were found from literature where the population consume water with higher concentration of arsenic for a long period. The risk of cancer development is higher among the child population than adult population because from the very early stage of life they are consuming such large portion of arsenic, they are still in developing phase of their life and cannot excrete the total amount of arsenic from their body. As a result, the deposition of arsenic in different body parts develop different types of cancer in later life.

Risk has been considered as a potential negative impact on someone or something that can create deleterious effects. In the present study, development of cancer due to arsenic contamination in groundwater has been considered as the risk. So, management of cancer risk is necessary for the study. Risk assessment is the first step towards risk management . To determine risk assessment, two components of risks- magnitude of the potential loss and probability of loss are calculated. Here comes the importance of risk matrix. The ranking of risk is based on a matrix whose axes are the ranks of consequences and probability (Ristic 2013).

Steps for the preparation of Risk Assessment Matrix (Ale et al. 2016)

a. Identification of the risk

b. Rating for probability and impact of the risk

c. Classification of the risk

d. Decision on Mitigation Planning

7.3.1.1. Development of Risk Assessment Matrix

A. Identification of the risk

The risk of cancer development associated with arsenic concentration in drinking water is the main concern in this study. Long term ingestion of arsenic contaminated water can increase the probability of developing different types of cancers, mainly skin and bladder cancer. A number of primary schools are present in arsenic contaminated region and the primary school children (6-10 years old) consume water with arsenic more than the permissible limit. The primary schools contain a good number of student population and the population is largely impacted by high arsenic concentration.

B. Rating for probability and impact of the risk

Student population per school and chances of cancer development are classified into different ranks for the rating for the level of probability and severity.

- **Rank for student population**

The population from each of the schools located in the study area was ranked into 3 classes. The ranking of student population was discussed in table 7.1.

Table:.7.1. Ranking of student population

Rank	Student population per school	% of total schools
1	20-50	36.3
2	51-100	28.35
3	100-951	35.34

From the table. 7.1, it was observed that 36.3% of schools contain student population ranges from 20-50. In 28.35% and 35.34% schools, the student population ranges from 51-100 and 101-951 respectively.

- **Rank for cancer risk in shallow tubewell**

Development of the risk of cancer is different in shallow and deep tubewell as the concentration is different. The cancer risk in shallow tubewell was ranked according to the concentration of arsenic in drinking water in table 7.2.

Table: 7.2. Ranking of cancer risk in different arsenic contaminated region in shallow tubewell

Rank	As conc (ppb)	Cancer risk	% of total population
1	1-100	$1\times10^{-4} – 138\times10^{-4}$	62.26
2	100.1-300	$139\times10^{-4} – 400\times10^{-4}$	31.99
3	more than 300.1	$401\times10^{-4} – 1410\times10^{-4}$	5.75

From the table 7.2 it was observed that the rank of low, medium and high are denoted as 1, 2 and 3. Most of the schools are located in rank 1 followed by rank 2 and rank 3. The development of cancer risk has been estimated among 1×10^{-4} to 138×10^{-4} population. For rank 1, arsenic concentration was considered from 1-100 ppb because it was found from the present study that the risk of cancer development persists even when 1 ppb of arsenic was present in the drinking water (table 6.26) and a carcinogenic risk of 1×10^{-4} gives rise to potential health hazard.

In fig 7.1, arsenic concentration in shallow groundwater, cancer risk among the student population who consumed the shallow groundwater and student population in the schools were mentioned.

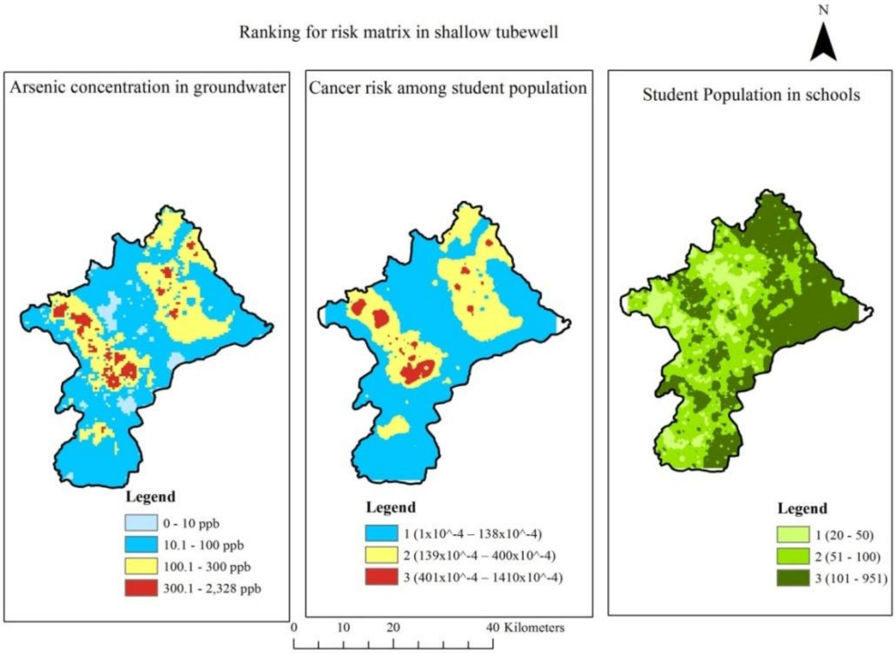


Fig: 7.1. Distribution of arsenic concentration, cancer risk among student population and student population among schools in shallow tubewell

It was observed from the figure 7.1 that the risk map shows that arsenic concentration in groundwater and cancer risk is correlated. Cancer risk was found increasing when the concentration of arsenic is high. The student population was observed widely distributed in the focus area. The student population was found higher in northern and eastern part of the focus area.

- **Rank for cancer risk in deep tubewell**

The cancer risk in different arsenic concentration and percentage of student population who were under risk were documented in table 7.3.

Table: 7.3. Ranking of cancer risk in different arsenic contaminated region in deep tubewell

Rank	**As conc (ppb)**	**Cancer risk**	**% of total population**
1	1-100	$1 \times 10^{-4} - 138 \times 10^{-4}$	98.85
2	100.1-300	$139 \times 10^{-4} - 216 \times 10^{-4}$	1.15

From table 7.3 it was found that the maximum number of student population (98.85%) are present in 1 to 100 ppb arsenic contaminated region (Zone I and II). Only 1.15% population are from 100.1-300 ppb concentration (Zone III). In fig 7.2 the distribution of arsenic concentration in deep tubewell, the cancer risk among child population and student population in schools were mentioned.

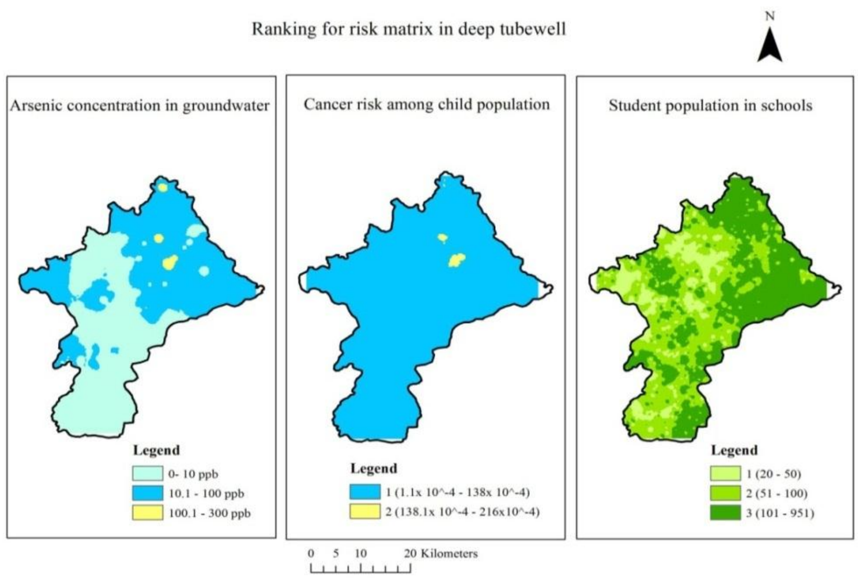


Fig: 7.2. Distribution of arsenic concentration, cancer risk among student population and student population among schools in deep tubewell

From fig 7.2, it was observed that in deep tubewell, Zone I and II and zone III has been denoted as 1 and 2. Rank for cancer risk is divided into 3 classes for the users of shallow depth tubewell and 2 classes for the users of deep depth tubewell. So, the risk matrix will be different for shallow and deep depth tubewell users.

C. Classification of the risk

Classification of risk was prepared on the basis of rank. School population was placed in x axes and cancer risk in y axes. The classification of risk was done in shallow and deep tubewell both. In fig 7.3 the risk matrix at shallow tubewell was summarized.

- **Shallow tubewell**

Risk	High (3)	3 High risk Low population	6 High risk Medium population	9 High risk High population
	Medium (2)	2 Medium risk Low population	4 Medium risk Medium population	6 Medium risk High population
	Low (1)	1 Low risk Low population	2 Low risk Medium population	3 Low risk High population
		Low (1)	Medium (2)	High (3)
		School population		

Fig: 7.3. Risk matrix at shallow depth

For shallow zone, risk was classified into 1-9 scales where 1 stands for low risk and 9 for high risk. The measures of common mitigation are summarized in table no.7.4.

The common suggestions for mitigative measures were mentioned in table 7.4.

Table: 7.4. Suggestions for mitigative measures

High risk (6 and 9)	the level of risk is highly prioritized zone and requires immediate action to resolve the problem
Medium risk (3 and 4)	the level of risk is not severe, but if not checked early the condition will be deterioted within few years
Low risk (1 and 2)	the level is safe, but regular monitoring is necessary

The following mitigative measures can be taken for the schools mentioned in table no. 7.5

Table: 7.5. Risk mitigations at shallow tubewell

Rating	**Classification**	**% of schools**	**% of students**	**Mitigative measures**
1	Low risk- Low student population (1×1)	23.66	7.16	addition of student population from other risk zone. Arsenic treatment may be done when concentration is more than 10 ppb.
2	Low risk-Medium student population (1×2)	10.44	3.17	addition of student population from other risk zone. Arsenic treatment may be done when concentration is more than 10 ppb.
2	Medium risk- Low student population (2×1)	17.62	12.10	addition of student population from other risk zone. Arsenic treatment may be done when concentration is more than 10 ppb.
3	High risk- Low student population (3×1)	21.07	41.34	installation of arsenic removal plant and student population can be transferred to other schools
3	Low risk- High student population (1×3)	2.11	0.69	installation of arsenic removal plants where arsenic concentration is more than 10 ppb
4	Medium risk- Medium student population (2×2)	9.29	6.62	installation of arsenic removal plant
6	Medium risk-High student population (2×3)	1.44	1.03	closing of the schools and transfer the students to other schools
6	High risk- Medium student population (3×2)	12.16	23.42	installation of As removal plant and students can be transferred to other schools
9	High risk- High student population (3×3)	2.2	4.47	closing of the schools and transfer the students to other schools

The following mitigative measures were taken on the basis of risk matrix for the shallow tubewell from the focus area.

- ✓ 22% of total student population in around 52% schools belongs to low risk-low student population, low risk- medium student population and medium risk-low student population zone. As the schools are present in low and medium risk zone, students can be transferred from the high risk zone to these lower risk zone and arsenic removal plants can be installed in these region where arsenic concentration is more than 10 ppb.

- ✓ Only 2% schools having 0.7% of total student population is found in low risk-high student population zone, in this zone, arsenic removal plants will be the best option in these region where arsenic concentration is more than 10 ppb as transfer of students to the schools will not be possible.
- ✓ In medium risk medium student population zone, 9% schools contain around 7% student population. Installation of arsenic removal plant in those schools where arsenic concentration is more than 10 ppb is the best management option for this zone.
- ✓ In high risk- low student population zone, there are around 21 % schools with 41% of student population. Installation of arsenic removal plants is mandatory for those schools where arsenic concentration is more than 10 ppb and students are transferred from neighbouring small percentage of schools with high risk low population and medium risk high population schools
- ✓ High risk -medium population is also having around 24% students in 12% of total schools. Management in such schools are also similar to high risk low student population.
- ✓ In medium risk high student population and high risk high student population zone there are around 4% schools with 5.5% of student population were observed. As the percentage of schools and student population both were lower than the other zone, it was found better to take the decisions about closing of the schools, installation of arsenic removal costs will not be cost effective for these schools. The students can be transferred to the low risk low student population zone. The closed schools can be used as health centres as the health care facility was found very poor in the focus area.

- **Deep tubewell**

The risk matrix at deep tubewell was summarized at fig 7.4

Risk	Medium (2)	2 Medium risk Low Population	4 Medium risk Medium population	6 Medium risk High population
	Low (1)	1 Low risk Low population	2 Low risk Medium population	3 Low risk High population
		Low (1)	Medium (2)	High (3)
		School population		

Fig: 7.4. Risk matrix at deep depth

For deep depth, risk was classified into 6 scales where 1 was low and 6 was high (fig 7.4)

The risk mitigations at the schools were mentioned in table 7.6.

Table:7.6. Risk mitigations at deep tubewell

Rating	Classification	% of schools	% of population	Mitigative measures
1	Low risk- Low student population (1×1)	36.02	10.94	addition of student population from other risk zone. Arsenic treatment may be done when concentration is more than 10 ppb.
2	Low risk-Medium student population (1×2)	0.29	0.1	addition of student population from other risk zone. Arsenic treatment may be done when concentration is more than 10 ppb.
2	Medium risk- Low student population (2×1)	28.07	19.72	Installation of As removal plant and students can be transferred to other schools
3	Low risk- High student population (1×3)	34.77	68.02	Remain same
4	Medium risk- Medium student population (2×2)	0.29	0.2	Closing the school and transfer the students to other schools
6	Medium risk- high population (2×3)	0.57	1.03	Closing the school and transfer the students to other schools

The following mitigative measures were taken on the basis of risk matrix for the deep tubewell from the focus area.

- ✓ 11% student population in around 36% schools was found in low risk- low student population and low risk- medium student population. Being a low risk zone, student population from higher risk zone can be transferred to these region and arsenic removal plant can be installed in those schools where the arsenic concentration is more than 10 ppb.
- ✓ In Medium risk- Low student population, there are 20% student population was observed in 28% of school, installation of arsenic removal plants was found mandatory for the schools where the arsenic concentration is more than 10 ppb and student should be transferred from neighbouring high student population schools.
- ✓ In Low risk- High student population, 68% of student populations were observed among 35% schools, arsenic removal plants may be requirred for this zone where the arsenic concentration is more than 10 ppb.
- ✓ For Medium risk- Medium student population and Medium risk- high population, only 1% school students were found in 1% schools in those zones, The schools can be closed and the students were transferred to other schools in low risk low populated zone.

D. Blockwise mitigation of arsenic concentration in the schools

The following results were applied for the mitigation among the schools blockwise in shallow and deep tubewell.

In the table 7.7 and 7.8, the blockwise distribution of schools and student population was mentioned at different risk zone at shallow and deep depth.

The blockwise mitigation of arsenic concentration in shallow and deep groundwater was done by the solutions mentioned in table no 7.5 and 7.6.

The following parameters should be checked before the mitigation solution done-

- Infrastructure cost for school development for both physical and academic including water supply system- the students from higher arsenic contaminated zone should be transferred to neighbouring lower arsenic contaminated zone with low student population. So, the capacity and educational infrastructure should also be increased for those low populated schools.
- Academic infrastructure should be increased for the low populated schools, the teachers from the closed schools can be shifted to those schools.
- Proper accessibility to schools like road infrastructure, transport system should be maintained.
- The closed schools can be transformed into community centres.

Considering this conclusion as mentioned, the economic viability study of different alternatives have been discussed in the next part of the chapter.

- **Shallow tubewell**

Table: 7.7. Blockwise arsenic mitigation in the shallow depth from the primary schools

Blocks	1×1		1×2		2×1		1×3		3×1		2×2		2×3		3×2		3×3	
	S	P	S	P	S	P	S	P	S	P	S	P	S	P	S	P	S	P
Baruipur	15.8	5.6	19.7	14.7	18.2	5.8	14.9	30.5	2.9	0.9	11.5	9.1	8.7	19.4	1.4	1.0	6.7	12.8
Bhangar I	13.5	4.5	14.2	10.4	12.1	4.3	14.2	26.4	3.6	1.3	21.3	16.7	18.4	31.5	0.7	0.6	2.1	4.4
Bhangar II	8.9	2.1	8.9	4.4	5.9	1.5	26.7	32.8	0.0	0.0	8.9	5.0	38.6	52.8	1.0	0.6	1.0	0.8
Bishnupur I	50.0	27.1	26.5	34.4	8.8	3.7	14.7	34.8	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Canning II	10.6	1.9	3.0	0.9	9.1	3.7	51.5	65.3	0.0	0.0	4.6	1.7	21.2	26.5	0.0	0.0	0.0	0.0
Jaynagar I	15.9	3.9	23.9	14.4	8.9	2.6	30.1	52.7	0.9	0.2	4.4	2.3	13.3	22.2	1.8	0.9	0.9	0.8
Jaynagar II	41.9	11.3	22.6	13.5	0.0	0.0	33.9	73.9	0.0	0.0	1.6	1.3	0.0	0.0	0.0	0.0	0.0	0.0
Magrahat II	35.9	11.2	22.6	16.8	7.6	2.9	26.4	58.5	0.0	0.0	3.8	2.4	3.8	8.2	0.0	0.0	0.0	0.0
Mandirbazar	58.3	31.5	27.1	33.0	0.0	0.0	14.6	35.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Sonarpur	32.4	11.6	12.8	11.1	15.2	5.5	11.3	27.9	4.9	2.2	11.3	9.9	6.4	19.4	3.9	3.7	2.0	8.8
Mathurapur I	35.7	16.2	35.7	30.6	0.0	0.0	28.6	53.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

S= percentage of schools at that risk

P= percentage of population at that risk

- **Deep tubewell**

Table: 7.8. Blockwise arsenic mitigation in the deeper depth from the primary schools

Blocks	1×1		2×1		1×2		3×1		1×3		2×2		2×3	
	S	**P**	**S**	**P**	**S**	**P**	**S**	**P**	**S**	**P**	**S**	**P**	**S**	**P**
Baruipur	37.98	12.68	32.69	24.8	0	0	29.33	62.52	0	0	0	0	0	0
Bhangar I	27.66	9.48	34.75	26.65	1.42	0.54	32.62	58.48	0	0	1.42	1.1	2.13	3.74
Bhangar II	14.85	3.62	18.81	10.01	0	0	64.36	82.76	0	0	0	0	1.98	3.6
Bishnupur I	58.82	30.28	26.47	34.91	0	0	14.71	34.81	0	0	0	0	0	0
Canning II	10.61	1.91	16.67	6.37	0	0	72.73	91.72	0	0	0	0	0	0
Jaynagar I	24.78	6.46	30.09	17.64	0.88	0.53	42.48	74.07	0	0	0.88	0.49	0.88	0.81
Jaynagar II	41.94	12.59	24.19	14.81	0	0	33.87	72.6	0	0	0	0	0	0
Magrahat II	41.51	13.5	28.3	20.52	0	0	30.19	65.98	0	0	0	0	0	0
Mandirbazar	58.33	31.6	27.08	32.9	0	0	14.58	35.5	0	0	0	0	0	0
Sonarpur	52.45	19.04	27.45	24.21	0	0	20.1	56.75	0	0	0	0	0	0
Mathurapur I	35.71	16.19	28.57	23.76	0	0	35.71	60.05	0	0	0	0	0	0

S= percentage of schools at that risk

P= percentage of population at that risk

From literature survey it was found that elevated level of arsenic in drinking water can cause different arsenic induced illnesses among the population exposed to arsenic. The illness results the rise in morbidity, mortality, health cost, loss in work productivity, loss of income, lower school enrollment and the list will go on. According to Roy (2008), health cost includes the cost for health damage, treatment cost for arsenic induced illnesses, loss of wages due to illness, cost of averting activities (water purification cost to reduce arsenic concentration). So, there is a social cost related to arsenic concentration in groundwater. In the present study, the social cost was considered the economic loss due to arsenic in groundwater and economic gain due to installation of arsenic removal plants.

7.4. Cost analysis of risk mitigation

According to Roy (2008), poor water quality can have an intense consequences on human well being, rural households often accept several averting and adaptive measures to either reduce the level of exposure to the family members to high arsenic contaminated water or to decrease the health effects due to consumption of arsenic contaminated water. In West Bengal, people spend a lot of time or money for arsenic free water and medical treatment. The averting and adaptation behaviour of the household was considered to vary with the concentration level. The lower income households was reported to suffer most from both arsenic and non arsenic diseases and have less capability to spend on the maintenace of health as reflected through relatively lower medical expenditure and the distance travelled for accessing health services.

7.4.1. Determination of economic loss for different arsenic contaminated region

In the present study, the economic loss was calculated by assuming that an adult consumed 10 litre (for drinking and cooking purposes) of water and child consumed 6 lit (drinking and cooking purposes) of water (explained in section 6.7.2.1)

In the focus area most of the population are from low income group, as per Roy, the monthly income of the low income group was INR 2000 at 2008. If arsenic concentration is reduced from 688 μg/L to permissible limit (50 μg/L), the cost benefits for per household is INR 297 per month. If arsenic concentration is reduced from 344 μg/L to permissible limit (50 μg/L) , the cost benefits for per household is INR 161 per month (Roy, 2008)

In present study, it was considered if arsenic concentration was increased from the permissible limit (10 ppb) to 344 and 688 μg/L, the economic loss for per household would be INR 161 and 297 per month.

7.4.2. Calculation of the economic loss per household at 100 μg/L arsenic conc

Economic loss for increasing arsenic level for each μg/L is (297-161)/(688-344)= INR 0.39 in drinking water

The loss was found INR 0.39 per household per month when 1 µg/L arsenic is increased from arsenic contaminated water. The annual loss will be INR 4.68 (INR 0.39×12) in the focus area. In Assam the estimated annual cost was found about INR 4 per household (Mahanta, Chowdhury and Nath, 2016) which supports the finding from the present study.

For 100 µg/L to 344 µg/L increase of arsenic concentration in drinking water, INR 161-[0.39×(344-100)]= INR 65.84 per household per month was spent.

In the focus area, the area was divided into 3 zones- Zone II (10-100 ppb), zone III (100-300 ppb) and zone IV (more than 300 ppb). As a result three different costs were estimated for each zone. No cost was determined for zone I as the arsenic concentration was within the permissible limit in this zone.

7.4.2.1. Calculation of economic loss in zone IV (300.1-600 ppb):

To calculate economic loss in zone IV, the upper limit of arsenic was considered 600 ppb because the higher concentration (more than 600 ppb) was found in very small part of the focus area. When arsenic concentration is 600 µg/L, the economic loss is INR 297. The permissible limit is considered 10 µg/L as per WHO limit. Roy considered the permissible limit 50 µg/L in 2008, the permissible limit was reduced from the recommended maximum contaminant level from 50 µg/L to 10 µg/L in 2012 by WHO on the basis of knowledge of cancer risk (Amrose et al, 2014, BIS, 2012). So, the present work was done with 10 µg/L. In South 24 Parganas, the average household size is 4.6 (Census 2011) . The cost was taken from the data that was calculated in the year of 2008. So, average inflation rate 5.98% (World Bank, 2020) was applied per year from 2008-2022 and was added to the economic loss.

Considering 4.6 person per household per capita economic loss for zone IV is 297/4.6= INR 64.56 per month= INR 64.56×12 per year= INR 774.72 per year have been spent.

Considering inflation rate 5.98% (World Bank 2020) per year from 2008-2022, per capita economic loss is INR $774.72(1+5.98/100)^{14}$ = INR 1746.94 per year at 2022.

The same procedure was done for zone III and zone II.

7.4.2.2. Calculation of economic loss in zone III (100.1- 300 ppb):

Considering 4.6 person per household per capita economic loss for zone III = 161/4.6= INR 35 per month= INR 35×12 per year= INR 420 per year

Considering inflation rate 5.98% per year from 2008-2022, i.e. INR $420(1+5.98/100)^{14}$ = INR 947.07 per year at 2022.

7.4.2.3. Calculation of economic loss in Zone II (10 -100 ppb) :

Considering 4.6 person per household per capita economic loss for Zone II (10-100 μg/L)= 65.84/4.6= INR 14.31 per month= INR 14.31×12 per year= INR 171.75 per year

Considering inflation rate 5.98% per year from 2008-2022, i.e. INR 171.75× $(1+5.98/100)^{14}$ = INR 387.28 per year at 2022.

In table 7.9, per capita economic loss were summarized for zone II, III and IV.

Table: 7.9. Per capita economic loss in zone II, III and IV

Description	Values		
	Zone IV	Zone III	Zone II
Arsenic concentration (μg/L)	more than 300	100-300	10-100
Per capita annual cost in 2022 when consumption of water was 10 lit for adult and 6 lit for child population (INR)	1746.94	947.07	387.28

The annual loss was assumed same for both adult and child population at different arsenic concentration zone because a child is more prone to catch different types of diseases than an adult. In spite of a child is drinking less water than an adult, the cost was considered similar as the application of medicine and their cost both were found higher than an adult.

From a study done by Amrose et al. (2014) considering inflation rate 5.98% per year from 2014-2022, the loss for arsenic related health care was found INR 1011.01(1+5.98/100)8= INR 1608.96, the cost supported the result obtained from the present study.

7.4.2.4. Calculation of total economic loss at shallow tubewell

The per capita economic loss was determined for three different arsenic concentration zones. The loss for total population was calculated by multiplying the population with cost. An example is shown with zone II-

A village named Indrapala in Baruipur block, the projected total population of 2022 was 4752. Among them 4293 is adult population and 459 is child population (9.65% of total population, Census data (2011)). The concentration of arsenic in the village was 51 ppb (Zone II). So, the child and adult both the population are exposed to 51 ppb of arsenic.

Total economic loss for adult population= 4293× INR 387.28= INR 16,62,707

Total economic loss for child population= 459× INR 387.28= INR 1,77,589

Per capita annual economic loss were found different in three arsenic contaminated zone because the averting cost, medical treatment cost were different in the three zones. The population from each of the villages were multiplied with the per capita economic loss to determine the economic loss per village. Then the economic loss per block was determined by adding the villages blockwise. The economic loss for adult, child and total population are mentioned in the table 7.10.

Table: 7.10. Total economic loss in zone II, III and IV in shallow tubewell

Block names	**Economic Loss in million INR among population at different zone**									
	Zone II			**Zone III**			**Zone IV**			**Block wise total loss**
	Adult	**Child**	**Total**	**Adult**	**Child**	**Total**	**Adult**	**Child**	**Total**	
Baruipur	45.93	4.91	50.84	137.92	14.73	152.65	83.43	8.91	92.34	295.83
Bhangar I	31.78	3.39	35.17	47.58	5.08	52.66	85.69	9.15	94.84	182.67
Bhangar II	46.2	4.93	51.13	113.25	12.1	125.35	13.42	1.43	14.85	191.33
Bishnupur I	24.42	2.61	27.03	5.39	0.58	5.97	0	0	0	33
Canning II	60.28	6.44	66.72	80.99	8.65	89.64	0	0	0	156.36
Jaynagar I	56.86	6.07	62.93	53.14	5.68	58.82	28.48	3.04	31.52	153.27
Jaynagar II	69.75	7.45	77.2	3.18	0.34	3.52	0	0	0	80.72
Mandirbazar	24.28	2.59	26.87	0	0	0	0	0	0	26.87
Magrahat II	61.01	6.52	67.53	0	0	0	0	0	0	67.53
Sonarpur	55.88	5.97	61.85	10.54	1.13	11.67	37.56	4.01	41.57	115.09
Mathurapur I	7.39	0.79	8.18	0	0	0	0	0	0	8.18
Total loss	483.78	51.67	535.45	451.99	48.29	500.28	248.58	26.54	275.12	1310.85

From the table 7.10, it was observed that in Baruipur block, the total economic loss for zone II, zone III and zone IV is highest among all of the blocks, 22.5% among the total economic loss followed by Bhangar II and Bhangar I. If we consider the total cost, in zone II, the economic loss was observed 41%, 38% in zone III and 21% in zone IV. In Canning-II, maximum number of population are found living in the zone II and the economic loss is more than Sonarpur block.

So, the consequences of arsenic contamination in groundwater can cause different health problems along with economic loss. Arsenic remediation from groundwater can be an alternative choice for the supply of arsenic free water.

Considering the intensity of the problem, extensive works on arsenic remediation technologies have been formulated around the world to get rid of the problem. Several conventional treatments are available for the remediation of arsenic concentration from groundwater under both laboratory and field conditions. The conventional arsenic removal technologies were found mainly physicochemical treatment processes i.e. oxidation, coagulation-flocculation, adsorption, biological sorption, ion exchange, membrane process, treatment with bio organism and electrocoagulation, and biological treatment processes i.e., biological sorption, treatment with bio organism etc (Ghosh (Nath), Debsarkar and Dutta 2019).

According to Amrose et al (2014), an arsenic removal technology must be

- consistently effective to international and local arsenic standards in diverse and relevent groundwater compositions
- reliable and robust in the field with minimal and low skilled maintenance
- low cost enough for clean water to be locally affordable
- operable with minimal risk to safety
- culturally acceptable to the local population

Electro-chemical arsenic remediation (ECAR) is such an arsenic removal technology that works on the principle of electro coagulation (EC) process. In EC, electrolytic oxidation of a sacrificial iron anode forms Fe (III) (oxyhydr)oxides in arsenic contaminated water. Arsenic forms binuclear, inner sphere complexes with Fe (III) precipitates which then aggregate to form a floc. In ECAR, the arsenic laden flocs are separated from clean water through gravitational settling aided by a small amount of alum as a coagulant (Amrose et al. 2014).

7.4.3. Arsenic Treatment cost with ECAR

The cost for a prototype ECAR reactor was estimated based on custom build in India including materials, labour, manufacturer overhead and retail purchase of all pumps and pipes. The reactor cost consists of two settling tanks to increase throughput. To predict the reactor cost at 10000 L/day capacity, 2 nos. 5500 L/day capacity each was assumed (Amrose et al, 2014). Assuming 6 days/week operation and amortizing over 10 years at 5% (assuming social rate for infrastructure investment) or 15% (assuming commercial rate for business investment) result in a total material cost (amortized capital + consumables) for lower concentration of arsenic is \$0.0008/L i.e. INR $0.0008\times55.3649=$ INR 0.044/L and for higher concentration of Arsenic is \$0.001/L i.e. INR $0.001\times55.3649=$ INR 0.055/L. From 2014 to 2022 i.e. for 8 decades considering 5.98% of average inflation rate/year

The cost for the treatment was found different at zone II, III and IV because more electricity was needed to lower down the high concentration to the permissible limit, the iron anode sacrifies more to form iron oxyhydroxides, more alum is needed for floc formation than the low arsenic concentration.

7.4.3.1. ECAR operation cost in zone II

The remediation cost was INR 0.044/L in 2014, after considering the inflation rate 5.98% for 8 decades, the remediation cost in 2022 will be INR $0.044(1+5.98/100)^8=$ INR 0.07/L.

The same calculation was done for zone III and IV.

7.4.3.2. ECAR operation cost in zone IV

The remediation cost was INR 0.055/L in 2014, after considering the inflation rate 5.98% for 8 decades, the remediation cost in 2022 will be INR $0.055(1+5.98/100)^8$= INR 0.08/L

7.4.3.3. ECAR operation cost in zone III

For zone III, considering average of these two values, the remediation cost will be INR 0.075/L.

7.4.3.4. Estimation of ECAR operation cost among adult and child population

A. Zone II

It was assumed that 10 and 6 lpcd water were requirred for an adult and child respectively (explained in section 6.7.2.1)

For annual treatment cost of supplying 10 lpcd of treated water for adult population is

INR 0.07×10×365= INR 255.5 per capita/year

For annual treatment cost of supplying 6 lpcd of treated water for child population is

INR 0.07×6×365= INR 153.3 per capita/year

The same calculation was done for zone III and zone IV

B. Zone III

For annual treatment cost of supplying 10 lpcd of treated water for adult population is

INR 0.075×10×365= INR 273.75

For annual treatment cost of supplying 6 lpcd of treated water for child population is

INR 0.075×6×365= INR 164.25

C. Zone IV

For annual treatment cost of supplying 10 lpcd of treated water for adult population is

INR 0.08×10×365= INR 292

For annual treatment cost of supplying 6 lpcd of treated water for child population is

INR 0.08×6×365= INR 175.2

In table 7.11, the per capita operational cost for ECAR for zone II, III and IV was discussed.

Table:7.11. Per capita ECAR operational cost for zone II, III and IV

Description	**Values**		
	Zone IV	**Zone III**	**Zone II**
Arsenic concentration (μg/L)	more than 300	100-300	10-100
Annual treatment cost of supplying 10 lpcd of treated water in 2022 for adult population (INR)	292	273.75	255.5
Annual treatment cost of supplying 6 lpcd of treated water in 2022 for child population (INR)	175.2	164.25	153.3

7.4.3.5. Calculation for estimation of arsenic remediation cost by ECAR

Baruipur was considered as the sample block and the sample calculations were done with the village data from Baruipur block.

In Begampur, a village from Baruipur block, As concentration was observed 12 ppb and in 2022 adult population was 12729 and child population was 1360. The remediation cost was per capita INR 255.5 for adult and per capita INR 153.3 for child.

For adult population

Remediation cost= INR 255.5 × 12729= INR 3252318.5

For child population

Remediation cost= INR 153.3 × 1360= INR 208422

The calculation was done for the rest of the villages from Baruipur block. The same calculation was done for zone III and IV to determine the remediation cost. The ECAR operational cost was discussed in table 7.12.

Table: 7.12. ECAR operational cost for zone II, III and IV

Blocks	**ECAR operational cost in million INR**									
	Zone II			**Zone III**			**Zone IV**			**Total cost (zone II+III+IV)**
	Adult	**Child**	**Total**	**Adult**	**Child**	**Total**	**Adult**	**Child**	**Total**	
Baruipur	30.3	1.94	32.24	39.87	2.55	42.42	13.94	0.89	14.83	89.49
Bhangar I	20.96	1.34	22.3	13.75	0.88	14.63	14.32	0.92	15.24	52.17
Bhangar II	30.48	1.95	32.43	32.74	2.1	34.84	2.24	0.14	2.38	69.65
Bishnupur I	16.11	1.03	17.14	1.56	0.1	1.66	0	0	0	18.8
Canning II	39.77	2.55	42.32	23.41	1.5	24.91	0	0	0	67.23
Jaynagar I	37.51	2.4	39.91	15.36	0.98	16.34	4.76	0.31	5.07	61.32
Jaynagar II	46.02	2.95	48.97	0.92	0.06	0.98	0	0	0	49.95
Mandirbazar	16.02	1.03	17.05	0	0	0	0	0	0	17.05
Magrahat II	40.25	2.58	42.83	0	0	0	0	0	0	42.83
Sonarpur	36.87	2.36	39.23	3.05	0.2	3.25	6.28	0.4	6.68	49.16
Mathurapur I	4.87	0.31	5.18	0	0	0	0	0	0	5.18
Total	319.16	20.44	339.6	130.66	8.37	139.03	41.54	2.66	44.2	522.83

From the table 7.12, it was observed that the total remediation cost was estimated around 523 million INR in the focus area . The remediation cost was found maximum in Baruipur block. The remediation cost in zone II was observed 65% of the total remediation cost followed by 26.6% in zone III and 8.4% in zone IV.

If ECAR is installed in a shallow tubewell, the water will be free from arsenic contamination. The cost of installation of ECAR treatment cost was found lower than the economic loss due to arsenic. So, an economic benefit was observed after the installation of ECAR at the shallow tubewell.

7.4.3.6. Estimation of total gain due to installation of ECAR in shallow tubewell

Total gain was estimated by the difference between economic loss due to arsenic contamination in groundwater and remediation cost by ECAR.

Baruipur was considered as the sample block and the sample calculations were done with the village data from Baruipur block.

In Begampur, a village from Baruipur block, arsenic concentration was observed 12 ppb and in 2022 adult population was 12729 and child population was 1360. The economic loss for both adult and child population was considered per capita INR 387.28. The remediation cost was per capita INR 255.5 for adult and per capita INR 153.3 for child.

So, the total gain in Begumpur village will be different for adult and child population.

For adult population

Economic loss= INR 387.28× 12729= INR 4929776.5

Remediation cost= INR 255.5 × 12729= INR 3252318.5

The net gain= INR (4929776.5-3252318.5)= INR 1677458 or INR 1.67 million.

For child population

Economic loss= INR 387.28× 1360= INR 526534

Remediation cost= INR 153.3 × 1360= INR 208422

The net gain= INR (526534-208422)= INR 318112 or INR 0.31 million.

Total gain from adult and child population was INR (1.67+0.31) million= INR 1.98 million.

The same calculation was done for all the villages from zone II, III and IV. The calculated costs for all villages were added and discussed in table 7.13.

Table: 7.13. Estimation of total gain after installation of ECAR in shallow tubewell in zone II, III and IV

Blocks	Total gain in million INR									
	Zone II			Zone III			Zone IV			Total (zone II+III+IV)
	Adult	Child	Total	Adult	Child	Total	Adult	Child	Total	
Baruipur	15.63	2.96	18.59	98.06	12.18	110.23	69.48	8.02	77.5	206.32
Bhangar I	10.81	2.05	12.86	33.82	4.2	38.02	71.36	8.23	79.6	130.48
Bhangar II	15.72	2.98	18.7	80.52	10	90.52	11.18	1.29	12.47	121.69
Bishnupur I	8.31	1.58	9.88	3.83	0.48	4.31	0	0	0	14.19
Canning II	20.51	3.89	24.4	57.58	7.15	64.73	0	0	0	89.13
Jaynagar I	19.35	3.67	23.02	37.78	4.69	42.47	23.72	2.74	26.45	91.94
Jaynagar II	23.73	4.5	28.24	2.26	0.28	2.55	0	0	0	30.79
Mandirbazar	8.26	1.57	9.83	0	0	0	0	0	0	9.83
Magrahat II	20.76	3.94	24.69	0	0	0	0	0	0	24.69
Sonarpur	19.01	3.61	22.62	7.5	0.93	8.43	31.28	3.61	34.89	65.94
Mathurapur I	2.51	0.48	2.99	0	0	0	0	0	0	2.99
Total	164.6	31.23	195.82	321.35	39.91	361.26	207.02	23.89	230.91	787.99

From the table 7.13, the total gain was observed ≈INR 788 million. It means that arsenic contaminated water when treated with ECAR, 788 million INR would be benefitted. The maximum gain was derived from Zone II- almost 46% of the total gain. Maximum total gain was observed in Baruipur block after installation of ECAR, 200 million INR followed by Bhangar I and II blocks.

The top aquifer within 100 m bgl was found the most arseniferous part of the study area. The deeper aquifers (below 100 m bgl) were observed arsenic free and had the potential with capacity to yield 5-20 litres per second (lps) and provide the need for both the rural and urban water supply (Kunar et al, 2009)

7.4.4. Determination of installation cost of deep tubewell

In West Bengal arsenic free aquifers has been identified (by CGWB) in the depth zone of 120-160 m bgl and 200-250 mbgl where tubewells have been constructed with suitable design to get arsenic free water. (Kunar et al, 2009). Only 5% of deep tubewells in Bangladesh exceed 10 ppb standard while 46% of shallow tubewells contain arsenic more than 10 ppb standard (the boundary of the shallow and deep tubewells was considered 150 m) suggesting that the deeper aquifer is less contaminated than the shallow aquifer (Chakraborty et al, 2015). Deep tubewells were installed in rural areas of West Bengal to supply arsenic free water compared to shallow tubewells as the deeper aquifer was considered as arsenic free source of water. A common mitigation policy was applied for households to shift from a contaminated shallow tubewell to deep tubewell. So, deep tubewells are considered as an alternative source of drinking water in arsenic contaminated regions. The households are arranged spatially in clusters and members of the same households depends for water from the same tubewell. Each household does not own a tubewell, they usually collect water from neighbouring or community well. If that tubewell is arsenic contaminated, all the households will be impacted by arsenic contamination.

From the field survey in the present study it was observed that in urban areas like Baruipur blocks, each 5 families own a tubewell whereas in rural areas like Canning II, the people are dependent on community wells.

PHED installs two types of tubewells- hand tubewell and tubewells with submersible pumps. The tubewells with submersible pumps were installed to supply water to the larger population of the area.

7.4.4.1. Determination of population served by per deep tubewell

Total number of tubewells for each blocks was collected from the portal of JJM-IMIS (Department of Drinking Water and Sanitation, Ministry of Jal Shakti, Govt. of India). The total population was known for each block (discussed in section 6.4.5)

For example, in Baruipur block, the total number of deep tubewells were 7450 (IMIS reports 2017). Total population in 2022 was 514926. So, population dependent on each tubewell was 514926/7450= 69 person per tubewell. The average household size in the focus area is 4.6. 1 tubewell serves 69/4.6= 15 families. The process was repeated for all the blocks from the focus area.

In fig 7.5, the number of population served by each tubewell was summarized.

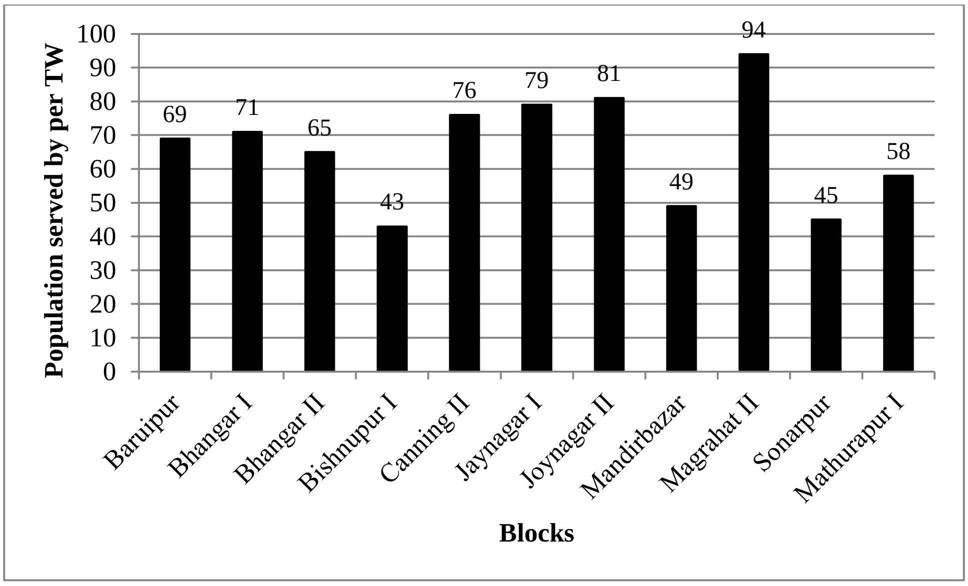


Fig: 7.5. Population served by per deep tubewell in rural areas

From fig 7.5 it was found that in the focus area 43- 94 persons are dependent on each tubewell. In Magrahat II block, the highest number of people are dependent on each deep well.

7.4.4.2. Estimation of number of deep tubewells per block for affected population

Total number of deep tubewells per block for affected population were calculated by dividing the arsenic affected population by population served by each deep tubewell.

For example, in Baruipur, it was estimated that 69 people were dependent on 1 deep tubewell. If the affected population of the block was 3,45,297, the total number of tubewells for the affected people will be 345297/69= 4996. The total number of tubewells in each block was calculated and presented in fig no. 7.6

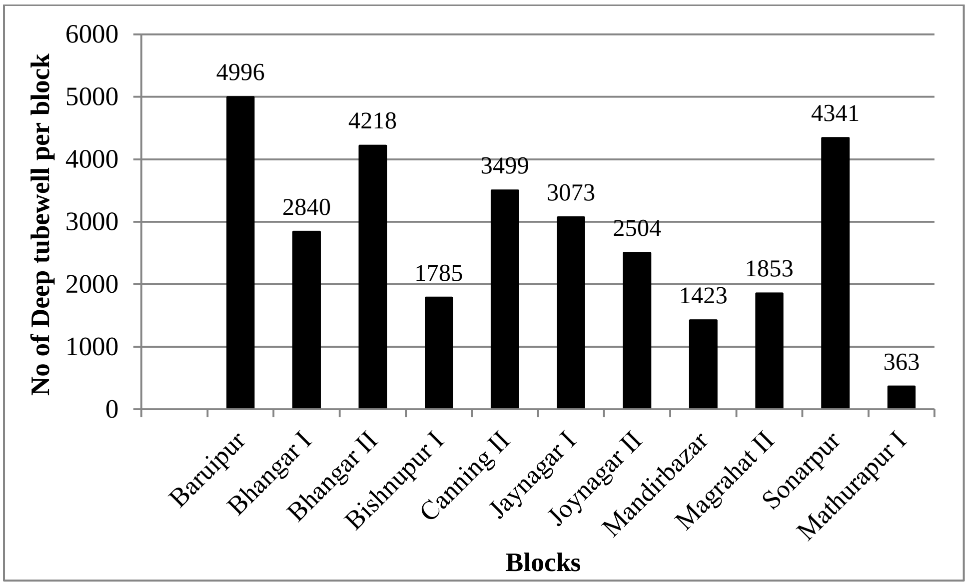


Fig: 7.6. Blockwise distribution of deep tubewells in the focus area

From fig 7.6 it was found that the number of tubewells are high in Baruipur, Sonarpur, Bhangar II and Canning II blocks. More than 4000 deep tubewells were found in Baruipur, Bhangar II and Sonarpur block.

7.4.4.3. Estimation of average aquifer depth for the installation of deep tubewell:

The aquifer depth varies from block to block. The minimum and maximum depth of the aquifer was found from PHED data (PHED, 2017). The average was calculated from the depth range and was summarized in table 7.14.

Table: 7.14. Average aquifer depth for the installation of deep tubewell

Block	Min Aquifer depth (m)	Max Aquifer depth (m)	Average aquifer Depth (m)
Baruipur	250	300	275
Bhangar I	220	260	240
Bhangar II	220	260	240
Bishnupur I	250	300	275
Canning II	280	340	310
Jaynagar I	220	260	240
Joynagar II	220	300	260
Mandirbazar	220	260	240
Magrahat II	220	260	240
Sonarpur	150	250	200
Mathurapur I	220	260	240

The average aquifer depths in the blocks range from 200-300 m bgl (table 7.14). In Canning II, the average aquifer depth was maximum (310 m bgl) and in Sonarpur the depth is minimum (200 m bgl). Majumdar and Kar (2013) studied that the aquifers in South 24 Parganas are loacted in Quaternary and Tertiary sediments at depths ranging from ~75 to ~360 m. The confined aquifers were found to be divided into two vertical divisions- shallow aquifer (~20 to ~160 m) and lower aquifer (~160 to ~360 m). The two layers were separated by clay aquitard of varying thickness. In Sonarpur and adjoining areas, the deep aquifer is located from 163.4 to 180.4 m. According to Central Ground Water Board (Ghosh and Roy, 1996), two impervious clay layers were observed at depth ranging from 78 to 108 m (between the saline and brackish water zones) and at 198.0 to 227.1 m (between the saline and brackish water zones).

7.4.4.4. Estimation of cost for installation of deep tubewell

The cost for installation of deeper tubewell depends on the depth of the water table. The cost is divided into cost of labour and cost of materials.

The estimate for sinking of 1 no of 100 mm × 50 mm diameter having 5 number of strainer upto 250 m (average) depth fitted with India Mark II DWP (deep well pump) tubewell with PVC pipe was found INR 2,52,388 including GST, Labour Welfare Cess and Contingency (PHED 2019). The cost changes when the average depth change occurs. For example, the cost for labour for boring of 50 mm diameter top enlargement upto 30 meter was INR 424 per meter, boring for 50 mm diameter TW upto 150 m depth was INR 285 per meter for 120 meter and above 150 m the cost is INR 351 per meter for 100 meter. The cost for materials changes when the number of PVC pipes are different. For 50 mm diameter PVC pipes, 210 meter (INR 282 per meter) and for 100 mm diameter PVC pipes, 30 meter (INR 874 per meter) was required. The lifespan of each Mark II DWP hand pumps was considered 10 years.

7.4.4.5. Cost estimation for sinking of deep tubewell in Baruipur block

For Baruipur, the estimate for sinking of 1 no of 100 mm × 50 mm diameter having 5 number of strainer upto 275 m (average) depth fitted with India Mark II DWP hand pump Deep tubewell with PVC pipe was found INR 2,70,821 including GST, Labour Welfare Cess and Contingency. Here the cost for labour for boring 50 mm diameter TW above 150 m depth was 125 meters (INR 351 per meter) and cost for PVC pipes for 50 mm diameter was 235 m (INR 282 per meter). The costs are mentioned in the table 7.15.

Table: 7.15. Estimation of installation cost of deep tubewell in Baruipur block

Cost associated with	**Cost in INR**
Labour for boring tubewell	90,795
Mobilization and transportation of all machinery set, development of tubewells, supply and packing of coarse sand, chemical tests for water sampling including arsenic test, construction of masonary platform, installation of India Mark II hand pump, colour photograph of the completed tubewell	30,644
Supply of PVC pipes and fittings, reducing sockets, PVC strainer	97,551
Supply and delivery of India Mark-II DWP hand pump set	13,624
Total	2,32,614
After addding GST, cost of Civil Work, contingency total cost	2,70,821

In Baruipur block, the estimated cost for installation of deep tubewell was INR 2,70,821. Same calculations were done for rest of the blocks and the cost was found varying mainly for the cost of the labour charge and PVC pipes as the aquifer depth was not at similar depth for all the blocks. The costs were summarized in annexure III

7.4.4.6. Estimation of cost for installation of deep tubewell according to depth in the blocks

The installation cost of a deep tubewell depends on the depth of the aquifer of the region. The estimated cost of installation of Mark II DWP hand pump was mentioned in the table no. 7.16.

Table: 7.16. Blockwise installation cost for deep tubewells

Block	**Average depth**	**Cost of installation of Mark II DWP hand pump (INR)**
Baruipur	275	2,70,821
Bhangar I	240	2,45,015
Bhangar II	240	2,45,015
Bishnupur I	275	2,70,821
Canning II	310	2,96,627
Jaynagar I	240	2,45,015
Joynagar II	260	2,59,760
Mandirbazar	240	2,45,015
Magrahat II	240	2,45,015
Sonarpur	200	2,15,522
Mathurapur I	240	2,45,015

From 7.16, it was observed that installation cost is maximum in Canning II block and minimum in Sonarpur block.

According to Jamil et al. (2019), the cost for the installation of a standard hand pump with 1.5 m diameter including PVC, galvanised iron pipe, a hand pump, a concrete platform and labour was found proportional to well depth at a rate of about US$3.30 (INR 78.95/$1) per meter. The same rate was found applying on wells up to 90 m deep to 300 m depth.

7.4.4.7. Cost for installation of deep tubewells with submersible pumps

According to PHED (2019) data, 3 tubewells were recorded with submersible pumps per village. The installation cost of 3 tubewells in each village were INR 50,00,000 and the life span of each tubewell was 20 years. The aim of the installation of the tubewells with submersible pump was to lift water from deep tubewell and storage it in an over head tank. The storage water was then supplied to the inhabitants of the village by piped water supply.

7.4.4.8. Determination of per capita total annual cost for deep tubewell and tubewell with submersible pump

A. Determination of per capita annual cost for Mark II DWP

A specific number of people are dependent on a hand pump. The life span of a hand pump was considered 10 years (PHED 2019). For example, in Baruipur block, 69 people are served by per hand pump and the life span of the hand pump is 10 years. The estimated cost for the installation of the hand pump was INR 2,70,821.

So, per capita cost for DWP hand pump for 10 years will be INR 2,70,821/69= INR 3924.94

Per capita annual cost for DWP hand pump will be INR 3924.94/10= INR 391.83

B. Determination of per capita annual cost for deep tubewells with submersible pumps

Sample calculation for Baruipur block,

3 tubewells with submersible pumps were observed in each of the villages from the study area. There are 99 arsenic affected villages in Baruipur block. The total arsenic affected population of Baruipur block is 3,45,297. The life span of each of the tubewell is 20 years. The estimated total cost for installation of 3 tubewells were approximately INR 50,00,000. Per capita annual cost per village will be INR (50,00,000/ 3,45,297)/20= INR 0.72. The total cost for 99 villages will be INR 0.72× 99= INR 71.68

So, total annual cost for DWP hand pump and deep tubewell with submersible pump will be-INR (391.83+ 71.68)= INR 463.50.

The same procedure was applied for rest of the blocks present in focus area and the total costs were summarized in table 7.17.

Table: 7.17. Per capita total annual cost for deep tubewell and tubewell with submersible pump

Blocks	**Per capita annual cost in INR**		
	Deep tubewell	**Tubewells with submersible pumps**	**total cost**
Baruipur	391.83	71.68	463.50
Bhangar I	346.68	69.75	416.43
Bhangar II	378.75	48.56	427.30
Bishnupur I	635.23	82.15	717.38
Canning II	388.82	53.39	442.20
Jaynagar I	310.26	60.79	371.05
Joynagar II	320.31	34.47	354.78
Mandirbazar	502.41	126.08	628.50
Magrahat II	260.38	57.36	317.74
Sonarpur	477.82	62.56	540.38
Mathurapur I	421.30	71.05	492.35

From table 7.17, it was found that in Bishnupur I and Mandirbazar blocks, per capita annual cost for deep tubewell was found higher because the number of the tubewells were found higher in those two blocks. Only 43 and 49 people are dependent on each tubewell in Bishnupur I and Mandirbazar block respectively.

C. Determination of economic loss and benefits for construction of deep tubewells at different arsenic concentration zone

Determination of economic loss was calculated with Baruipur block to show the calculation,
Per capita annual total cost for DWP and submersible pump is INR 463.50.

Per capita annual economic loss due to arsenic concentration in zone II was INR 387.28.

Per capita annual economic loss due to arsenic concentration in zone III was INR 947.07.

Per capita annual economic loss due to arsenic concentration in zone IV was INR 1746.94.

The sample calculation for zone II will be-

Economic benefit for constructing DWP and submersible pumps for supplying low to within permissible limit of arsenic contaminated water is INR 387.28-463.50= -76.22. It means INR 76.22 per capita economic loss will take place in low arsenic contaminated area if the installation of deep tubewells are occured in Baruipur block.

The population at Zone II in Baruipur block is 1,31,255. So, the total loss will be 1,31,255×76.22= INR 1,00,04,729.22.

The economic loss due to the installation of deep tubewells in the arsenic affected blocks are calculated in the table 7.18.

Table:7.18. Blockwise installation cost for deep tubewell

Blocks	**Total cost for installation of deep TW (million INR)**			
	Zone II	**Zone III**	**Zone IV**	**Total**
Baruipur	60.84	74.71	24.50	160.05
Bhangar I	37.82	23.15	22.61	83.58
Bhangar II	56.41	56.55	3.63	116.60
Bishnupur I	50.06	4.52	0.00	54.58
Canning II	76.17	41.85	0.00	118.03
Jaynagar I	60.29	23.04	6.69	90.03
Joynagar II	70.72	1.32	0.00	72.04
Mandirbazar	43.62	0.00	0.00	43.62
Magrahat II	55.40	0.00	0.00	55.40
Sonarpur	86.30	6.66	12.86	105.82
Mathurapur I	10.39	0.00	0.00	10.39
Total cost in focus area	608.03	231.81	70.29	910.13

From the table 7.18 it was observed that the estimated total cost for installation of deep tubewell was 910 million INR. In Baruipur, the installation cost is maximum in zone III.

The economic benefit from economic loss due to arsenic in shallow tubewell and installation of ECAR in shallow tubewell was determined in table 7.19.

Table: 7.19. Economic benefit for construction of deep tubewell

Blocks	**Block wise economic benefit for construction of deep TW in (million INR)**			
	Zone II	**Zone III**	**Zone IV**	**Total**
Baruipur	-10	77.94	67.83	135.77
Bhangar I	-2.65	29.5	72.23	99.08
Bhangar II	-5.28	68.79	11.21	74.72
Bishnupur I	-23.04	1.44	0	-21.6
Canning II	-9.46	47.78	0	38.32
Jaynagar I	2.64	35.77	24.82	63.23
Joynagar II	6.48	2.2	0	8.68
Mandirbazar	-16.74	0	0	-16.74
Magrahat II	12.12	0	0	12.12
Sonarpur	-24.45	5.01	28.71	9.27
Mathurapur I	-2.22	0	0	-2.22
Total	-72.6	268.43	204.8	400.63

The total economic benefit for installation of deep tubewell was found 401 million INR (table 7.19). From the above table it can be observed that the installation of deep tubewell is not beneficial for in zone II. The estimated installation cost was found greater than the economic loss.

ECAR may be the one of the best option for that zone. Installation of deep tubewell in zone III and IV is beneficial.

7.4.5. The scenario of arsenic concentration in groundwater after installation of deep tubewells

After installation of deep well, arsenic was also found in that deep depth. So, the deeper water was not safe to use for drinking purposes too. The data on arsenic concentration in deep tubewells were collected from PHED (2019). The percentage of affected villages were calculated from the prepared map.

7.4.5.1. Distribution of arsenic concentration in deep tubewell

The villages were classified into zone I, II and III on the basis of arsenic concentration in deep tubewell. Percentage of villages affected by arsenic concentration in deep tubewell was summarized in table 7.20.

Table:. 7.20. Percentage of villages affected by arsenic concentration in deep tubewell

Blocks	**Zone I**	**Zone II**	**Zone III**	**Total village**	**As affected villages**	**% of As affected villages**
Baruipur	95	43	0	138	43	31.2
Bhangar I	0	73	11	84	84	100.0
Bhangar II	0	54	6	60	60	100.0
Sonarpur	32	35	0	67	35	52.2
Bishnupur I	0	34	0	34	34	100.0
Canning II	0	57	0	57	57	100.0
Jaynagar I	59	0	0	59	0	0.0
Joynagar II	28	0	0	28	0	0.0
Mandirbazar	35	0	0	35	0	0.0
Magrahat II	26	14	0	40	14	35.0
Mathurapur I	6	0	0	6	0	0.0
Total	281	310	17	608	327	53.8

After installation of deep tubewells, groundwater was withdrawn extensively and arsenic concentration more than permissible limit was observed in many blocks. In Bhangar I, Bhangar II, Bishnupur I and Canning II blocks, 100% of the total villages were affected by arsenic. Total 54% of blocks are found arsenic contaminated in deeper aquifer. In Baruipur and Sonarpur blocks, arsenic concentration more 100 ppb was not found (table 7.20).

7.4.5.2. Economic loss due to arsenic concentration in deep tubewell

The focus area was classified into 3 zones- safe, low and medium arsenic contaminated region. In zone I, no ECAR treatment is required, the treatment was requirred only in Zone II and medium zone. The economic loss was calculated for the shallow zone. Same calculation was used for deep tubewell and cost for Zone II and medium zone was taken for the zone.

The economic loss in deep tubewell was calculated same as the calculation shown in shallow tubewell. arsenic contaminated regions were divided into 2 classes- zone II (10-100 ppb) and medium (100.1- 300 ppb). More than 300 ppb arsenic concentration was not reported from the focus area. The estimation was mentioned in table 7.21.

Table: 7.21. Estimation of economic loss in deep tubewell

Block	**Economic loss (million INR)**						
	Zone II			**Zone III**			**Total (Zone II+III)**
	Adult	**Child**	**Total**	**Adult**	**Child**	**Total**	
Baruipur	70.23	7.5	77.73	0	0	0	77.73
Bhangar I	90.46	9.66	100.12	29.71	3.17	32.88	133
Bhangar II	91.02	9.72	100.74	26.56	2.84	29.4	130.14
Bishnupur I	32.42	3.46	35.88	0	0	0	35.88
Canning II	93.39	9.98	103.37	0	0	0	103.37
Jaynagar I	0	0	0	0	0	0	0
Jaynagar II	0	0	0	0	0	0	0
Mandirbazar	0	0	0	0	0	0	0
Magrahat II	29.18	3.12	32.3	0	0	0	32.3
Sonarpur	42.29	4.52	46.81	0	0	0	46.81
Mathurapur I	0	0	0	0	0	0	0
Total	448.99	47.96	496.95	56.27	6.01	62.28	559.23

From fig 7.21 it was observed that around 90% of economic loss was reported from zone II. The economic loss was found higher in Bhangar I, Bhangar II and Canning II due to elevated level of arsenic concentration in deep tubewell (table 7.21). These three blocks comprise of 65.5% of total economic loss from the focus area. In Baruipur, Bishnupur I, Magrahat II and Sonarpur the loss is 33.5% of the total loss. The deep tubewells from Jaynagar I and II, Mandirbazar and Mathurapur I are free from arsenic contamination. So, the economic loss due to arsenic contamination in deep tubewell was 0. The estimated total economic loss due to arsenic concentration in deep tubewell was around 559 million INR.

7.4.5.3. Estimation of arsenic remediation cost in deep tubewell

The remediation was done with ECAR and the cost was calculated in table no 7.22.

Table:7.22. Estimation of arsenic remediation cost by ECAR in deep tubewell

Block	**Remediation cost (million INR)**						
	Zone II			**Zone III**			**Total (Zone II+III)**
	Adult	**Child**	**Total**	**Adult**	**Child**	**Total**	
Baruipur	46.33	2.97	49.3	0	0	0	49.3
Bhangar I	59.68	3.82	63.5	8.59	3.17	11.76	75.26
Bhangar II	60.05	3.85	63.9	7.68	2.84	10.52	74.42
Bishnupur I	21.39	1.37	22.76	0	0	0	22.76
Canning II	61.61	3.95	65.56	0	0	0	65.56
Jaynagar I	0	0	0	0	0	0	0
Jaynagar II	0	0	0	0	0	0	0
Mandirbazar	0	0	0	0	0	0	0
Magrahat II	19.25	1.23	20.48	0	0	0	20.48
Sonarpur	27.9	1.79	29.69	0	0	0	29.69
Mathurapur I	0	0	0	0	0	0	0
Total	296.21	18.98	315.19	16.27	6.01	22.28	337.47

The highest remediation cost has been observed in Bhangar I, Bhangar II and Canning II blocks (table 7.22). The total remediation cost was found INR 337.5 million in the focus area. Almost 88% of remediation cost are spent in the zone II in deeper aquifer.

7.4.5.4. Estimation of total gain in deep tubewell

The total gain was calculated from the economic loss due to asrenic contamination in groundwater and arsenic remediation cost. The estimated total gain was summarized in table no. 7.23.

Table: 7.23. Estimation of total gain by installation of ECAR in deep tubewell

Blocks	**Total gain (million INR)**						
	Zone II			**Zone III**			**Total (zone II+III)**
	Adult	**Child**	**Total**	**Adult**	**Child**	**Total**	
Baruipur	23.9	4.53	28.43	0	0	0	28.43
Bhangar I	30.78	5.84	36.62	21.13	2.62	23.75	60.37
Bhangar II	30.97	5.87	36.84	18.89	2.35	21.24	58.08
Bishnupur I	11.03	2.09	13.12	0	0	0	13.12
Canning II	31.78	6.03	37.81	0	0	0	37.81
Jaynagar I	0	0	0	0	0	0	0
Jaynagar II	0	0	0	0	0	0	0
Mandirbazar	0	0	0	0	0	0	0
Magrahat II	9.93	1.88	11.81	0	0	0	11.81
Sonarpur	14.39	2.73	17.12	0	0	0	17.12
Mathurapur I	0	0	0	0	0	0	0
Total	152.78	28.97	181.75	40.02	4.97	44.99	226.74

The estimated total gain from zone II and zone III was found 227 million INR. The total gain was maximum in Bhangar I and Bhangar II blocks (table 7.23)

7.4.6. Comparison of cost between shallow tubewell, installation of deep tubewell and ECAR

A comparison was done between the economic loss due to the presence of arsenic concentration in shallow ground water, the cost for installation of deep tubewell, economic benefit for the installation of deep tubewells instead of shallow tubewell, economic loss due to arsenic concentration in deep tubewell and arsenic remediation cost by ECAR in table 7.24.

Table: 7.24. Comparison of cost between shallow tubewell, installation of deep tubewell and ECAR

Block name	**Cost in million INR**							
	Shallow tubewell			**Deep tubewell**				
	EL	**RC**	**TG**	**I**	**B**	**EL**	**RC**	**TG**
Baruipur	295.83	89.49	206.34	160.05	135.77	77.73	49.3	28.43
Bhangar I	182.67	52.17	130.5	83.58	99.08	133	75.26	57.74
Bhangar II	191.33	69.65	121.68	116.6	74.72	130.14	74.42	55.72
Bishnupur I	33	18.8	14.2	54.58	-21.6	35.88	22.76	13.12
Canning II	156.36	67.23	89.13	118.03	38.32	103.37	65.56	37.81
Jaynagar I	153.27	61.32	91.95	90.03	63.23	0	0	0
Jaynagar II	80.72	49.95	30.77	72.04	8.68	0	0	0
Mandirbazar	26.87	17.05	9.82	43.62	-16.74	0	0	0
Magrahat II	67.53	42.83	24.7	55.4	12.12	32.3	20.48	11.82
Sonarpur	115.09	49.16	65.93	105.82	9.27	46.81	29.69	17.12
Mathurapur I	8.18	5.18	3	10.39	-2.22	0	0	0
Total cost in focus area	1310.85	522.83	788.02	910.13	400.63	559.23	337.47	221.76

In the above study EL stands for economic loss, RC means remediation cost, TG means total gain, I means installation, B for benefit for construction.

The total estimated economic loss due to arsenic concentration in shallow tubewell was found around 1311 million INR (table 7.24). When the arsenic contaminated water has been treated with ECAR, the estimated cost was calculated around 523 million INR. So, around 788 million INR can be saved by installation of ECAR. If deep tubewell has been installed in the arsenic contaminated region, the total estimated cost will be around 910 million INR which is found also lower than the economic loss due to arsenic concentration in the shallow tubewell. The total estimated total benefit was 400 million INR when deep tubewell is installed in the arsenic contaminated region. The main objective of installation of deep tubewells were to get safe water, but after extensive withdrawal of groundwater from the deep depth, the deep aquifer became contaminated. So, the population who use deep depth water, again will be affected by arsenic concentration and economic loss due to arsenic contamination will be observed here too. The economic loss in deep tubewell was found 559 million INR which is lower than the economic cost from shallow tubewell. The arsenic remediation cost in deep tubewell was 337 million INR. The total gain estimated by installation of deep tubewell was almost 222 million INR.

From the present study it was observed that Bhangar I and II are the most arsenic contaminated blocks, the groundwater from both shallow and deep tubewell are arsenic affected. The groundwater from shallow depth of Baruipur and Sonarpur are also arsenic affected, but the deeper aquifer are less affected. In Jaynagar I and II, Mandirbazar and Mathurapur, the deep aquifer was found free from arsenic contamination.

7.5. Social upliftment for risk management

Although solving of socio-demographic challenges are not the part of this research work, but a holistic management solution against arsenic induced risk to vulnerable child population cannot be achieved without a holistic solution involving technological, social, demographic and economic upliftment. Some of the socio-demographic parameters are mentioned below-

a) Economic status – The lower income group was found suffering more from both arsenic and non arsenic diseases than middle and high income group and has less potentiallity to spend on the medical expenditure and the distance- travelled for accessing health services. The poor people was found to have a higher number of sick days on average. Most of the households has an idea about the quality of the water they are using is the main cause of the arsenic related diseases (Roy 2008).

The economic status of the focus can be improved by increase of local job practice in the field of agriculture, fishery, epiculture etc. The focus area has got ample amount of rainfall throughout the year. If the rain water can be stored, it will help to do the agricultural activities.

b) Nutrition- nutritional status has been considered as an important parameter in the susceptability to arsenic induced diseaes (Argos et al. 2007). Low nutrition can induce arsenic toxicity. The higher income group are relatively safer may be due to the nutritious food intake than the other two groups. The population from some of the arsenic affected villages from West Bengal consuming nutritious food, does not show any sign of arsenical skin diseases. The people can tolerate up to a certain range although the arsenic concentration was found high in their hair, nail and urine samples. In a comparison to under nourished families, it was found that arsenical skin lesions are often prominent, although both the families were consuming the same arsenic contaminated water and food stuff (Samal et al. 2013). When an arsenic induced patient switch to a safe drinking water source from the contaminated water, the skin lesions were found to be improved and the rate of improvement was found to be accelerated by taking high protein diet, vitamin B complex and Anti-oxidant supplements i.e. vitamin A, C, E and Selenium.

Consumption of healthy diet is necessary for the people living arsenic contaminated region.

c) Health education- Health education is an important factor that changes the community behaviour regarding the use of water, which in turn can help to prevent arsenic induced illnesses. The vulnerable population should also be aware about the common signs and symptoms of arsenic induced illness at the community and facility levels.

If the people from arsenic contaminated region observe any type of arsenic related health hazards, should immediately contact the local health care centres.

d) General health care- Special attention must be given to the population from the rural area to control the spread of diseases and reduce the growing rates of mortality due to the lack of adequate health facilities. The health care facilities with experienced health care personnel having proper knowledge on arsenic symptoms should be appointed in those health care centres.

e) Treated surface water supply- Rain water harvesting has been considered as one of the most reliable technique to get safe water. After some proper basic treatments, the rainwater can be used for drinking purposes in arsenic contaminated region.

Proper planning to overcome these challenges should be made appropriate level ensuring adequate awareness and total participation of the local people as well as stake holders.

For those type of social vulnerability, a typical risk identification map was prepared with the help of number of population depending upon each health care facility.

The medical facilities available in South 24 Parganas district are

- Hospitals, block primary health centres and primary health centres run by Health and Family Welfare Deptt, Govt. of West Bengal
- Medical institutions run by other Departments of Govt. of West Bengal including Dtatte Govt. Undertaking
- Medical facilities run by local bodies
- Nursing homes run by NGOs or Private bodies

The total population of the district is dependent on these health care facilities. The population density per medical faciliy was described in the fig no.7.7.

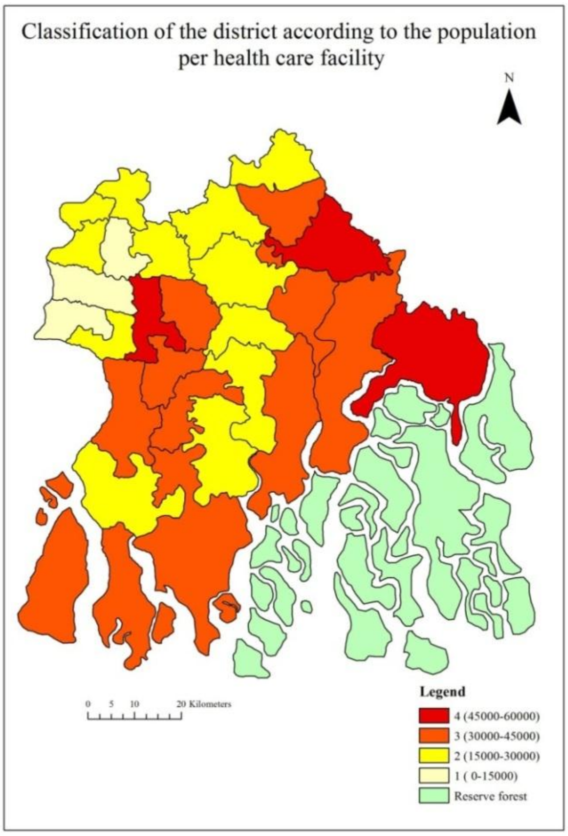


Fig: 7.7. Classification of the district according to the population per health care facility

The block has been classified as 5 zones according to the population based on per health care facility in fig 7.7. The green part signifies the reserve forest from Sundarban and habitation is restricted in this region. The rest part of the block was divided into 4 parts- zone 1 (population range 0-15000), zone 2 (population range 15001- 30000), zone 3 (population range 30001-45000) and zone 4 (population range 45001-60000). In Canning II, Mograhat II and Gosaba block, more than 45000 people depends on 1 medical facility (red coloured zone) whereas in Bishnupur II, Diamond Harbour II and Falta the number is less than 15000 (light yellow zone). The rest of the blocks are placed among zone 2 (15001 to 30000) and 3 (30001-45000) which are present among the maximum number of the blocks. The arsenic affected blocks are mainly presents in zone 2 and 3 where the pressure per health care facilility was high.

7.6. Implementation of suggestive method

As there is no specific treatment method for arsenic induced illnesses, consumption of arsenic free water will be the only way to get rid from the problem. In general, the water supply option for an area depends on the availability, quality and development potentials of available alternative water sources in a given area. A single option may not be suitable or affordable for the people with different social and economic conditions. Some of the main strategies for safe water sources should include-

- The tubewells whose arsenic concentration is less than 100 ppb in shallow depth, ECAR should be installed to the water sources because operation of ECAR is most cost effective in this region than the installation of deep tubewell.
- The tubewells contain arsenic concentration more than 100 ppb, installation of deep tubewell is required. If the water from deep tubewell is also contaminated, then ECAR should be installed in that school.
- In zone I for both shallow and deep aquifer, groundwater withdrawal can be done from both the aquifers, but the uncontrolled withdrawal of groundwater from this zone can transfer the zone into high arsenic contaminated zone
- From the zone II, III and IV for shallow aquifer and zone II and III for deeper aquifer, withdrawal of groundwater is not acceptable from this zone, surface water should be used after proper treatment method, water can be withdrawn from safe zone and distributed through the pipeline in the arsenic distributed region. Uncontrolled withdrawal of groundwater from this zone will worsen the situation of the region.
- In case of high risk zone, a cluster of schools can be selected, a tubewell location can be identified with ordinary kriging where As safe aquifer zone is available and supply of As free water can be done by pipeline to those schools.

7.7. Observations from the present study

Arsenic can cause adverse health effects mainly cancer on the population who consume arsenic contaminated water for a prolonged period. So, supply of arsenic free water to the arsenic affected population should be mandatory in arsenic contaminated zone. Arsenic removal from groundwater and search for an alternative source of arsenic free water would be the best option to mitigate arsenic concentration from arsenic contaminated zone. Cancer risk matrix was calculated to develop mitigation strategies caused by arsenic in the primary schools where the age range of the children were 6 to 10 years. . The ranking of student population and cancer risk was prepared to make the risk matrix. The primary schools present in the focus area contain a good number of student population and they are largely impacted by high arsenic concentration. In the focus area, it was observed that 36.3% of schools contain student population ranges from 20-50. In 28.35% and 35.34% schools, the student population ranges from 51-100 and 101-951 respectively. 62% of the total primary student population have the risk to generate cancer among 1×10^{-4} to 138×10^{-4} population followed by 32% population with 139×10^{-4} to 400×10^{-4} cancer risk and 5.75% population with 401×10^{-4} to 1410×10^{-4} cancer risk when they use shallow tubewell for drinking purposes. In deep tubewell, 99% and 1% of population have the chances to develop cancer among 1×10^{-4} to 138×10^{-4} and 139×10^{-4} – 216×10^{-4} population respectively. For shallow zone, risk was classified into 1-9 scales where 1 stands for low risk and 9 for high risk and for deep aquifer, risk was classified into 1-6 scales. Scale 1 and 2 have been considered as low risk zone, scale 3 and 4 are medium risk zone and scale 6 and 9 are considered as high risk zone.

The following mitigative measures were taken on the basis of risk matrix for the shallow tubewell from the focus area. In scale 1 [1×1 (low risk-low population) and 2 [1×2 (low risk- medium population) and 2×1 (medium risk-low population)], 22.4% of total population are present in around 52% schools. As the schools are present in low risk zone, students can be transferred from the high risk zone to these low risk zone and arsenic removal plants can be installed in these region. For scale 3 [(1×3) low risk-high student population zone], no change was required, as the zone is a safe zone. In scale 3 [(3×1) high risk low student population zone], 4 [(2×2) medium risk -medium population] and 6 [(3×2) high risk- medium student population] zone, there are 42.5% schools with 71% of student population. Installation of arsenic removal plants is mandatory for those schools as the huge student population can not be transferred to other schools. In scale 6 [(2×3) medium risk high student population zone] and 9 [(3×3) high risk high student population zone] there are around 4% schools with 5.5% of student population were observed. As the percentage of schools and student population both were lower than the other zone, it was found better to take the decisions about closing of the schools, installation of arsenic removal costs will not be cost effective for these schools. The students can be transferred to the low risk low student population zone.by increasing the proper infrastructure of the low populated schools. The closed schools can be used as health centres as the health care system was found very poor in the focus area.

In deep tubewell, 11% student population in around 36% schools was found in scale 1 [(1×1) Low risk- Low student population zone] and 2 [(1×2) Low risk- medium student population]. Being a low risk zone, student population from higher risk zone can be transferred to these region and arsenic removal plant can be installed in those schools. In scale 2 [(2×1) Medium risk- Low student population], there are 20% student population was observed in 28% of school, installation of arsenic removal plants was found mandatory for the schools. In scale 3 [(1×3) Low risk- High student population], 68% of student populations were observed among 35% schools, no change will be requirred for this zone. For scale 4 [(2×2) Medium risk- Medium student population] and 6 [(2×3) Medium risk- high population], only 1% school students were found in 1% schools in those zones, The schools can be closed and the students were transferred to other schools in low risk low populated zone.

There is an economic loss related to arsenic concentration in ground water. The cost is different in different arsenic concentration zone because the annual mean averting expenditure, medical expenditure and number of sick days all are higher in case of higher arsenic contaminated zone and lower in low arsenic contaminated zone. In 2022, per capita annual economic loss consideing the inflation cost 6% were INR 387.28 in zone I (10-100 ppb), INR 947.07 in zone II (100-300 ppb) and INR 1746.94 in zone III (more than 300 ppb) when the consumption of water was 10 lit for adult and 6 lit for child population. The cost was considered same for both adult and child population because the children are more prone to develop different types of diseases and the cost is also higher than adult population. For shallow tubewells, the economic loss in the villages was determined for both adult and child population in three different arsenic contaminated zone. In Baruipur block, the economic loss was highest, INR 300 million followed by villages in Bhangar I and Bhangar II blocks (approximately INR 200 million) when the population use the shallow water source for drinking. So, arsenic remediation technology should be implied in shallow tubewell to lower down the effects and costs related to arsenic contamination in ground water. The total economic loss in the focus area was found around around 1310 million INR. In zone II, the economic loss was observed 41%, 38% in zone III and 21% in zone IV.

So, the consequences of arsenic contamination in groundwater can cause different health problems along with economic loss. Arsenic remediation from groundwater can be an alternative for the supply of arsenic free water. Electro chemical arsenic remediation (ECAR) is a form of electro coagulation that has been used to remove arsenic concentration from groundwater in rural parts of West Bengal. It is a low cost, robust, highly effective technology that requires a little maintenace and lowers the arsenic concentration into 5 ppb. Different ECAR operation cost was observed for different arsenic contaminated regions (zone II, zone III and zone IV). As the water requirement is different among adult and child population, the annual treatment cost was also different. In zone II, the annual treatment cost of supplying 10 lpcd of treated water in adult population was INR 255.5 and 6 lpcd of treated water in child population was INR 153.3. For zone III, the cost was INR 273.75 and 164.25 for adult and child population and zone IV, it was INR 292 and 175.2 for adult and child population. If the population consumes water that was supplied from ECAR treatment plant, the population will be less affected, thus a total gain will be observed. The total gain was found varying in the blocks at different concentration level. Maximum total gain was observed in the villages of Baruipur block. The total remediation cost was estimated around 523 million INR in the focus area. The total remediation cost in zone II was observed 65% of the total remediation cost followed by 26.6% in zone III and 8.4% in zone IV. After the installation of ECAR in shallow tubewell, 788 million INR was observed as total gain (from zone II, zone III and zone IV)in the focus area.

When the shallow depth aquifer is contaminated with elevated level of arsenic contamination, deep tubewells were installed to supply arsenic free water. There are several number of deep tubewells in the focus area and 43-94 persons were found dependent on each tubewells in the rural areas. The average aquifer depth was found different in the range from 200-300 m bgl. In Canning II, the average aquifer depth was maximum (310 m bgl) and in Sonarpur the depth is minimum (200 m bgl). The estimated cost for the installation of each tubewell in the deep aquifer calculated for Canning II was INR 2,96,627 and for Sonarpur it was INR 2,15,522. The installation cost of each deep tubewell in rest of the blocks ranges in between the two costs. According to PHED data, three tubewells were recorded with submersible pumps per village. The installation cost of three tubewells in each village were INR 50,00,000 and the life span of each tubewell was 20 years. Per capita total cost for the installation of deep tubewell and tubewell with submersible pump was observed in between INR 317.74 (Magrahat II) to INR 717.38 (Bishnupur I). The total installation cost of deep tubewell was found 910 million INR. Zone II comprises of 66.8% of the total installation cost.

The total economic benefit for installation of deep tubewell was found 401 million INR. The annual economic loss in zone II is lower than the total annual cost for installation of deep tubwell. So, installation of deep tubewell is not benefiacial in zone II. Installation of ECAR in those villages will be the best option. INR 24.45 million loss was calculated in Sonarpur block due to installation of deep tubewell in zone II. But in zone III, economic benefit was found in all blocks except Mandirbazar, Magrahat II and Mathurapur I. The maximum economic benefit was observed in Baruipur (INR 77.94 million) and Bhangar II (INR 68.79 million). In zone IV, the economic benefit was found maximum in Bhangar I and Baruipur block. Here, the economic benefit implies that if the people can consume arsenic free water from deep tubewell, they will not suffer from arsenic induced diseases, thus a society can save upto that huge amount of money by spending a little cost for deep tubewell.

It was found from the study that after installation of deep tubewells with such huge expenses, arsenic contamination was still found in small part of the focus area in deep depth tubewells. The deep tubewells from 54% of total villages are found arsenic affected. The concentration was found more than the permissible limit. In Bhangar I and Bhangar II, Bishnupur I and Canning II, 100% of the deep tubewells from the villages are arsenic affected. The blocks were divided into zone II (10-100 ppb) and zone III (100.1-300 ppb) . The economic loss was found higher in Bhangar I, Bhangar II and Canning II due to elevated level of arsenic concentration in groundwater extracted from deep tubewell. Total gain was found maximum in Bhangar I and II, after the installation of ECAR in deep groundwater source. Installation of deep tubewell was found beneficial in zone III and zone IV. In Zone II it is better to install ECAR to the sources of groundwater instead of deep tubewell. So, a cost benefit analysis should always been done to take the decision about the installation of deep tubewell or ECAR or deep tubewell cooperated with ECAR.

The estimated total economic loss due to arsenic concentration in deep tubewell was around 559 million INR. The total remediation cost was found INR 337.5 million in the deep tubewell from the focus area.

It can be concluded from the chapter that installtion of deep tubewell is not necessary for all the arsenic affected blocks. In zone II, if the shallow tubewells can be treated with ECAR, the cost will be less than the installation of the deep tubewell. In Jaynagar I and II, Mandirbazar and Mathurapur I, groundwater from deep tubewell can be used because arsenic concentration was within permissible limit in those blocks. . But in Baruipur,Bhangar I and II and Sonarpur, installation of ECAR is mandatory in deep tubewell as both the aquifer are arsenic contaminated. So, the cost benefit analysis is important to install either deep well or ECAR or both deep tubewell with ECAR to supply arsenic free water.

In that case, the location for the installation of the tubewells is very important. At first, the safe location should be predicted by Geostatistical method near the schools in both shallow and deep tubewell. If the shallow and deep tubewell both were found safe, then the tubewell should be installed in the shallow depth. If arsenic concentration was found less than 100 ppb, then ECAR treatment plant can be installed at that shallow tubewell. If both the depths are arsenic affected and the concentration is lower in deep aquifer, ECAR can be installed at that depth. Otherwise a cluster of schools can be prepared, a tubewell location was predicted with As safe aquifer zone at deep aquifer and supply of As free water by pipeline to those schools.

For social upliftment for risk management, the socio demographic parameters were taken, i.e. economic status, nutrition, health education, general health care and treated surface water supply. For those type of social vulnerability, a typical risk identification map was prepared with the help of number of population depending upon each health care facility. From the risk map, it can be concluded that around 15000 to 30000 population in the arsenic contaminated blocks depend on only 1 health care unit.

CHAPTER 8
CONCLUSION AND FUTURE SCOPE OF WORK

8.1. Conclusion

The present study has been conducted with the objective to predict arsenic concentration in groundwater in an effective and economic way with the help of GIS and Geostatistics and assessment of arsenic induced health and societal risk with possible mitigation measures with special reference to primary school going children considering South 24 Parganas as the study area.

The following conclusions can be drawn on the basis of the outcomes of the study-

- Arsenic contamination in groundwater and the health hazards related to arsenic has been considered as a ‘high profile problem’ throughout the globe. South 24 Parganas was found as the one of the most arsenic affected districts of West Bengal.
- South 24 Parganas has been considered as largely rural district with 75% of the total population living in the rural areas.
- Arsenic concentration in groundwater was reported in the blocks those were present adjacent to Kolkata and arsenic free blocks were found located in the southern part of the district.
- The present study was done on the basis of distribution of arsenic concentration in shallow tubewell in the district, so, a focus area was determined where the arsenic concentration was recorded more than 10 ppb. A very small patches contain arsenic less than 10 ppb.
- Shallow aquifer is the most contaminated aquifer in South 24 Parganas. Higher level of arsenic concentration was confined in shallow aquifer (within 100 m bgl). Low arsenic concentration was reported in deeper depth.
- Baruipur, Bhangar I, Bhangar II and Sonarpur were found as the most severely arsenic contaminated blocks in total and the partially contaminated blocks were Bishnupur I, Canning II, Jaynagar I, Jaynagar II, Magrahat II, Mandirbazar and Mathurapur I in the focus area.
- In Baruipur, Bhangar I, Bhangar II, Jaynagar II and Sonarpur blocks, the percentage of tubewells that contained arsenic more than 10 ppb was found in more than 70% tubewells.

- The focus area was located at the lower Gangetic Delta Plain and formed by the late Holocene to recent sediment deposition from the River Ganges and the presence of arsenic contamination was found dependent on the geological settings of the area.
- The focus area was classified as zone I (0-10 ppb), zone II (10.1-100 ppb), zone III (100.1-300 ppb) and zone IV (more than 300 to 2400 ppb) on the basis of distribution of arsenic concentration in shallow tubewell.
- Zone I was present in very small part of the focus area. Zone III was found in different clusters surrounded by zone II and small epicentres of zone IV was found surrounded by zone III.
- The epicentres of arsenic concentrations were found near the municipal areas of the focus area except in Bhangar I and Bhangar II.
- No significant pattern of spatial distribution of arsenic concentration in groundwater from shallow aquifer was observed.
- The estimation of arsenic concentration at unsampled locations were found very difficult due to the wide range of spatial variability of arsenic concentration between neighbouring tubewells at shallow depth.
- Geostatistics was found as one of the best methods that could estimate arsenic concentration at unknown spatial locations where no measurements were done.
- The problem of estimating arsenic concentration in groundwater at unsampled locations was tried to solve by using Geostatistical methods in three steps - spatial analysis using the semivariance function, rose diagram and modeling of spatial distribution and estimation by using the method of ordinary kriging.
- The computed semivariogram model was working properly that was made with the data sets of Baruipur block. The semivariogram graph started from the origin and an increasing trend was observed upto a certain maximum range. Beyond this point, the curve became almost parallel to the horizontal axis.
- For estimation of arsenic concentration at a spefic location in both shallow and deep depth, the major influential zone (critical angle) for estimation was oriented at 52.5^{o} - 232.5^{o} (measured from east) line. The separation distance (critical range) was 6592 m for shallow tubewell and 7859 m for deep tubewell. The points located within the separation distance were found correlated.
- In the semivariogram model of focus area, the variation of $\gamma(h)$ vs h is found to follow a typical mathematical model followed by Power equation.
- The location points those are present within the critical range and critical angle are called the influencing points and total 6-10 influencing points were considered for the estimation of arsenic concentration.

- The deviation between estimated and actual value was found higher in shallow depth, as the range of spatial distribution of arsenic was found higher in shallow depth. The deviation between estimated and actual values was observed as 20% samples at 0.01 to 0.1, 60% in 0.1 to 0.5, 13.3% in 0.5 to 1 and 6.6% was present in more than 1.
- Smaller deviation was found between estimated and actual value in deeper depth. The deviation observed between the actual and estimated values were 33.3% in 0.01 to 0.1, 46.7% in 0.1 to 0.5 and 10% in both 0.5 to 1 and more than 1.
- The field samples were collected from the deeper depth. The deviation of arsenic concentration between actual and estimated values in field samples were 6.7% in 0.01 to 0.1, 66.7% in 0.1 to 0.5, 24.4% in 0.5 to 1 and 2.2% in more than 1. The deviation was occured due to error in data collection, measurement error and geological settings of the focus area.
- The higher discrepancies were observed where arsenic hotspot zones lie very close to low arsenic contaminated zone or vice versa.
- Appreciable cross correlation exists between arsenic and iron at different locations, but not so good cross correlation was observed between arsenic and chloride.
- Choice of arsenic sampling may be made based upon the spatial distribution of iron, which will save time and money both.
- The population projection of the year of 2022 in rural and municipal areas and schools done for the focus area was calculated with the help of individual methods like Arithmetic increase method, Incremental increase mothod and Geometric increase method and also with combinaton of these methods.
- Among the 608 villages from the focus area, it was found that 83% of total villages and 85% of total population live in arsenic affected region with different level of arsenic concentration of the focus area. Only 15% population of the focus area are safe from arsenic concentration. 10 to 100 ppb is the predominant concentration in the focus area and 59% population are using arsenic contaminated water at this level followed by 19% using 100.1-300 ppb and 7% using more than 300 ppb.
- All the wards from the three municipal areas were found arsenic contaminated and the total population were supposed to be exposed to arsenic contaminated groundwater. In municipal areas the arsenic affected population can get arsenic safe water sources as in that area availability of As free water supply system, better health care facilities, awareness and better economic condition than the rural people. 79% population share comes from rural areas in focus area, so rural population was in the focus point in the present study.

- Around 1000 primary schools with approximately 1,10,000 student population were present in the focus area and they were found dependent on groundwater for drinking purposes and mid day meal was also cooked with that water.
- As the schools were present in the arsenic contaminated regions, the tubewells present in the schools were also contaminated. The children from the primary schools consume that arsenic contaminated water without knowing about the presence of arsenic. So, there was a need to monitor arsenic concentration in the ground water sources. Prediction of arsenic concentration with ordinary kriging from the drinking water sources in the schools was considered as one of the best interpolation method for regular monitoring to determine arsenic concentration level.
- Based on the kriging estimation in shallow tubewell, it has been found that in about 6% of schools the estimated arsenic concentration was within permissible limit, in about 56% schools, the estimated concentration was in zone II (10-100 ppb), in about 32%, the estimated value was zone III (100-300 ppb) and in about 6% in zone IV (more than 300 ppb) with highest concentration was estimated as more than 1000 ppb in a school at Sonarpur and more than 950 ppb in a school at Baruipur.
- In case of kriging estimation in deep tubewell, it has been observed that in about 54% of schools, the estimation was within permissible limit, in about 45% it was in zone II (10-100 ppb) and in about 1%, it was in zone III (100-300) with around 150 ppb arsenic concentration in Bhangar I and Jaynagar I.
- Exposure risk and health risk was assessed among the child and adult population as the population was affected by arsenic concentration. The school students from around 1000 schools were considered as the child (6-10 years) population and the adult (35 years) residing nearby to the schools were considered as the adult population.
- The ingestion rate of water for child and adult population was taken as 6 and 10 L/day considering only direct and indirect (cooking) consumption of water.
- If a child consumes 6 litre of water with 100 ppb arsenic concentration, the daily intake will be 1.5 fold more than the permissible daily intake value (2.1 µg/kg body weight). The value will be 4 fold more for the adult population when the consumption rate was 10 L/day.
- HQ>1 means that there is chances to develop adverse non-carcinogenic risks. The HQ was found 10 for child and 28 for adult population when they consume 100 ppb arsenic contaminated water. Hazard Quotient (HQ) more than 1 was found in 99% primary schools indicating that there is a risk to develop adverse non-carcinogenic effects among the child population.

- There is a chance to develop skin cancer in 125 adults among 10,000 populations and 138 children among 10,000 population if they consume 100 ppb arsenic contaminated water daily for 70 years. A carcinogenic risk greater than 1×10^{-4} gives rise to potential health hazard.
- The values of total daily intake, hazard quotient and cancer risk were found higher because higher arsenic concentration (more than 1000 ppb) was observed in the schools. So, all the values would be 10 times more than the results found with 100 ppb calculation.
- From the present study it was found that the permissible limit of arsenic in groundwater which is 10 ppb is not suitable for the child population. The HQ was found more than 1 and development of cancer risk was found 13 times more than the children who consumes arsenic water even at its permissible limit.
- Neurotoxic effects of arsenic was also found among human beings. Early exposure to arsenic can reduce the Intelligence Quotient (IQ) which results the reduction of cognitive development and neurobehavioral function over the life time of a child. The average IQ score is 99.5 for arsenic free water. If a child consumes water with 10 ppb arsenic concentration, the estimated IQ will be 98.7 whereas the concentration is 100 ppb, the estimated IQ will be 91.5.
- In shallow aquifer when the range of arsenic concentration was 1 to 1000 ppb, around 60% of school students were found to be present in average (90-109 IQ score), 23% in low average (80-89 IQ score), 10% in borderline (70-79 IQ score) and 7% in extremely low (≤69 IQ score) scale.
- In deep tubewell, 98% of school students were found to be present in 90-109 IQ score (average) and 2% in 80-89 IQ score (low average) when the range of arsenic concentration was 1 to 150 ppb.
- The risk matrix was generated to develop the mitigative solutions against arsenic in primary schools.
- The risk matrix was developed with the help of risk zone on the basis of arsenic concentration of the schools and student population per school.
- Three risk zone was classified into- low (1-100 ppb), medium (100.1-300 ppb) and high (more than 300.1 ppb).
- The schools were ranked on the basis of student population per school- low (20-50 students per school), medium (51-100 students per school) and high (100-951 students per school).
- The following mitigative measures were taken on the basis of risk matrix for the shallow tubewell from the focus area.

- ✓ 22% of total student population in around 52% schools belongs to low risk-low student population, low risk- medium student population and medium risk-low student population zone. As the schools are present in low and medium risk zone, students can be transferred from the high risk zone to these lower risk zone and arsenic removal plants can be installed in these region where arsenic concentration is more than 10 ppb.
- ✓ Only 2% schools having 0.7% of total student population is found in low risk-high student population zone, in this zone, arsenic removal plants will be the best option in these region where arsenic concentration is more than 10 ppb as transfer of students to the schools will not be possible.
- ✓ In medium risk medium student population zone, 9% schools contain around 7% student population. Installation of arsenic removal plant in those schools where arsenic concentration is more than 10 ppb is the best management option for this zone.
- ✓ In high risk- low student population zone, there are around 21 % schools with 41% of student population. Installation of arsenic removal plants is mandatory for those schools where arsenic concentration is more than 10 ppb and students are transferred from neighbouring small percentage of schools with high risk low population and medium risk high population schools
- ✓ High risk -medium population is also having around 24% students in 12% of total schools. Management in such schools are also similar to high risk low student population.
- ✓ In medium risk high student population and high risk high student population zone there are around 4% schools with 5.5% of student population were observed. As the percentage of schools and student population both were lower than the other zone, it was found better to take the decisions about closing of the schools, installation of arsenic removal costs will not be cost effective for these schools. The students can be transferred to the low risk low student population zone. The closed schools can be used as health centres as the health care facility was found very poor in the focus area.

- The following mitigative measures were taken on the basis of risk matrix for the deep tubewell from the focus area.
  - ✓ 11% student population in around 36% schools was found in low risk-low student population and low risk- medium student population. Being

a low risk zone, student population from higher risk zone can be transferred to these region and arsenic removal plant can be installed in those schools where the arsenic concentration is more than 10 ppb.

- ✓ In Medium risk- Low student population, there are 20% student population was observed in 28% of school, installation of arsenic removal plants was found mandatory for the schools where the arsenic concentration is more than 10 ppb and student should be transferred from neighbouring high student population schools.
- ✓ In Low risk- High student population, 68% of student populations were observed among 35% schools, arsenic removal plants may be requirred for this zone where the arsenic concentration is more than 10 ppb.
- ✓ For Medium risk- Medium student population and Medium risk- high population, only 1% school students were found in 1% schools in those zones, The schools can be closed and the students were transferred to other schools in low risk low populated zone.

- Electrochemical Arsenic Remediation (ECAR) which is one of the most effective Arsenic removal technologies used for arsenic remediation.
- Per capita annual economic loss due to arsenic exposure as estimated as on 2022 considering daily consumption of water as 10 lpcd for adult and 6 lpcd for child were found as INR 387.28 in zone II (10-100 ppb), INR 947.07 in zone III (100-300 ppb) and INR 1746.94 in zone IV (more than 300 ppb). No economic loss was calculated for zone I because arsenic concentration was within permissible limit in this region, so the population was considered to consume safe drinking water.
- Different ECAR operation cost was observed for different arsenic contaminated regions (zone II, III and IV). As the water requirement is different among adult and child population, the annual arsenic treatment cost was also different. On an average the arsenic treatment cost for zone II, III and IV are INR 0.07/L, INR 0.075/L and INR 0.08/L respectively.
- The estimated total economic loss due to arsenic concentration in shallow tubewell was around 1300 million INR. The share of economic loss in zone II, III and IV was observed 41%, 38% and 21% respectively.
- The estimated operational cost of ECAR installed in shallow tubewell was found around 520 million INR. The remediation cost in zone II was observed 65% of the total remediation cost followed by 27% in zone III and 8% in zone IV respectively.

- In case of shallow tubewell, if the water is treated by ECAR, the estimated total gain was around 780 million INR i.e. 60% total gain. The maximum gain (46%) gain was observed in zone II.
- For supplying low arsenic water, if we depends on deep tubewell only, then the estimated total installation cost for deep tubewell was around 900 million INR for total focus area.
- It was found from the study that after installation of deep tubewells with such huge expenses, arsenic contamination more than permissible limit was observed in 54% of villages of the of the focus area in deep depth aquifers.
- The installation of deep tubewell was found not beneficial for zone II. The estimated installation cost was found greater than the economic loss due to arsenic concentration in shallow tubewell. Installation of ECAR in shallow tubewell may be the one of the best option for that zone. Installation of deep tubewell in zone III and IV was found beneficial to get arsenic safe water.
- The estimated economic loss due to arsenic concentration even if after installation of deep tubewell was found as around 560 million INR. Around 90% of economic loss due to arsenic concentration in deep tubewell in zone II was found.
- To remove the arsenic contamination from deep tubewell water, the estimated remediation cost by ECAR was found around 340 million INR.
- The estimated total gain due to installation of ECAR to treat the deep tubewell water was around 220 million INR i.e. around 40% total gain.
- After the total cost analysis, it was observed that around 60 million INR i.e. around 5% would be assumed as total benefit from the economic loss due to arsenic concentration in shallow tubewell (1300 million INR), installation cost for deep tubewell (900 million INR) and installation cost for ECAR in deep tubewell (340 million INR).
- From the study it can be summarized as - the safe location should be predicted by Geostatistical method near the schools in both shallow and deep tubewell. If the shallow and deep tubewell both were found safe, then the tubewell should be installed in the shallow depth. If arsenic concentration was found less than 100 ppb in shallow tubewell, then ECAR treatment plant can be installed at that shallow tubewell. If both the depths are arsenic affected and the concentration is lower in deep aquifer, ECAR can be installed at that depth. In case of high risk zone, a cluster of schools can be identified, a tubewell location can be predicted where the water is arsenic free at deep aquifer and supply of the water by pipeline to those schools.
- A holistic management solution against arsenic induced risk to vulnerable child population cannot be achieved without a holistic solution involving technological, social, demographic and economic upliftment. Some of the socio-demographic parameters

including nutrition, health education, total health care, supply of treated surface water were also discussed.

- In South 24 Parganas district, the health care facility for the arsenic affected population was found very low. So, there is a need to increase the number of health care centres that will treat the arsenic affected illnesses.

8.2. Future scope of work

- Development of a three dimensional model where the depth of the tubewell will also be considered in the model.
- Using other estimation method like Inverse Distance Squared Estimate for estimation of arsenic in groundwater.
- Collection of data from Bhangar I and II block for data validation as the variation of arsenic concentration is very high in deep aquifer too
- Use of other low cost arsenic remediation technologies for arsenic removal from groundwater.
- Economic cost analysis with the help of nutritional status and general health care with respect to arsenic concentration in groundwater.
- Assessment of arsenic induced health risk with dietary intake of food among population
- Designing of rain water harvesting unit for the schools located in high risk zone to avoid the groundwater sources.

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Annexure I

1. Data for Baruipur block (used for data validation of semivariogram modelling)

No	X	Y	As (ppb)
1	652275	2474641	12
2	655551	2476666	12
3	649023	2468043	20
4	650166	2468065	20
5	651418	2469616	20
6	646962	2468079	20
7	648845	2467277	20
8	647100	2469774	20
9	649016	2467711	20
10	647986	2467656	20
11	648326	2467660	20
12	649866	2468173	20
13	654313	2466467	20
14	653200	2469645	20
15	651909	2470009	20
16	653121	2469279	20
17	651722	2471236	20
18	650191	2469715	30
19	652782	2474413	30
20	652738	2472685	30
21	653505	2473158	30
22	652913	2472687	30
23	652737	2472785	30
24	652571	2472872	30
25	652741	2474424	30
26	653597	2473247	30
27	653285	2469369	30
28	648971	2464865	40
29	647075	2468135	40
30	651447	2473049	40
31	655248	2465701	40
32	650529	2474181	47
33	657027	2463061	48
34	650213	2474953	49
35	650618	2470361	50
36	649007	2468596	50
37	650592	2467682	50
38	649252	2467768	50
39	650343	2472186	50
40	652765	2469917	50

No	X	Y	As (ppb)
41	650536	2470305	50
42	651243	2467522	50
43	651374	2472085	52
44	653896	2477425	56
45	648234	2466518	57
46	653225	2472325	57
47	649194	2470591	60
48	651193	2472670	60
49	647845	2474819	67
50	650368	2469584	70
51	650224	2466294	70
52	650141	2466393	70
53	649152	2470624	70
54	650366	2469717	70
55	652306	2471540	73
56	648061	2473825	74
57	651518	2467879	78
58	655745	2467588	79
59	650060	2466204	80
60	650243	2466482	80
61	648986	2467577	80
62	651446	2473138	80
63	649047	2467667	80
64	647721	2466292	80
65	652486	2474200	86
66	651075	2473101	90
67	650531	2470826	90
68	650357	2470724	90
69	650701	2470307	90
70	650109	2469714	90
71	650696	2470827	90
72	646776	2468077	90
73	650440	2470636	90
74	649349	2468411	90
75	651024	2473045	90
76	651496	2470093	93
77	652551	2467557	95
78	650542	2469718	100
79	650543	2469530	100
80	652181	2468527	100

No	X	Y	As (ppb)
81	655237	2466808	103
82	651102	2468207	108
83	651204	2468319	109
84	651377	2469627	110
85	649153	2470591	110
86	650420	2469529	110
87	649343	2468987	110
88	649933	2469801	110
89	650108	2469803	110
90	652353	2468806	110
91	652262	2468628	110
92	644567	2473017	111
93	651617	2468212	117
94	649046	2467744	117
95	651401	2469317	119
96	647454	2472712	120
97	649329	2470437	120
98	647986	2467656	120
99	647643	2474485	125
100	651388	2470646	130
101	649604	2468691	130
102	650849	2473043	130
103	649685	2468780	130
104	648163	2473936	130
105	651250	2468928	130
106	652768	2469552	130
107	648151	2475154	132
108	651502	2467414	133
109	656200	2470472	133
110	652099	2471649	137
111	646376	2466833	138
112	652219	2469879	138
113	648195	2470615	140
114	650562	2467593	140
115	650372	2469163	140
116	651062	2469170	140
117	649678	2466311	142
118	648549	2465857	142
119	650026	2469802	150
120	649522	2468601	150
121	651564	2473637	150
122	651077	2467598	150
123	648139	2465632	151

No	X	Y	As (ppb)
124	649638	2470518	151
125	652281	2474087	151
126	652009	2470320	152
127	648024	2466849	153
128	651910	2469876	155
129	649474	2466087	155
130	648197	2470393	163
131	647235	2474038	164
132	658742	2470752	164
133	648838	2467964	165
134	647973	2472274	166
135	649473	2466198	167
136	651066	2468793	170
137	649683	2468968	170
138	649520	2468878	170
139	648630	2468183	170
140	649086	2468962	170
141	651404	2468985	170
142	656322	2471691	170
143	650023	2470079	180
144	649170	2468775	180
145	650377	2468610	180
146	651312	2467877	183
147	650282	2467756	183
148	650540	2473073	187
149	648139	2465632	188
150	650534	2468423	190
151	650425	2468975	190
152	647332	2474703	192
153	652224	2469436	196
154	650790	2470640	200
155	652013	2469877	200
156	648295	2467626	200
157	652749	2468334	201
158	650819	2467684	209
159	650615	2470638	210
160	649297	2468433	210
161	650036	2468783	210
162	652357	2468441	210
163	649666	2467529	210
164	651516	2467989	211
165	651887	2472201	215
166	649849	2469966	216

No	X	Y	As (ppb)
167	649480	2465534	218
168	652315	2470655	220
169	649862	2468605	220
170	650419	2469606	220
171	649480	2476163	220
172	652760	2467227	220
173	647661	2472603	225
174	650810	2466432	227
175	652072	2474417	229
176	650286	2469528	230
177	655019	2471102	235
178	652075	2474085	237
179	652948	2469111	238
180	650556	2468235	240
181	651024	2473045	240
182	653270	2470908	240
183	650377	2468610	240
184	648192	2470836	243
185	650456	2467946	245
186	649148	2467856	249
187	651486	2473227	250
188	649349	2468411	250
189	647747	2474375	250
190	652422	2470213	255
191	652466	2465673	255
192	648407	2469953	256
193	652249	2469968	260
194	652228	2468993	261
195	650588	2468091	270
196	651066	2468793	270
197	651284	2470733	271
198	650962	2468848	271
199	652135	2467995	274
200	650881	2469755	274
201	648714	2470177	280
202	652258	2465893	280
203	651398	2469627	280
204	650374	2468975	280
205	650262	2469860	289
206	648152	2467481	290
207	652941	2469819	290
208	648050	2474932	291
209	651714	2468877	293
210	651206	2468097	299
211	651109	2472857	310
212	648137	2465853	310
213	652089	2469545	310
214	650852	2472744	313
215	647653	2473378	315
216	650107	2469891	320
217	651562	2470736	320
218	650884	2469423	335
219	647767	2472272	338
220	650355	2468786	340
221	649852	2469612	350
222	648664	2464640	350
223	651805	2470096	350
224	650365	2467757	350
225	652548	2467889	357
226	652508	2471985	360
227	651550	2471943	360
228	652766	2469829	360
229	647549	2473488	360
230	651538	2473138	370
231	650222	2466571	380
232	651729	2470505	390
233	651405	2468896	400
234	651212	2470721	406
235	652038	2467330	412
236	648358	2475045	420
237	655439	2467253	428
238	652731	2470216	430
239	647872	2472051	433
240	649855	2469335	440
241	653009	2474448	440
242	650701	2470274	470
243	650460	2468610	470
244	652636	2469440	472
245	651637	2466219	481
246	648177	2472497	510
247	650699	2470451	510
248	650622	2467781	510
249	651050	2473577	510
250	650543	2469619	520
251	652630	2470016	520
252	650354	2470968	520

No	X	Y	As (ppb)
253	650456	2467891	525
254	651554	2471566	530
255	650813	2468337	530
256	651402	2469206	550
257	650767	2470861	552
258	652088	2469634	553
259	651162	2472637	560
260	651435	2465774	560
261	651163	2472526	563
262	650792	2468292	570
263	651926	2468215	575
264	651187	2473224	580
265	649819	2467696	600
266	650293	2468786	600
267	650725	2467782	610
268	650823	2468315	610
269	651637	2471479	610
270	651228	2469072	630
271	651490	2468620	630
272	647541	2474373	638
273	649271	2476494	648
274	647955	2474156	650
275	650813	2468337	652
276	647453	2472822	660
277	652598	2470104	690
278	652245	2467221	730
279	652832	2470438	740
280	650823	2467296	740
281	651843	2466221	753
282	651739	2466331	764
283	651492	2470536	810
284	652940	2469886	810
285	652783	2471246	810
286	651046	2470831	850
287	652529	2469771	920
288	651427	2466549	1060
289	650459	2467647	1180
290	655229	2467694	2560

2. Data for shallow tubewell used for prediction (Depth within 100 m bgl)

The data was listed according to the depth of the tubewells.

No	Block	Village	X	Y	Depth (m)	As (ppb)	Iron (ppm)	Chloride (ppm)
1	Baruipur	Ramnagar I	652508	2471985	5.24	360	30.06	196
2	Jaynagar I	Sripur	650390	2456574	6.06	610	33	196
3	Jaynagar I	Sripur	650087	2455907	6.06	360	25.8	147
4	Jaynagar I	Rajapur Korabeg	655740	2457733	6.09	42	4.9	165
5	Jaynagar I	Sripur	650600	2456244	6.09	40	4.8	159
6	Sonarpur	Kheyadaha I	650389	2488574	6.1	40	12.37	314
7	Baruipur	Rana	650542	2469718	8	100	2	502
8	Baruipur	Baliaghata	649194	2470591	8	60	1.9	354
9	Baruipur	Sitakundu	651538	2473138	9	370	12	179
10	Baruipur	Balbalia	650060	2466204	9	80	4	163
11	Baruipur	Shankarpur II	649473	2466198	9.15	167	13.6	100
12	Sonarpur	Pratapnagar	655706	2481651	9.15	130	16.4	401.93
13	Sonarpur	Kheyadaha I	652031	2489033	9.15	32	11.55	365
14	Sonarpur	Kamrabad	650867	2481824	10.67	50	19.2	430
15	Baruipur	Padmajola	651377	2469627	11	110	2.6	199
16	Baruipur	Sitakundu	651075	2473101	11	90	1.6	186
17	Baruipur	Sitakundu	651554	2471566	12	530	19	168
18	Baruipur	Dudhnai	650618	2470361	12	50	1.1	126
19	Baruipur	Kalyanpur	647653	2473378	12.15	315	3.29	182
20	Baruipur	Kalyanpur	647973	2472274	12.15	166	5.59	189
21	Baruipur	Kalyanpur	647872	2472051	12.19	433	10.21	163
22	Baruipur	Ramnagar II	652315	2470655	12.19	220	30.56	224
23	Jaynagar I	Narayani tala	651377	2461123	12.19	170	16.5	187
24	Jaynagar I	Dakshin Barasat	648516	2458549	12.19	143	11.4	157
25	Sonarpur	Langalberia	644433	2476337	12.19	130	11.85	391.33
26	Jaynagar I	Sripur	651017	2455694	12.19	100	11.5	155
27	Baruipur	Ramnagar I	652306	2471540	12.19	73	15.02	196
28	Jaynagar I	Dakshin Barasat	651595	2459907	12.19	70	7.4	129
29	Jaynagar I	Dakshin Barasat	650867	2460564	12.19	59	5.5	147
30	Jaynagar I	Harinarayanpur	651718	2457915	12.19	21	2.3	201
31	Baruipur	Kalyanpur	648177	2472497	12.2	510	11.29	193
32	Baruipur	Dhopdhopi I	651206	2468097	12.2	299	17.27	301
33	Baruipur	Dhopdhopi I	650588	2468091	12.2	270	25.03	354
34	Baruipur	Dhopdhopi I	651312	2467877	12.2	183	12.51	310
35	Baruipur	Dhopdhopi I	650282	2467756	12.2	183	12	269
36	Baruipur	Dhopdhopi I	651518	2467879	12.2	78	8.73	254
37	Baruipur	Shankarpur II	646376	2466833	12.29	138	30.31	142
38	Baruipur	Surjapur	649819	2467696	14	600	19	276

No	Block	Village	X	Y	Depth (m)	As (ppb)	Iron (ppm)	Chloride (ppm)
39	Baruipur	Shakharipur	650699	2470451	14	510	7	199
40	Baruipur	Shakharipur	650701	2470274	14	470	15	197
41	Baruipur	Rana	649852	2469612	14	350	13	236
42	Baruipur	Rana	650107	2469891	14	320	11	249
43	Baruipur	Sitakundu	651486	2473227	14	250	6.6	154
44	Baruipur	Shakharipur	650790	2470640	14	200	21	189
45	Baruipur	Chandukhali	650534	2468423	14	190	4.6	305
46	Baruipur	Baliaghata	649153	2470591	14	110	6.1	269
47	Baruipur	Rana	650420	2469529	14	110	3.2	289
48	Baruipur	Shakharipur	650531	2470826	14	90	2.6	206
49	Baruipur	Shakharipur	650357	2470724	14	90	2.8	168
50	Baruipur	Shakharipur	650701	2470307	14	90	2	146
51	Baruipur	Kumarhat	649007	2468596	14	50	2	156
52	Baruipur	Rana	650191	2469715	14	30	2.7	289
53	Baruipur	Alampur	649023	2468043	14	20	3.4	186
54	Baruipur	Ramnagar	651562	2470736	15	320	9.9	152
55	Baruipur	Chandukhali	649862	2468605	15	220	8.8	263
56	Baruipur	Shakharipur	650615	2470638	15	210	6.1	182
57	Baruipur	Surjapur	650819	2467684	15	209	7.5	354
58	Baruipur	Rana	650023	2470079	15	180	4.7	146
59	Baruipur	Padmajola	651066	2468793	15	170	8	199
60	Baruipur	Kumarhat	649683	2468968	15	170	20	219
61	Baruipur	Rana	650026	2469802	15	150	4.2	193
62	Baruipur	Kumarhat	649522	2468601	15	150	5	196
63	Baruipur	Ramnagar	651388	2470646	15	130	5.8	165
64	Baruipur	Kumarhat	649604	2468691	15	130	5.4	156
65	Baruipur	Sitakundu	650849	2473043	15	130	6.3	218
66	Baruipur	Kumarhat	649343	2468987	15	110	2.5	199
67	Baruipur	Rana	650543	2469530	15	100	3.4	184
68	Baruipur	Rana	650109	2469714	15	90	3.1	510
69	Baruipur	Balbalia	650243	2466482	15	80	1.9	187
70	Baruipur	Rana	650368	2469584	15	70	1.5	512
71	Baruipur	Balbalia	650224	2466294	15	70	2.2	168
72	Baruipur	Balbalia	650141	2466393	15	70	2.9	189
73	Baruipur	Shankarpur II	648971	2464865	15.22	40	0.79	106
74	Baruipur	Kalyanpur	647453	2472822	15.24	660	10.2	168
75	Baruipur	Shankarpur II	648664	2464640	15.24	350	21.84	156
76	Baruipur	Shikharbali I	648714	2470177	15.24	280	12.88	153
77	Baruipur	Shikharbali I	648407	2469953	15.24	256	11.63	204
78	Baruipur	Shikharbali I	648192	2470836	15.24	243	2.4	168
79	Jaynagar I	Uttar Durgapur	648665	2453678	15.24	220	20.9	155
80	Baruipur	Ramnagar II	652013	2469877	15.24	200	20.49	199
81	Jaynagar I	Baharu	646687	2455653	15.24	170	6.3	204

No	Block	Village	X	Y	Depth (m)	As (ppb)	Iron (ppm)	Chloride (ppm)
82	Baruipur	Shikharbali I	648197	2470393	15.24	163	19.24	197
83	Baruipur	Ramnagar II	651910	2469876	15.24	155	21.4	301
84	Baruipur	Shikharbali I	648195	2470615	15.24	140	14.09	194
85	Baruipur	Ramnagar II	652219	2469879	15.24	138	11.54	225
86	Jaynagar I	Baharu	645864	2455534	15.24	130	3.3	145
87	Sonarpur	Kamrabad	641547	2476643	15.24	121	23.6	542
88	Jaynagar I	Narayani tala	651582	2461236	15.24	100	15.6	204
89	Jaynagar I	Dakshin Barasat	650975	2460123	15.24	80	8.7	158
90	Sonarpur	Kheyadaha I	653911	2486173	15.24	70	11.25	356
91	Jaynagar I	Baharu	651195	2458685	15.24	64	6.8	155
92	Bhangar II	Bhogabanpur	661553	2493449	15.24	47	3.05	225
93	Jaynagar I	Dakshin Barasat	649650	2458560	15.24	32	2.5	196
94	Baruipur	Dhopdhopi I	651617	2468212	15.44	117	10.26	179
95	Baruipur	Dhopdhopi I	651204	2468319	15.44	109	24.65	256
96	Baruipur	Rana	650543	2469619	16	520	18	710
97	Baruipur	Surjapur	650562	2467593	16	140	5	310
98	Baruipur	Baliaghata	649152	2470624	16	70	1.3	241
99	Baruipur	Surjapur	650592	2467682	16	50	3.8	301
100	Baruipur	Kalyanpur	647661	2472603	16.1	225	9.73	114
101	Baruipur	Rana	650419	2469606	17	220	23	283
102	Baruipur	Shakharipur	650696	2470827	17	90	2.1	215
103	Baruipur	Ratanpur	648986	2467577	17	80	2.3	197
104	Baruipur	Alampur	650166	2468065	17	20	1.3	192
105	Baruipur	Padmajola	651228	2469072	18	630	18	265
106	Baruipur	Surjapur	650622	2467781	18	510	17	269
107	Baruipur	Ramnagar	651212	2470721	18	406	13	190
108	Baruipur	Kumarhat	649170	2468775	18	180	6.5	195
109	Baruipur	Kumarhat	649520	2468878	18	170	6.5	106
110	Baruipur	Banberia	646776	2468077	18	90	4.7	86
111	Baruipur	Rana	650366	2469717	18	70	1.7	308
112	Baruipur	Banberia	647075	2468135	18	40	3.2	184
113	Baruipur	Bazarancha	652782	2474413	18	30	0.99	203
114	Baruipur	Padmajola	651418	2469616	18	20	4.2	225
115	Baruipur	Banberia	646962	2468079	18	20	3.9	137
116	Jaynagar I	Baharu	646587	2455320	18.19	80	3.8	169
117	Jaynagar I	Baharu	649950	2459448	18.24	29	2.9	157
118	Baruipur	Dhopdhopi I	651427	2466549	18.26	1060	44	237
119	Baruipur	Dhopdhopi I	651739	2466331	18.26	764	30.57	322
120	Bhangar II	Bhogaly II	665576	2492384	18.28	117	6.25	287
121	Baruipur	Dhopdhopi I	651843	2466221	18.29	753	36.2	305
122	Bhangar I	Narayanpur	662659	2486152	18.29	348	4.22	287
123	Baruipur	Dhopdhopi I	650884	2469423	18.29	335	20.02	455

No	Block	Village	X	Y	Depth (m)	As (ppb)	Iron (ppm)	Chloride (ppm)
124	Baruipur	Dhopdhopi I	652135	2467995	18.29	274	36.62	265
125	Bhangar II	Bhogaly II	666296	2492392	18.29	220	6.25	245
126	Baruipur	Shikharbali I	649849	2469966	18.29	216	3.78	153
127	Bhangar II	Bhogaly II	666090	2492500	18.29	215	12.72	265
128	Baruipur	Rana	651516	2467989	18.29	211	14.71	296
129	Baruipur	Rana	652749	2468334	18.29	201	21.66	196
130	Bhangar II	Polerhat II	661697	2499319	18.29	178	4.33	354
131	Jaynagar I	Uttar Durgapur	648656	2454675	18.29	150	13.7	186
132	Sonarpur	Langalberia	641856	2476645	18.29	150	13.72	326.71
133	Bhangar II	Bhogabanpur	661433	2495108	18.29	143	4.03	455
134	Baruipur	Shankarpur II	649678	2466311	18.29	142	15.85	167
135	Baruipur	Ramnagar I	652099	2471649	18.29	137	22.66	124
136	Sonarpur	Poleghat	647928	2476924	18.29	110	16.1	391.42
137	Baruipur	Motherat	652486	2474200	18.29	86	5.73	186
138	Sonarpur	Kamrabad	648887	2484241	18.29	70	3.65	246
139	Jaynagar I	Uttar Durgapur	648342	2455115	18.29	60	6.8	125
140	Sonarpur	Kamrabad	648787	2484018	18.29	56	15.02	304
141	Bhangar II	Chaltaberia	662402	2491021	18.29	40	6.32	357
142	Sonarpur	Kamrabad	647966	2483789	18.29	30	2.86	277
143	Baruipur	Surjapur	650725	2467782	19	610	19	205
144	Sonarpur	Pratapnagar	653962	2481079	19.82	50	12.92	409.47
145	Baruipur	Chandukhali	650823	2468315	20	610	21	302
146	Baruipur	Chandukhali	650792	2468292	20	570	18	341
147	Baruipur	Chandukhali	650813	2468337	20	530	16	275
148	Baruipur	Kumarhat	649297	2468433	20	210	11	203
149	Baruipur	Kumarhat	649685	2468780	20	130	3	100
150	Baruipur	Rana	649933	2469801	20	110	3.5	249
151	Baruipur	Shakharipur	650440	2470636	20	90	5.1	167
152	Baruipur	Ratanpur	649252	2467768	20	50	2.4	245
153	Baruipur	Chitra-Shali	652738	2472685	20	30	3.8	152
154	Baruipur	Ratanpur	648845	2467277	20	20	2	188
155	Baruipur	Kumarhat	649349	2468411	21	250	7.5	203
156	Baruipur	Rana	650286	2469528	21	230	6.4	316
157	Baruipur	Chandukhali	650036	2468783	21	210	9.2	391.24
158	Baruipur	Rana	650108	2469803	21	110	17	209
159	Baruipur	Sitakundu	651446	2473138	21	80	3.6	169
160	Baruipur	Shikarbali	647100	2469774	21	20	3.2	162
161	Sonarpur	Poleghat	647310	2477028	21.34	700	40.9	437.63
162	Baruipur	Hariharpur	647955	2474156	21.34	650	7.61	164
163	Baruipur	Mallikpur	649271	2476494	21.34	648	4.24	171
164	Baruipur	Hariharpur	647541	2474373	21.34	638	6.56	165
165	Baruipur	Dhopdhopi I	651637	2466219	21.34	481	29.07	214
166	Baruipur	Kalyanpur	647767	2472272	21.34	338	9.13	154

No	Block	Village	X	Y	Depth (m)	As (ppb)	Iron (ppm)	Chloride (ppm)
167	Bhangar I	Sanksahar	662575	2484379	21.34	303	3.43	268
168	Baruipur	Hariharpur	648050	2474932	21.34	291	7.24	188
169	Bhangar II	Bhogaly II	667839	2492409	21.34	280	5.73	422
170	Bhangar I	Durgapur	664787	2479641	21.34	276	3.05	256
171	Sonarpur	Langalberia	646189	2475800	21.34	270	11.29	399.06
172	Baruipur	Hariharpur	647747	2474375	21.34	250	5.39	141
173	Bhangar II	Shanpukur	662787	2493462	21.34	210	13.28	321
174	Jaynagar I	Baharu	646383	2455096	21.34	197	8.2	145
175	Baruipur	Shankarpur II	648630	2468183	21.34	170	2.64	156
176	Baruipur	Shankarpur I	648838	2467964	21.34	165	6.89	196
177	Sonarpur	Langalberia	646696	2476580	21.34	140	39.24	387.15
178	Baruipur	Kalyanpur	647454	2472712	21.34	120	12.11	130
179	Jaynagar I	Baharu	646173	2455537	21.34	120	4.4	185
180	Sonarpur	Langalberia	647011	2475918	21.34	120	8.35	343.21
181	Bhangar II	Shanpukur	663093	2493797	21.34	110	8.24	387
182	Bhangar II	Benota II	655279	2493384	21.34	64	8.29	269
183	Baruipur	Shikharbali I	648234	2466518	21.34	57	22.04	218
184	Sonarpur	Poleghat	647207	2477028	21.34	50	6.1	391.42
185	Sonarpur	Kalikapur II	655234	2477438	21.34	40	13.01	378
186	Sonarpur	Kheyadaha I	647848	2485338	21.34	14	0.57	328
187	Baruipur	Chandukhali	650813	2468337	22	652	20	455
188	Baruipur	Chandukhali	650293	2468786	22	600	20	236
189	Baruipur	Kumarhat	649349	2468411	22	90	1.9	183
190	Baruipur	Ratanpur	649047	2467667	22	80	2.5	199
191	Baruipur	Sitakundu	650343	2472186	22	50	25	265
192	Baruipur	Dhopdhopi I	651926	2468215	22.87	575	32.06	341
193	Baruipur	Ratanpur	649016	2467711	23	20	1.7	343
194	Baruipur	Surjapur	650459	2467647	24	1180	38	193
195	Baruipur	Sitakundu	651637	2471479	24	610	21	153
196	Baruipur	Sitakundu	651550	2471943	24	360	13	204
197	Baruipur	Chandukhali	650355	2468786	24	340	9.7	214
198	Baruipur	Sitakundu	651109	2472857	24	310	12	197
199	Baruipur	Chandukhali	650372	2469163	24	140	3.4	322
200	Baruipur	Sitakundu	651193	2472670	24	60	1.2	153
201	Baruipur	Uttar Bagh	653505	2473158	24	30	3.8	298
202	Baruipur	Chitra-Shali	652913	2472687	24	30	4.3	130
203	Baruipur	Shikharbali I	648024	2466849	24.34	153	30.29	265
204	Baruipur	Dhopdhopi II	651805	2470096	24.39	350	23.34	241
205	Baruipur	Dhopdhopi II	652422	2470213	24.39	255	22.47	269
206	Bhangar II	Shanpukur	663405	2493468	24.39	220	9.63	354
207	Baruipur	Shankarpur II	648139	2465632	24.39	151	0	199
208	Baruipur	Shikharbali I	649638	2470518	24.39	151	2.78	198
209	Bhangar II	Shanpukur	663299	2493688	24.39	150	8.33	316

No	Block	Village	X	Y	Depth (m)	As (ppb)	Iron (ppm)	Chloride (ppm)
210	Baruipur	Shankarpur II	648549	2465857	24.39	142	9.6	189
211	Baruipur	Dhopdhopi II	655237	2466808	24.39	103	9.8	263
212	Baruipur	Hariharpur	647845	2474819	24.39	67	3.4	169
213	Baruipur	Ramnagar I	651374	2472085	24.39	52	5.54	153
214	Bhangar II	Bhogabanpur	658342	2495630	24.39	50	5.01	415
215	Bhangar II	Polerhat II	661897	2499875	24.39	24	7.23	331
216	Baruipur	Padmajola	651405	2468896	26	400	15	203
217	Baruipur	Kumarhat	649086	2468962	26	170	5.1	114
218	Baruipur	Shankarpur II	652258	2465893	26.9	280	11.53	114
219	Baruipur	Balbalia	650222	2466571	27	380	12	224
220	Baruipur	Baliaghata	649329	2470437	27	120	5.7	264
221	Baruipur	Dhopdhopi II	652009	2470320	27.31	152	2.67	209
222	Bhangar II	Bhogaly II	666086	2492832	27.43	53	6.43	367
223	Baruipur	Dhopdhopi I	651714	2468877	27.44	293	26.86	275
224	Baruipur	Shankarpur II	652466	2465673	27.44	255	13.88	298
225	Baruipur	Shankarpur II	649148	2467856	27.44	249	0.14	219
226	Jaynagar I	Uttar Durgapur	649070	2454457	27.44	180	13.9	165
227	Baruipur	Hariharpur	648163	2473936	27.44	130	5.99	245
228	Sonarpur	Bonhooghly II	640364	2482168	27.44	100	31.73	369.87
229	Sonarpur	Kheyadaha II	648033	2487444	27.44	20	7.94	439.74
230	Baruipur	Padmajola	651398	2469627	28	280	9	196
231	Baruipur	Mirpur	648295	2467626	28	200	6.1	164
232	Baruipur	Chandukhali	650377	2468610	28	180	6.5	286
233	Baruipur	Mirpur	647986	2467656	28	120	2.4	182
234	Sonarpur	Langalberia	642180	2474988	28.05	20	22.2	411.73
235	Baruipur	Ramnagar	651046	2470831	30	850	28	154
236	Baruipur	Ramnagar	652598	2470104	30	690	24	100
237	Baruipur	Ramnagar	652630	2470016	30	520	17	100
238	Baruipur	Sitakundu	651050	2473577	30	510	17	198
239	Baruipur	Ramnagar	651284	2470733	30	271	9.1	186
240	Baruipur	Ramnagar	652357	2468441	30	210	8.3	105
241	Baruipur	Padmajola	651404	2468985	30	170	8.3	224
242	Baruipur	Padmajola	651062	2469170	30	140	5.6	256
243	Baruipur	Sitakundu	651024	2473045	30	90	2.7	179
244	Baruipur	Ramnagar	652765	2469917	30	50	3.4	251
245	Baruipur	Sitakundu	651447	2473049	30	40	3.3	193
246	Baruipur	Chitra-Shali	652737	2472785	30	30	3.1	114
247	Baruipur	Chitra-Shali	652571	2472872	30	30	3.8	146
248	Baruipur	Mirpur	647986	2467656	30	20	1.9	197
249	Baruipur	Mirpur	648326	2467660	30	20	4.7	169
250	Baruipur	Alampur	649866	2468173	30	20	2.3	212
251	Bhangar I	Sanksahar	664415	2485506	30.48	364	3.73	244
252	Baruipur	Motherat	650852	2472744	30.48	313	3.57	203

No	Block	Village	X	Y	Depth (m)	As (ppb)	Iron (ppm)	Chloride (ppm)
253	Bhangar I	Durgapur	664454	2481852	30.48	281	6.03	267
254	Bhangar II	Bhogali I	669991	2493207	30.48	264	14.03	365
255	Bhangar I	Sanksahar	663182	2485382	30.48	231	3.82	276
256	Baruipur	Motherat	652072	2474417	30.48	229	23.28	212
257	Bhangar II	Bhogali I	669575	2493646	30.48	210	3.11	378
258	Bhangar II	Bhogali I	669989	2493429	30.48	206	15.25	301
259	Bhangar II	Polerhat I	662536	2497778	30.48	190	7.33	196
260	Bhangar II	Bhogabanpur	660303	2494986	30.48	184	4.03	367
261	Bhangar II	Polerhat II	662106	2499545	30.48	180	4.02	367
262	Bhangar II	Shanpukur	662585	2493127	30.48	170	6.85	364
263	Bhangar I	Narayanpur	660077	2487010	30.48	148	13.59	403
264	Bhangar II	Bhogabanpur	660298	2495429	30.48	131	4.22	421
265	Bhangar II	Benota II	657948	2493965	30.48	120	14.69	325
266	Bhangar II	Benota II	658980	2493643	30.48	117	4.84	256
267	Bhangar I	Sanksahar	663069	2486267	30.48	116	6.83	245
268	Bhangar II	Bhogaly II	666291	2492945	30.48	95	5.83	322
269	Bhangar II	Shanpukur	663704	2494357	30.48	92	6.62	341
270	Bhangar II	Bhogabanpur	660509	2494988	30.48	91	4.19	469
271	Bhangar II	Benota II	656720	2493288	30.48	87	4.69	258
272	Bhangar II	Chaltaberia	660539	2492109	30.48	78	13.72	339
273	Bhangar II	Benota II	653017	2493361	30.48	70	16.28	236
274	Bhangar II	Benota II	657654	2492522	30.48	67	4.72	254
275	Bhangar II	Bhogabanpur	660407	2494876	30.48	66	6.42	428
276	Bhangar II	Bhogabanpur	659359	2496748	30.48	64	3.03	367
277	Bhangar II	Chaltaberia	661885	2491237	30.48	55	5.05	369
278	Bhangar II	Bhogaly II	666500	2492615	30.48	54	6.29	312
279	Bhangar II	Bhogabanpur	655365	2495046	30.48	30	12.35	245
280	Jaynagar I	Khakurdaha	654659	2462816	30.48	30	3.8	205
281	Bhangar II	Benota II	656206	2493282	30.48	14	3.87	354
282	Baruipur	Dhopdhopi II	652832	2470438	30.49	740	4.25	289
283	Baruipur	Madarat	651162	2472637	30.49	560	34.44	84
284	Baruipur	Dhopdhopi I	651402	2469206	30.49	550	22.32	276
285	Baruipur	Dhopdhopi II	650354	2470968	30.49	520	11.12	249
286	Sonarpur	Poleghat	646789	2477577	30.49	520	42.2	409.21
287	Sonarpur	Poleghat	641318	2479187	30.49	440	25.2	386
288	Baruipur	Dhopdhopi II	655439	2467253	30.49	428	15	236
289	Baruipur	Dhopdhopi I	652038	2467330	30.49	412	22.54	234
290	Baruipur	Dhopdhopi I	652548	2467889	30.49	357	23.26	203
291	Baruipur	Shankarpur II	648137	2465853	30.49	310	13.1	182
292	Baruipur	Motherat	652075	2474085	30.49	237	2.52	197
293	Baruipur	Hariharpur	649480	2476163	30.49	220	18.21	173
294	Sonarpur	Poleghat	643068	2479203	30.49	220	13.3	411.09
295	Baruipur	Ramnagar I	651887	2472201	30.49	215	27.65	156

No	Block	Village	X	Y	Depth (m)	As (ppb)	Iron (ppm)	Chloride (ppm)
296	Jaynagar I	Baharu	646994	2455877	30.49	210	7.5	122
297	Baruipur	Hariharpur	647332	2474703	30.49	192	1.7	197
298	Baruipur	Shankarpur II	648139	2465632	30.49	188	11.5	215
299	Baruipur	Motherat	650540	2473073	30.49	187	1.53	192
300	Baruipur	Ramnagar I	656322	2471691	30.49	170	21.56	165
301	Baruipur	Hariharpur	647235	2474038	30.49	164	1.41	162
302	Baruipur	Shankarpur II	649474	2466087	30.49	155	16.7	146
303	Baruipur	Motherat	652281	2474087	30.49	151	7.67	86
304	Baruipur	Madarat	651564	2473637	30.49	150	3.28	126
305	Jaynagar I	Dakshin Barasat	650155	2459561	30.49	150	15.6	168
306	Baruipur	Hariharpur	648151	2475154	30.49	132	6.03	197
307	Baruipur	Kalyanpur	644567	2473017	30.49	111	12.2	179
308	Baruipur	Ramnagar II	651102	2468207	30.49	108	11.9	205
309	Baruipur	Ramnagar II	651496	2470093	30.49	93	6.49	199
310	Sonarpur	Bonhooghly-I	644183	2481096	30.49	80	11.21	341
311	Sonarpur	Kamrabad	648882	2484794	30.49	80	19.1	410
312	Jaynagar I	Dakshin Barasat	651297	2458797	30.49	66	6.2	187
313	Baruipur	Ramnagar I	653225	2472325	30.49	57	16.41	100
314	Sonarpur	Kalikapur II	655120	2478544	30.49	50	11.25	415
315	Sonarpur	Kheyadaha I	654863	2483635	30.49	50	18.96	341
316	Sonarpur	Kheyadaha II	647528	2486442	30.49	50	10.9	354
317	Baruipur	Begumpur	650213	2474953	30.49	49	10.52	100
318	Sonarpur	Bonhooghly II	640372	2481282	30.49	40	13.44	391.08
319	Sonarpur	Kalikapur II	654508	2477985	30.49	30	12.54	449
320	Sonarpur	Kamrabad	647853	2484785	30.49	30	8.4	440
321	Sonarpur	Kheyadaha I	654936	2486626	30.49	30	12.65	347
322	Sonarpur	Bonhooghly-I	642963	2479424	30.49	20	2.17	376.04
323	Baruipur	Begumpur	652275	2474641	30.49	12	3.42	105
324	Sonarpur	Poleghat	641117	2478632	30.5	80	9.5	354
325	Baruipur	Chandukhali	650556	2468235	31	240	9.8	348
326	Baruipur	Chandukhali	650425	2468975	31	190	5	237
327	Baruipur	Surjapur	650823	2467296	32	740	24	296
328	Bhangar I	Pranganj	663272	2486601	32.53	90	14.33	357
329	Sonarpur	Bonhooghly II	640982	2482174	32.62	72	39.95	409.63
330	Baruipur	Mirpur	648152	2467481	33	290	12	191
331	Baruipur	Padmajola	651066	2468793	33	270	9.4	234
332	Bhangar II	Benota II	653938	2493813	33.53	65	4.83	329
333	Sonarpur	Poleghat	641004	2479738	33.54	2400	82	364
334	Baruipur	Hariharpur	648061	2473825	33.54	74	6.6	213
335	Baruipur	Motherat	650529	2474181	33.54	47	9.97	137
336	Baruipur	Sitakundu	651187	2473224	34	580	21	110
337	Baruipur	Chandukhali	649855	2469335	34	440	14	411.93

No	Block	Village	X	Y	Depth (m)	As (ppb)	Iron (ppm)	Chloride (ppm)
338	Baruipur	Ramnagar	652766	2469829	34	360	13	1011
339	Baruipur	Ramnagar	652353	2468806	34	110	5.2	423
340	Baruipur	Ramnagar	652262	2468628	34	110	6	205
341	Baruipur	Dudhnai	650536	2470305	34	50	4.4	84
342	Baruipur	Bazarancha	652741	2474424	34	30	3.6	197
343	Baruipur	Nabagram	657027	2463061	34.88	48	2.27	203
344	Baruipur	Nabagram	655248	2465701	34.88	40	1.18	203
345	Bhangar II	Bhogaly II	668552	2493081	36.5	184	3.49	451
346	Baruipur	Dhopdhopi II	655229	2467694	36.58	2320	43	286
347	Baruipur	Dhopdhopi II	652529	2469771	36.58	920	26.06	193
348	Baruipur	Dhopdhopi II	651492	2470536	36.58	810	2.4	264
349	Baruipur	Dhopdhopi II	652940	2469886	36.58	810	5.122	502
350	Baruipur	Shankarpur II	651435	2465774	36.58	560	5.8	183
351	Baruipur	Dhopdhopi II	652731	2470216	36.58	430	9.68	184
352	Bhangar II	Polerhat I	663965	2498789	36.58	280	12.75	215
353	Bhangar II	Bhogabanpur	660506	2495209	36.58	244	5.04	421
354	Baruipur	Dhopdhopi I	652948	2469111	36.58	238	20.3	193
355	Baruipur	Shankarpur II	649480	2465534	36.58	218	11.86	168
356	Baruipur	Shankarpur II	649666	2467529	36.58	210	47.9	197
357	Baruipur	Dhopdhopi I	652224	2469436	36.58	196	12.07	302
358	Bhangar II	Bhogali I	667914	2494956	36.58	120	12.46	414
359	Bhangar II	Bhogaly II	666391	2493168	36.58	120	3.23	421
360	Baruipur	Shankarpur II	649046	2467744	36.58	117	2.38	195
361	Bhangar II	Benota II	653937	2493924	36.58	103	17.22	369
362	Bhangar II	Benota II	657245	2492296	36.58	103	16.82	247
363	Baruipur	Dhopdhopi II	652551	2467557	36.58	95	9.9	252
364	Bhangar II	Polerhat I	661814	2497991	36.58	95	11.13	305
365	Bhangar II	Polerhat I	660588	2497203	36.58	93	6.22	398
366	Bhangar II	Polerhat I	660491	2496649	36.58	88	6.52	327
367	Baruipur	Dhopdhopi II	655745	2467588	36.58	79	7.9	307
368	Bhangar II	Polerhat I	661914	2498214	36.58	58	5.84	299
369	Bhangar II	Bhogabanpur	659785	2495313	36.58	54	6.22	458
370	Bhangar I	Chandaneswar II	659908	2483465	36.58	53	5.32	215
371	Bhangar II	Polerhat II	661477	2500646	36.58	52	4.42	315
372	Bhangar II	Bamanghata	652524	2491142	36.58	29	6.21	419
373	Bhangar II	Polerhat II	661579	2500757	36.58	26	4.64	346
374	Baruipur	Dhopdhopi II	654313	2466467	36.58	20	1.2	354
375	Baruipur	Ramnagar	652783	2471246	37	810	26	156
376	Baruipur	Padmajola	651490	2468620	37	630	20	179
377	Baruipur	Surjapur	650456	2467891	37	525	17	302
378	Baruipur	Ramnagar	651729	2470505	37	390	14	172
379	Baruipur	Ramnagar	652089	2469545	37	310	9.3	153

No	Block	Village	X	Y	Depth (m)	As (ppb)	Iron (ppm)	Chloride (ppm)
380	Baruipur	Sitakundu	651024	2473045	37	240	8	194
381	Baruipur	Sherpur	651077	2467598	37	150	5.9	126
382	Baruipur	Bhatpowa	651502	2467414	37	133	3.4	141
383	Baruipur	Padmajola	651250	2468928	37	130	4.4	301
384	Baruipur	Ramnagar	652181	2468527	37	100	5.1	554
385	Baruipur	Sherpur	651243	2467522	37	50	3.2	156
386	Baruipur	Uttar Bagh	653597	2473247	37	30	3.8	114
387	Bhangar II	Polerhat I	662339	2497000	37.19	145	7.52	246
388	Bhangar II	Chaltaberia	660435	2492219	37.19	90	13.81	367
389	Bhangar I	Durgapur	664066	2479633	38.48	381	4.03	309
390	Baruipur	Chandukhali	650460	2468610	39	470	14	307
391	Bhangar I	Narayanpur	660388	2486792	39.36	150	13.6	299
392	Baruipur	Shankarpur II	647721	2466292	39.42	80	16.2	206
393	Bhangar II	Bamanghata	652847	2489705	39.63	68	7.33	391.44
394	Baruipur	Ramnagar	652088	2469634	40	553	17	105
395	Baruipur	Surjapur	650456	2467946	40	245	9	365
396	Baruipur	Ramnagar	652768	2469552	40	130	3.1	163
397	Baruipur	Ramnagar	653285	2469369	40	30	2	175
398	Jaynagar I	Uttar Durgapur	647327	2453444	40.39	90	9.2	169
399	Bhangar I	Durgapur	664168	2479745	42.58	611	5.04	214
400	Baruipur	Dhopdhopi I	652636	2469440	42.68	472	27.8	365
401	Bhangar I	Chandaneswar II	658674	2483342	42.68	119	2.62	302
402	Baruipur	Ramnagar	652941	2469819	43	290	9.1	165
403	Baruipur	Ramnagar	652249	2469968	43	260	9.2	124
404	Baruipur	Ramnagar	653270	2470908	43	240	9	210
405	Baruipur	Uttar Bagh	655019	2471102	43	235	9.6	142
406	Baruipur	Ramnagar	656200	2470472	43	133	3.5	196
407	Baruipur	Surjapur	650365	2467757	44	350	11	256
408	Baruipur	Chandukhali	650377	2468610	45	240	7.8	254
409	Baruipur	Hariharpur	648358	2475045	45.73	420	28.92	199
410	Bhangar I	Sanksahar	663798	2485499	45.73	384	5.22	257
411	Baruipur	Dhopdhopi I	652228	2468993	45.73	261	28.24	256
412	Bhangar II	Bhogali I	668535	2494631	45.73	250	4.01	154
413	Bhangar I	Sanksahar	665027	2486066	45.73	174	5.84	255
414	Bhangar I	Narayanpur	662763	2486042	45.73	131	7.55	267
415	Bhangar II	Polerhat I	662322	2498550	45.73	130	13.26	265
416	Bhangar I	Durgapur	664353	2481740	45.73	96	4.21	285
417	Bhangar II	Polerhat I	664069	2498680	45.73	94	5.27	267
418	Bhangar II	Bhogabanpur	659170	2495085	45.73	80	3.05	419
419	Bhangar II	Polerhat I	660691	2497204	45.73	78	23.52	269
420	Bhangar II	Bhogali I	670291	2493986	45.73	75	2.71	367
421	Bhangar II	Polerhat II	661799	2499431	45.73	74	4.84	346

No	Block	Village	X	Y	Depth (m)	As (ppb)	Iron (ppm)	Chloride (ppm)
422	Bhangar II	Bhogali I	666582	2494499	45.73	73	4.03	558
423	Bhangar II	Bhogali I	668643	2494189	45.73	71	3.25	442
424	Bhangar I	Bodra	667403	2485206	45.73	65	2.81	167
425	Bhangar I	Chandaneswar I	662714	2480948	45.73	58	3.02	213
426	Bhangar II	Benota II	654458	2493265	45.73	58	5.07	354
427	Bhangar II	Bhogali I	667176	2496609	45.73	20	5.05	226
428	Bhangar II	Bhogali I	666369	2495161	45.73	17	5.01	367
429	Baruipur	Ramnagar	653200	2469645	46	20	1	900
430	Bhangar I	Sanksahar	661547	2484257	49.73	474	6.82	458
431	Bhangar I	Sanksahar	664929	2485622	49.73	130	5.68	425
432	Sonarpur	Bonhooghly II	641084	2482285	50	100	37.61	467.07
433	Baruipur	Dhopdhopi II	650767	2470861	51.82	552	11.08	510
434	Bhangar II	Bamanghata	652748	2489372	51.82	66	3.5	367.96
435	Bhangar I	Pranganj	663458	2488486	52.43	630	6.3	189
436	Bhangar I	Sanksahar	663082	2485049	52.43	310	3.95	421
437	Bhangar I	Tardaha	658732	2487772	54.87	369	16.29	425
438	Bhangar I	Sanksahar	661758	2483706	54.87	188	4.16	126
439	Bhangar II	Benota I	658692	2491647	54.87	181	16.24	545
440	Bhangar II	Bamanghata	652730	2491144	54.87	62	3.56	561
441	Baruipur	Padmajola	650962	2468848	55	271	7.4	196
442	Bhangar I	Jagulgachi	665837	2487293	57.92	74	16.82	248
443	Baruipur	Kalabaru	658742	2470752	59	164	5.7	186
444	Bhangar I	Durgapur	665074	2481637	60.67	697	5.22	297
445	Bhangar I	Sanksahar	663171	2486379	60.97	673	13.82	256
446	Jaynagar I	Baharu	646684	2455985	60.97	300	9.8	153
447	Bhangar I	Pranganj	664698	2487945	60.97	186	4.54	348
448	Bhangar II	Bhogaly II	667516	2493734	60.97	170	2.44	266
449	Bhangar II	Chaltaberia	661472	2491344	60.97	110	5.02	299
450	Bhangar II	Benota II	656922	2493733	60.97	67	4.69	336
451	Bhangar II	Bhogali I	667608	2494731	60.97	65	3.05	462
452	Bhangar I	Jagulgachi	665823	2488622	60.97	16	6.32	169
453	Baruipur	Bazarancha	653009	2474448	61	440	16	210
454	Baruipur	Chandukhali	650374	2468975	61	280	9.6	252
455	Baruipur	Ramnagar	651909	2470009	61	20	3.4	214
456	Bhangar I	Chandaneswar II	658472	2483008	62.19	14	1.69	345
457	Baruipur	Ramnagar	653121	2469279	65	20	1.7	171
458	Baruipur	Dhopdhopi II	650262	2469860	68.59	289	5.54	283
459	Sonarpur	Poleghat	643790	2478988	70.12	770	23.32	456
460	Bhangar II	Polerhat I	661103	2497098	70.12	78	5.93	249
461	Bhangar II	Polerhat I	662438	2497334	71.21	83	14.72	287
462	Sonarpur	Poleghat	645347	2477674	71.95	480	44.38	419.76
463	Sonarpur	Poleghat	645659	2477345	71.95	220	13.9	341.22

No	Block	Village	X	Y	Depth (m)	As (ppb)	Iron (ppm)	Chloride (ppm)
464	Bhangar II	Bhogaly II	667623	2493403	76.21	650	13.27	298
465	Bhangar I	Sanksahar	661860	2483818	76.21	616	13.82	145
466	Bhangar II	Bhogaly II	668240	2493410	76.21	490	13.54	356
467	Bhangar II	Bhogali I	668843	2494745	76.21	270	3.24	455
468	Bhangar II	Bhogali I	668745	2494301	76.21	251	5.41	229
469	Bhangar II	Bhogali I	666888	2494724	76.21	250	12.54	448
470	Bhangar II	Polerhat I	661205	2497210	76.21	240	13.52	273
471	Bhangar I	Narayanpur	660080	2486789	76.21	163	3.93	276
472	Bhangar II	Benota I	658593	2491203	76.21	107	7.22	541
473	Bhangar II	Bamanghata	652626	2491253	76.21	97	13.26	487
474	Bhangar II	Benota I	658489	2491313	76.21	71	4.53	412
475	Bhangar II	Bhogabanpur	661657	2493339	76.21	68	6.02	336
476	Bhangar I	Pranganj	665825	2488400	76.21	63	3.85	279
477	Bhangar I	Tardaha	656581	2486753	76.21	30	15.33	355
478	Bhangar II	Benota I	656744	2490963	76.21	30	13.22	569
479	Bhangar II	Benota I	657044	2491852	76.21	20	15.22	542
480	Bhangar II	Chaltaberia	662309	2490024	76.21	20	5.02	296
481	Bhangar II	Bhogabanpur	653850	2492262	76.21	18	3.02	259
482	Bhangar II	Benota I	658911	2490320	76.21	16	4.84	458
483	Bhangar II	Benota II	655682	2494274	76.21	14	2.98	263
484	Bhangar I	Pranganj	665539	2486293	76.21	12	3.53	587
485	Sonarpur	Langalberia	645771	2476350	76.22	880	30.93	403.87
486	Baruipur	Dhopdhopi II	652245	2467221	76.22	730	23.9	391.24
487	Baruipur	Kalyanpur	647549	2473488	76.22	360	2.99	187
488	Baruipur	Dhopdhopi II	650881	2469755	76.22	274	5.09	249
489	Baruipur	Dhopdhopi I	650810	2466432	76.22	227	11.02	348
490	Baruipur	Dhopdhopi II	652760	2467227	76.22	220	16.1	411.93
491	Sonarpur	Langalberia	645145	2477230	76.22	140	19.1	450
492	Baruipur	Hariharpur	647643	2474485	76.22	125	4.8	191
493	Baruipur	Dhopdhopi I	651401	2469317	76.22	119	17.8	302
494	Jaynagar I	Khakurdaha	652597	2462907	76.22	60	5.4	174
495	Baruipur	South Garia	653896	2477425	76.22	56	31.29	423
496	Sonarpur	Kalikapur I	656342	2479885	76.22	30	7.15	391.84
497	Sonarpur	Kalikapur I	655408	2480651	76.22	30	10.1	391.43
498	Sonarpur	Kalikapur I	654282	2479975	76.22	30	10.2	391.43
499	Sonarpur	Langalberia	644126	2476113	76.22	29	2.61	411.06
500	Sonarpur	Kalikapur I	655404	2480983	76.22	20	3.9	379.89
501	Sonarpur	Langalberia	641130	2477192	76.22	20	3.2	344.63
502	Sonarpur	Kalikapur I	653258	2479412	76.22	13	3.01	418
503	Baruipur	Champahati	655551	2476666	76.22	12	4.07	1011
504	Bhangar II	Benota I	658590	2491535	76.26	89	3.63	475
505	Bhangar I	Pranganj	663552	2489262	79.26	167	14.52	444
506	Bhangar I	Tardaha	659132	2488883	82.31	220	15.02	361

No	Block	Village	X	Y	Depth (m)	As (ppb)	Iron (ppm)	Chloride (ppm)
507	Bhangar I	Durgapur	664864	2482078	82.31	180	13.02	254
508	Bhangar I	Tardaha	659030	2488771	82.31	74	7.06	354
509	Bhangar I	Pranganj	665020	2486730	82.31	64	6.71	298
510	Bhangar II	Benota II	658881	2493199	82.41	46	6.92	544
511	Bhangar I	Narayanpur	662865	2486154	85.36	380	23.43	193
512	Bhangar I	Narayanpur	662133	2487253	85.36	280	15.84	265
513	Bhangar II	Polerhat II	663124	2500552	85.36	123	7.22	319
514	Bhangar I	Pranganj	664601	2487390	85.36	114	4.53	367
515	Bhangar I	Bodra	664740	2484070	85.36	112	2.85	301
516	Bhangar I	Pranganj	665918	2489287	85.36	62	8.14	267
517	Bhangar I	Pranganj	663970	2488712	85.36	62	14.22	408
518	Bhangar I	Pranganj	664322	2484619	85.85	36	5.37	566
519	Baruipur	Ramnagar	651722	2471236	87	20	3.2	153
520	Bhangar I	Sanksahar	662985	2484494	88.41	420	14.33	233
521	Sonarpur	Langalberia	641050	2474645	89.63	30	11.74	396.93
522	Bhangar II	Bhogabanpur	659995	2494872	91.46	762	5.01	435
523	Bhangar I	Pranganj	662950	2487816	91.46	747	5.42	265
524	Bhangar I	Pranganj	663567	2487822	91.46	736	13.26	367
525	Baruipur	Motherat	651163	2472526	91.46	563	22.53	210
526	Bhangar I	Bodra	666584	2484865	91.46	527	15.13	245
527	Bhangar I	Pranganj	663776	2487603	91.46	407	4.54	359
528	Bhangar I	Sanksahar	661857	2484150	91.46	390	5.82	287
529	Bhangar II	Bhogali I	670808	2493770	91.46	372	13.25	265
530	Bhangar I	Bodra	665149	2484296	91.46	370	8.82	216
531	Bhangar I	Sanksahar	662265	2484486	91.46	370	4.52	215
532	Bhangar II	Bhogali I	670495	2494099	91.46	370	3.22	369
533	Bhangar I	Pranganj	666030	2488513	91.46	330	25.32	298
534	Bhangar I	Bodra	664951	2483518	91.46	281	2.81	269
535	Bhangar II	Bhogali I	669887	2493317	91.46	255	13.09	301
536	Bhangar II	Bhogaly II	668555	2492859	91.46	250	13.02	276
537	Bhangar I	Sanksahar	665033	2485512	91.46	220	3.02	239
538	Bhangar I	Pranganj	664801	2487946	91.46	203	23.82	459
539	Bhangar I	Pranganj	664186	2487718	91.46	197	6.22	185
540	Bhangar I	Pranganj	665929	2488291	91.46	187	5.32	366
541	Bhangar I	Bodra	667607	2485429	91.46	170	3.42	195
542	Bhangar II	Bhogali I	668239	2493520	91.46	170	4.22	249
543	Bhangar I	Bodra	665047	2484184	91.46	134	3.26	254
544	Bhangar II	Bhogali I	670192	2493653	91.46	134	2.32	269
545	Bhangar I	Sanksahar	661651	2484148	91.46	132	5.54	357
546	Bhangar I	Pranganj	666024	2489067	91.46	120	5.92	361
547	Bhangar II	Polerhat II	661577	2500979	91.46	120	5.47	297
548	Bhangar I	Pranganj	665920	2489176	91.46	111	4.61	378
549	Bhangar I	Sanksahar	662481	2483492	91.46	100	2.35	256

No	Block	Village	X	Y	Depth (m)	As (ppb)	Iron (ppm)	Chloride (ppm)
550	Bhangar I	Chandaneswar I	662611	2480947	91.46	90	6.52	225
551	Bhangar I	Chandaneswar I	663225	2481285	91.46	86	2.39	197
552	Bhangar I	Jagulgachi	665112	2487728	91.46	81	14.03	165
553	Bhangar I	Jagulgachi	665935	2487737	91.46	80	4.52	258
554	Bhangar I	Narayanpur	662029	2487363	91.46	80	13.42	239
555	Bhangar I	Jagulgachi	668094	2487982	91.46	66	3.75	369
556	Bhangar I	Narayanpur	660181	2486901	91.46	66	5.84	266
557	Bhangar I	Chandaneswar II	658574	2483119	91.46	64	1.82	314
558	Bhangar II	Bamanghata	652832	2491255	91.46	61	3.53	544
559	Bhangar I	Durgapur	665075	2481526	91.46	60	1.03	341
560	Bhangar II	Polerhat I	661919	2497771	91.46	59	5.41	367
561	Bhangar I	Bodra	665657	2484855	91.46	53	6.03	193
562	Bhangar II	Bhogali I	666265	2495271	91.46	53	12.36	198
563	Bhangar II	Bhogabanpur	661449	2493558	91.46	33	4.02	129
564	Bhangar II	Chaltaberia	662409	2490357	91.46	30	13.25	354
565	Bhangar I	Bodra	669758	2486339	91.46	26	2.82	136
566	Bhangar I	Chandaneswar I	658583	2482234	91.46	24	1.84	164
567	Bhangar I	Pranganj	668297	2488205	91.46	24	2.55	287
568	Bhangar II	Shanpukur	663111	2492025	91.46	20	0.14	398
569	Bhangar I	Pranganj	663876	2487826	91.46	14	2.63	249
570	Bhangar I	Jagulgachi	666130	2488736	91.46	13	5.82	249
571	Bhangar II	Polerhat II	663121	2500774	91.95	130	6.32	349
572	Bhangar I	Jagulgachi	668612	2487655	91.95	106	5.83	268
573	Bhangar I	Bodra	665462	2483856	91.95	32	3.13	215
574	Bhangar II	Bhogali I	670193	2493542	92.43	230	3.06	345
575	Bhangar II	Bhogali I	671115	2493884	92.43	130	4.03	264
576	Sonarpur	Kalikapur II	653986	2478644	92.68	40	13.5	396.47
577	Sonarpur	Kalikapur II	653883	2478643	92.68	40	12.71	416
578	Sonarpur	Kalikapur II	653369	2478638	92.68	30	13.51	425
579	Bhangar I	Jagulgachi	666758	2487746	95.85	310	12.65	159
580	Bhangar II	Shanpukur	662272	2493567	95.85	193	13.05	354
581	Bhangar II	Bhogali I	669051	2494526	95.85	130	5.01	228
582	Bhangar II	Polerhat I	662222	2498328	96.47	86	3.73	245
583	Bhangar II	Bhogaly II	668032	2493629	96.7	710	9.31	345
584	Bhangar II	Bhogali I	669056	2494083	96.7	280	16.21	364
585	Bhangar II	Bhogali I	669884	2493538	96.7	275	5.25	299
586	Bhangar I	Chandaneswar I	663121	2481395	96.7	156	4.04	206
587	Bhangar I	Jagulgachi	666761	2487524	96.7	146	6.37	289
588	Bhangar I	Pranganj	664690	2488720	96.7	129	7.22	398
589	Bhangar II	Bhogabanpur	659451	2497745	96.7	78	3.05	354

No	Block	Village	X	Y	Depth (m)	As (ppb)	Iron (ppm)	Chloride (ppm)
590	Bhangar I	Chandaneswar I	659709	2482799	96.7	26	1.73	156
591	Bhangar I	Chandaneswar I	663429	2481509	97.19	340	6.28	265
592	Bhangar I	Pranganj	664909	2487504	97.56	818	15.83	387
593	Bhangar I	Bodra	666280	2484418	97.56	160	4.53	149
594	Bhangar II	Polerhat I	660901	2496764	97.56	102	3.27	376
595	Bhangar I	Chandaneswar I	663327	2481397	97.56	100	4.35	241
596	Bhangar II	Polerhat II	663020	2500662	97.56	99	5.03	371
597	Bhangar I	Pranganj	664076	2488381	97.56	82	8.14	367
598	Bhangar I	Pranganj	663657	2489041	97.56	73	13.52	286
599	Bhangar II	Chaltaberia	660860	2490894	97.56	30	5.25	256

3. Data for Deep tubewell used for prediction

The data was organized according to the depth of the tubewells.

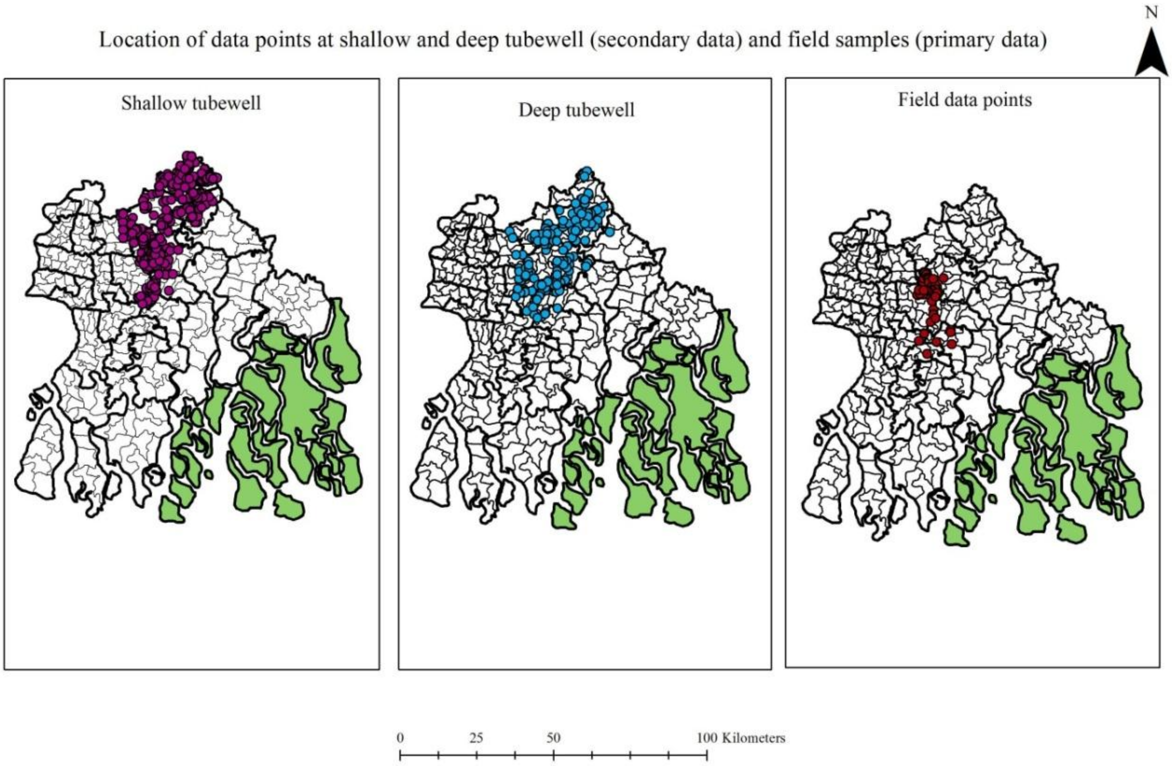
No	Block name	GP	X	Y	Depth (m)	As (ppb)
1	Bhangar II	Polerhat II	664253	2500675	106.7	10
2	Bhangar II	Shanpukur	662703	2491689	106.7	98
3	Bhangar II	Shanpukur	664548	2492373	106.7	25
4	Baruipur	Chani	659865	2472735	107	102
5	Bhangar I	Bodra	667706	2485760	120	1
6	Bhangar I	Tardaha	655335	2487850	120	2
7	Bhangar I	Chandaneswar II	656420	2482320	120	2
8	Bhangar I	Chandaneswar II	656409	2483430	120	3
9	Bhangar I	Durgapur	660583	2477940	120	3
10	Bhangar I	Durgapur	663672	2477970	120	3
11	Bhangar I	Bodra	668723	2486880	120	4
12	Bhangar I	Narayanpur	658467	2483450	120	4
13	Bhangar I	Narayanpur	659462	2486780	120	4
14	Bhangar I	Jagulgacchi	669728	2489110	120	4
15	Bhangar I	Bodra	667730	2483550	120	10
16	Bhangar I	Jagulgacchi	667682	2487980	120	10
17	Bhangar I	Jagulgacchi	665636	2486850	120	12
18	Bhangar I	Chandaneswar I	659519	2481250	120	26
19	Bhangar I	Tardaha	656398	2484540	120	30
20	Bhangar I	Bodra	667718	2484660	120	30
21	Bhangar I	Pranganj	664607	2486840	120	30
22	Bhangar I	Pranganj	664631	2484620	120	40
23	Bhangar I	Bodra	666713	2482430	120	60
24	Bhangar I	Chandaneswar I	659542	2479030	120	90
25	Bhangar I	Shanksahar	661578	2481270	120	10
26	Bhangar I	Bodra	664654	2482410	120	16
27	Bhangar I	Pranganj	662537	2487920	120	16
28	Bhangar I	Bodra	665672	2483530	120	17
29	Bhangar I	Narayanpur	661509	2487910	120	28
30	Bhangar I	Jagulgacchi	664619	2485730	120	31
31	Bhangar I	Narayanpur	660514	2484580	120	30
32	Bhangar I	Shanksahar	661567	2482380	120	40
33	Bhangar I	Shanksahar	660549	2481260	120	52
34	Bhangar I	Bodra	663613	2483500	120	53
35	Bhangar I	Pranganj	662549	2486820	120	82
36	Bhangar II	Chaltaberiya	660457	2490120	120	90
37	Bhangar II	Polerhat II	663449	2499010	120	130
38	Bhangar II	Shanpukur	663543	2490150	120	25
39	Bhangar II	Shanpukur	663531	2491250	120	12

No	Block name	GP	X	Y	Depth (m)	As (ppb)
40	Sonarpur	Kalikapur I	650288	2477830	137.2	26
41	Sonarpur	Kheyadaha I	655335	2487850	146.34	5
42	Sonarpur	Pratapnagar	651285	2481160	152.44	13
43	Sonarpur	Sonarpur II	651328	2476740	152.44	31
44	Bhangar II	Shanpukur	664853	2492708	176.7	25
45	Baruipur	Brindakhali	654505	2467910	225.61	2
46	Baruipur	Begumpur	650935	2474849	243.9	4
47	Bhangar II	Shanpukur	664742	2493482	243.9	12
48	Baruipur	Belegachia	664470	2470668	246.95	2
49	Canning I	Sarangabad	671672	2480823	248	0
50	Magrahat II	Dhamua north	644318	2466592	248	10
51	Magrahat II	Dhamua north	643284	2466915	248	0
52	Magrahat II	Dhamua south	642788	2464807	248	20
53	Magrahat II	Dhamua south	641958	2465463	248	10
54	Magrahat II	Dhanpota	644631	2454969	248	0
55	Magrahat II	Dihikalas	641483	2461030	248	0
56	Magrahat II	Dihikalas	641485	2460809	248	50
57	Magrahat II	Gokorne	646117	2461516	248	0
58	Magrahat II	Gokorne	643638	2462046	248	220
59	Magrahat II	Gokorne	643752	2460940	248	0
60	Magrahat II	Gokorne	643540	2461492	248	0
61	Magrahat II	Hotor Morjada	644117	2466037	248	70
62	Magrahat II	Hotor Morjada	645853	2467714	248	0
63	Magrahat II	Hotor Morjada	645135	2467375	248	0
64	Magrahat II	Hotor Morjada	646904	2465509	248	0
65	Magrahat II	Jugdia	649013	2460436	248	20
66	Magrahat II	Jugdia	648813	2459770	248	10
67	Magrahat II	Mograhat East	644059	2461164	248	0
68	Magrahat II	Mograhat West	642412	2460928	248	0
69	Magrahat II	Mograhat West	640981	2459586	248	10
70	Magrahat II	Nainan	641679	2462139	248	10
71	Magrahat II	Urel Chandpur	647086	2457096	248	0
72	Magrahat II	Urel Chandpur	646579	2456205	248	0
73	Magrahat II	Urel Chandpur	647999	2458655	248	0
74	Sonarpur	Bonhooghly II	638933	2481050	250	86
75	Baruipur	Belegacchi	657562	2471260	256.09	2
76	Baruipur	Brindakhali	654527	2465690	256.1	1
77	Baruipur	Brindakhali	654516	2466800	256.1	1
78	Sonarpur	Sonarpur II	652928	2481512	259	10
79	Sonarpur	Sonarpur II	649854	2480043	259	0
80	Sonarpur	Sonarpur II	650984	2480386	259	0

No	Block name	GP	X	Y	Depth (m)	As (ppb)
81	Sonarpur	Sonarpur II	652821	2481954	259	0
82	Sonarpur	Sonarpur II	651571	2483492	259	0
83	Sonarpur	Sonarpur II	651796	2481501	259	0
84	Sonarpur	Sonarpur II	651081	2480940	259	0
85	Sonarpur	Sonarpur II	652318	2480731	259	0
86	Sonarpur	Sonarpur II	649248	2478930	259.15	9
87	Sonarpur	Sonarpur II	648218	2478920	259.15	1
88	Sonarpur	Pratapnagar	653376	2477860	259.15	1
89	Sonarpur	Langalberiya	643122	2473340	259.15	11
90	Baruipur	Belegachia	663865	2469444	259.16	4
91	Baruipur	Belegacchi	658603	2470160	259.16	4
92	Baruipur	Belegacchi	657585	2469050	262.19	2
93	Sonarpur	Kamrabad	650660	2481933	274	0
94	Baruipur	Harda	655513	2470130	274.39	1
95	Baruipur	Harda	655502	2471240	274.39	3
96	Baruipur	Sankarpur II	648366	2463420	274.39	0
97	Sonarpur	Kamrabad	648208	2480030	274.39	1
98	Sonarpur	Kalikapur I	649258	2477820	274.39	16
99	Sonarpur	Kalikapur II	650299	2476730	274.39	30
100	Sonarpur	Pratapnagar	652325	2480070	289.63	2
101	Sonarpur	Langalberiya	641063	2473320	289.63	30
102	Jaynagar I	Rajapur Korabeg	654625	2455840	292	10
103	Jaynagar I	Sripur	649290	2453020	292	0
104	Jaynagar I	Sripur	650720	2454473	292	0
105	Jaynagar I	Sripur	650519	2453918	292	0
106	Jaynagar I	Uttar Durgapur	646911	2453773	292	0
107	Jaynagar I	Uttar Durgapur	648056	2452676	292	0
108	Baruipur	Mallikpur	651944	2476963	292.68	2
109	Jaynagar I	Dakshin Barasat	647792	2458763	292.68	10
110	Baruipur	Sikharbali II	645213	2470030	292.68	5
111	Baruipur	Brindakhali	654549	2463480	292.68	0
112	Baruipur	Sankarpur I	644214	2466700	292.68	10
113	Sonarpur	Kalikapur II	649258	2477820	292.68	34
114	Sonarpur	Bonhooghly II	639983	2478840	292.68	32
115	Baruipur	Brindakhali	658026	2466172	298.78	0
116	Baruipur	Brindakhali	658522	2468059	298.78	0
117	Baruipur	Belegacchi	657585	2469050	300.3	4
118	Jaynagar I	Jangalia	653539	2461366	304	0
119	Jaynagar I	Jangalia	653436	2461365	304	0
120	Jaynagar I	Jangalia	653321	2462582	304	0
121	Jaynagar I	Jangalia	653947	2461813	304	0

No	Block name	GP	X	Y	Depth (m)	As (ppb)
122	Jaynagar I	Jangalia	654263	2461151	304	10
123	Jaynagar I	Khakurdaha	655675	2464266	304	0
124	Jaynagar I	Khakurdaha	655488	2462382	304	0
125	Sonarpur	Pratapnagar	653647	2481741	304	10
126	Sonarpur	Pratapnagar	654790	2480645	304	0
127	Jaynagar I	Khakurdaha	655180	2462268	304.8	0
128	Jaynagar I	Khakurdaha	655289	2461604	304.8	0
129	Jaynagar I	Narayani tala	650960	2461673	304.8	0
130	Jaynagar I	Narayani tala	650945	2463223	304.8	10
131	Jaynagar I	Narayani tala	651457	2463560	304.8	0
132	Jaynagar I	Narayani tala	650632	2463552	304.8	0
133	Jaynagar I	Narayani tala	650643	2462445	304.8	0
134	Baruipur	Champahati	657821	2476136	304.88	0
135	Baruipur	Begumpur	656393	2474792	304.88	2
136	Baruipur	Nabagram	657111	2464945	304.88	0
137	Baruipur	Sikharbali II	642133	2468900	304.88	10
138	Baruipur	Sikharbali II	643173	2467800	304.88	5
139	Baruipur	Sikharbali II	642143	2467790	304.88	1
140	Baruipur	Sikharbali II	644193	2468920	304.88	1
141	Baruipur	Sikharbali II	645223	2468930	304.88	4
142	Baruipur	Harda	656532	2471250	304.88	1
143	Baruipur	Harda	654483	2470120	304.88	10
144	Baruipur	Harda	656543	2470140	304.88	2
145	Baruipur	Harda	654472	2471230	304.88	0
146	Baruipur	Nabagram	653508	2464580	304.88	1
147	Baruipur	Nabagram	653519	2463470	304.88	50
148	Baruipur	Nabagram	651447	2464560	304.88	0
149	Baruipur	Sankarpur II	649397	2463430	304.88	40
150	Sonarpur	Sonarpur II	646159	2478900	304.88	1
151	Sonarpur	Sonarpur II	647189	2478910	304.88	2
152	Sonarpur	Sonarpur II	649237	2480040	304.88	2
153	Sonarpur	Sonarpur II	647178	2480020	304.88	1
154	Sonarpur	Sonarpur II	648229	2477810	304.88	3
155	Sonarpur	Pratapnagar	654406	2477870	304.88	0
156	Sonarpur	Kalikapur I	651296	2480060	304.88	19
157	Sonarpur	Kalikapur II	650288	2477830	304.88	35
158	Baruipur	Sikharbali II	645202	2471140	341.46	4
159	Baruipur	Belegacchi	658581	2472380	348.78	0

4. Location of data points



5. Formulation of the model

A. Algorithm for calculating semivariance for spatial relationship of arsenic concentration

Step ID	Step Details
1	Start calculation of semivariance for Spatial Relationship of Arsenic Concentration
2	Get number of pairs from different location points by combination
3	Get separation distance between each pair found in step 2 by Pythagorean Theorem on basis of X,Y co-ordinates of location points
4	Get lag separation distance by rounding up separation distance found in step 3
5	Get concentration difference between each pair found in step 2
6	Get bearing angle (Theta) between each pair found in step 2
7	Group all pairs on basis of same lag separation distance
8	For each group found in step 7, get semivariance on basis of number of pairs and corresponding concentration difference between each pair
9	Group bearing angle within an interval of 15 degrees along with corresponding semivariance
10	End calculation of Semi-Variance for Spatial Relationship of Arsenic Concentration

B. Algorithm for calculating estimating point location

Step ID	Step details
1	Start calculation of Estimating point location
2	Get number of pairs between different location points and Estimating point by combination
3	Get separation distance between each pair found in step 2 by Pythagorean Theorem on basis of X,Y co-ordinates of location points
4	Get lag separation distance by rounding up separation distance found in step 3
5	Get bearing angle (Theta) between each pair found in step 2
6	Get sample points which lies in between the zone of influence and range of the semivariogram, also known as Influencing sample point
7	Get number of pairs between different influencing sample points and Estimating point by combination
8	Get separation distance between each pair found in step 7 by Pythagorean Theorem on basis of X,Y co-ordinates of location points
9	Get Semivariance between each pair found in step 7 by using equations on basis of corresponding separation distance
10	Get estimation point location by using equations for each pair in step 7 (Equation solver can be used for concerned purpose)
11	End calculation of Estimating point location

C. Algorithm for calculating semivariance for cross correlation

Step ID	Step details
1	Start calculation of semivariance for Cross Co-Relationship
2	Get number of pairs from different location points by combination
3	Get separation distance between each pair found in step 2 by Pythagorean Theorem on basis of X,Y co-ordinates of location points
4	Get lag separation distance by rounding up separation distance found in step 3
5	Get concentration difference between each pair found in step 2
6	Get bearing angle (Theta) between each pair found in step 2
7	Group all pairs on basis of same lag separation distance
8	For each group found in step 7, get semivariance on basis of number of pairs and corresponding concentration difference between each pair and between Arsenic and other component's concentration
9	Group bearing angle within an interval of 15 degrees along with corresponding semivariance
10	End calculation of Semi-Variance for Cross Co-Relationship

Annexure II

1. Nature of the curve and projected population in 2022 in the blocks

No.	Block	GP	Village	Nature of the curve	Projected pop in 2022
1	Baruipur	Begampur	Begampur	Arithmetic	14987
2			Kamra	Geometric	1621
3			Haral	Geometric	3031
4			Madhabpur	Incremental	795
5		Belegacchi	Ghola	Geometric	2669
6			Ramdhari	Incremental	3706
7			Betberia	Geometric	6904
8			Belgachhi	Geometric	10668
9			Dakshin Ghola	Geometric	3613
10			Harimul	Geometric	3584
11			Atniramish	Incremental	4247
12			Jelerhat	Incremental	2736
13		Brindakhali	Brinda Khali	Arithmetic	12910
14			Paruldaha	Arithmetic	2928
15			Joyatala	Arithmetic	2236
16			Mautala	Incremental+arithmetic	1557
17		Champahati	Solgohalia	Arithmetic	11985
18			Champahati	Arithmetic	14089
19		Dhapdhapi I	Komarhat	Incremental	6827
20			Beliaghata	Incremental	1131
21			Nachangachha	Geometric+arithmetic	1642
22			Padmajala	Arithmetic	5720
23			Rana	Incremental increase	2947
24		Dhopdhopi II	Purushottampur	Arithmetic	2604
25			Auliapur	Arithmetic	492
26			Surjapur	Arithmetic	1727
27			Paschim Mallikpur	Geometric	1669
28			Alipur	Geometric	1803
29			Bhatpoa	Incremental+arithmetic	3883
30		Hardah	Kuruli	Arithmetic	6726
31			Joykrishna Nagar	Arithmetic	3500
32			Kalabaru	Incremental	4265
33			Hardaha	Arithmetic	3717
34			Shrirampur	Arithmetic	2040
35			Purba Mallikpur	Geometric	3012
36			Chhani	Incremental	3807
37			Uttar Kalyanpur	Arithmetic	1299
38			Khasmallik	Arithmetic	4904
39			Khodar Bazar	Geometric	8589
40		Hariharpur	Beralia	Arithmetic	2761

No.	Block	GP	Village	Nature of the curve	Projected pop in 2022
41	Baruipur	Hariharpur	Biraldham Nagar	Arithmetic	1338
42			Dehimedan Malla	Arithmetic+incremental	4255
43			Baikunthapur	Geometric	1982
44			Salipur	Incremental	6255
45			Hariharpur	Incremental	14798
46		Kalyanpur	Madhya Kalyanpur	Arithmetic	1393
47			Tangtala	Arithmetic	956
48			Jagadishpur	Arithmetic	893
49			Purandarpur	Arithmetic	2359
50			Malayapur	Geometric	2822
51			Nihata	Geometric	2094
52			Chandipur	Geometric	2116
53			Maheshpur	Geometric	1170
54			Paschim Madhabpur	Geometric	1252
55			Dakshin Kalyanpur	Geometric	1820
56			Chakarberia	Incremental	2303
57			Dhopa Gachhi	Arithmetic+incremental	4048
58			San Pukuria	Geometric	992
59		Madarat	Madhubanpur	Arithmetic	2326
60			Kapindapur	Arithmetic	1036
61			Atghara	Arithmetic	1021
62			Baruipur	Arithmetic	26102
63			Subuddhipur	Arithmetic	355
64			Tagar Baria	Arithmetic	1386
65			Sultanpur	Geometric	1568
66			Bhurkul	Geometric	727
67		Mallickpur	Akna Mirzzapur	Arithmetic	2124
68			Faridpur	Geometric	5835
69			Kholapota	Geometric	1493
70			Mallickpur	Geometric	25486
71			Petua	Geometric	12440
72			Ganespur	Geometric	5890
73			Panchghara	Geometric	7993
74			Paschim Ramnagar	Geometric+arithmetic	1376
75		Nabagram	Gordaha	Arithmetic	1411
76			Nabagram	Arithmetic	9911
77			Kharam Para	Arithmetic	586
78			Teurhat	Arithmetic	5048
79			Keshabpur	Arithmetic	2584
80			Panch Gachhia	Geometric	5459
81			Keatala	Incremental	2883

No.	Block	GP	Village	Nature of the curve	Projected pop in 2022
82	Baruipur	Nabagram	Ramchandrapur	Incremental	1328
83			Dadpur	Incremental	4240
84		Ramnagar I	Phuldubi	Geometric	795
85			Bejeorancha	Geometric	1073
86		Ramnagar II	Dudhnai	Incremental	2504
87			Uttar Bhag	Incremental	7562
88			Ramnagar	Incremental	19835
89			Beledahari	Arithmetic	1238
90			Sankharipur	Arithmetic+incremental	3877
91		Sankarpur I	Sitakundu	Arithmetic	13192
92			Kanthal Beria	Arithmetic	2604
93			Ratanpur	Arithmetic	3307
94			Khanpur	Arithmetic	443
95			Teka	Arithmetic	2855
96			Sankarpur	Arithmetic+geometric	1952
97			Mirpur	Incremental	2982
98			Alampur	Incremental	826
99		Sankarpur II	Gangaduara	Arithmetic	2044
100			Balbalia	Geometric	6556
101			Chandkhali	Arithmetic	3444
102			Chitrasali	Arithmetic	2131
103			Gazirhat	Arithmetic	1041
104			Durga	Arithmetic	1757
105			Gocharan	Arithmetic	1366
106			Dhankhola	Arithmetic	263
107			Nor	Geometric	3608
108			Rajgora	Geometric	2558
109		Shikharbali I	Sikhar Bali	incremental	6860
110			Sonagachhi	Arithmetic	622
111			Gopalpur	Geometric	1666
112			Sasan (P)	Geometric	8157
113			Chandanpukur	Geometric+arithmetic	2162
114			Durgapur Gazipur	Incremental	1492
115			Bagdaha	Arithmetic	1553
116			Tripura Nagar	Incremental+geometric	2131
117			Banbere	Incremental	1190
118		Sikharbali II	Indrapala	Arithmetic	4752
119			Dhanberia	Arithmetic	927
120			Mamudpur	Arithmetic	1427
121			Kundarali	Incremental	4292
122			Kalikapur	Incremental	2317
123			Tengar Baria	Incremental	1480
124			Bolbamni	Arithmetic	769

No.	Block	GP	Village	Nature of the curve	Projected pop in 2022
125	Baruipur	Sikharbali II	Dandapur	Incremental	455
126		South Garia	Bhanta	Geometric	2423
127			Garia	Geometric	5260
128			Jamalhati	Geometric	2020
129			Tegachhi Mamudpur	Arithmetic	1282
130			Ghoshpur Baora	Arithmetic	2391
131			Kharupatalia	Incremental	1041
132			Naridana	Incremental	4250
133			Malanga	Incremental+arithmetic	1412
134	Bhangar I	Bodra	Khar Gachhi	Arithmetic	5486
135			Bodra	Arithmetic	6118
136			Naora	Arithmetic	5246
137			Dakshin Narikel Beria	Arithmetic	1605
138			Srirampur	Arithmetic+geometric	1735
139			Gokulpur	Geometric	1159
140			Kanjdia	Geometric	3602
141			Noapara	geometric	2382
142			Erenda	Geometric	6800
143			Chandpur	Incremental	4611
144			Santra	Incremental	1321
145			Pita Simulia	incremental	707
146		Chandaneswar-I	Sundia	Arithmetic	1218
147			Dakshin Kasipur	Arithmetic	2840
148			Satbaria	Arithmetic	5918
149			Dharmatala	Arithmetic	765
150			Karunarhati	Arithmetic	2491
151			Kashinathpur	Geometric	6265
152			Jalalabad	Incremental	2586
153			Chandaneswar	Incremental	5926
154		Chandaneswar-II	Mahes Pukuria	Arithmetic	690
155			Kasinagar	Arithmetic	583
156			Kamar Hati	Arithmetic+geometric	1567
157			Dari Madhabpur	Geometric	8669
158			Taldighi	Incremental	2772
159			Kashia Danga	Incremental	3399
160			Hogaldara	Incremental	1600
161			Madhabpur	Incremental	370
162		Durgapur	Sondalia	Arithmetic	4326
163			Dakshin Rajapur	Arithmetic	3431
164			Garanbaria	Arithmetic	3346
165			Durgapur	Arithmetic	3115
166			Dakshin Kathalia	Arithmetic	1175

No.	Block	GP	Village	Nature of the curve	Projected pop in 2022
167	Bhangar I	Durgapur	Mathurapur	Arithmetic+geometric	4470
168			Harispur	Arithmetic+geometric	898
169			Badi	Arithmetic+geometric	4958
170			Bhandarkua	Geometric	2078
171			Bakri	Incremental	2965
172			Hariharpur	Incremental	3192
173			Binarat	Incremental	2588
174		Jagulgachi	Ghatak Pukur	Arithmetic	6039
175			Phulbari Bamunia	Arithmetic	1263
176			Chandipur	Arithmetic+geometric	1026
177			Barjuli	Arithmetic+geometric	2289
178			Rangsara	Incremental	2169
179			Gobindapur	Incremental	12166
180			Dhara	Incremental	5788
181			Debipur	Incremental	1946
182			Jagulgachhi	Incremental	3356
183		Narayanpur	Kharamba	Arithmetic	5462
184			Narayanpur	Arithmetic	10563
185			Ghunimeghi	Arithmetic+geometric	4917
186			Dakshin Gazipur	Arithmetic+geometric	853
187			Dara	Arithmetic+geometric	1588
188			Padma Pukuria	Arithmetic+geometric	4592
189			Bagbari	Incremental	840
190			Amreswar	Incremental	3409
191			Bairampur	Incremental	2438
192		Pranganj	Serpur	Arithmetic	2193
193			Malancha	Arithmetic	2505
194			Kalikapur	Arithmetic	5283
195			Saitgachhi	Arithmetic	1798
196			Saihati	Arithmetic	1359
197			Rani Gachhi	Arithmetic	4963
198			Bhangar Raghunathpur	Arithmetic	7081
199			Maricha	Arithmetic	5814
200			Serpur	Geometric	915
201			Nalmuri	Geometric	4529
202			Chak Barali	Incremental	7136
203		Sanksahar	Shaksahar	Arithmetic	4235
204			Jhungri	Arithmetic	2681
205			Chak Bhika	Arithmetic	1922
206			Situri	Geometric	5139
207			Balipur	Geometric	1999
208			Bangoda	Geometric	2407

No.	Block	GP	Village	Nature of the curve	Projected pop in 2022
209	Bhangar I	Sanksahar	Bausahar	Geometric	3162
210			Bazarati	Incremental	2416
211		Tardaha	Ushpara	Arithmetic	3737
212			Karaidandga	Incremental	1347
213			Andulgari	Incremental	3003
214			Gangapur	Incremental	3394
215			Tardaha Kapasati	Incremental	13750
216			Mousal	Incremental	1811
217			Bhatipota	Incremental	3824
218	Bhangar II	Bamanghata	Dhapa Manpur	Arithmetic+incremental	1033
219			Koch Pukur	Arithmetic+incremental	2830
220			Jot Bhim	Arithmetic+incremental	2123
221			Hat Gachha	Arithmetic+incremental	6926
222			Hadia	Incremental	8626
223		Beonta-I	Krolbaria	Arithmetic	4112
224			Benota	Arithmetic	8961
225			Chariswar	Arithmetic	4775
226			Suk Pukuria	Arithmetic	880
227		Beonta-II	Dharmatala Pachuria	Arithmetic	6638
228			Kulberia	Arithmetic	4341
229			Chandakanthal Beria	Arithmetic	1446
230			Wari	Geometric	4119
231			Hatisala	Geometric	4389
232			Paikan	Incremental	1711
233		Bhogabanpur	Abua	Arithmetic	2089
234			Bhagabanpur	Arithmetic	3951
235			Saduli	Arithmetic	4990
236			Uttar Narikel Beria	Arithmetic	2303
237			Nangalbeki	Arithmetic	2003
238			Tara Hadia	Arithmetic	1613
239			Dakshin Khayerpur	Arithmetic+incremental	777
240			Pitha Pukuria	Geometric	14378
241			Jiran Gachhi	Incremental+arithmetic	6308
242		Bhogali-I	Nangla Palpur	Arithmetic	5500
243			Jamirgachhi	Arithmetic	1751
244			Raghunathpur	Arithmetic	4063
245			Sat Bhaiya	Geometric	2458
246			Bhogali	Geometric+incremental	8830
247		Bhogali-II	Kantadanga	Arithmetic	1797
248			Bankachua	Arithmetic	3893
249			Uttar Kathalia	Arithmetic	10186

No.	Block	GP	Village	Nature of the curve	Projected pop in 2022
250	Bhangar II	Bhogali-II	Chilatala	Arithmetic	3074
251			Baniara	Arithmetic	4439
252		Chaltaberia	Chak Maricha	Arithmetic	4727
253			Chalta Beria	Arithmetic	4867
254			Jawpur	Arithmetic	2422
255			Panapukur	Arithmetic	6794
256			Kachua	Arithmetic	4171
257			Bamunia	Geometric+arithmetic	19448
258		Polerhat-I	Naoabad	Arithmetic	5852
259			Swastayan Gachhi	Arithmetic	8133
260			Jaynagar	Arithmetic	5647
261			Anantapur	Incremental	3688
262		Polerhat-II	Uttar Gazipur	Arithmetic	4259
263			Uriaparaur	Arithmetic	5863
264			Uttar Swarup Nagar	Arithmetic+incremental	2085
265			Dakshin Swarup Nagar	Arithmetic+incremental	2522
266			Tona	Incremental	10615
267			Shyamnagar	Incremental	5702
268		Shanpukur	Rampur	Arithmetic	1700
269			Majerhat	Arithmetic	8884
270			Sonpur	Arithmetic	3938
271			Dheati	Arithmetic	619
272			Nimkuria	Arithmetic	6651
273			Sanpukuria	Arithmetic	3056
274			Uttar Kasipur	Geometric	12663
275			Uttar Rajapur	Incremental	1765
276			Chandi Hat	Incremental	6495
277			Gara Gachha	Incremental+geometric	1294
278	Bishnupur I	Amgachhia	Krishnarampur	Arithmetic	2465
279			Amgachhi	Arithmetic	11869
280			Chhota Ramnagar	Geometric	1452
281			Majerdari	Incremental	925
282			Kasthamahal	Incremental	5791
283		Andharmanik	Gangarai	Arithmetic	3666
284			Keoapukuria	Arithmetic	1602
285			Chak Nitai	Arithmetic	1640
286			Andharmanik	Arithmetic	7614
287			Kalipur	Incremental	931
288			Kalmikhali	Incremental	5377
289		Kulerdari	Karimpur Kismat	Arithmetic	561
290			Sarmaster Chak	Arithmetic	1066
291			Daulatpur	Arithmetic	7760

No.	Block	GP	Village	Nature of the curve	Projected pop in 2022
292	Bishnupur I I	Kulerdari	Rajarampur	Arithmetic	1388
293			Rammakhaler Chak	Arithmetic	2841
294			Debipur	Arithmetic	542
295			Raghudebpur	Arithmetic	1759
296			Kulerdari	Geometric	2779
297			Karimpur	Incremental	666
298		Panakua	Kalicharanpur	Arithmetic	831
299			Panakua	Arithmetic	4342
300			Magurkhali	Arithmetic	1916
301			Cheyari	Arithmetic+incremental	1556
302			Chak Balaibag	Arithmetic+incremental	3546
303			Jhanjhra	Arithmetic+incremental	666
304			Chak Sitaram	Arithmetic+incremental	117
305			Ramkantapur	Arithmetic+incremental	1363
306			Chak Nursikdar	Arithmetic+incremental	2382
307			Bakeswar	Arithmetic+incremental	5728
308			Harir Chak	Arithmetic+incremental	761
309			Chak Kalmi	Arithmetic+incremental	463
310			Raghabpur	Geometric	2754
311			Salpukuria	Geometric	3544
312	Canning II	Deuli-I	Ghikhali	Arithmetic	3263
313			Par Kalugachhi	Geometric	604
314			Mallik Kati	Geometric	5680
315			Chandibari	Geometric	6472
316			Chung Hata	Geometric	1291
317			Sastakhali	Geometric	4169
318			Kalugachhi	Incremental	5140
319		Deuli-II	Jay Khali	Arithmetic	533
320			Kaluakhali	Arithmetic	2587
321			Parganti	Arithmetic	3071
322			Deuli	Geometric	3177
323			Kayam Khan	Geometric	631
324			Hatiamari	Geometric	2052
325			Madan Khali	Geometric	1827
326			Balidaghata	Geometric	2005
327			Bamunia	Geometric	2857
328			Mukhujya Para	Geometric	2757
329			Gutri	Incremental	1589
330			Ganti	Incremental	1999
331		Kalikatala	Jogendra Nagar	Arithmetic	17639
332			Kalikatala	Geometric	23148
333		Narayanpur	Narayanpur	Arithmetic	10995

No.	Block	GP	Village	Nature of the curve	Projected pop in 2022
334	Canning II	Narayanpur	Srinagar	Arithmetic+geometric	4066
335			Banamalipur	Geometric+arithmetic	6411
336			Makhal Tala	Incremental	13069
337		Sarangabad	Haora Mari	Arithmetic	5019
338			Bhabananda	Arithmetic	1152
339			Hadiya	Arithmetic	1944
340			Netra	Arithmetic	5005
341			Hansarabad	Arithmetic	1096
342			Iswaripur	Arithmetic	9327
343			Moktarpur	Arithmetic	1883
344			Ramrayer Gheri	Arithmetic	1832
345			Miagheri	Arithmetic+geometric	5251
346			Gangacheri	Geometric	6725
347			Jibantala	Geometric	4209
348			Singheswar	Geometric	4872
349			Saranger Abad	Geometric	18842
350			Paina	Incremental	2770
351		Tambuldah-I	Bibir Abad	Arithmetic	5362
352			Bakultala	Arithmetic	2102
353			Jal Ghata	Arithmetic	758
354			Chunpuri	Arithmetic	279
355			Patikhali	Geometric	12522
356			Khagra	Geometric	3974
357			Kaora Khali	Geometric	2796
358			Sabek Mahisahara	Geometric	1134
359			Tambul Daha	Geometric	1657
360			Khun Khali	Geometric+arithmetic	1468
361			Maukhali Kumarkhali	Geometric+arithmetic	9791
362			Chelikati	Incremental	1037
363			Kaparpuri	Incremental	1916
364			Baintala	Incremental	434
365		Tambuldah-II	Nagartala	Arithmetic	12596
366			Homra Palta	Arithmetic	7533
367			Kuler Khoj	Arithmetic	527
368			Chengdona	Geometric	4065
369	Jaynagar I	Baharu	Baharu	Incremental	18043
370		Baman Gachi	Arunnagar Dakshin	Arithmetic	4063
371			Kamaria	Arithmetic	30886
372			Purba Gabberia	Geometric	14661
373			Chatra	Geometric+arithmetic	1959
374			Maldari	Incremental	1259
375		Chalta Beria	Hogaldahari	Geometric+arithmetic	383

No.	Block	GP	Village	Nature of the curve	Projected pop in 2022
376	Jaynagar I	Chalta Beria	Uttar Arunnagar	Incremental	347
377		Dakshin Barasat	Padmerhat	Arithmetic	6184
378			Ramkanta Bati	Arithmetic	1274
379			Kalikapur Barasat	Arithmetic	7181
380			Beladanga	Arithmetic	5738
381			Nurulpur	Arithmetic	3303
382			Abdul Karimpur	Arithmetic	1776
383			Mukundapur	Arithmetic	1143
384			Khatsara	Geometric	3563
385			Rajapur	Geometric	657
386			Mastikari	Incremental	4192
387		Hari Narayanpur	Harinarayanpur	Arithmetic	4635
388			Nandanpur	Arithmetic	1725
389			Lakshmi Narayanpur	Arithmetic	2493
390			Ramchandrapur	Arithmetic	3649
391			Panchghora	Arithmetic	3081
392			Baneshwarpur	Arithmetic	1872
393			Raynagar	Geometric	7682
394			Paschim Gabberia	Geometric+arithmetic	1326
395		Jangalia	Punpo	Arithmetic	3947
396			Srikrishnanagar	Arithmetic	5740
397			Purba Chak Panchghara	Arithmetic	383
398			Jangalia	Geometric	8353
399			Nilkanthapur	Geometric	1251
400			Ramrudrapur	Incremental	1654
401			Paschim Chakpanchghora	Incremental+geometric	1369
402		Khakur Daha	Khakurdaha	Arithmetic	3970
403			Santipur	Arithmetic	1648
404			Kismat Goalberia	Arithmetic	2313
405			Uttar Raghunathpur	Arithmetic	781
406			Dewanganj	Arithmetic	2759
407			Neutala	Incremental	3760
408			Goalberia	Incremental	3527
409		Narayani Tala	Belechandi	Arithmetic	2788
410			Sarberia	Arithmetic	3582
411			Bejra	Arithmetic	1255
412			Hogla	Arithmetic	3195
413			Narayani Tala	Geometric	2997
414			Kanta Pukuria	Incremental	2980
415		Sripur	Ramkrishnapur	Arithmetic	5104
416			Kashimpur Ganga	Arithmetic	1263

No.	Block	GP	Village	Nature of the curve	Projected pop in 2022
417	Jaynagar I	Sripur	Sripur	Arithmetic	2933
418			Uttarpara Abad	Arithmetic	1633
419			Hatpara	Geometric	4290
420			Uttarparanij	Geometric	8838
421			Ganganarayanpur	Incremental	161
422		Uttar Durgapur	Uttar Durgapur (Ct)	Arithmetic	6518
423			Ajodhya Nagar	Arithmetic	1187
424			Ramnarayanpur (P)	Arithmetic	850
425			Alipur	Arithmetic	7019
426			Tajpur Fatepur (P)	Incremental	8040
427			Joynagar (P)	Incremental	3484
428	Jaynagar II	Chuprijhara	Sonatikri	Arithmetic	17787
429			Radhaballabhpur	Geometric	20147
430			Bhubankhali	Geometric	9083
431			Chuprijhara	Geometric	15530
432		Futigoda	Tulshighata	Arithmetic	4787
433			Banamalipur (P)	Geometric	757
434			Srirampur	Geometric	2000
435			Phutigoda	Geometric	3399
436			Dashra Bhagabanpur	Geometric	3988
437			Nimpith	Incremental	8867
438		Gordwani	Gordoani	Geometric	24640
439			Paschim Raghunathpur	Geometric	1847
440			Mallar Chak	Incremental	6376
441		Mayahowri	Mayahauri	Arithmetic	22341
442		Moydah	Mahishghat	Geometric	2748
443			Khaiyamara	Geometric	13954
444			Chandipur	Incremental	1109
445			Mayda	Incremental	3049
446			Napukuria	Incremental	2629
447			Gangapur	Incremental+arithmetic	2141
448		Nalgora	Nalgora	Geometric	10711
449		Sahajadapur	Khania Sahazadapur	Arithmetic	2759
450			Kalinagar	Arithmetic	7586
451			Sahajadapur	Arithmetic	2701
452			Kamalpur	Arithmetic	1170
453			Serhangampur	Arithmetic	2686
454			Bagbaria Narayanpur	Geometric	1036
455			Bijaynagar	Incremental	7241
456	Magrahat II	Dhamua South	Shyampur	Arithmetic	25241

No.	Block	GP	Village	Nature of the curve	Projected pop in 2022
457	Magrahat II	Dhanpota	Dhanpota	Arithmetic	3717
458			Bankadwar	Arithmetic	1452
459			Bishweshwarpur	Arithmetic	5146
460			Dakshin Mukundapur	Arithmetic	2093
461			Kalkina Ishwaripur	Arithmetic	1718
462			Paran Khali	Incremental	684
463			Uttar Kalas	Arithmetic	7577
464			Dihi Kalas	Arithmetic	13562
465			Dakshin Mohanpur	Arithmetic	2646
466			Belgachhia	Geometric	1958
467			Mallarchak Ishwaripur	Incremental	2675
468		Gokorne	Maitir Hat	Arithmetic	534
469			Gokarni	Arithmetic	9399
470			Benipur	Arithmetic	2595
471			Shyamnagar	Geometric	2405
472			Gotbaria	Geometric	570
473			Ramchandranagar	Geometric	12595
474			Ghanashyampur	Incremental	2309
475		Hotor Morjada	Hotar	Arithmetic	4705
476			Makaltala	Arithmetic	1659
477			Baniber	Arithmetic	1707
478			Tapukur	Geometric	1385
479			Uttar Mukundapur	Incremental	2049
480			Marjyada	Incremental	4387
481		Jugdia	Jugdia	Incremental	15747
482		Multi	Barat Kamdebpur	Arithmetic	10042
483			Multi	Arithmetic	11597
484			Bansundaria	Arithmetic	1781
485			Tasrala	Arithmetic	1712
486			Tantihati	Incremental	887
487			Jaldhapa	Incremental+arithmetic	1717
488		Urel Chandpur	Taldi	Arithmetic	1819
489			Urel Chandpur	Arithmetic	5196
490			Abad Ishwaripur	Arithmetic	2104
491			Abad Chandpur	Geometric	374
492			Ishwaripur	Geometric+arithmetic	395
493			Purba Kamarpukuria	Incremental	4393
494			Kanta Pukuria	Incremental	797
495			Gobindapur	Incremental+arithmetic	1022
496	Mandirbazar	Chandpur Chaitanyapur	Raghunathpur	Arithmetic	1481

No.	Block	GP	Village	Nature of the curve	Projected pop in 2022
497	Mandirbazar	Chandpur Chaitanyapur	Chandpur	Arithmetic	7666
498			Dakshin Amratola	Arithmetic	340
499			Bangabari	Geometric	1118
500			Mirzanagar	Geometric	1216
501			Bhabanipur	Geometric	949
502			Bademaheshpur	Geometric	3018
503			Daulatbad	Geometric	115
504			Pukuria	Incremental	897
505			Gokulnagar	Incremental	1089
506			Chaitanyapur	Incremental	983
507			Saradana	Incremental	2383
508			Ramnarayanpur	Incremental+arithmetic	261
509		Jagadishpur	Dhananjoypur	Arithmetic	1264
510			Uttar Ballabhpur	Arithmetic	1921
511			Bansberia Zafarpur	Arithmetic	1158
512			Maukhali	Arithmetic	531
513			Maheshpur	Arithmetic	1078
514			Uttar Jagadeishpur	Geometric	3432
515			Matilal	Geometric	227
516			Kalikapur	Geometric	533
517			Purba Gopalnagar	Geometric	4887
518			Durlavpur	Geometric	1761
519			Mauraltala Mukundapur	Incremental	901
520			Badedurgapur	Incremental	164
521		South Bishnupur	Bade Muldia	Arithmetic	1079
522			Gobindabati	Arithmetic	2468
523			Alemaheshpur	Arithmetic	383
524			Dakshin Radhanagar	Arithmetic	264
525			Bangsidharpur	Arithmetic	6193
526			Purba Bishnupur	Arithmetic	15013
527			Nurmahammadpur	Incremental	2090
528			Bade Gokulnagar	Incremental	590
529			Krishnarampur	Incremental	620
530			Adityapur	Incremental	1329
531	Mathurapur I	Debipur	Bazar	Arithmetic	1595
532			Uttar Durgapur	Arithmetic	3571
533		Lalpur	Talukranaghat	Arithmetic	3880
534			Ranaghat	Arithmetic	5926
535			Paschim Ranaghat	Arithmetic	2705
536			Khodadadpur	Arithmetic	3435
537	Sonarpur	Bon Hooghly-I	Joyenpur	Arithmetic	1599

No.	Block	GP	Village	Nature of the curve	Projected pop in 2022
538	Sonarpur	Bon Hooghly-I	Banhugli	Arithmetic	12819
539			Dingelpota	Arithmetic	1731
540			Ramchandrapur	Incremental	11071
541			Hogalkuria	Incremental	2125
542		Bon Hooghly-II	Joykrishnapur Chairi	Arithmetic	7625
543			Danga	Arithmetic	7649
544		Kalikapur-I	Jardaha	Arithmetic	1653
545			Muragachha	Arithmetic	818
546			Kalikapur	Arithmetic	6607
547			Natagachhi	Arithmetic	2610
548			Chak Baria	Arithmetic	5770
549		Kalikapur-II	Benebou	Arithmetic	3194
550			Sahebpur	Arithmetic	8195
551			Kharigoda	Arithmetic	1434
552			Hasanpur	Arithmetic	2117
553			Jafarpur	Arithmetic	1215
554			Raypur	Incremental	4724
555		Kamrabad	Gangajora	Arithmetic	4118
556			Khurigochhi	Arithmetic	7452
557			Dihi	Arithmetic	2563
558			Chandpur	Geometric	5659
559			Radhanagar	Geometric	8796
560			Jagadishpur	Geometric + incremental	2090
561			Nayabad	Arithmetic	4215
562		Kheodah-I	Khodhati	Arithmetic	4226
563			Kumar Pukuria	Arithmetic	730
564			Kheadaha	Arithmetic	2173
565			Tihuria	Arithmetic	4271
566			Goalapota	Arithmetic	219
567			Tardaha	Arithmetic	5369
568		Kheodah-II	Deara	Arithmetic	3675
569			Bhagabanpur	Arithmetic	13724
570			Kantipota	Arithmetic	1956
571			Chak Kolarkhal	Geometric + incremental	1796
572			Jagatipata	Geometric + incremental	2778
573			Mukundapur	Geometric + incremental	3097
574			Ranabhutia	Geometric + incremental	5538
575			Kharki	Geometric + incremental	1438
576			Karimpur	Geometric + incremental	617
577			Atghara	Incremental	6017
578		Langal Baria	Bamangachhi	Arithmetic	2677
579			Bara Gachhia	Arithmetic	3953

No.	Block	GP	Village	Nature of the curve	Projected pop in 2022
580	Sonarpur	Langal Baria	Radhaballavpur	Arithmetic	1006
581			Sri Krishnapur	Arithmetic	305
582			Jaynagar	Arithmetic	1172
583			Srirampur	Arithmetic	906
584			Langalber	Geomertrical+incremental	2270
585			Andharia	Geometric + incremental	835
586			Baruli	Geometric+arithmetic	4675
587			Gobindapur	Incremental increase	2677
588		Poleghat	Sarmastapur	Arithmetic	1373
589			Palghat	Geometric	2908
590			Raghabpur	Geometric + incremental	1400
591			Raghunathpur	Incremental increase	3058
592			Badehugli	Incremental increase	4556
593			Samukpota	Arithmetic	2181
594			Metiari	Arithmetic	1758
595			Makrampur	Arithmetic	2169
596			Kustia	Geometric	2545
597			Pratapnagar	Geometric + incremental	3155
598			Garal	Geometric + incremental	2106
599			Nabhasan	Geometric + incremental	1865
600			Sangur	Incremental	4470
601		Sonarpur-II	Arapanch	Arithmetic	3133
602			Hasanpur	Arithmetic	3335
603			Mali Pukuria	Geometric + incremental	7700
604			Gopal Pur	Geometric + incremental	1301
605			Rampur	Geometric + incremental	2421
606			Bidyadharpur	Geometric + incremental	5830
607			Bhabanipur	Geometric + incremental	5217
608			Mathurapur	Geometric + incremental	5799

2. Location and estimation of As concentration in the focus area:

- Details of the schools for model validation

Shallow tubewell

No	Block	Village	School	X	Y	Shallow depth (less than 100 m bgl)	
						Actual value (ppb)	Estimated value (ppb)
1	Baruipur	Dhapdhapi	Alipur Suryapur JB	651219	2466769	584	526.3
2		Kalyanpur	Wesley FP	644886	2471912	12	71.6
3		Ramnagar	Sasari Rakshit Chandra FP	652609	2472097	240	253.2
4		Ramnagar	Uttarbhag Taltala SSK	655091	2471125	235	243.2
5		Shanpukur	Khanpur Mirpur JB	647808	2467954	82	217
6		Shanpukur	Sanpukur Anchal FP	647613	2466734	121	116.4
7		Sikharbali	Sikharbali JB	647479	2470054	86	108
8	Bhangar I	Bodra	Naora Lalit Mohan FP	666480	2484974	360	385.1
9		Pranganj	Ranigachi Purba Das Para SSK	662554	2486372	278	287.4
10		Pranganj	Saitgachi FP	664606	2486947	198	219
11		Tardaha	Haripora FP	652137	2488702	43	54.3
12		Tardaha	Shauradaria FP	657215	2485099	13	198.6
13	Bhangar II	Bhagawanpur	Pithapukuria Junior High School	659479	2495088	183	152.3
14		Bhogali I	Purba Bhogali FP	666479	2494498	103	123
15		Bhogali I	Raghunathpur FP	665982	2492942	105	127.8
16		Bhogali I	Chilatala FP	667626	2493071	452	519.8
17		Bhogali II	Uttar Kanthalia FP	665476	2492161	117	97.8
18		Bodra	Srirampur SSK	667889	2487869	52	84.7
19		Pranganj	Nalmuri FP	664690	2488720	129	281
20		Shanpukur I	Paschim Majherhat FP	662645	2497225	127	136
21	Canning II	Motherdighi	Keoratala FP	679748	2476928	42	33.2
22		Sarengabad	Payna FP	672313	2478726	80	72.5
23		Tambuldaha	Patikhali FP	667626	2474135	121	127.9
24	Jaynagar I	Baharu Kshetra	Kamdebnagar FP	646989	2456431	118	103.6
25		Chaltaberia	Gabberia FP	656421	2461837	10	27
26		Chaltaberia	Phulbagicha FP	654924	2456840	23	45.1
27		Dakshin Barasat	Beliadanga FP	649234	2458888	52	54.1
28	Sonarpur	Kamrabad	Kelegore FP	651465	2483823	10	29.6
29		Ward 10	Gorkhara FP	647658	2483675	30	168.1
30		Ward 24	Chohati JB	645239	2478227	356	343.2

Deep tubewell

	Block	Village	School	X	Y	Deep depth (more than 100 m bgl)	
						Actual value (ppb)	Estimated value (ppb)
1	Baruipur	Dhapdhapi	Alipur Suryapur JB	651219	2466769	6	4.01
2		Kalyanpur	Wesley FP	644886	2471912	4	2.52
3		Ramnagar	Sasari Rakshit Chandra FP	652609	2472097	5	1.72
4		Ramnagar	Uttarbhag Taltala SSK	655091	2471125	9	6.49
5		Shanpukur	Khanpur Mirpur JB	647808	2467954	8	7.73
6		Shanpukur	Sanpukur Anchal FP	647613	2466734	8	7.57
7		Sikharbali	Sikharbali JB	647479	2470054	5	6.02
8		Bodra	Naora Lalit Mohan FP	666480	2484974	46	58.95
9	Bhangar I	Pranganj	Ranigachi Purba Das Para SSK	662554	2486372	80	107.86
10		Pranganj	Saitgachi FP	664606	2486947	35	40.62
11		Tardaha	Haripora FP	652137	2488702	7	11.49
12		Tardaha	Shauradaria FP	657215	2485099	22	25.96
13	Bhangar II	Bhagawanpur	Pithapukuria Junior High School	659479	2495088	55	64.25
14		Bhogali I	Purba Bhogali FP	666479	2494498	31	34.52
15		Bhogali I	Raghunathpur FP	665982	2492942	21	33.94
16		Bhogali I	Chilatala FP	667626	2493071	22	27.46
17		Bhogali II	Uttar Kanthalia FP	665476	2492161	25	21.22
18		Bodra	Srirampur SSK	667889	2487869	13	15.51
19		Pranganj	Nalmuri FP	664690	2488720	42	69.73
20		Shanpukur I	Paschim Majherhat FP	662645	2497225	76	83.85
21	Canning II	Motherdighi	Keoratala FP	679748	2476928	9	5.24
22		Sarengabad	Payna FP	672313	2478726	21	33.45
23		Tambuldaha	Patikhali FP	667626	2474135	35	35.67
24	Jaynagar I	Baharu Kshetra	Kamdebnagar FP	646989	2456431	5	8.4
25		Chaltaberia	Gabberia FP	656421	2461837	2	6.87
26		Chaltaberia	Phulbagicha FP	654924	2456840	3	4.3
27		Dakshin Barasat	Beliadanga FP	649234	2458888	3	0.57
28	Sonarpur	Kamrabad	Kelegore FP	651465	2483823	1	1.76
29		Ward 10	Gorkhara FP	647658	2483675	0	1.31
30		Ward 24	Chohati JB	645239	2478227	6	5.05

3. Blockwise distribution of schools and student population

Block	School	Population
Baruipur	208	19753
Bhangar I	141	13645
Bhangar II	101	13772
Bishnupur I	34	1965
Canning II	66	12745
Jaynagar I	113	13144
Jaynagar II	62	7324
Magrahat II	53	5214
Mandirbazar	48	2848
Sonarpur	204	17116
Mathurapur I	14	1149

4. Estimated arsenic concentration and assessment of exposure risk , health risk and decrease of IQ among school students

No	Block name	Village name	School name	Student pop	Shallow tubewell					Deep tubewell				
					As conc (ppb)	TDI (10^{-4})	HQ	CR (10^{-4})	IQ	As conc (ppb)	TDI (10^{-4})	HQ	CR (10^{-4})	IQ
1	Baruipur	Begumpur	Begumpur Colony FP	23	65	19.90	6.63	89.54	94.3	8	2.45	0.82	11.02	98.86
2			Begumpur R Nandanpur FP	54	59	18.06	6.02	81.28	94.78	7	2.14	0.71	9.64	98.94
3			Dedangi SSK	25	69	21.12	7.04	95.05	93.98	5	1.53	0.51	6.89	99.1
4			Haral JB	69	9	2.76	0.92	12.40	98.78	5	1.53	0.51	6.89	99.1
5			Kamra Begumpur JB	30	28	8.57	2.86	38.57	97.26	8	2.45	0.82	11.02	98.86
6			Kamra Tentulia FP	50	74	22.65	7.55	101.94	93.58	4	1.22	0.41	5.51	99.18
7			Madhabpur SSK	46	90	27.55	9.18	123.98	92.3	10	3.06	1.02	13.78	98.7
8			Paschim Puri SSK	36	154	47.14	15.71	212.14	87.18	27	8.27	2.76	37.19	97.34
9			Punri Abad FP	27	45	13.78	4.59	61.99	95.9	6	1.84	0.61	8.27	99.02
10			Punri FP	79	36	11.02	3.67	49.59	96.62	10	3.06	1.02	13.78	98.7
11			Uttar Bhag Colony JB	143	63	19.29	6.43	86.79	94.46	42	12.8	4.29	57.86	96.14
12		Belegachi	Belegachi 3rd 5th Plan FP	313	10	3.06	1.02	13.78	98.7	8	2.45	0.82	11.02	98.86
13			Belegachi A Harendra FP	44	41	12.55	4.18	56.48	96.22	6	1.84	0.61	8.27	99.02
14			Belegachi Special FP	235	7	2.14	0.71	9.64	98.94	6	1.84	0.61	8.27	99.02
15			Betberia FP	411	10	3.06	1.02	13.78	98.7	4	1.22	0.41	5.51	99.18
16			Dakshin Ghola FP	149	10	3.06	1.02	13.78	98.7	9	2.76	0.92	12.40	98.78
17			Ghola FP	93	5	1.53	0.51	6.89	99.1	10	3.06	1.02	13.78	98.7
18			Ghola FP (new) School	121	9	2.76	0.92	12.40	98.78	10	3.06	1.02	13.78	98.7
19			Harimul FP	174	12	3.67	1.22	16.53	98.54	8	2.45	0.82	11.02	98.86
20			Harimul Natun FP	290	15	4.59	1.53	20.66	98.3	4	1.22	0.41	5.51	99.18
21			Jelerhat FP	58	4	1.22	0.41	5.51	99.18	9	2.76	0.92	12.40	98.78
22			Ramkrishnapally AS Niketan FP	150	11	3.37	1.12	15.15	98.62	7	2.14	0.71	9.64	98.94
23			Vidyadhari Pally FP	42	43	13.16	4.39	59.23	96.06	5	1.53	0.51	6.89	99.1
24		Brindakhali	Bangheri Sarada Vidyapith	24	134	41.02	13.67	184.59	88.78	9	2.76	0.92	12.40	98.78

No	Block name	Village name	School name	Student pop	Shallow tubewell					Deep tubewell				
					As conc (ppb)	TDI (10^{-4})	HQ	CR (10^{-4})	IQ	As conc (ppb)	TDI (10^{-4})	HQ	CR (10^{-4})	IQ
25	Baruipur	Brindakhali	Brindakhali FP	71	51	15.61	5.20	70.26	95.42	8	2.45	0.82	11.02	98.86
26			Brindakhali Sardarpara SSK	56	36	11.02	3.67	49.59	96.62	5	1.53	0.51	6.89	99.1
27			Dumdum FP	204	67	20.51	6.84	92.30	94.14	9	2.76	0.92	12.40	98.78
28			Ghatkanda FP	107	15	4.59	1.53	20.66	98.3	10	3.06	1.02	13.78	98.7
29			Jayatala FP	22	47	14.39	4.80	64.74	95.74	12	3.67	1.22	16.53	98.54
30			Jayatala New FP	43	45	13.78	4.59	61.99	95.9	7	2.14	0.71	9.64	98.94
31			Jayatala SSK	27	37	11.33	3.78	50.97	96.54	3	0.92	0.31	4.13	99.26
32			Khutiberia FP	160	178	54.49	18.16	245.20	85.26	59	18.06	6.02	81.28	94.78
33			Machpukur FP	166	153	46.84	15.61	210.77	87.26	29	8.88	2.96	39.95	97.18
34			Paruldaha FP	35	46	14.08	4.69	63.37	95.82	6	1.84	0.61	8.27	99.02
35		Champahati	Baje Haral Vivekananda FP	74	42	12.86	4.29	57.86	96.14	4	1.22	0.41	5.51	99.18
36			Champahati Balika SSK	401	36	11.02	3.67	49.59	96.62	10	3.06	1.02	13.78	98.7
37			Champahati JB	70	26	7.96	2.65	35.82	97.42	9	2.76	0.92	12.40	98.78
38			Kholaghata Bidyasagar SSK	145	50	15.31	5.10	68.88	95.5	10	3.06	1.02	13.78	98.7
39			Kholaghata FP	240	41	12.55	4.18	56.48	96.22	9	2.76	0.92	12.40	98.78
40			Kholaghata SSK	107	35	10.71	3.57	48.21	96.7	12	3.67	1.22	16.53	98.54
41			Solagohaliya Saphui Para SSK	57	35	10.71	3.57	48.21	96.7	7	2.14	0.71	9.64	98.94
42			Solegoalia JB	108	49	15.00	5.00	67.50	95.58	9	2.76	0.92	12.40	98.78
43		Dhapdhapi 1	Alipur Suryapur JB	109	526	161.02	53.67	724.59	57.42	4	1.22	0.41	5.51	99.18
44			Dakshin Padmajala SSK	50	221	67.65	22.55	304.44	81.82	10	3.06	1.02	13.78	98.7
45			Dhapdhapi Suryapur FP	111	652	199.59	66.53	898.16	47.34	10	3.06	1.02	13.78	98.7
46			Kumarhat Chandkhali JB	144	263	80.51	26.84	362.30	78.46	7	2.14	0.71	9.64	98.94
47			Padmajala JB	222	230	70.41	23.47	316.84	81.1	50	15.31	5.10	68.88	95.5
48			Ranabeliaghata JB	28	239	73.16	24.39	329.23	80.38	5	1.53	0.51	6.89	99.1
49			Uttar Kumarhat SSK	61	264	80.82	26.94	363.67	78.38	78	23.88	7.96	107.45	93.26
50			Uttar Padmajala FP	65	173	52.96	17.65	238.32	85.66	33	10.10	3.37	45.46	96.86

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51	Baruipur	Dhapdhapi 2	Dhapdhapi FP	295	382	116.94	38.98	526.22	68.94	9	2.76	0.92	12.40	98.78
52			Madanpur N Vidyapith FP	99	2	0.61	0.20	2.76	99.34	5	1.53	0.51	6.89	99.1
53			Majlishpukur JB	135	715	218.88	72.96	984.95	42.3	9	2.76	0.92	12.40	98.78
54			Olberia FP	52	427	130.71	43.57	588.21	65.34	6	1.84	0.61	8.27	99.02
55			Paschim Mallikpur	116	835	255.61	85.20	1150.26	32.7	9	2.76	0.92	12.40	98.78
56			Purushuttam SP Bhatpoa	45	263	80.51	26.84	362.30	78.46	4	1.22	0.41	5.51	99.18
57			Rana SSK	47	257	78.67	26.22	354.03	78.94	4	1.22	0.41	5.51	99.18
58			Serpur JB	113	482	147.55	49.18	663.98	60.94	61	18.67	6.22	84.03	94.62
59			Suryapur Nachangacha FP	89	362	110.82	36.94	498.67	70.54	7	2.14	0.71	9.64	98.94
60		Hardaha	Baje Makhaltala FP	69	70	21.43	7.14	96.43	93.9	19	5.82	1.94	26.17	97.98
61			Baly Bamoni FP	61	67	20.51	6.84	92.30	94.14	15	4.59	1.53	20.66	98.3
62			Chakraborty Abad FP	154	89	27.24	9.08	122.60	92.38	29	8.88	2.96	39.95	97.18
63			Chhayani Kalabaru FP	120	129	39.49	13.16	177.70	89.18	11	3.37	1.12	15.15	98.62
64			Dakshin Kalabaru SSK	32	97	29.69	9.90	133.62	91.74	13	3.98	1.33	17.91	98.46
65			Dakshin Sahapur SSK	98	69	21.12	7.04	95.05	93.98	11	3.37	1.12	15.15	98.62
66			Hardaha FP	269	25	7.65	2.55	34.44	97.5	14	4.29	1.43	19.29	98.38
67			Jaykrishnanagar FP	70	38	11.63	3.88	52.35	96.46	19	5.82	1.94	26.17	97.98
68			Kalabaru FP	58	42	12.86	4.29	57.86	96.14	12	3.67	1.22	16.53	98.54
69			Kulari Hardaha FP	72	24	7.35	2.45	33.06	97.58	54	16.53	5.51	74.39	95.18
70			Majherhat FP	64	8	2.45	0.82	11.02	98.86	10	3.06	1.02	13.78	98.7
71			Purba Mallickpur FP	83	34	10.41	3.47	46.84	96.78	6	1.84	0.61	8.27	99.02
72			Sahapur FP	155	10	3.06	1.02	13.78	98.7	3	0.92	0.31	4.13	99.26
73		Hariharpur	Biraldham Nagar JB	24	249	76.22	25.41	343.01	79.58	12	3.67	1.22	16.53	98.54
74			Dihi Madan M Baikuntha JB	21	255	78.06	26.02	351.28	79.1	17	5.20	1.73	23.42	98.14
75			Dihi Madan Mollah B JB	33	214	65.51	21.84	294.80	82.38	17	5.20	1.73	23.42	98.14
76			Hariharpur Beniadanga JB	100	137	41.94	13.98	188.72	88.54	19	5.82	1.94	26.17	97.98

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77	Baruipur	Hariharpur	Hariharpur JB	93	142	43.47	14.49	195.61	88.14	18	5.51	1.84	24.80	98.06
78			Khasmallick FU FP	57	139	42.55	14.18	191.48	88.38	16	4.90	1.63	22.04	98.22
79			Khasmallick Kajipara FP	23	324	99.18	33.06	446.33	73.58	9	2.76	0.92	12.40	98.78
80			Salepur FP	23	273	83.57	27.86	376.07	77.66	3	0.92	0.31	4.13	99.26
81			Uttar Tangar Bariya SSK	39	243	74.39	24.80	334.74	80.06	9	2.76	0.92	12.40	98.78
82		Kalyanpur	Chakarberia Dhopagachi JB	54	80	24.49	8.16	110.20	93.1	9	2.76	0.92	12.40	98.78
83			Chandipur Nihata JB	76	51	15.61	5.20	70.26	95.42	10	3.06	1.02	13.78	98.7
84			Dhopagachi FP	79	127	38.88	12.96	174.95	89.34	8	2.45	0.82	11.02	98.86
85			Hanta Maheshpur FP	24	101	30.92	10.31	139.13	91.42	9	2.76	0.92	12.40	98.78
86			Kalyanpur State Plan FP	21	204	62.45	20.82	281.02	83.18	14	2.76	0.92	12.40	98.78
87			Khodarbazar Nischintapur JB	159	352	107.76	35.92	484.90	71.34	6	1.84	0.61	8.27	99.02
88			Madhya Kalyanpur JB	69	209	63.98	21.33	287.91	82.78	7	2.14	0.71	9.64	98.94
89			Malayapur Kaora Para SSK	28	45	13.78	4.59	61.99	95.9	9	2.76	0.92	12.40	98.78
90			Nihata FP	36	55	16.84	5.61	75.77	95.1	9	2.76	0.92	12.40	98.78
91			Paschim Madhabpur SSK	26	253	77.45	25.82	348.52	79.26	84	25.71	8.57	115.71	92.78
92			Purandarpur FP	40	236	72.24	24.08	325.10	80.62	11	3.37	1.12	15.15	98.62
93			Purandarpur Math SSS FP	92	201	61.53	20.51	276.89	83.42	25	7.65	2.55	34.44	97.5
94			Tangtala FP	62	53	16.22	5.41	73.01	95.26	6	1.84	0.61	8.27	99.02
95			Uttar Khodarbazar Golam R FP	112	215	65.82	21.94	296.17	82.3	7	2.14	0.71	9.64	98.94
96			Wesley FP	25	72	22.04	7.35	99.18	93.74	4	1.22	0.41	5.51	99.18
97		Madarat	Atghara Kalikrishna BFP	40	165	50.51	16.84	227.30	86.3	7	2.14	0.71	9.64	98.94
98			Balban FP	82	247	75.61	25.20	340.26	79.74	11	3.37	1.12	15.15	98.62
99			Kalinagar FP	82	172	52.65	17.55	236.94	85.74	9	2.76	0.92	12.40	98.78
100			Kantapukur FP	74	134	41.02	13.67	184.59	88.78	7	2.14	0.71	9.64	98.94
101			Madarat Daspara SSK	33	323	98.88	32.96	444.95	73.66	9	2.76	0.92	12.40	98.78
102			Madarat Paschim JB	80	235	71.94	23.98	323.72	80.7	8	2.45	0.82	11.02	98.86

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103	Baruipur	Madarat	Madarat Popular Academy	314	169	51.73	17.24	232.81	85.98	9	2.76	0.92	12.40	98.78
104			Madarat Popular Academy	314	341	104.39	34.80	469.74	72.22	9	2.76	0.92	12.40	98.78
105			Madarat Purba JB	21	153	46.84	15.61	210.77	87.26	9	2.76	0.92	12.40	98.78
106			Madarhat Balika FP	26	146	44.69	14.90	201.12	87.82	40	12.24	4.08	55.10	96.3
107			Madhubanpur FP School	34	215	65.82	21.94	296.17	82.3	10	3.06	1.02	13.78	98.7
108			Majherhat FP	44	75	22.96	7.65	103.32	93.5	10	3.06	1.02	13.78	98.7
109			Najirpur JB	24	101	30.92	10.31	139.13	91.42	32	9.80	3.27	44.08	96.94
110			Tagarberia FP	47	105	32.14	10.71	144.64	91.1	8	2.45	0.82	11.02	98.86
111			U Madarhat Dasnagar FP	22	110	33.67	11.22	151.53	90.7	7	2.14	0.71	9.64	98.94
112		Mallickpur	Akna Mirzapur Friendship Unit FP	101	10	3.06	1.02	13.78	98.7	11	3.37	1.12	15.15	98.62
113			Balarampur JB	42	10	3.06	1.02	13.78	98.7	10	3.06	1.02	13.78	98.7
114			Beralia FP School	64	49	15.00	5.00	67.50	95.58	10	3.06	1.02	13.78	98.7
115			Faridpur JB	451	43	13.16	4.39	59.23	96.06	27	8.27	2.76	37.19	97.34
116			Ganeshpur FP	119	11	3.37	1.12	15.15	98.62	16	4.90	1.63	22.04	98.22
117			Kholapota FP	155	19	5.82	1.94	26.17	97.98	20	6.12	2.04	27.55	97.9
118			Mallickpur JB	743	114	34.90	11.63	157.04	90.38	28	8.57	2.86	38.57	97.26
119			Mallickpur Urdu FP	609	121	37.04	12.35	166.68	89.82	10	3.06	1.02	13.78	98.7
120			Panchghara FP	91	14	4.29	1.43	19.29	98.38	15	4.59	1.53	20.66	98.3
121			Petua Daspara FP	145	17	5.20	1.73	23.42	98.14	20	6.12	2.04	27.55	97.9
122			Petua Jr Basic School	56	12	3.67	1.22	16.53	98.54	4	1.22	0.41	5.51	99.18
123			Purandarpur New JB	67	15	4.59	1.53	20.66	98.3	26	7.96	2.65	35.82	97.42
124			Sree Rampur SSK	42	8	2.45	0.82	11.02	98.86	7	2.14	0.71	9.64	98.94
125		Nabagram	Beledhari SSK	25	10	3.06	1.02	13.78	98.7	9	2.76	0.92	12.40	98.78
126			Dumnan FP	52	28	8.57	2.86	38.57	97.26	8	2.45	0.82	11.02	98.86
127			Gordah FP	231	21	6.43	2.14	28.93	97.82	9	2.76	0.92	12.40	98.78

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128	Baruipur	Nabagram	Himchi FP	192	116	35.51	11.84	159.80	90.22	8	2.45	0.82	11.02	98.86
129			Kasthagara Panchgachia FP	73	42	12.86	4.29	57.86	96.14	9	2.76	0.92	12.40	98.78
130			Keyatala FP	353	326	99.80	33.27	449.08	73.42	19	5.82	1.94	26.17	97.98
131			Kumrakhali Bhatgoa SSK	35	172	52.65	17.55	236.94	85.74	41	12.55	4.18	56.48	96.22
132			Mollapara FP	82	181	55.41	18.47	249.34	85.02	22	6.73	2.24	30.31	97.74
133			Nabagram FP	141	85	26.02	8.67	117.09	92.7	26	7.96	2.65	35.82	97.42
134			Nabagram Vidyasagar	28	48	14.69	4.90	66.12	95.66	15	4.59	1.53	20.66	98.3
135			Paschim Panchgachia FP	51	81	24.80	8.27	111.58	93.02	24	1.53	0.51	6.89	99.1
136			Purba Panchgachia FP	54	142	43.47	14.49	195.61	88.14	9	2.76	0.92	12.40	98.78
137			Ramchandrapur FP	88	43	13.16	4.39	59.23	96.06	8	2.45	0.82	11.02	98.86
138			Salepur Kadampur FP	47	10	3.06	1.02	13.78	98.7	31	9.49	3.16	42.70	97.02
139			Teurhat FP	123	25	7.65	2.55	34.44	97.5	91	27.86	9.29	125.36	92.22
140			Uttar Nabagram Adibasi FP	21	78	23.88	7.96	107.45	93.26	4	1.22	0.41	5.51	99.18
141		Ramnagar 1	Sasari Rakshit Chandra FP	84	253	77.45	25.82	348.52	79.26	2	0.64	0.21	2.27	99.21
142			Uttarbhag Taltala SSK	51	243	74.39	24.80	334.74	80.06	4	1.22	0.41	5.51	99.18
143			Chittashali JB	95	201	61.53	20.51	276.89	83.42	9	2.76	0.92	12.40	98.78
144			Hariraj Chatarpar FP	106	239	73.16	24.39	329.23	80.38	8	2.45	0.82	11.02	98.86
145			Kailash Babur Abad	21	165	50.51	16.84	227.30	86.3	10	3.06	1.02	13.78	98.7
146			Kazirabad FP	30	146	44.69	14.90	201.12	87.82	12	3.67	1.22	16.53	98.54
147			Madhya Sita Chere Janyal Para SSK	26	962	294.49	98.16	1325.20	22.54	9	2.76	0.92	12.40	98.78
148			Madhya Sitakundu	115	302	92.45	30.82	416.02	75.34	26	7.96	2.65	35.82	97.42
149			Paschim Chitra Shali FP	25	115	35.20	11.73	158.42	90.3	4	1.22	0.41	5.51	99.18
150			Sitakundu JB	167	216	66.12	22.04	297.55	82.22	8	2.45	0.82	11.02	98.86
151			Changagram FP	110	224	68.57	22.86	308.57	81.58	11	3.37	1.12	15.15	98.62
152			Dudhanyi SSK	20	201	61.53	20.51	276.89	83.42	6	1.84	0.61	8.27	99.02

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153	Baruipur	Ramnagar 2	Dudhnai FP	25	218	66.73	22.24	300.31	82.06	5	1.53	0.51	6.89	99.1
154			Gurmirchak Chawalfeli FP	40	123	37.65	12.55	169.44	89.66	9	2.76	0.92	12.40	98.78
155			Nivedita Vidyapith FP	64	534	163.47	54.49	735.61	56.78	26	7.96	2.65	35.82	97.42
156			Ramnagar JB	219	118	36.12	12.04	162.55	90.06	8	2.45	0.82	11.02	98.86
157			Sankaripukur FP	26	129	39.49	13.16	177.70	89.18	7	2.14	0.71	9.64	98.94
158			Subhas Colony FP School	80	92	28.16	9.39	126.73	92.14	7	2.14	0.71	9.64	98.94
159			Uttar Ramnagar FP	50	213	65.20	21.73	293.42	82.46	28	8.57	2.86	38.57	97.26
160			Uttarbhag Ghat CS FP	228	301	92.14	30.71	414.64	75.42	6	1.84	0.61	8.27	99.02
161		Shankarpur 1	Alampur SSK	41	351	107.45	35.82	483.52	71.42	6	1.84	0.61	8.27	99.02
162			Dadpur SSK	77	83	25.41	8.47	114.34	92.86	16	3.06	1.02	13.78	98.7
163			Gazirhat Ratanpur FP	79	112	34.29	11.43	154.29	90.54	11	2.14	0.71	9.64	98.94
164			Kanthalberia HJB	78	169	51.73	17.24	232.81	85.98	9	2.76	0.92	12.40	98.78
165			Keshabpur JB	66	145	44.39	14.80	199.74	87.9	71	21.73	7.24	97.81	93.82
166			Khargeswar FP	106	109	33.37	11.12	150.15	90.78	74	22.65	7.55	101.94	93.58
167			Mirpur FP	95	125	38.27	12.76	172.19	89.5	14	2.14	0.71	9.64	98.94
168			Ratanpur FP	128	416	127.35	42.45	573.06	66.22	7	2.14	0.71	9.64	98.94
169			Tenka FP	120	624	191.02	63.67	859.59	49.58	6	1.84	0.61	8.27	99.02
170		Shankarpur 2	Balbalia JB	240	427	130.71	43.57	588.21	65.34	7	2.14	0.71	9.64	98.94
171			Banbariya SSK	21	452	138.37	46.12	622.65	63.34	7	2.14	0.71	9.64	98.94
172			Chaltaberiya SSK	28	370	113.27	37.76	509.69	69.9	10	3.06	1.02	13.78	98.7
173			Dakshin Gangaduara FP	34	76	23.27	7.76	104.69	93.42	22	6.73	2.24	30.31	97.74
174			Narayanpur SSK	28	110	33.67	11.22	151.53	90.7	13	2.45	0.82	11.02	98.86
175			Nore JB	101	173	52.96	17.65	238.32	85.66	56	17.14	5.71	77.14	95.02
176			Rajgara FP	186	98	30.00	10.00	135.00	91.66	18	5.51	1.84	24.80	98.06
177			Sankarpur Anchal FP	199	29	8.88	2.96	39.95	97.18	85	26.02	8.67	117.09	92.7
178		Shikharbali 1	Dakshin Kalyanpur JB	24	138	42.24	14.08	190.10	88.46	12	3.67	1.22	16.53	98.54

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179	Baruipur	Sikharbali 1	Banberia FP	57	109	33.37	11.12	150.15	90.78	10	0.92	0.31	4.13	99.26
180			Sikharbali JB	147	108	33.06	11.02	148.78	90.86	6	1.84	0.61	8.27	99.02
181			Dakshin Sasan FP	78	75	22.96	7.65	103.32	93.5	6	1.84	0.61	8.27	99.02
182			Goalbari FP	26	152	46.53	15.51	209.39	87.34	8	2.45	0.82	11.02	98.86
183			Paschim Ramnagar SSK	67	215	65.82	21.94	296.17	82.3	6	1.84	0.61	8.27	99.02
184			Ramgopalpur GS FP	51	235	71.94	23.98	323.72	80.7	36	11.02	3.67	49.59	96.62
185			Sikharbali Junior Basic	101	201	61.53	20.51	276.89	83.42	40	12.24	4.08	55.10	96.3
186			Tripuranagar Madhabpur FP	39	152	46.53	15.51	209.39	87.34	8	2.45	0.82	11.02	98.86
187		Sikharbali 2	Dakshin Indrapala FP	96	68	20.82	6.94	93.67	94.06	14	1.53	0.51	6.89	99.1
188			Dakshin Indrapala SSK	47	54	16.53	5.51	74.39	95.18	8	2.45	0.82	11.02	98.86
189			Debipur FP	24	163	49.90	16.63	224.54	86.46	8	2.45	0.82	11.02	98.86
190			Dhanberia FP	38	84	25.71	8.57	115.71	92.78	5	1.53	0.51	6.89	99.1
191			Durgo FP	139	48	14.69	4.90	66.12	95.66	8	2.45	0.82	11.02	98.86
192			Gopalpur FP	57	62	18.98	6.33	85.41	94.54	9	2.76	0.92	12.40	98.78
193			Indrapala JB	71	50	15.31	5.10	68.88	95.5	12	3.67	1.22	16.53	98.54
194			Kalikapur FP	58	91	27.86	9.29	125.36	92.22	9	2.76	0.92	12.40	98.78
195			Kotalpur FP	95	78	23.88	7.96	107.45	93.26	6	1.84	0.61	8.27	99.02
196			Mamudpur FP	65	47	14.39	4.80	64.74	95.74	21	6.43	2.14	28.93	97.82
197			Sonagachhi FP	26	42	12.86	4.29	57.86	96.14	23	7.04	2.35	31.68	97.66
198		South Garia	Bhanta Bairampur FP	23	71	21.73	7.24	97.81	93.82	7	2.14	0.71	9.64	98.94
199			Ghoshpur JB	26	114	34.90	11.63	157.04	90.38	8	2.45	0.82	11.02	98.86
200			Jamalhati SSK	28	19	5.82	1.94	26.17	97.98	9	2.76	0.92	12.40	98.78
201			Kharupatalia Umesh Tarak FP	24	29	8.88	2.96	39.95	97.18	15	4.59	1.53	20.66	98.3
202			Malanga FP	24	135	41.33	13.78	185.97	88.7	6	1.84	0.61	8.27	99.02
203			Naridana JB	60	70	21.43	7.14	96.43	93.9	9	2.76	0.92	12.40	98.78
204			Orancha FP	41	51	15.61	5.20	70.26	95.42	13	3.98	1.33	17.91	98.46

No	Block name	Village name	School name	Student pop	Shallow tubewell					Deep tubewell				
					As conc (ppb)	TDI (10^{-4})	HQ	CR (10^{-4})	IQ	As conc (ppb)	TDI (10^{-4})	HQ	CR (10^{-4})	IQ
205	Baruipur	South Garia	South Garia Amiyabala Fp	76	51	15.61	5.20	70.26	95.42	5	1.53	0.51	6.89	99.1
206			South Garia Jadunath Fp	167	48	14.69	4.90	66.12	95.66	7	2.14	0.71	9.64	98.94
207			South Garia P Para Jb	48	49	15.00	5.00	67.50	95.58	38	11.63	3.88	52.35	96.46
208			Tegachi FP	20	72	22.04	7.35	99.18	93.74	8	2.45	0.82	11.02	98.86
209	Bhangar I	Bodra	Arappur SSK	60	79	24.18	8.06	108.83	93.18	14	4.29	1.43	19.29	98.38
210			Baulia Para SSK	76	82	25.10	8.37	112.96	92.94	18	5.51	1.84	24.80	98.06
211			Bodra JB	159	65	19.90	6.63	89.54	94.3	12	3.67	1.22	16.53	98.54
212			Burangore FP	156	31	9.49	3.16	42.70	97.02	16	4.90	1.63	22.04	98.22
213			Chandpur FP	217	66	20.20	6.73	90.92	94.22	19	5.82	1.94	26.17	97.98
214			Dakhin Khargachi SSK	36	79	24.18	8.06	108.83	93.18	23	7.04	2.35	31.68	97.66
215			Erenda	91	72	22.04	7.35	99.18	93.74	19	5.82	1.94	26.17	97.98
216			Gokulpur FP	35	101	30.92	10.31	139.13	91.42	25	7.65	2.55	34.44	97.5
217			Kanjdia Gokulpur FB	154	83	25.41	8.47	114.34	92.86	25	7.65	2.55	34.44	97.5
218			Khargachi FP	413	86	26.33	8.78	118.47	92.62	7	2.14	0.71	9.64	98.94
219			Nakelberia FP	89	99	30.31	10.10	136.38	91.58	51	15.61	5.20	70.26	95.42
220			Naora Lalit Mohan FP	127	385	117.86	39.29	530.36	68.7	59	15.7	5.92	72.40	94.78
221			Noapara FP	218	48	14.69	4.90	66.12	95.66	26	7.96	2.65	35.82	97.42
222			Nowapara SSK	98	102	31.22	10.41	140.51	91.34	5	1.53	0.51	6.89	99.1
223			Pitha Simulia SSK	71	113	34.59	11.53	155.66	90.46	52	15.92	5.31	71.63	95.34
224			Sanpa SSK	143	119	36.43	12.14	163.93	89.98	8	2.45	0.82	11.02	98.86
225			Santra FP	83	110	33.67	11.22	151.53	90.7	5	1.53	0.51	6.89	99.1
226			Sree Rampur FP	45	115	35.20	11.73	158.42	90.3	27	8.27	2.76	37.19	97.34
227			Srirampur SSK	79	85	26.02	8.67	117.09	92.7	12	3.67	1.22	16.53	98.54
228		Chandaneswar I	Banagram FP	88	210	64.29	21.43	289.29	82.7	87	26.63	8.88	119.85	92.54
229			Chandaneswar FP	237	165	50.51	16.84	227.30	86.3	97	29.69	9.90	133.62	91.74
230			Dakshin Kasipur FP	165	180	55.10	18.37	247.96	85.1	95	29.08	9.69	130.87	91.9

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231	Bhangar I	Chandaneswar I	Dharmatala FP	48	192	58.78	19.59	264.49	84.14	99	30.31	10.10	136.38	91.58
232			Dharmatala SSK	26	100	30.61	10.20	137.76	91.5	82	25.10	8.37	112.96	92.94
233			Dighir Par SSK	113	135	41.33	13.78	185.97	88.7	74	22.65	7.55	101.94	93.58
234			Jalalabad FP	67	142	43.47	14.49	195.61	88.14	55	16.84	5.61	75.77	95.1
235			Kashinathpur FP	191	142	43.47	14.49	195.61	88.14	48	14.69	4.90	66.12	95.66
236			Kashinathpur SSK	55	201	61.53	20.51	276.89	83.42	20	6.12	2.04	27.55	97.9
237			Lawjunge SSK	62	100	30.61	10.20	137.76	91.5	5	1.53	0.51	6.89	99.1
238			Nakurait SSK	23	142	43.47	14.49	195.61	88.14	70	21.43	7.14	96.43	93.9
239			Sadur Ait SSK	42	99	30.31	10.10	136.38	91.58	7	2.14	0.71	9.64	98.94
240			Sardar Para SSK	50	453	138.67	46.22	624.03	63.26	34	10.41	3.47	46.84	96.78
241			Satberia SSK	42	272	83.27	27.76	374.69	77.74	16	4.90	1.63	22.04	98.22
242			Shakuntala SSK	41	211	64.59	21.53	290.66	82.62	113	34.59	11.53	155.66	90.46
243			Sundia Kamarhati JB	361	416	127.35	42.45	573.06	66.22	9	2.76	0.92	12.40	98.78
244		Chandaneswar II	Beliadanga FP	57	252	77.14	25.71	347.14	79.34	16	14.39	4.80	64.74	95.74
245			Dakhin Banagram SSK	42	370	113.27	37.76	509.69	69.9	60	18.37	6.12	82.65	94.7
246			Dakhin Madhabpur Naskarpara SSK	52	85	26.02	8.67	117.09	92.7	41	12.55	4.18	56.48	96.22
247			Dakshin Madhabpur FP	69	76	23.27	7.76	104.69	93.42	46	14.08	4.69	63.37	95.82
248			Hogoldara FP	55	32	9.80	3.27	44.08	96.94	33	10.10	3.37	45.46	96.86
249			Jhijer Ait SSK	60	163	49.90	16.63	224.54	86.46	65	19.90	6.63	89.54	94.3
250			Kalerite FP	120	265	81.12	27.04	365.05	78.3	81	24.80	8.27	111.58	93.02
251			Karunar Ait SSK	25	318	97.35	32.45	438.06	74.06	64	19.59	6.53	88.16	94.38
252			Kashi Danga M Pukuria FP	27	185	56.63	18.88	254.85	84.7	77	23.57	7.86	106.07	93.34
253			Kashinagar SSK	21	32	9.80	3.27	44.08	96.94	29	8.88	2.96	39.95	97.18
254			Kharkarite FP	51	210	64.29	21.43	289.29	82.7	12	3.67	1.22	16.53	98.54
255			Madhabpur Bacharpara SSK	29	68	20.82	6.94	93.67	94.06	8	2.45	0.82	11.02	98.86

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256	Bhangar I	Chandaneswar II	Maheshpukur FP	32	272	83.27	27.76	374.69	77.74	6	1.84	0.61	8.27	99.02
257			Taldighi FP	138	268	82.04	27.35	369.18	78.06	4	1.22	0.41	5.51	99.18
258			Uttar Kashia Danga SSK	34	327	100.10	33.37	450.46	73.34	15	4.59	1.53	20.66	98.3
259			Uttar Madhabpur FP	84	305	93.37	31.12	420.15	75.1	6	1.84	0.61	8.27	99.02
260		Durgapur	Badi Enayatpur FP	199	242	74.08	24.69	333.37	80.14	10	3.06	1.02	13.78	98.7
261			Bankri Durgapur FP	213	80	24.49	8.16	110.20	93.1	66	20.20	6.73	90.92	94.22
262			Bhandar Kuria SSK	93	140	42.86	14.29	192.86	88.3	59	18.06	6.02	81.28	94.78
263			Binar Aait SSK	117	192	58.78	19.59	264.49	84.14	67	20.51	6.84	92.30	94.14
264			Binarait Kantalia FP	108	306	93.67	31.22	421.53	75.02	28	8.57	2.86	38.57	97.26
265			Durgapur FP	123	198	60.61	20.20	272.76	83.66	9	2.76	0.92	12.40	98.78
266			Gajoapur SSK	67	193	59.08	19.69	265.87	84.06	27	8.27	2.76	37.19	97.34
267			Garanberia FP	84	161	49.29	16.43	221.79	86.62	26	7.96	2.65	35.82	97.42
268			Gorai Aait(Enaetpur) SSK	44	223	68.27	22.76	307.19	81.66	38	11.63	3.88	52.35	96.46
269			Hariharpur Dubjali FB	102	201	61.53	20.51	276.89	83.42	52	15.92	5.31	71.63	95.34
270			Harishpur FP	70	58	17.76	5.92	79.90	94.86	63	19.29	6.43	86.79	94.46
271			Kachuya SSK	30	160	48.98	16.33	220.41	86.7	55	16.84	5.61	75.77	95.1
272			Mathurapur FP	224	55	16.84	5.61	75.77	95.1	5	1.53	0.51	6.89	99.1
273			Methoraeit SSK	55	174	53.27	17.76	239.69	85.58	37	11.33	3.78	50.97	96.54
274			Paulpara Hariharpur SSK	78	230	70.41	23.47	316.84	81.1	33	10.10	3.37	45.46	96.86
275			Rajapur FP	145	214	65.51	21.84	294.80	82.38	8	2.45	0.82	11.02	98.86
276			Satberia FP	73	136	41.63	13.88	187.35	88.62	90	27.55	9.18	123.98	92.3
277			Sondalia JB	149	178	54.49	18.16	245.20	85.26	21	6.43	2.14	28.93	97.82
278			Sondalia SSK	87	175	53.57	17.86	241.07	85.5	26	7.96	2.65	35.82	97.42
279			Swarup Beria SSK	77	224	68.57	22.86	308.57	81.58	104	31.84	10.61	143.27	91.18
280		Jagulgacchi	Bagan-Ait SSK	52	106	32.45	10.82	146.02	91.02	16	4.90	1.63	22.04	98.22
281			Bamunia FP	100	73	22.35	7.45	100.56	93.66	9	2.76	0.92	12.40	98.78

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282	Bhangar I	Jagulgacchi	Barjuli FP	99	110	33.67	11.22	151.53	90.7	5	1.53	0.51	6.89	99.1
283			Bhangore Bazar SSK	44	79	24.18	8.06	108.83	93.18	8	2.45	0.82	11.02	98.86
284			Bhangore FP	191	75	22.96	7.65	103.32	93.5	11	3.37	1.12	15.15	98.62
285			Chandipur Rangsara FP	119	73	22.35	7.45	100.56	93.66	8	2.45	0.82	11.02	98.86
286			Debipur FP	140	78	23.88	7.96	107.45	93.26	10	3.06	1.02	13.78	98.7
287			Dhara Barjuti FP	99	108	33.06	11.02	148.78	90.86	14	4.29	1.43	19.29	98.38
288			Fulbari Bamunia Khamarait FP	28	174	53.27	17.76	239.69	85.58	9	2.76	0.92	12.40	98.78
289			Fulbari FP	167	106	32.45	10.82	146.02	91.02	14	4.29	1.43	19.29	98.38
290			Gab Tala SSK	60	73	22.35	7.45	100.56	93.66	12	3.67	1.22	16.53	98.54
291			Gadhuni Ait SSK	58	78	23.88	7.96	107.45	93.26	9	2.76	0.92	12.40	98.78
292			Gobindapur FB	126	62	18.98	6.33	85.41	94.54	9	2.76	0.92	12.40	98.78
293			Jagulgachi JB	106	72	22.04	7.35	99.18	93.74	8	2.45	0.82	11.02	98.86
294			Kulti Block No 5 G S FP	326	68	20.82	6.94	93.67	94.06	12	3.67	1.22	16.53	98.54
295			Nalpukur FP	90	96	29.39	9.80	132.24	91.82	6	1.84	0.61	8.27	99.02
296			Paschim Barjuli SSK	52	72	22.04	7.35	99.18	93.74	29	8.88	2.96	39.95	97.18
297			Rangsara FP	40	75	22.96	7.65	103.32	93.5	10	3.06	1.02	13.78	98.7
298			Rangsara SSK	29	63	19.29	6.43	86.79	94.46	23	7.04	2.35	31.68	97.66
299		Pranganj	Bhangar Office Para SSK	30	90	27.55	9.18	123.98	92.3	27	8.27	2.76	37.19	97.34
300			Chockborali FP	292	105	32.14	10.71	144.64	91.1	18	5.51	1.84	24.80	98.06
301			Dakhin Kalikapur SSK	44	78	23.88	7.96	107.45	93.26	26	7.96	2.65	35.82	97.42
302			Dakshin Kalikapur FP	86	116	35.51	11.84	159.80	90.22	22	6.73	2.24	30.31	97.74
303			Garai Juli SSK	29	300	91.84	30.61	413.27	75.5	38	11.63	3.88	52.35	96.46
304			Kalikapur FP	297	142	43.47	14.49	195.61	88.14	37	11.33	3.78	50.97	96.54
305			Kalikapur SSK	23	210	64.29	21.43	289.29	82.7	19	5.82	1.94	26.17	97.98
306			Malancha FP	105	70	21.43	7.14	96.43	93.9	10	3.06	1.02	13.78	98.7
307			Maricha FP	172	160	48.98	16.33	220.41	86.7	9	2.76	0.92	12.40	98.78

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308	Bhangar I	Pranganj	Mobarak Ali Shah FP	88	160	48.98	16.33	220.41	86.7	7	2.14	0.71	9.64	98.94
309			Moricha SSK	23	60	18.37	6.12	82.65	94.7	5	1.53	0.51	6.89	99.1
310			Nalmuri FP	92	281	86.02	28.67	387.09	77.02	70	20.5	7.84	84.80	93.06
311			No 4 Kulti G S FP	89	140	42.86	14.29	192.86	88.3	58	17.76	5.92	79.90	94.86
312			Raghunathpur FP	108	76	23.27	7.76	104.69	93.42	15	4.59	1.53	20.66	98.3
313			Rajapur D Ali FP	181	49	15.00	5.00	67.50	95.58	52	15.92	5.31	71.63	95.34
314			Ram Krishna Pally SSK	42	210	64.29	21.43	289.29	82.7	4	1.22	0.41	5.51	99.18
315			Rani Gachi Purba Das Parassk	72	83	25.41	8.47	114.34	92.86	5	1.53	0.51	6.89	99.1
316			Ranigachi Purba Das Para SSK	72	287	87.86	29.29	395.36	76.54	107	32.5	11.1	146	91.01
317			Saihati FP	136	62	18.98	6.33	85.41	94.54	4	1.22	0.41	5.51	99.18
318			Saitgachi FP	138	219	67.04	22.35	301.68	81.98	40	12.2	4.1	55.5	96.22
319			Serpur FP	193	118	36.12	12.04	162.55	90.06	7	2.14	0.71	9.64	98.94
320		Sanksahar	Baksahar FP	227	170	52.04	17.35	234.18	85.9	100	30.61	10.20	137.76	91.5
321			Balipur FP	126	196	60.00	20.00	270.00	83.82	106	32.45	10.82	146.02	91.02
322			Bangoda FP	122	121	37.04	12.35	166.68	89.82	98	30.00	10.00	135.00	91.66
323			Bazar Aait SSK	34	134	41.02	13.67	184.59	88.78	157	48.06	16.02	216.28	86.94
324			Bazaraite FP	78	52	15.92	5.31	71.63	95.34	125	38.27	12.76	172.19	89.5
325			Chockvika FP	183	210	64.29	21.43	289.29	82.7	127	38.88	12.96	174.95	89.34
326			Dingabhanga FP	97	239	73.16	24.39	329.23	80.38	98	30.00	10.00	135.00	91.66
327			Ghunri FP	90	172	52.65	17.55	236.94	85.74	94	28.78	9.59	129.49	91.98
328			Sanksahar SSK	33	212	64.90	21.63	292.04	82.54	56	17.14	5.71	77.14	95.02
329			Shanksahar FP	201	228	69.80	23.27	314.08	81.26	31	9.49	3.16	42.70	97.02
330			Situri FP	108	231	70.71	23.57	318.21	81.02	9	2.76	0.92	12.40	98.78
331		Tardaha	1no.Kanta Tala FB	77	38	11.63	3.88	52.35	96.46	9	2.76	0.92	12.40	98.78
332			Andulgaria FP	35	47	14.39	4.80	64.74	95.74	9	2.76	0.92	12.40	98.78
333			Beder Aait FP	76	36	11.02	3.67	49.59	96.62	10	3.06	1.02	13.78	98.7

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334	Bhangar I	Tardaha	Bhantipota FP	61	134	41.02	13.67	184.59	88.78	18	5.51	1.84	24.80	98.06
335			Durgapur Chandipur FP	115	81	24.80	8.27	111.58	93.02	22	6.73	2.24	30.31	97.74
336			Gangapur Bagdipara SSK	53	54	16.53	5.51	74.39	95.18	19	5.82	1.94	26.17	97.98
337			Gangapur JB	61	118	36.12	12.04	162.55	90.06	21	6.43	2.14	28.93	97.82
338			Haderait FP	30	230	70.41	23.47	316.84	81.1	15	4.59	1.53	20.66	98.3
339			Haripora FP	29	54	16.53	5.51	74.39	95.18	11	3.37	1.12	15.15	98.62
340			Haripota FP	29	63	19.29	6.43	86.79	94.46	18	5.51	1.84	24.80	98.06
341			Karaidanga FP	39	11	3.37	1.12	15.15	98.62	12	3.67	1.22	16.53	98.54
342			Kulti 2 No G S FP	189	40	12.24	4.08	55.10	96.3	7	2.14	0.71	9.64	98.94
343			Mousal FP	35	39	11.94	3.98	53.72	96.38	29	8.88	2.96	39.95	97.18
344			Sawradaria F.P	22	256	78.37	26.12	352.65	79.02	6	1.84	0.61	8.27	99.02
345			Shauradaria FP	53	199	60.92	20.31	274.13	83.58	26	8.6	2.7	37.6	97.1
346			Sonatikari FP	26	85	26.02	8.67	117.09	92.7	18	5.51	1.84	24.80	98.06
347			Sonatikari SSK	29	38	11.63	3.88	52.35	96.46	9	2.76	0.92	12.40	98.78
348			Tardaha Naskarait FP	128	122	37.35	12.45	168.06	89.74	7	2.14	0.71	9.64	98.94
349			Tong Para SSK	24	40	12.24	4.08	55.10	96.3	6	1.84	0.61	8.27	99.02
350	Bhangar II	Bamanghata	Bagdoba Garumara FP	21	18	5.51	1.84	24.80	98.06	45	13.78	4.59	61.99	95.9
351			Bamanghata FP	143	51	15.61	5.20	70.26	95.42	42	12.86	4.29	57.86	96.14
352			Bokdoba SSK	48	80	24.49	8.16	110.20	93.1	38	11.63	3.88	52.35	96.46
353			Dakshin Bamanghata FP	140	60	18.37	6.12	82.65	94.7	34	10.41	3.47	46.84	96.78
354			Dhalipara FP	52	65	19.90	6.63	89.54	94.3	25	7.65	2.55	34.44	97.5
355			Hatgachha FP	26	48	14.69	4.90	66.12	95.66	25	7.65	2.55	34.44	97.5
356			Hatgachha Sardarpara FP	68	55	16.84	5.61	75.77	95.1	12	3.67	1.22	16.53	98.54
357			Jothbhim FP	54	82	25.10	8.37	112.96	92.94	15	4.59	1.53	20.66	98.3
358			Konchpukur F.P	167	54	16.53	5.51	74.39	95.18	56	17.14	5.71	77.14	95.02
359			Kulti 1 No. G S FP	110	70	21.43	7.14	96.43	93.9	20	6.12	2.04	27.55	97.9

No	Block name	Village name	School name	Student pop	Shallow tubewell					Deep tubewell				
					As conc (ppb)	TDI (10^{-4})	HQ	CR (10^{-4})	IQ	As conc (ppb)	TDI (10^{-4})	HQ	CR (10^{-4})	IQ
360	Bhangar II	Bamanghata	Uttar Hatgacha Sardar Para FP	118	58	17.76	5.92	79.90	94.86	67	20.51	6.84	92.30	94.14
361		Benota I	Beonta JB	58	51	15.61	5.20	70.26	95.42	20	6.12	2.04	27.55	97.9
362			Chariswar FP	106	48	14.69	4.90	66.12	95.66	31	9.49	3.16	42.70	97.02
363			Gaskhali SSK	20	41	12.55	4.18	56.48	96.22	38	11.63	3.88	52.35	96.46
364			Ghashkhali FP	50	79	24.18	8.06	108.83	93.18	39	11.94	3.98	53.72	96.38
365			Kantatala FP	214	78	23.88	7.96	107.45	93.26	53	16.22	5.41	73.01	95.26
366			Krol Beria FP	90	103	31.53	10.51	141.89	91.26	8	2.45	0.82	11.02	98.86
367			Suk Pukur FP	59	105	32.14	10.71	144.64	91.1	9	2.76	0.92	12.40	98.78
368		Benota II	Dharmatala Panchuria FP	32	65	19.90	6.63	89.54	94.3	80	24.49	8.16	110.20	93.1
369			Hatishala JB	228	112	34.29	11.43	154.29	90.54	62	18.98	6.33	85.41	94.54
370			Kanthalberia FP	166	120	36.73	12.24	165.31	89.9	58	17.76	5.92	79.90	94.86
371			Kulberia Dharmatala FP	85	102	31.22	10.41	140.51	91.34	58	17.76	5.92	79.90	94.86
372			Kulberia Vivekananda FP	116	64	19.59	6.53	88.16	94.38	69	21.12	7.04	95.05	93.98
373			Paikan FP	143	38	11.63	3.88	52.35	96.46	30	9.18	3.06	41.33	97.1
374			Pukur Ait SSK	25	72	22.04	7.35	99.18	93.74	37	11.33	3.78	50.97	96.54
375			Pukurait FP	25	48	14.69	4.90	66.12	95.66	5	1.53	0.51	6.89	99.1
376			Wari FP	170	75	22.96	7.65	103.32	93.5	3	0.92	0.31	4.13	99.26
377		Bhagawanpur	74 No. Paschim Satuliya Ssk	79	363	111.12	37.04	500.05	70.46	57	17.45	5.82	78.52	94.94
378			Bhagabanpur FP	222	160	48.98	16.33	220.41	86.7	58	17.76	5.92	79.90	94.86
379			Chayani FP	184	172	52.65	17.55	236.94	85.74	56	17.14	5.71	77.14	95.02
380			Gabtala FP	122	61	18.67	6.22	84.03	94.62	56	17.14	5.71	77.14	95.02
381			Girengachi FP	230	142	43.47	14.49	195.61	88.14	54	16.53	5.51	74.39	95.18
382			Jirangacha SSK	87	60	18.37	6.12	82.65	94.7	47	14.39	4.80	64.74	95.74
383			Langalbenki FP	232	162	49.59	16.53	223.16	86.54	10	3.06	1.02	13.78	98.7
384			Natapurkur FP	210	130	39.80	13.27	179.08	89.1	8	2.45	0.82	11.02	98.86
385			Pithapukuria FP	264	152	42.47	14.49	182.11	91.06	64	19.59	6.53	88.16	94.38

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					As conc (ppb)	TDI (10^{-4})	HQ	CR (10^{-4})	IQ	As conc (ppb)	TDI (10^{-4})	HQ	CR (10^{-4})	IQ
386	Bhangar II	Bhagawanpur	Pithapukuria junior high school	123	152	46.53	15.51	209.39	87.34	11	3.37	1.12	15.15	98.62
387			Purba satulia f.p	107	80	24.49	8.16	110.20	93.1	8	2.45	0.82	11.02	98.86
388			Satulia FP	219	82	25.10	8.37	112.96	92.94	20	6.12	2.04	27.55	97.9
389			Tarahadia FP	126	85	26.02	8.67	117.09	92.7	48	14.69	4.90	66.12	95.66
390		Bhogali I	Alakulia FP	297	180	55.10	18.37	247.96	85.1	32	9.80	3.27	44.08	96.94
391			Bhogali JB	226	156	47.76	15.92	214.90	87.02	35	10.71	3.57	48.21	96.7
392			Chilatala FP	106	520	159.18	53.06	716.33	57.9	27	8.27	2.76	37.19	97.34
393			Jamirgachhi FP	154	190	58.16	19.39	261.73	84.3	31	9.49	3.16	42.70	97.02
394			Nangla FP	126	236	72.24	24.08	325.10	80.62	18	5.51	1.84	24.80	98.06
395			Nanla sonarjel SSK	88	160	48.98	16.33	220.41	86.7	59	18.06	6.02	81.28	94.78
396			Nibondhua FP	28	124	37.96	12.65	170.82	89.58	7	2.14	0.71	9.64	98.94
397			Paschim raghunathpur SSK	38	252	77.14	25.71	347.14	79.34	39	11.94	3.98	53.72	96.38
398			Purba bhogali FP	123	123	37.65	12.55	169.44	89.66	34	10.41	3.47	46.84	96.38
399			Raghunathpur FP	165	252	77.14	25.71	347.14	79.34	34	10.41	3.47	46.84	96.78
400			Raghunathpur FP	146	128	39.18	13.06	176.33	89.26	34	10.41	3.47	46.84	96.78
401			Satbhaiya FP	151	240	73.47	24.49	330.61	80.3	8	2.45	0.82	11.02	98.86
402		Bhogali II	Baniara FP	139	232	71.02	23.67	319.59	80.94	15	4.59	1.53	20.66	98.3
403			Baniyara purbapara SSK	34	224	68.57	22.86	308.57	81.58	11	3.37	1.12	15.15	98.62
404			Bhumru FP	198	225	68.88	22.96	309.95	81.5	9	2.76	0.92	12.40	98.78
405			GhonJBaniara FB	122	290	88.78	29.59	399.49	76.3	16	4.90	1.63	22.04	98.22
406			Kantadanga FP	157	241	73.78	24.59	331.99	80.22	19	5.82	1.94	26.17	97.98
407			Kantalia f.p	125	208	63.67	21.22	286.53	82.86	25	7.65	2.55	34.44	97.5
408			Panchgachia FP	101	156	47.76	15.92	214.90	87.02	6	1.84	0.61	8.27	99.02
409			Paschim kathaliya SSK	166	128	39.18	13.06	176.33	89.26	12	3.67	1.22	16.53	98.54
410			Purba kathaliya SSK	23	136	41.63	13.88	187.35	88.62	7	2.14	0.71	9.64	98.94
411			Uttar kanthalia SSK	165	230	70.41	23.47	316.84	81.1	21	6.43	2.14	28.93	97.82

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412	Bhangar II	Bhogali II	Uttar Kanthalia FP	144	98	30.00	10.00	135.00	91.66	22	17.14	5.71	77.14	95.02
413		Polerhat I	Anantapur F.P	125	130	39.80	13.27	179.08	89.1	57	17.45	5.82	78.52	94.94
414			Dakshin Gagipur SSK	82	142	43.47	14.49	195.61	88.14	53	16.22	5.41	73.01	95.26
415			Joynagar Shyamnagar FP	307	105	32.14	10.71	144.64	91.1	67	20.51	6.84	92.30	94.14
416			Kesher Ait FP	109	132	40.41	13.47	181.84	88.94	7	2.14	0.71	9.64	98.94
417			Khyerpur FP	159	115	35.20	11.73	158.42	90.3	5	1.53	0.51	6.89	99.1
418			Nowabad FP	140	100	30.61	10.20	137.76	91.5	37	11.33	3.78	50.97	96.54
419			Purba Nowabad FP	182	103	31.53	10.51	141.89	91.26	7	2.14	0.71	9.64	98.94
420			Swastyangachi FP	199	114	34.90	11.63	157.04	90.38	13	3.98	1.33	17.91	98.46
421		Polerhat II	Khamaraite F.P	100	92	28.16	9.39	126.73	92.14	19	5.82	1.94	26.17	97.98
422			Shyamnagar FP	250	128	39.18	13.06	176.33	89.26	9	2.76	0.92	12.40	98.78
423			Swarupnagar FP	246	116	35.51	11.84	159.80	90.22	42	12.86	4.29	57.86	96.14
424			Tona FP	145	135	41.33	13.78	185.97	88.7	66	20.20	6.73	90.92	94.22
425			Tona Machibhanga FP	112	120	36.73	12.24	165.31	89.9	67	20.51	6.84	92.30	94.14
426			Tona Uriapara Gazipur FP	355	118	36.12	12.04	162.55	90.06	14	4.29	1.43	19.29	98.38
427			Uttar Gazipur Jamadarpukur FP	82	143	43.78	14.59	196.99	88.06	16	4.90	1.63	22.04	98.22
428			Uttar Swarupnagar FP	54	105	32.14	10.71	144.64	91.1	15	4.59	1.53	20.66	98.3
429		Shanpukur	Chini Pukur SSK	70	72	22.04	7.35	99.18	93.74	48	14.69	4.90	66.12	95.66
430			Dakshin Kashipur Adarsha FP	268	81	24.80	8.27	111.58	93.02	40	12.24	4.08	55.10	96.3
431			Dheyati Chinipukur FP	235	72	22.04	7.35	99.18	93.74	39	11.94	3.98	53.72	96.38
432			Dheyati FP	145	81	24.80	8.27	111.58	93.02	39	11.94	3.98	53.72	96.38
433			Garagacha FP	406	80	24.49	8.16	110.20	93.1	34	10.41	3.47	46.84	96.78
434			Kashipur FP	113	52	15.92	5.31	71.63	95.34	27	8.27	2.76	37.19	97.34
435			Katjala FP	62	72	22.04	7.35	99.18	93.74	28	8.57	2.86	38.57	97.26
436			Khanpur Mirpur Jb	65	217	66.43	22.14	298.93	82.14	8	2.9	0.96	13.54	98.74
437			Majherhat C Goalia FP	187	48	14.69	4.90	66.12	95.66	10	3.06	1.02	13.78	98.7

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438	Bhangar II	Shanpukur	Mangalpur FP	35	102	31.22	10.41	140.51	91.34	20	6.12	2.04	27.55	97.9
439			Maniktala FP	146	139	42.55	14.18	191.48	88.38	26	7.96	2.65	35.82	97.42
440			Maniktala SSK	58	76	23.27	7.76	104.69	93.42	18	5.51	1.84	24.80	98.06
441			Metoaite FP	109	98	30.00	10.00	135.00	91.66	16	4.90	1.63	22.04	98.22
442			Nimkuria JB	327	116	35.51	11.84	159.80	90.22	5	1.53	0.51	6.89	99.1
443			Sanpukur Anchal FP	199	116	35.51	11.84	159.80	90.22	7	2.1	0.7	9.65	99.01
444			Shanpukur FP	189	92	28.16	9.39	126.73	92.14	26	7.96	2.65	35.82	97.42
445			Sonepur FP	152	32	9.80	3.27	44.08	96.94	9	2.76	0.92	12.40	98.78
446			Uttar Kachua FP	49	119	36.43	12.14	163.93	89.98	16	4.90	1.63	22.04	98.22
447			Uttar Rajapur FP	86	161	49.29	16.43	221.79	86.62	5	1.53	0.51	6.89	99.1
448			Chandihat FP	162	72	22.04	7.35	99.18	93.74	30	9.18	3.06	41.33	97.1
449			Paschim Majherhat FP	294	136	41.63	13.88	187.35	88.62	84	25.1	8.37	113	92.3
450			Chandihat Khanner Pole SSK	45	75	22.96	7.65	103.32	93.5	38	11.63	3.88	52.35	96.46
451	Bishnupur I	Amgachhia	Amgacchia Ashwathatala FP	96	23	7.04	2.35	31.68	97.66	22	6.73	2.24	30.31	97.74
452			Amgachhia FP	81	18	5.51	1.84	24.80	98.06	24	7.35	2.45	33.06	97.58
453			Amgachhia Lalbahadur Gs FP	138	22	6.73	2.24	30.31	97.74	30	9.18	3.06	41.33	97.1
454			Amgachhia Vidyachandra FP	67	23	7.04	2.35	31.68	97.66	32	9.80	3.27	44.08	96.94
455			Dakshin Amgacchia SSK	106	21	6.43	2.14	28.93	97.82	28	8.57	2.86	38.57	97.26
456			Debipur Krishnarampur FP	22	21	6.43	2.14	28.93	97.82	32	9.80	3.27	44.08	96.94
457			Kalinagar FP	79	25	7.65	2.55	34.44	97.5	35	10.71	3.57	48.21	96.7
458			Kasto Mohol FP	60	23	7.04	2.35	31.68	97.66	21	6.43	2.14	28.93	97.82
459			Krishanarampur Malanga FP	39	20	6.12	2.04	27.55	97.9	58	17.76	5.92	79.90	94.86
460		Andharmanik	Altaberia FP	62	38	11.63	3.88	52.35	96.46	5	1.53	0.51	6.89	99.1
461			Andhar Manik Jb	143	19	5.82	1.94	26.17	97.98	16	4.90	1.63	22.04	98.22
462			Chak Netai FP	82	10	3.06	1.02	13.78	98.7	16	4.90	1.63	22.04	98.22
463			Durgabati FP	45	11	3.37	1.12	15.15	98.62	19	5.82	1.94	26.17	97.98

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464	Bishnupur I	Andharmanik	Ganga Rai FP	87	10	3.06	1.02	13.78	98.7	22	6.73	2.24	30.31	97.74
465			Kalipur FP	30	12	3.67	1.22	16.53	98.54	19	5.82	1.94	26.17	97.98
466			Kalmikhali FP	20	10	3.06	1.02	13.78	98.7	18	5.51	1.84	24.80	98.06
467			Keapukuria FP	34	19	5.82	1.94	26.17	97.98	17	5.20	1.73	23.42	98.14
468			Prasadpur FP	25	18	5.51	1.84	24.80	98.06	60	18.37	6.12	82.65	94.7
469		Kulerdari	Daulatpur FP	162	42	12.86	4.29	57.86	96.14	82	25.10	8.37	112.96	92.94
470			Kulerdari (Stipendari) FP	32	10	3.06	1.02	13.78	98.7	51	15.61	5.20	70.26	95.42
471			Kulerdari FP	34	11	3.37	1.12	15.15	98.62	7	2.14	0.71	9.64	98.94
472			Raghudebpur FP	33	13	3.98	1.33	17.91	98.46	38	11.63	3.88	52.35	96.46
473			Raghudebpur Karimpur	29	22	6.73	2.24	30.31	97.74	12	3.67	1.22	16.53	98.54
474			Sarmostachak FP	62	21	6.43	2.14	28.93	97.82	2	0.61	0.20	2.76	99.34
475		Panakua	Bakesor FP	33	78	23.88	7.96	107.45	93.26	47	14.39	4.80	64.74	95.74
476			Chak B Fpalai Bag Nonilal	28	262	80.20	26.73	360.92	78.54	36	11.02	3.67	49.59	96.62
477			Chak Kalmi Nabin FP	21	142	43.47	14.49	195.61	88.14	31	9.49	3.16	42.70	97.02
478			Kalicharanpur FP	25	45	13.78	4.59	61.99	95.9	26	7.96	2.65	35.82	97.42
479			Magurkhali FP	29	38	11.63	3.88	52.35	96.46	6	1.84	0.61	8.27	99.02
480			Nepalgonj Senhamoyee FP	48	25	7.65	2.55	34.44	97.5	15	4.59	1.53	20.66	98.3
481			Newshal FP	32	15	4.59	1.53	20.66	98.3	8	2.45	0.82	11.02	98.86
482			Panakua FP	135	17	5.20	1.73	23.42	98.14	40	12.24	4.08	55.10	96.3
483			Ramkantapur FP	24	104	31.84	10.61	143.27	91.18	6	1.84	0.61	8.27	99.02
484			Salpukur FP	20	44	13.47	4.49	60.61	95.98	15	4.59	1.53	20.66	98.3
485	Canning II	Bansra	Bansra Nutun FP	55	12	3.67	1.22	16.53	98.54	18	5.51	1.84	24.80	98.06
486			Bansra Pratapgar Colony FP	56	21	6.43	2.14	28.93	97.82	22	6.73	2.24	30.31	97.74
487			Biplabi Nagar SSK	61	48	14.69	4.90	66.12	95.66	49	15.00	5.00	67.50	95.58
488			Ganthi FP	67	45	13.78	4.59	61.99	95.9	32	9.80	3.27	44.08	96.94
489			Ghutiari Sharif FP	151	72	22.04	7.35	99.18	93.74	75	22.96	7.65	103.32	93.5

No	Block name	Village name	School name	Student pop	Shallow tubewell					Deep tubewell				
					As conc (ppb)	TDI (10^{-4})	HQ	CR (10^{-4})	IQ	As conc (ppb)	TDI (10^{-4})	HQ	CR (10^{-4})	IQ
490	Canning II	Bansra	Kolaria FP	420	63	19.29	6.43	86.79	94.46	15	4.59	1.53	20.66	98.3
491		Deuli I	2 No Chanditala SSK	92	82	25.10	8.37	112.96	92.94	20	6.12	2.04	27.55	97.9
492			Burimari FP	130	72	22.04	7.35	99.18	93.74	22	6.73	2.24	30.31	97.74
493			Chandibari FP	411	78	23.88	7.96	107.45	93.26	24	7.35	2.45	33.06	97.58
494			Chunaghata Sanatanpur FP	215	70	21.43	7.14	96.43	93.9	25	7.65	2.55	34.44	97.5
495			D. Mallickkati Bererkhal Ssk	105	72	22.04	7.35	99.18	93.74	25	7.65	2.55	34.44	97.5
496			Gheekhali FP	241	75	22.96	7.65	103.32	93.5	26	7.96	2.65	35.82	97.42
497			Kalugacchi Bademari FP	234	71	21.73	7.24	97.81	93.82	26	7.96	2.65	35.82	97.42
498			Mallickkati JB	96	74	22.65	7.55	101.94	93.58	25	7.65	2.55	34.44	97.5
499			Mulchatki Adhibasi Para SSK	28	72	22.04	7.35	99.18	93.74	6	1.84	0.61	8.27	99.02
500			Sastakhali FP	128	79	24.18	8.06	108.83	93.18	20	6.12	2.04	27.55	97.9
501		Deuli II	Bamunia Banshidhar Smriti SSK	125	70	21.43	7.14	96.43	93.9	25	7.65	2.55	34.44	97.5
502			Bamunia FP	41	70	21.43	7.14	96.43	93.9	25	7.65	2.55	34.44	97.5
503			Deuli Ganti FP	27	72	22.04	7.35	99.18	93.74	23	7.04	2.35	31.68	97.66
504			Deuli Jamadar Para SSK	44	80	24.49	8.16	110.20	93.1	25	7.65	2.55	34.44	97.5
505			Deuli JB	145	75	22.96	7.65	103.32	93.5	24	7.35	2.45	33.06	97.58
506			Ganti FP	370	82	25.10	8.37	112.96	92.94	26	7.96	2.65	35.82	97.42
507			Guntri FP	168	78	23.88	7.96	107.45	93.26	26	7.96	2.65	35.82	97.42
508			Gutri SSK	28	78	23.88	7.96	107.45	93.26	28	8.57	2.86	38.57	97.26
509			Joykhali SSK	28	72	22.04	7.35	99.18	93.74	29	8.88	2.96	39.95	97.18
510			Kaluakhali FP	248	60	18.37	6.12	82.65	94.7	28	8.57	2.86	38.57	97.26
511			Kayemkha FP	68	102	31.22	10.41	140.51	91.34	30	9.18	3.06	41.33	97.1
512			Madan Khali FP	183	76	23.27	7.76	104.69	93.42	4	1.22	0.41	5.51	99.18
513			Mukherjee Para FP	227	72	22.04	7.35	99.18	93.74	6	1.84	0.61	8.27	99.02
514		Motherdighi	Keoratala FP	139	33	10.10	3.37	45.46	96.86	6	1.84	0.61	8.27	99.02

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515	Canning II	Sarengabad	Araibanki SSK	47	49	15.00	5.00	67.50	95.58	20	6.12	2.04	27.55	97.9
516			Gangacheri FP	336	38	11.63	3.88	52.35	96.46	9	2.76	0.92	12.40	98.78
517			Gangacheri SSK	122	112	34.29	11.43	154.29	90.54	27	8.27	2.76	37.19	97.34
518			Hadia FP	141	121	37.04	12.35	166.68	89.82	27	8.27	2.76	37.19	97.34
519			Hedia Kacharipara SSK	145	84	25.71	8.57	115.71	92.78	24	7.35	2.45	33.06	97.58
520			Howramari FP	442	86	26.33	8.78	118.47	92.62	22	6.73	2.24	30.31	97.74
521			Iswaripur FP	232	142	43.47	14.49	195.61	88.14	30	9.18	3.06	41.33	97.1
522			Iswaripur New FP	95	144	44.08	14.69	198.37	87.98	34	10.41	3.47	46.84	96.78
523			Itkhola FP	214	161	49.29	16.43	221.79	86.62	37	11.33	3.78	50.97	96.54
524			Jibantala FP	565	30	9.18	3.06	41.33	97.1	25	7.65	2.55	34.44	97.5
525			Khagra FP	415	32	9.80	3.27	44.08	96.94	8	2.45	0.82	11.02	98.86
526			Mirergheri FP	282	45	13.78	4.59	61.99	95.9	7	2.14	0.71	9.64	98.94
527			Netrabad FP	328	124	37.96	12.65	170.82	89.58	31	9.49	3.16	42.70	97.02
528			Payna FP	170	72	22.04	7.35	99.18	93.74	19	5.82	1.94	26.17	97.98
529			Ramrayer Gheri FP	135	105	32.14	10.71	144.64	91.1	9	2.76	0.92	12.40	98.78
530			Sarengabad 2 No. FP	467	158	48.37	16.12	217.65	86.86	7	2.14	0.71	9.64	98.94
531			Singheswar FP	106	164	50.20	16.73	225.92	86.38	7	2.14	0.71	9.64	98.94
532		Tambuldaha I	Patikhali FP	53	128	39.18	13.06	176.33	89.26	35	10.7	3.57	48.21	96.7
533			Bagmari Janata FP	122	100	30.61	10.20	137.76	91.5	43	13.16	4.39	59.23	96.06
534			Bagmari New FP	330	58	17.76	5.92	79.90	94.86	35	10.71	3.57	48.21	96.7
535			Bakultala FP	253	36	11.02	3.67	49.59	96.62	32	9.80	3.27	44.08	96.94
536			Bibirabad FP	563	52	15.92	5.31	71.63	95.34	31	9.49	3.16	42.70	97.02
537			Chelikathi SSK	103	72	22.04	7.35	99.18	93.74	28	8.57	2.86	38.57	97.26
538			Datta Babur Abadh FP	190	94	28.78	9.59	129.49	91.98	30	9.18	3.06	41.33	97.1
539			Khunkhali FP	336	162	49.59	16.53	223.16	86.54	7	2.14	0.71	9.64	98.94
540			Mahisara FP	164	81	24.80	8.27	111.58	93.02	5	1.53	0.51	6.89	99.1

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541	Canning II	Tambuldaha I	Moukhali FP	268	80	24.49	8.16	110.20	93.1	6	1.84	0.61	8.27	99.02
542			Patikhali Natunpara FP	208	40	12.24	4.08	55.10	96.3	30	9.18	3.06	41.33	97.1
543			Patikhali New FP	94	80	24.49	8.16	110.20	93.1	45	13.78	4.59	61.99	95.9
544			Tambuldaha Adibasi FP	125	61	18.67	6.22	84.03	94.62	45	13.78	4.59	61.99	95.9
545			Tambuldaha Natun Basti FP	133	160	48.98	16.33	220.41	86.7	12	3.67	1.22	16.53	98.54
546		Tambuldaha II	Changdona FP	188	178	54.49	18.16	245.20	85.26	42	12.86	4.29	57.86	96.14
547			Homra Palta FP	299	105	32.14	10.71	144.64	91.1	27	8.27	2.76	37.19	97.34
548			Nabapalli SSK	66	45	13.78	4.59	61.99	95.9	12	3.67	1.22	16.53	98.54
549			Nagartala SSK	486	174	53.27	17.76	239.69	85.58	2	0.61	0.20	2.76	99.34
550			Palta JB	193	138	42.24	14.08	190.10	88.46	39	11.94	3.98	53.72	96.38
551	Jaynagar I	Baharu Kshetra	Kamdebnagar FP	27	104	31.84	10.61	143.27	91.18	8	2.45	0.82	11.02	98.86
552		Bamangachi	Bamangachi FP	58	10	3.06	1.02	13.78	98.7	7	2.14	0.71	9.64	98.94
553			Biswaschak FP	27	10	3.06	1.02	13.78	98.7	5	1.53	0.51	6.89	99.1
554			Chaltaberia FP	444	10	3.06	1.02	13.78	98.7	9	2.76	0.92	12.40	98.78
555			Chatra FP	93	22	6.73	2.24	30.31	97.74	6	1.84	0.61	8.27	99.02
556			Chatra Sakuntala SSK	30	18	5.51	1.84	24.80	98.06	9	2.76	0.92	12.40	98.78
557			Chhoto Kamariya SSK	79	10	3.06	1.02	13.78	98.7	5	1.53	0.51	6.89	99.1
558			Dakshin Kashipur FP	247	36	11.02	3.67	49.59	96.62	8	2.45	0.82	11.02	98.86
559			Daluakhaki Bamangachi FP	270	36	11.02	3.67	49.59	96.62	8	2.45	0.82	11.02	98.86
560			Holidia FP	57	15	4.59	1.53	20.66	98.3	4	1.22	0.41	5.51	99.18
561			Kamariya FP	198	25	7.65	2.55	34.44	97.5	9	2.76	0.92	12.40	98.78
562			Kripatala A Tarapada FP	26	32	9.80	3.27	44.08	96.94	19	5.82	1.94	26.17	97.98
563			Maldanri Arunnagar FP	99	20	6.12	2.04	27.55	97.9	8	2.45	0.82	11.02	98.86
564			Maldanri FP	38	10	3.06	1.02	13.78	98.7	12	3.67	1.22	16.53	98.54
565			Moriswar Motilal FP	336	10	3.06	1.02	13.78	98.7	10	3.06	1.02	13.78	98.7
566		Chaltaberia	Bamunia Dakshin FB	224	62	18.98	6.33	85.41	94.54	72	22.04	7.35	99.18	93.74

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567	Jaynagar I	Chaltaberia	Bamunia FP	193	80	24.49	8.16	110.20	93.1	68	20.82	6.94	93.67	94.06
568			Chakmoricha FB	218	72	22.04	7.35	99.18	93.74	87	26.63	8.88	119.85	92.54
569			Chaltaberia FB	461	70	21.43	7.14	96.43	93.9	71	21.73	7.24	97.81	93.82
570			Gabberia FP	143	27	8.27	2.76	37.19	97.34	7	2.14	0.71	9.64	98.94
571			Ganiraite FP	253	41	12.55	4.18	56.48	96.22	60	18.37	6.12	82.65	94.7
572			Joypur FP	201	102	31.22	10.41	140.51	91.34	52	15.92	5.31	71.63	95.34
573			Kabildanga SSK	61	320	97.96	32.65	440.82	73.9	85	26.02	8.67	117.09	92.7
574			Kachua FP	223	140	42.86	14.29	192.86	88.3	30	9.18	3.06	41.33	97.1
575			Konchpukur FB	331	182	55.71	18.57	250.71	84.94	7	2.14	0.71	9.64	98.94
576			Krishnamati FP	466	101	30.92	10.31	139.13	91.42	48	14.69	4.90	66.12	95.66
577			Panapukur Bijoygang SSK	64	119	36.43	12.14	163.93	89.98	34	10.41	3.47	46.84	96.78
578			Panapukur FP	180	110	33.67	11.22	151.53	90.7	21	6.43	2.14	28.93	97.82
579			Phulbagicha FP	52	45	13.78	4.59	61.99	95.9	4	1.31	0.39	6.23	99.06
580			Purba Bamunia FP	191	58	17.76	5.92	79.90	94.86	5	1.53	0.51	6.89	99.1
581			Uttar Chaltaberia Pakhimara SSK	53	56	17.14	5.71	77.14	95.02	84	25.71	8.57	115.71	92.78
582			Uttar Kachhua SSK	63	115	35.20	11.73	158.42	90.3	26	7.96	2.65	35.82	97.42
583		Dakshin Barasat	Abdul Karimpur SSK	73	80	24.49	8.16	110.20	93.1	9	2.76	0.92	12.40	98.78
584			Beliadanga FP	273	54	16.53	5.51	74.39	95.18	1	0.31	0.10	1.38	99.42
585			Dakshin Barasat Balika FP	244	75	22.96	7.65	103.32	93.5	8	2.45	0.82	11.02	98.86
586			Kalikapur FP	102	78	23.88	7.96	107.45	93.26	6	1.84	0.61	8.27	99.02
587			Khatsar FP	29	76	23.27	7.76	104.69	93.42	6	1.84	0.61	8.27	99.02
588			Mastikari Khagendranath FP	112	75	22.96	7.65	103.32	93.5	7	2.14	0.71	9.64	98.94
589			Mastikari Nurullapur FP	120	96	29.39	9.80	132.24	91.82	7	2.14	0.71	9.64	98.94
590			Nurullapur FP	105	201	61.53	20.51	276.89	83.42	10	3.06	1.02	13.78	98.7
591			Padmerhat FP	264	142	43.47	14.49	195.61	88.14	20	15.00	5.00	67.50	95.58

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592	Jaynagar I	Dakshin Barasat	Rajapur Sarojini Balika FP	51	100	30.61	10.20	137.76	91.5	5	1.53	0.51	6.89	99.1
593		Harinarayanpur	Baneswarpur FP	26	48	14.69	4.90	66.12	95.66	7	2.14	0.71	9.64	98.94
594			Harinarayanpur Nandanpur FP	96	24	7.35	2.45	33.06	97.58	6	1.84	0.61	8.27	99.02
595			Harinarayanpur SSK	22	26	7.96	2.65	35.82	97.42	5	1.53	0.51	6.89	99.1
596			Lakshmi Narayanpur FP	90	21	6.43	2.14	28.93	97.82	7	2.14	0.71	9.64	98.94
597			Nandanpur SSK	34	18	5.51	1.84	24.80	98.06	28	8.57	2.86	38.57	97.26
598			Panchghara FP	41	51	15.61	5.20	70.26	95.42	23	7.04	2.35	31.68	97.66
599			Paschim Gabberia FP	194	15	4.59	1.53	20.66	98.3	15	4.59	1.53	20.66	98.3
600			Ramchandrapur FP	104	50	15.31	5.10	68.88	95.5	15	4.59	1.53	20.66	98.3
601			Ramchandrapur SSK	24	12	3.67	1.22	16.53	98.54	10	3.06	1.02	13.78	98.7
602			Roynagar FP	67	21	6.43	2.14	28.93	97.82	41	12.55	4.18	56.48	96.22
603			Sarishadaha FP	170	32	9.80	3.27	44.08	96.94	13	3.98	1.33	17.91	98.46
604		Jungalia	Chak Panchghora FP	127	36	11.02	3.67	49.59	96.62	5	1.53	0.51	6.89	99.1
605			Jangalia FP	138	10	3.06	1.02	13.78	98.7	9	2.76	0.92	12.40	98.78
606			Punpua FP	76	10	3.06	1.02	13.78	98.7	7	2.14	0.71	9.64	98.94
607			Purba Chak Panchgoira SSK	21	10	3.06	1.02	13.78	98.7	8	2.45	0.82	11.02	98.86
608			Purba Jangalia FP	71	10	3.06	1.02	13.78	98.7	10	3.06	1.02	13.78	98.7
609			Ramrudrapur FP	52	10	3.06	1.02	13.78	98.7	7	2.14	0.71	9.64	98.94
610			Ramrudrapur SSK	84	10	3.06	1.02	13.78	98.7	11	3.37	1.12	15.15	98.62
611			Sri Krishnanagar FP	139	10	3.06	1.02	13.78	98.7	30	9.18	3.06	41.33	97.1
612		Khakurdaha	Dewangunge FP	138	32	9.80	3.27	44.08	96.94	4	1.22	0.41	5.51	99.18
613			Dewangunge Paschimpara FP	25	34	10.41	3.47	46.84	96.78	21	6.43	2.14	28.93	97.82
614			Goyal Beria Adarsha Muslim Para SSK	75	11	3.37	1.12	15.15	98.62	9	2.76	0.92	12.40	98.78
615			Goyal Beria SSK	65	10	3.06	1.02	13.78	98.7	8	2.45	0.82	11.02	98.86
616			Khakurdaha Jangalia FP	482	10	3.06	1.02	13.78	98.7	76	23.27	7.76	104.69	93.42

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617	Jaynagar I	Khakurdaha	Kismat Goalberia FP	202	10	3.06	1.02	13.78	98.7	7	2.14	0.71	9.64	98.94
618			Kismat Goyal Beria SSK	59	12	3.67	1.22	16.53	98.54	5	1.53	0.51	6.89	99.1
619			Newtala FP	109	10	3.06	1.02	13.78	98.7	6	1.84	0.61	8.27	99.02
620			Santipur FP	120	20	6.12	2.04	27.55	97.9	40	12.24	4.08	55.10	96.3
621			Uttar Raghunathpur FP	197	21	6.43	2.14	28.93	97.82	27	8.27	2.76	37.19	97.34
622			Uttar Sreekrishnanagar SSK(I) SSK	42	38	11.63	3.88	52.35	96.46	4	1.22	0.41	5.51	99.18
623			Uttar Sreekrishnanagar(Ii) SSK	54	24	7.35	2.45	33.06	97.58	89	27.24	9.08	122.60	92.38
624		Narayanitala	Bazra Malighati FP	21	10	3.06	1.02	13.78	98.7	9	2.76	0.92	12.40	98.78
625			Beliachandi FP	60	10	3.06	1.02	13.78	98.7	8	2.45	0.82	11.02	98.86
626			Beliyachandi SSK	24	10	3.06	1.02	13.78	98.7	9	2.76	0.92	12.40	98.78
627			Dakshin Sarberia FP	53	21	6.43	2.14	28.93	97.82	7	2.14	0.71	9.64	98.94
628			Gacharan Girls FP	95	52	15.92	5.31	71.63	95.34	8	2.45	0.82	11.02	98.86
629			Hogla FP	121	158	48.37	16.12	217.65	86.86	6	1.84	0.61	8.27	99.02
630			Kantapukuria FP	78	35	10.71	3.57	48.21	96.7	7	2.14	0.71	9.64	98.94
631			Narayanitala FP	21	39	11.94	3.98	53.72	96.38	11	3.37	1.12	15.15	98.62
632			Nilkantapur SSK	62	11	3.37	1.12	15.15	98.62	27	8.27	2.76	37.19	97.34
633			Sarberia Sonatan FP	34	11	3.37	1.12	15.15	98.62	62	18.98	6.33	85.41	94.54
634		Narayanpur	3 No Kulti G S FP	25	263	80.51	26.84	362.30	78.46	136	41.63	13.88	187.35	88.62
635			Amreswar FP	107	490	150.00	50.00	675.00	60.3	125	38.27	12.76	172.19	89.5
636			Bagbari Mondal Para FP	24	338	103.47	34.49	465.61	72.46	60	18.37	6.12	82.65	94.7
637			Bairampur FP	126	271	82.96	27.65	373.32	77.82	47	14.39	4.80	64.74	95.74
638			Banamalipur FP	74	96	29.39	9.80	132.24	91.82	25	7.65	2.55	34.44	97.5
639			Bibiraite Narayanpur FP	145	156	47.76	15.92	214.90	87.02	55	16.84	5.61	75.77	95.1
640			Dakhin Gajipur SSK	64	312	95.51	31.84	429.80	74.54	110	33.67	11.22	151.53	90.7
641			Dara FP	49	280	85.71	28.57	385.71	77.1	42	12.86	4.29	57.86	96.14

No	Block name	Village name	School name	Student pop	Shallow tubewell					Deep tubewell				
					As conc (ppb)	**TDI (10^{-4})**	**HQ**	**CR (10^{-4})**	**IQ**	**As conc (ppb)**	**TDI (10^{-4})**	**HQ**	**CR (10^{-4})**	**IQ**
642	Jaynagar I	Narayanpur	Dhoaghata Jb	206	10	3.06	1.02	13.78	98.7	25	7.65	2.55	34.44	97.5
643			Ghojer Math Bibiraite FP	148	278	85.10	28.37	382.96	77.26	56	17.14	5.71	77.14	95.02
644			Ghojer Math SSK	39	276	84.49	28.16	380.20	77.42	71	21.73	7.24	97.81	93.82
645			Ghuni Meghi Purbapara SSK	62	179	54.80	18.27	246.58	85.18	80	24.49	8.16	110.20	93.1
646			Ghunimeghi FP	55	200	61.22	20.41	275.51	83.5	67	20.51	6.84	92.30	94.14
647			Kharamba FP	146	210	64.29	21.43	289.29	82.7	8	2.45	0.82	11.02	98.86
648			Narayanpur A JB	178	65	19.90	6.63	89.54	94.3	68	20.82	6.94	93.67	94.06
649			Narayanpur M Mukunda FP	196	228	69.80	23.27	314.08	81.26	71	21.73	7.24	97.81	93.82
650			Narayanpur Paschim SSK	36	198	60.61	20.20	272.76	83.66	11	3.37	1.12	15.15	98.62
651			Padma Pukur Uttar SSK	107	242	74.08	24.69	333.37	80.14	9	2.76	0.92	12.40	98.78
652			Padmapukur FP	159	276	84.49	28.16	380.20	77.42	6	1.84	0.61	8.27	99.02
653			Shaitala SSK	21	220	67.35	22.45	303.06	81.9	112	34.29	11.43	154.29	90.54
654			Srinagar FP	163	42	12.86	4.29	57.86	96.14	17	5.20	1.73	23.42	98.14
655		Sreepur	Dakshin Ramkrishnapur FP	47	130	39.80	13.27	179.08	89.1	9	2.76	0.92	12.40	98.78
656			Hatpara FP	36	122	37.35	12.45	168.06	89.74	5	1.53	0.51	6.89	99.1
657			Kashimpur Nanda FP	27	30	9.18	3.06	41.33	97.1	7	2.14	0.71	9.64	98.94
658			Ramkrishnapur FP	66	42	12.86	4.29	57.86	96.14	8	2.45	0.82	11.02	98.86
659			Sreepur FP	127	36	11.02	3.67	49.59	96.62	9	2.76	0.92	12.40	98.78
660			Sreepur SSK	20	255	78.06	26.02	351.28	79.1	5	1.53	0.51	6.89	99.1
661			Uttarpara B Tala FP	38	259	79.29	26.43	356.79	78.78	7	2.14	0.71	9.64	98.94
662			Uttarpara FP	55	172	52.65	17.55	236.94	85.74	8	2.45	0.82	11.02	98.86
663			Uttarpara Moyda FP	107	76	23.27	7.76	104.69	93.42	6	1.84	0.61	8.27	99.02
664	Jaynagar II	Baishata	B Hata L S Amirali Halder FP	112	42	12.86	4.29	57.86	96.14	6	1.84	0.61	8.27	99.02
665			Baidyerchak FP	237	36	11.02	3.67	49.59	96.62	3	0.92	0.31	4.13	99.26
666			Baish Hata	47	19	5.82	1.94	26.17	97.98	5	1.53	0.51	6.89	99.1
667			Baishata Jamiruddin FP	45	12	3.67	1.22	16.53	98.54	9	2.76	0.92	12.40	98.78

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					As conc (ppb)	TDI (10^{-4})	HQ	CR (10^{-4})	IQ	As conc (ppb)	TDI (10^{-4})	HQ	CR (10^{-4})	IQ
668	Jaynagar II	Baishata	Damdama FP	58	24	7.35	2.45	33.06	97.58	7	2.14	0.71	9.64	98.94
669			Gopalnagar taltala FP	192	25	7.65	2.55	34.44	97.5	8	2.45	0.82	11.02	98.86
670			Kalikapur FP	79	48	14.69	4.90	66.12	95.66	6	1.84	0.61	8.27	99.02
671			Killa durganar FP	226	52	15.92	5.31	71.63	95.34	7	2.14	0.71	9.64	98.94
672			Paschim baishata FP	172	26	7.96	2.65	35.82	97.42	5	1.53	0.51	6.89	99.1
673			Pathpukur FP	618	11	3.37	1.12	15.15	98.62	36	11.02	3.67	49.59	96.62
674		Futigoda	Banamalipur JB	27	72	22.04	7.35	99.18	93.74	5	1.53	0.51	6.89	99.1
675			Dakshin tulsighata FP	128	73	22.35	7.45	100.56	93.66	5	1.53	0.51	6.89	99.1
676			Dangarabad SSK	28	65	19.90	6.63	89.54	94.3	7	2.14	0.71	9.64	98.94
677			Dasara bhagabanpur d abad FP	21	65	19.90	6.63	89.54	94.3	7	2.14	0.71	9.64	98.94
678			Dosora bhagabanpur north SSK	29	62	18.98	6.33	85.41	94.54	5	1.53	0.51	6.89	99.1
679			Futigoda FP	85	65	19.90	6.63	89.54	94.3	4	1.22	0.41	5.51	99.18
680			Nimpith FP	31	60	18.37	6.12	82.65	94.7	6	1.84	0.61	8.27	99.02
681			Paschim nimpith bharpara SSK	28	65	19.90	6.63	89.54	94.3	8	2.45	0.82	11.02	98.86
682			Purba nimpith adhikari para SSK	25	70	21.43	7.14	96.43	93.9	51	15.61	5.20	70.26	95.42
683			Radhakrishna SSK	24	78	23.88	7.96	107.45	93.26	8	2.45	0.82	11.02	98.86
684			Ramkrishna ashram JB	931	78	23.88	7.96	107.45	93.26	5	1.53	0.51	6.89	99.1
685			Sreerampur SSK	25	76	23.27	7.76	104.69	93.42	8	2.45	0.82	11.02	98.86
686			Srirampur FP	46	81	24.80	8.27	111.58	93.02	14	4.29	1.43	19.29	98.38
687			Tulsighata FP	24	81	24.80	8.27	111.58	93.02	9	2.76	0.92	12.40	98.78
688		Gardoani	Arun ghosh smriti FP	42	21	6.43	2.14	28.93	97.82	4	1.22	0.41	5.51	99.18
689			Bakultala FP	636	19	5.82	1.94	26.17	97.98	7	2.14	0.71	9.64	98.94
690			Bamunerchak FP	111	42	12.86	4.29	57.86	96.14	5	1.53	0.51	6.89	99.1
691			Chuner pukur FP	62	22	6.73	2.24	30.31	97.74	6	1.84	0.61	8.27	99.02
692			Daktar kader gaji SSK	71	60	18.37	6.12	82.65	94.7	3	0.92	0.31	4.13	99.26

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693	Jaynagar II	Gardoani	Gardawani FP	73	30	9.18	3.06	41.33	97.1	7	2.14	0.71	9.64	98.94
694			Mallerchak FP	104	48	14.69	4.90	66.12	95.66	28	8.57	2.86	38.57	97.26
695			Raghunathpur FP	211	34	10.41	3.47	46.84	96.78	8	2.45	0.82	11.02	98.86
696			Talipukur Thakurchak FP	211	18	5.51	1.84	24.80	98.06	8	2.45	0.82	11.02	98.86
697		Mayahauri	Anandapur FP	26	61	18.67	6.22	84.03	94.62	7	2.14	0.71	9.64	98.94
698			Bapulirchak FP	52	30	9.18	3.06	41.33	97.1	5	1.53	0.51	6.89	99.1
699			Dara FP	72	20	6.12	2.04	27.55	97.9	8	2.45	0.82	11.02	98.86
700			Deoaner Chak SSK	92	20	6.12	2.04	27.55	97.9	7	2.14	0.71	9.64	98.94
701			Gazier Dhal SSK	37	15	4.59	1.53	20.66	98.3	4	1.22	0.41	5.51	99.18
702			Jadukhali R A FP	70	23	7.04	2.35	31.68	97.66	7	2.14	0.71	9.64	98.94
703			Maya Hauri SSK	25	12	3.67	1.22	16.53	98.54	6	1.84	0.61	8.27	99.02
704			Nibedita SSK	48	22	6.73	2.24	30.31	97.74	30	9.18	3.06	41.33	97.1
705			Taltala FP	133	48	14.69	4.90	66.12	95.66	32	9.80	3.27	44.08	96.94
706		Moydah	Battala FP	283	96	29.39	9.80	132.24	91.82	7	2.14	0.71	9.64	98.94
707			Chandipur FP	81	49	15.00	5.00	67.50	95.58	7	2.14	0.71	9.64	98.94
708			Hath Chapri FP	64	40	12.24	4.08	55.10	96.3	5	1.53	0.51	6.89	99.1
709			Mahisgot FP	205	58	17.76	5.92	79.90	94.86	6	1.84	0.61	8.27	99.02
710			Maydah FP	33	71	21.73	7.24	97.81	93.82	53	16.22	5.41	73.01	95.26
711			Nayapukuria Banstala FP	38	78	23.88	7.96	107.45	93.26	27	8.27	2.76	37.19	97.34
712			Padmapukur Ujjore FP	155	82	25.10	8.37	112.96	92.94	8	2.45	0.82	11.02	98.86
713		Sahajadapur	Anamika SSK	28	75	22.96	7.65	103.32	93.5	6	1.84	0.61	8.27	99.02
714			Bagmari FP	66	85	26.02	8.67	117.09	92.7	4	1.22	0.41	5.51	99.18
715			Chuknagar FP	215	100	30.61	10.20	137.76	91.5	8	2.45	0.82	11.02	98.86
716			Chuknagar SSK	92	102	31.22	10.41	140.51	91.34	7	2.14	0.71	9.64	98.94
717			Hanerbati FP	304	82	25.10	8.37	112.96	92.94	7	2.14	0.71	9.64	98.94
718			Kalinagar Vijoynagar FP	32	64	19.59	6.53	88.16	94.38	5	1.53	0.51	6.89	99.1

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719	Jaynagar II	Sahajadapur	Khania Sahajadapur FP	104	62	18.98	6.33	85.41	94.54	8	2.45	0.82	11.02	98.86
720			Kultala SSK	123	62	18.98	6.33	85.41	94.54	19	5.82	1.94	26.17	97.98
721			Nimpith Sherhangampur FP	36	64	19.59	6.53	88.16	94.38	11	3.37	1.12	15.15	98.62
722			Sahajadapur Chaknagar FP	23	78	23.88	7.96	107.45	93.26	6	1.84	0.61	8.27	99.02
723			Sahajadapur Vijoynagar JB	67	63	19.29	6.43	86.79	94.46	9	2.76	0.92	12.40	98.78
724			Serhangampur Roypara SSK	26	55	16.84	5.61	75.77	95.1	23	7.04	2.35	31.68	97.66
725			Vidyasagar SSK	34	61	18.67	6.22	84.03	94.62	8	2.45	0.82	11.02	98.86
726	Magrahat II	Dhamua South	Alida Bagnar FP	66	19	5.82	1.94	26.17	97.98	21	6.43	2.14	28.93	97.82
727		Dhanpota	Bankardar FP	77	22	6.73	2.24	30.31	97.74	6	1.84	0.61	8.27	99.02
728			Bisweswarpur Mukundapur FP	186	40	12.24	4.08	55.10	96.3	8	2.45	0.82	11.02	98.86
729			Chhoto Mukundapur FP	31	62	18.98	6.33	85.41	94.54	9	2.76	0.92	12.40	98.78
730			Daiji SSK	63	121	37.04	12.35	166.68	89.82	6	1.84	0.61	8.27	99.02
731			Dhanpota FP	27	128	39.18	13.06	176.33	89.26	6	1.84	0.61	8.27	99.02
732			Katkina Iswaripur FP	34	115	35.20	11.73	158.42	90.3	3	0.92	0.31	4.13	99.26
733			Mohanpur (Dihikalash) SSK	49	119	36.43	12.14	163.93	89.98	15	4.59	1.53	20.66	98.3
734			Mollaerchak Iswaripur FP	146	103	31.53	10.51	141.89	91.26	9	2.76	0.92	12.40	98.78
735			Parankhali FP	21	20	6.12	2.04	27.55	97.9	3	0.92	0.31	4.13	99.26
736		DihiKalas	Belgachia FB	173	22	6.73	2.24	30.31	97.74	19	5.82	1.94	26.17	97.98
737			Chargachia FB	141	22	6.73	2.24	30.31	97.74	37	11.33	3.78	50.97	96.54
738			Dihi Kalash FP	392	20	6.12	2.04	27.55	97.9	19	5.82	1.94	26.17	97.98
739			Kalash FP	644	24	7.35	2.45	33.06	97.58	21	6.43	2.14	28.93	97.82
740			Kashimpur SSK	92	10	3.06	1.02	13.78	98.7	7	2.14	0.71	9.64	98.94
741			Khan Pur SSK	43	22	6.73	2.24	30.31	97.74	5	1.53	0.51	6.89	99.1
742			Mohanpur Naria FP	83	10	3.06	1.02	13.78	98.7	4	1.22	0.41	5.51	99.18
743			Mohanpur SSK	139	12	3.67	1.22	16.53	98.54	5	1.53	0.51	6.89	99.1
744			Shurnipukur FB	236	20	6.12	2.04	27.55	97.9	102	31.22	10.41	140.51	91.34

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745	Magrahat II	Gokarnee	Benipur FP	280	124	37.96	12.65	170.82	89.58	75	22.96	7.65	103.32	93.5
746			Dulalpur FP	20	52	15.92	5.31	71.63	95.34	36	11.02	3.67	49.59	96.62
747			Ghanashyampur FP	32	10	3.06	1.02	13.78	98.7	5	1.53	0.51	6.89	99.1
748			Gokaree Sarderpara SSK	37	10	3.06	1.02	13.78	98.7	5	1.53	0.51	6.89	99.1
749			Gokarnee JB	211	23	7.04	2.35	31.68	97.66	8	2.45	0.82	11.02	98.86
750			Gokarnee Narkeldanga SSK	50	22	6.73	2.24	30.31	97.74	8	2.45	0.82	11.02	98.86
751			Gokarnee SSK	59	25	7.65	2.55	34.44	97.5	11	3.37	1.12	15.15	98.62
752			Gotberia FP	192	25	7.65	2.55	34.44	97.5	8	2.45	0.82	11.02	98.86
753			Hansageria Roypur FP	75	20	6.12	2.04	27.55	97.9	10	3.06	1.02	13.78	98.7
754			Makhalia Narikeldanga FP	45	32	9.80	3.27	44.08	96.94	5	1.53	0.51	6.89	99.1
755			Ramnagar FP	203	23	7.04	2.35	31.68	97.66	5	1.53	0.51	6.89	99.1
756			Raynagar FP	81	30	9.18	3.06	41.33	97.1	5	1.53	0.51	6.89	99.1
757		Hotor Marjada	Hotar Marjada Jatio FP	28	10	3.06	1.02	13.78	98.7	7	2.14	0.71	9.64	98.94
758			Makhaltala FP	28	78	23.88	7.96	107.45	93.26	8	2.45	0.82	11.02	98.86
759			Multi Baniberia FP	118	60	18.37	6.12	82.65	94.7	6	1.84	0.61	8.27	99.02
760			Purba Hotor FP	29	55	16.84	5.61	75.77	95.1	15	4.59	1.53	20.66	98.3
761			Purba Hottar Tarafder Para Sssk	24	52	15.92	5.31	71.63	95.34	4	1.22	0.41	5.51	99.18
762			Tapukuria FP	102	60	18.37	6.12	82.65	94.7	60	18.37	6.12	82.65	94.7
763			Uttar Mukundapur SSK	27	10	3.06	1.02	13.78	98.7	7	2.14	0.71	9.64	98.94
764			Vidyanikatan JB	27	10	3.06	1.02	13.78	98.7	5	1.53	0.51	6.89	99.1
765		Multi	Bansundaria FP	106	50	15.31	5.10	68.88	95.5	34	10.41	3.47	46.84	96.78
766			Barat Kamdebpur	206	30	9.18	3.06	41.33	97.1	22	6.73	2.24	30.31	97.74
767			Jaldhapa FP	58	42	12.86	4.29	57.86	96.14	19	5.82	1.94	26.17	97.98
768			Kamdebpur	29	38	11.63	3.88	52.35	96.46	11	3.37	1.12	15.15	98.62
769			Multi Dwaraknath Pal FP	68	34	10.41	3.47	46.84	96.78	9	2.76	0.92	12.40	98.78
770			Tasarala FP	55	42	12.86	4.29	57.86	96.14	8	2.45	0.82	11.02	98.86

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771	Magrahat II	Multi	Tatihati SSK	23	10	3.06	1.02	13.78	98.7	10	3.06	1.02	13.78	98.7
772		Urel Chandpur	Abadchandpur SSK	27	21	6.43	2.14	28.93	97.82	6	1.84	0.61	8.27	99.02
773			Iswaripur FP	30	24	7.35	2.45	33.06	97.58	5	1.53	0.51	6.89	99.1
774			Kantapukuria FP	34	42	12.86	4.29	57.86	96.14	7	2.14	0.71	9.64	98.94
775			Maitirhat	89	45	13.78	4.59	61.99	95.9	18	5.51	1.84	24.80	98.06
776			Paschim Urelchandpur FP	75	48	14.69	4.90	66.12	95.66	5	1.53	0.51	6.89	99.1
777			Taldi FP	38	184	56.33	18.78	253.47	84.78	74	22.65	7.55	101.94	93.58
778			Urel Chandpur FP	64	134	41.02	13.67	184.59	88.78	5	1.53	0.51	6.89	99.1
779	Mandirbazar	Chandpur Chaitanyapur	Bade Maheshpur FP	119	18	5.51	1.84	24.80	98.06	6	1.84	0.61	8.27	99.02
780			Bangaberia FP	50	16	4.90	1.63	22.04	98.22	7	2.14	0.71	9.64	98.94
781			Bazarberia Hat FP	59	12	3.67	1.22	16.53	98.54	6	1.84	0.61	8.27	99.02
782			Bhabanipur FP	54	48	14.69	4.90	66.12	95.66	6	1.84	0.61	8.27	99.02
783			Chaitanyapur FP	28	18	5.51	1.84	24.80	98.06	5	1.53	0.51	6.89	99.1
784			Chandpur FP	45	30	9.18	3.06	41.33	97.1	6	1.84	0.61	8.27	99.02
785			Digberia FP	34	22	6.73	2.24	30.31	97.74	5	1.53	0.51	6.89	99.1
786			Gandaberia	25	33	10.10	3.37	45.46	96.86	5	1.53	0.51	6.89	99.1
787			Gokul Nagar FP	28	51	15.61	5.20	70.26	95.42	6	1.84	0.61	8.27	99.02
788			Hattala SSK	26	38	11.63	3.88	52.35	96.46	7	2.14	0.71	9.64	98.94
789			Kadipukur FP	20	47	14.39	4.80	64.74	95.74	6	1.84	0.61	8.27	99.02
790			Makimpur Hattala Pfp	25	21	6.43	2.14	28.93	97.82	30	9.18	3.06	41.33	97.1
791			Mirzanagar FP	38	42	12.86	4.29	57.86	96.14	21	6.43	2.14	28.93	97.82
792			Purba Bazarberia FP	26	42	12.86	4.29	57.86	96.14	35	10.71	3.57	48.21	96.7
793			Saradana FP	27	22	6.73	2.24	30.31	97.74	10	3.06	1.02	13.78	98.7
794			Uddaypur FP	62	49	15.00	5.00	67.50	95.58	6	1.84	0.61	8.27	99.02
795		Jagadishpur	Atapara Vivekananda FP	43	51	15.61	5.20	70.26	95.42	9	2.76	0.92	12.40	98.78
796			Ballavpur FP	48	24	7.35	2.45	33.06	97.58	7	2.14	0.71	9.64	98.94

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					As conc (ppb)	TDI (10^{-4})	HQ	CR (10^{-4})	IQ	As conc (ppb)	TDI (10^{-4})	HQ	CR (10^{-4})	IQ
797	Mandirbazar	Jagadishpur	Bansbariya Jafarpur SSK	32	24	7.35	2.45	33.06	97.58	9	2.76	0.92	12.40	98.78
798			Bansberia Moukhali FP	37	15	4.59	1.53	20.66	98.3	7	2.14	0.71	9.64	98.94
799			Dadpur G Pur Dus FP	310	21	6.43	2.14	28.93	97.82	8	2.45	0.82	11.02	98.86
800			Dhananjoypur FP	68	22	6.73	2.24	30.31	97.74	7	2.14	0.71	9.64	98.94
801			Durlavpur SSK	40	19	5.82	1.94	26.17	97.98	5	1.53	0.51	6.89	99.1
802			Gopalnagar FP	124	32	9.80	3.27	44.08	96.94	8	2.45	0.82	11.02	98.86
803			Harindanga FP	21	20	6.12	2.04	27.55	97.9	6	1.84	0.61	8.27	99.02
804			Jagadishpur FP	65	52	15.92	5.31	71.63	95.34	4	1.22	0.41	5.51	99.18
805			Kalikapur FP	22	19	5.82	1.94	26.17	97.98	9	2.76	0.92	12.40	98.78
806			Maheshpur FP	90	25	7.65	2.55	34.44	97.5	36	11.02	3.67	49.59	96.62
807			Motilal RK FP	65	18	5.51	1.84	24.80	98.06	4	1.22	0.41	5.51	99.18
808			Mouraltala FP	22	18	5.51	1.84	24.80	98.06	13	3.98	1.33	17.91	98.46
809			Mukundapur Kolony SSK	24	45	13.78	4.59	61.99	95.9	26	7.96	2.65	35.82	97.42
810			Uriahat FP	127	31	9.49	3.16	42.70	97.02	5	1.53	0.51	6.89	99.1
811		South Bishnupur I I	Adityapur FP	35	58	17.76	5.92	79.90	94.86	5	1.53	0.51	6.89	99.1
812			Alemaheshpur FP	25	62	18.98	6.33	85.41	94.54	6	1.84	0.61	8.27	99.02
813			Baldevpur FP	90	51	15.61	5.20	70.26	95.42	5	1.53	0.51	6.89	99.1
814			Banshi Dharpur North FP	37	58	17.76	5.92	79.90	94.86	3	0.92	0.31	4.13	99.26
815			Banshidharpur FP	25	62	18.98	6.33	85.41	94.54	6	1.84	0.61	8.27	99.02
816			Bishnupur Boys FP	111	84	25.71	8.57	115.71	92.78	4	1.22	0.41	5.51	99.18
817			Dakshin Bishnupur Girls FP	107	82	25.10	8.37	112.96	92.94	6	1.84	0.61	8.27	99.02
818			Dakshin Krishnarampur FP	30	62	18.98	6.33	85.41	94.54	5	1.53	0.51	6.89	99.1
819			Kaneya FP	96	62	18.98	6.33	85.41	94.54	5	1.53	0.51	6.89	99.1
820			Moujpur FP	56	88	26.94	8.98	121.22	92.46	19	5.82	1.94	26.17	97.98
821			Muldia FP	84	59	18.06	6.02	81.28	94.78	8	2.45	0.82	11.02	98.86
822			Muldia Halderpara FP	113	63	19.29	6.43	86.79	94.46	8	2.45	0.82	11.02	98.86

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823	Mandirbazar	South Bishnupur I	Nur Mahammadpur FP	44	64	19.59	6.53	88.16	94.38	8	2.45	0.82	11.02	98.86
824			Nur Mahammadpur SSK	41	62	18.98	6.33	85.41	94.54	9	2.76	0.92	12.40	98.78
825			Ramakantanagar FP	82	21	6.43	2.14	28.93	97.82	8	2.45	0.82	11.02	98.86
826			Sudipukur FP	68	80	24.49	8.16	110.20	93.1	80	24.49	8.16	110.20	93.1
827	Mathurapur I	Debipur	Bamungachi FP	60	42	12.86	4.29	57.86	96.14	6	1.84	0.61	8.27	99.02
828			Belegachi FP	50	65	19.90	6.63	89.54	94.3	5	1.53	0.51	6.89	99.1
829			Debipur FP	78	50	15.31	5.10	68.88	95.5	9	2.76	0.92	12.40	98.78
830			Mirjapur FP	58	36	11.02	3.67	49.59	96.62	10	3.06	1.02	13.78	98.7
831			Rajapur SSK	29	51	15.61	5.20	70.26	95.42	8	2.45	0.82	11.02	98.86
832			Satghara SSK	106	39	11.94	3.98	53.72	96.38	7	2.14	0.71	9.64	98.94
833		Krishnachandrapur	Andhamanitala FP	85	28	8.57	2.86	38.57	97.26	8	2.45	0.82	11.02	98.86
834			Batiswar FP	29	24	7.35	2.45	33.06	97.58	7	2.14	0.71	9.64	98.94
835			Katan Dighi FP	155	20	6.12	2.04	27.55	97.9	5	1.53	0.51	6.89	99.1
836			Sadial FP	33	15	4.59	1.53	20.66	98.3	37	11.33	3.78	50.97	96.54
837		Lalpur	Jalghata FP	107	55	16.84	5.61	75.77	95.1	9	2.76	0.92	12.40	98.78
838			Lalpur FP	69	54	16.53	5.51	74.39	95.18	31	9.49	3.16	42.70	97.02
839			Ranaghata FP	244	38	11.63	3.88	52.35	96.46	15	4.59	1.53	20.66	98.3
840			Subuddhipur FP	44	42	12.86	4.29	57.86	96.14	4	1.22	0.41	5.51	99.18
841	Sonarpur	Bonhooghly I	Bonhoogly FP	22	270	82.65	27.55	371.94	77.9	22	6.73	2.24	30.31	97.74
842			Dingalpota FP	20	198	60.61	20.20	272.76	83.66	16	4.90	1.63	22.04	98.22
843			Hogolkuria FP	29	254	77.76	25.92	349.90	79.18	13	3.98	1.33	17.91	98.46
844			Joianpur FP	25	162	49.59	16.53	223.16	86.54	15	4.59	1.53	20.66	98.3
845			Ramchandrapur FP	61	140	42.86	14.29	192.86	88.3	5	1.53	0.51	6.89	99.1
846		Bonhooghly II	Balarampur M (1) JB	42	1024	313.47	104.49	1410.61	17.58	31	9.49	3.16	42.70	97.02
847			Balarampur M (2) JB	49	960	293.88	97.96	1322.45	22.7	31	9.49	3.16	42.70	97.02
848			Bonhooghly 2no. SSK	24	81	24.80	8.27	111.58	93.02	60	18.37	6.12	82.65	94.7

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849	Sonarpur	Bonhooghly II	Danga Karbala Math FP	23	116	35.51	11.84	159.80	90.22	62	18.98	6.33	85.41	94.54
850			Joykrishnapur FP	68	157	48.06	16.02	216.28	86.94	44	13.47	4.49	60.61	95.98
851			Paschim Bonhooghly FP	115	320	97.96	32.65	440.82	73.9	11	3.37	1.12	15.15	98.62
852		Kalikapur I	Jardha Beniabahu FP	204	20	6.12	2.04	27.55	97.9	4	1.22	0.41	5.51	99.18
853			Bansberiya Acdp Camp SSK	22	12	3.67	1.22	16.53	98.54	7	2.14	0.71	9.64	98.94
854			Chakberia FP	85	14	4.29	1.43	19.29	98.38	5	1.53	0.51	6.89	99.1
855			Chunaripota FP	93	18	5.51	1.84	24.80	98.06	7	2.14	0.71	9.64	98.94
856			Jardaha SSK	26	20	6.12	2.04	27.55	97.9	4	1.22	0.41	5.51	99.18
857			Kalikapur 1 No. SSK	21	9	2.76	0.92	12.40	98.78	6	1.84	0.61	8.27	99.02
858			Kalikapur 2 No. SSK	20	10	3.06	1.02	13.78	98.7	7	2.14	0.71	9.64	98.94
859			Natagachhi FP	124	12	3.67	1.22	16.53	98.54	41	12.55	4.18	56.48	96.22
860			Netaji Sangha Club SSK	20	15	4.59	1.53	20.66	98.3	30	9.18	3.06	41.33	97.1
861			Sitala Tala SSK	39	18	5.51	1.84	24.80	98.06	87	26.63	8.88	119.85	92.54
862		Kalikapur II	Dakshin Purba Sahebpur SSK	41	20	6.12	2.04	27.55	97.9	9	2.76	0.92	12.40	98.78
863			Hasanpur SSK	122	26	7.96	2.65	35.82	97.42	10	3.06	1.02	13.78	98.7
864			Jafarpur Laljiroy FP	64	32	9.80	3.27	44.08	96.94	5	1.53	0.51	6.89	99.1
865			Kalikapur Basantidevi FP	38	25	7.65	2.55	34.44	97.5	5	1.53	0.51	6.89	99.1
866			Kalikapur FP	28	36	11.02	3.67	49.59	96.62	7	2.14	0.71	9.64	98.94
867			Khorigoda Panchanan FP	30	12	3.67	1.22	16.53	98.54	4	1.22	0.41	5.51	99.18
868			Kushberia SSK	25	16	4.90	1.63	22.04	98.22	6	1.84	0.61	8.27	99.02
869			Paschim Raipur Uttarpara SSK	44	15	4.59	1.53	20.66	98.3	8	2.45	0.82	11.02	98.86
870			Purba Sahebpur SSK	26	18	5.51	1.84	24.80	98.06	57	17.45	5.82	78.52	94.94
871			Raipur Badapara SSK	21	15	4.59	1.53	20.66	98.3	16	4.90	1.63	22.04	98.22
872			Raipur SSK	29	11	3.37	1.12	15.15	98.62	15	4.59	1.53	20.66	98.3
873			Roypur FP	84	14	4.29	1.43	19.29	98.38	3	0.92	0.31	4.13	99.26
874			Roypur Hasanpur FP	27	31	9.49	3.16	42.70	97.02	9	2.76	0.92	12.40	98.78

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875	Sonarpur	Kalikapur II	Sahebpur FP	27	21	6.43	2.14	28.93	97.82	12	3.67	1.22	16.53	98.54
876			Sahebpur Paschimpara SSK	22	22	6.73	2.24	30.31	97.74	15	4.59	1.53	20.66	98.3
877		Kamrabad	Chandpur K Vivekananda FP	23	43	13.16	4.39	59.23	96.06	3	0.92	0.31	4.13	99.26
878			Chandpur SSK	22	34	10.41	3.47	46.84	96.78	3	0.92	0.31	4.13	99.26
879			Darigachi FP	60	18	5.51	1.84	24.80	98.06	3	0.92	0.31	4.13	99.26
880			Dihi Priyanath FP	40	6	1.84	0.61	8.27	99.02	4	1.22	0.41	5.51	99.18
881			Gangajoara FP	48	10	3.06	1.02	13.78	98.7	4	1.22	0.41	5.51	99.18
882			Kelegore FP	84	10	3.06	1.02	13.78	98.7	2	0.61	0.20	2.76	99.34
883			Kelegore JB	70	30	9.18	3.06	41.33	97.1	7	2.14	0.71	9.64	98.94
884			Kelegore SSK	30	10	3.06	1.02	13.78	98.7	5	1.53	0.51	6.89	99.1
885			Khurigachi FP	85	10	3.06	1.02	13.78	98.7	8	2.45	0.82	11.02	98.86
886			Radhanagar FP	27	10	3.06	1.02	13.78	98.7	7	2.14	0.71	9.64	98.94
887			Radhanagar Paschimpara FP	36	10	3.06	1.02	13.78	98.7	12	3.67	1.22	16.53	98.54
888		Kheadah I	Baburabad SSK	29	49	15.00	5.00	67.50	95.58	8	2.45	0.82	11.02	98.86
889			Bajbarantala FP	50	54	16.53	5.51	74.39	95.18	6	1.84	0.61	8.27	99.02
890			Banglapara FP	21	53	16.22	5.41	73.01	95.26	9	2.76	0.92	12.40	98.78
891			Boynala Adibasi FP	28	40	12.24	4.08	55.10	96.3	9	2.76	0.92	12.40	98.78
892			Chhapnamari FP	21	29	8.88	2.96	39.95	97.18	8	2.45	0.82	11.02	98.86
893			Harapur FP	42	21	6.43	2.14	28.93	97.82	7	2.14	0.71	9.64	98.94
894			Haropur Purbapara SSK	46	39	11.94	3.98	53.72	96.38	6	1.84	0.61	8.27	99.02
895			Khardanga A A S Nikatan FP	35	65	19.90	6.63	89.54	94.3	29	8.88	2.96	39.95	97.18
896			Kheadah FP	96	52	15.92	5.31	71.63	95.34	12	3.67	1.22	16.53	98.54
897			Moulihati FP	24	48	14.69	4.90	66.12	95.66	7	2.14	0.71	9.64	98.94
898			Nayabad FP	122	40	12.24	4.08	55.10	96.3	4	1.22	0.41	5.51	99.18
899			Nayabad Ramkrishna Smritisanghassk	20	42	12.86	4.29	57.86	96.14	6	1.84	0.61	8.27	99.02

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900	Sonarpur	Kheadah I	Saintala FB	21	32	9.80	3.27	44.08	96.94	41	12.55	4.18	56.48	96.22
901			Tehuria FP	69	26	7.96	2.65	35.82	97.42	9	2.76	0.92	12.40	98.78
902		Kheadah II	Atghara FP	35	40	12.24	4.08	55.10	96.3	2	0.61	0.20	2.76	99.34
903			Chak Kalar Khal FB	97	30	9.18	3.06	41.33	97.1	2	0.61	0.20	2.76	99.34
904			Chamurat FB	59	39	11.94	3.98	53.72	96.38	3	0.92	0.31	4.13	99.26
905			Dargatala FP	20	10	3.06	1.02	13.78	98.7	2	0.61	0.20	2.76	99.34
906			Deara Saraswati FP	22	12	3.67	1.22	16.53	98.54	2	0.61	0.20	2.76	99.34
907			Goalbati FP	73	22	6.73	2.24	30.31	97.74	3	0.92	0.31	4.13	99.26
908			Jagatipota FP	36	36	11.02	3.67	49.59	96.62	3	0.92	0.31	4.13	99.26
909			Kantipota FP	103	30	9.18	3.06	41.33	97.1	3	0.92	0.31	4.13	99.26
910			Khorki FP	29	38	11.63	3.88	52.35	96.46	42	12.86	4.29	57.86	96.14
911			Nagirabad FP	36	32	9.80	3.27	44.08	96.94	18	5.51	1.84	24.80	98.06
912			Ranabhutia FP	72	10	3.06	1.02	13.78	98.7	5	1.53	0.51	6.89	99.1
913		Langalberia	Bamangachhi FP	72	115	35.20	11.73	158.42	90.3	11	3.37	1.12	15.15	98.62
914			Bargachia FP	36	142	43.47	14.49	195.61	88.14	9	2.76	0.92	12.40	98.78
915			Baruli FP	34	174	53.27	17.76	239.69	85.58	9	2.76	0.92	12.40	98.78
916			Bibirchak FP	27	522	159.80	53.27	719.08	57.74	8	2.45	0.82	11.02	98.86
917			Gangadharpur A Friendship FP	21	280	85.71	28.57	385.71	77.1	9	2.76	0.92	12.40	98.78
918			Gobindapur Kaminidevi FP	60	190	58.16	19.39	261.73	84.3	12	3.67	1.22	16.53	98.54
919			Kamlet FP	64	264	80.82	26.94	363.67	78.38	11	3.37	1.12	15.15	98.62
920			Langalberia Amiyapathsala FP	21	267	81.73	27.24	367.81	78.14	10	3.06	1.02	13.78	98.7
921			Langalberia SSK	29	162	49.59	16.53	223.16	86.54	41	12.55	4.18	56.48	96.22
922			Radhaballavpur FP	44	201	61.53	20.51	276.89	83.42	6	1.84	0.61	8.27	99.02
923			Raghabpur FP	47	72	22.04	7.35	99.18	93.74	13	3.98	1.33	17.91	98.46
924			Sarmastapur FP	20	84	25.71	8.57	115.71	92.78	58	17.76	5.92	79.90	94.86
925			Srirampur FP	39	52	15.06	5.02	71.78	98.7	16	4.90	1.63	22.04	98.22

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926	Sonarpur	Poleghat II	Chak Jagatdal FP	28	180	55.10	18.37	247.96	85.1	12	3.67	1.22	16.53	98.54
927			Chandpur FP	86	135	41.33	13.78	185.97	88.7	13	3.98	1.33	17.91	98.46
928			D Badehugli Saharjan SSK	100	158	48.37	16.12	217.65	86.86	13	3.98	1.33	17.91	98.46
929			Poleghat FP	100	218	66.73	22.24	300.31	82.06	19	5.82	1.94	26.17	97.98
930			Raghabpur SSK	22	186	56.94	18.98	256.22	84.62	44	13.47	4.49	60.61	95.98
931			Raghunathpur Hridaynath JB	28	260	79.59	26.53	358.16	78.7	7	2.14	0.71	9.64	98.94
932			Gorkhara FP	100	168	51.43	17.14	231.43	86.06	1	0.31	0.10	1.38	99.42
933			Mandalpara FP	98	256	78.37	26.12	352.65	79.02	26	7.96	2.65	35.82	97.42
934			Shyamsundar FP	61	231	70.71	23.57	318.21	81.02	6	1.84	0.61	8.27	99.02
935			Padma Pukur U P FP	166	326	99.80	33.27	449.08	73.42	79	24.18	8.06	108.83	93.18
936			Baruipur G S FP	27	137	41.94	13.98	188.72	88.54	12	3.67	1.22	16.53	98.54
937			Ramsadhan Smriti FP	61	432	132.24	44.08	595.10	64.94	9	2.76	0.92	12.40	98.78
938			Bishalakshi Vidyamandir FP	50	325	99.49	33.16	447.70	73.5	27	8.27	2.76	37.19	97.34
939			Saraswati P Hindi FP	71	237	72.55	24.18	326.48	80.54	8	2.45	0.82	11.02	98.86
940			Suryasen Nagar FP	77	302	92.45	30.82	416.02	75.34	39	11.94	3.98	53.72	96.38
941			Chohati JB	72	343	105.00	35.00	472.50	72.06	5	1.53	0.51	6.89	99.1
942			Amiyaprova Smriti G S FP	22	245	75.00	25.00	337.50	79.9	17	5.20	1.73	23.42	98.14
943			Rashmoni Balika Vidyalaya FB	648	301	92.14	30.71	414.64	75.42	9	2.76	0.92	12.40	98.78
944			Binapani Pathshala FP	49	213	65.20	21.73	293.42	82.46	15	4.59	1.53	20.66	98.3
945			Nanilal Smriti Vidyamandir FP	22	209	63.98	21.33	287.91	82.78	28	8.57	2.86	38.57	97.26
946			Sukanta G S FP	29	175	53.57	17.86	241.07	85.5	7	2.14	0.71	9.64	98.94
947			Anandamayee Pathshala FP	110	120	36.73	12.24	165.31	89.9	20	6.12	2.04	27.55	97.9
948			Shibani Vidyapith FP	51	204	62.45	20.82	281.02	83.18	18	5.51	1.84	24.80	98.06
949			Sishu Siksha Sadan FP	224	197	60.31	20.10	271.38	83.74	29	8.88	2.96	39.95	97.18
950			Sashan FP	74	312	95.51	31.84	429.80	74.54	26	7.96	2.65	35.82	97.42
951		Pratapnagar	Addirabad FP	26	22	6.73	2.24	30.31	97.74	7	2.14	0.71	9.64	98.94

No	Block name	Village name	School name	Student pop	Shallow tubewell					Deep tubewell				
					As conc (ppb)	TDI (10^{-4})	HQ	CR (10^{-4})	IQ	As conc (ppb)	TDI (10^{-4})	HQ	CR (10^{-4})	IQ
952	Sonarpur	Pratapnagar	Addirabad Uttarpara SSK	20	10	3.06	1.02	13.78	98.7	7	2.14	0.71	9.64	98.94
953			Chakberia Kustia JB	32	22	6.73	2.24	30.31	97.74	11	3.37	1.12	15.15	98.62
954			Garal Kurunamoyee FP	31	22	6.73	2.24	30.31	97.74	15	4.59	1.53	20.66	98.3
955			Hatanga FP	51	10	3.06	1.02	13.78	98.7	21	6.43	2.14	28.93	97.82
956			Makrampur FP	107	16	4.90	1.63	22.04	98.22	15	4.59	1.53	20.66	98.3
957			Metiari Karunamoyee FP	62	15	4.59	1.53	20.66	98.3	25	7.65	2.55	34.44	97.5
958			Najirhat SSK	20	23	7.04	2.35	31.68	97.66	9	2.76	0.92	12.40	98.78
959			Navasan FP	106	24	7.35	2.45	33.06	97.58	55	16.84	5.61	75.77	95.1
960			Navasan SSK	26	32	9.80	3.27	44.08	96.94	9	2.76	0.92	12.40	98.78
961			Pratapnagar FP	109	20	6.12	2.04	27.55	97.9	24	7.35	2.45	33.06	97.58
962			Protapnagar Saralia SSK	25	24	7.35	2.45	33.06	97.58	40	12.24	4.08	55.10	96.3
963			Samukpota Uttar FP	21	21	6.43	2.14	28.93	97.82	8	2.45	0.82	11.02	98.86
964			Sangur Navasan FP	31	52	15.92	5.31	71.63	95.34	9	2.76	0.92	12.40	98.78
965			Sishumangal FP	50	16	4.90	1.63	22.04	98.22	5	1.53	0.51	6.89	99.1
966			Taramistry Abad SSK	52	21	6.43	2.14	28.93	97.82	15	4.59	1.53	20.66	98.3
967			Uttar Protapnagar SSK	46	20	6.12	2.04	27.55	97.9	7	2.14	0.71	9.64	98.94
968		Sonarpur II	Arapanch FP	206	12	3.67	1.22	16.53	98.54	9	2.76	0.92	12.40	98.78
969			Bhabanipur FP	78	20	6.12	2.04	27.55	97.9	5	1.53	0.51	6.89	99.1
970			Hasanpur Bidyadharpur F.P	142	10	3.06	1.02	13.78	98.7	7	2.14	0.71	9.64	98.94
971			Hasanpur FP	59	10	3.06	1.02	13.78	98.7	8	2.45	0.82	11.02	98.86
972			Malipukuria FP	82	10	3.06	1.02	13.78	98.7	5	1.53	0.51	6.89	99.1
973			Mathurapur FP	56	12	3.67	1.22	16.53	98.54	64	19.59	6.53	88.16	94.38
974			Rampur Nayapattan FP	205	12	3.67	1.22	16.53	98.54	8	2.45	0.82	11.02	98.86
975			Rampur SSK	36	15	4.59	1.53	20.66	98.3	24	7.35	2.45	33.06	97.58
976			Sitala Madan Shankar F.P	27	20	6.12	2.04	27.55	97.9	20	6.12	2.04	27.55	97.9
977			A Prafulla Nagar FP	440	196	60.00	20.00	270.00	83.82	7	2.14	0.71	9.64	98.94

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					As conc (ppb)	TDI (10^{-4})	HQ	CR (10^{-4})	IQ	As conc (ppb)	TDI (10^{-4})	HQ	CR (10^{-4})	IQ
978	Sonarpur	Sonarpur II	B Bhushan B Pith FP	21	212	64.90	21.63	292.04	82.54	10	3.06	1.02	13.78	98.7
979			B Chandra S Niketan FP	39	362	110.82	36.94	498.67	70.54	7	2.14	0.71	9.64	98.94
980			B Sarada Bidyapith FP	92	380	116.33	38.78	523.47	69.1	6	1.84	0.61	8.27	99.02
981			Bagharghole FP	93	300	91.84	30.61	413.27	75.5	7	2.14	0.71	9.64	98.94
982			Baikunthapur B B FP	24	15	4.59	1.53	20.66	98.3	8	2.45	0.82	11.02	98.86
983			Baikunthapur JB	325	37	11.33	3.78	50.97	96.54	7	2.14	0.71	9.64	98.94
984			Bibekananda B Pith FP	26	36	11.02	3.67	49.59	96.62	6	1.84	0.61	8.27	99.02
985			Bibekananda Ss FP	28	30	9.18	3.06	41.33	97.1	7	2.14	0.71	9.64	98.94
986			Boalia FP	121	34	10.41	3.47	46.84	96.78	5	1.53	0.51	6.89	99.1
987			Boral FP	69	35	10.71	3.57	48.21	96.7	6	1.84	0.61	8.27	99.02
988			Chohati A Block Gs FP	59	58	17.76	5.92	79.90	94.86	6	1.84	0.61	8.27	99.02
989			Chouhati D Block Gs FP	158	238	72.86	24.29	327.86	80.46	7	2.14	0.71	9.64	98.94
990			Dakshin Sreepur FP	43	310	94.90	31.63	427.04	74.7	8	2.45	0.82	11.02	98.86
991			Dhalu Naba Pgc Gs FP	90	312	95.51	31.84	429.80	74.54	8	2.45	0.82	11.02	98.86
992			Elachi Vivekananda Bidyabithi FP	60	224	68.57	22.86	308.57	81.58	8	2.45	0.82	11.02	98.86
993			G Sripur Gs FP	364	128	39.18	13.06	176.33	89.26	8	2.45	0.82	11.02	98.86
994			Garia Barada Prasad FP	81	201	61.53	20.51	276.89	83.42	9	2.76	0.92	12.40	98.78
995			Garia K Gs FP	24	272	83.27	27.76	374.69	77.74	7	2.14	0.71	9.64	98.94
996			Gashiara FP	394	220	67.35	22.45	303.06	81.9	5	1.53	0.51	6.89	99.1
997			Goragacha Ramkrishna FP	106	100	30.61	10.20	137.76	91.5	8	2.45	0.82	11.02	98.86
998			H Ranibala P B FP	35	338	103.47	34.49	465.61	72.46	7	2.14	0.71	9.64	98.94
999			Harinavi A S FP	584	376	115.10	38.37	517.96	69.42	6	1.84	0.61	8.27	99.02
1000			Hiralal Ssb Pith FP	25	308	94.29	31.43	424.29	74.86	8	2.45	0.82	11.02	98.86
1001			Jagaddal Gs FP	45	130	39.80	13.27	179.08	89.1	8	2.45	0.82	11.02	98.86
1002			Jagaddal K FP	44	124	37.96	12.65	170.82	89.58	9	2.76	0.92	12.40	98.78

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1003	Sonarpur	Sonarpur II	Jagaddal U Charan FP	37	102	31.22	10.41	140.51	91.34	10	3.06	1.02	13.78	98.7
1004			Jagannath Pur FP	23	257	78.67	26.22	354.03	78.94	22	6.73	2.24	30.31	97.74
1005			Jora Battala FP	41	60	18.37	6.12	82.65	94.7	5	1.53	0.51	6.89	99.1
1006			K Bidhan Pith FP	25	45	13.78	4.59	61.99	95.9	8	2.45	0.82	11.02	98.86
1007			K Prasanna B FP	358	42	12.86	4.29	57.86	96.14	8	2.45	0.82	11.02	98.86
1008			Kadarite G Chandra FP	51	36	11.02	3.67	49.59	96.62	7	2.14	0.71	9.64	98.94
1009			Kamalgazi FP	47	105	32.14	10.71	144.64	91.1	6	1.84	0.61	8.27	99.02
1010			Kamrabad Basanti B FP	652	97	29.69	9.90	133.62	91.74	6	1.84	0.61	8.27	99.02
1011			Kamrabad FP	389	265	81.12	27.04	365.05	78.3	5	1.53	0.51	6.89	99.1
1012			Kandarpapur Ma FP	50	116	35.51	11.84	159.80	90.22	4	1.22	0.41	5.51	99.18
1013			Kodalia Ambikadas FP	270	10	3.06	1.02	13.78	98.7	5	1.53	0.51	6.89	99.1
1014			Kodalia Balika FP	278	58	17.76	5.92	79.90	94.86	26	7.96	2.65	35.82	97.42
1015			Kumorpara FP	22	210	64.29	21.43	289.29	82.7	7	2.14	0.71	9.64	98.94
1016			Kusumba S Sikshalay FP	105	260	79.59	26.53	358.16	78.7	7	2.14	0.71	9.64	98.94
1017			Mahamayapur FP	35	320	97.96	32.65	440.82	73.9	51	15.61	5.20	70.26	95.42
1018			Malikapur FP	34	242	74.08	24.69	333.37	80.14	8	2.45	0.82	11.02	98.86
1019			Manikpur FP	39	38	11.63	3.88	52.35	96.46	27	8.27	2.76	37.19	97.34
1020			Nabagram Giribala FP	99	170	52.04	17.35	234.18	85.9	6	1.84	0.61	8.27	99.02
1021			Nabatara FP	458	224	68.57	22.86	308.57	81.58	9	2.76	0.92	12.40	98.78
1022			Nadan Mb Ss FP	24	410	125.51	41.84	564.80	66.7	42	12.86	4.29	57.86	96.14
1023			Natun Diyara FP	70	310	94.90	31.63	427.04	74.7	38	11.63	3.88	52.35	96.46
1024			Natun Pally Sarojini FP	110	150	45.92	15.31	206.63	87.5	41	12.55	4.18	56.48	96.22
1025			Noapara FP	28	192	58.78	19.59	264.49	84.14	6	1.84	0.61	8.27	99.02
1026			Panchpota Adarsha FP	263	263	80.51	26.84	362.30	78.46	5	1.53	0.51	6.89	99.1
1027			Paschim N Pur FP	77	165	50.51	16.84	227.30	86.3	4	1.22	0.41	5.51	99.18
1028			R Bidyanidhi U FP	104	26	7.96	2.65	35.82	97.42	4	1.22	0.41	5.51	99.18

No	Block name	Village name	School name	Student pop	Shallow tubewell					Deep tubewell				
					As conc (ppb)	TDI (10^{-4})	HQ	CR (10^{-4})	IQ	As conc (ppb)	TDI (10^{-4})	HQ	CR (10^{-4})	IQ
1029	Sonarpur	Sonarpur II	R Padmamoni B FP	234	28	8.57	2.86	38.57	97.26	9	2.76	0.92	12.40	98.78
1030			Ramkrishna B Pith FP	73	104	31.84	10.61	143.27	91.18	8	2.45	0.82	11.02	98.86
1031			Rania FP	198	53	16.22	5.41	73.01	95.26	108	33.06	11.02	148.78	90.86
1032			Ratna FP	76	24	7.35	2.45	33.06	97.58	8	2.45	0.82	11.02	98.86
1033			Satkari B Bidyalaya FP	105	97	29.69	9.90	133.62	91.74	65	19.90	6.63	89.54	94.3
1034			Sri Khanda B Bidya Bh FP	181	112	34.29	11.43	154.29	90.54	5	1.53	0.51	6.89	99.1
1035			Sripur FP	78	146	44.69	14.90	201.12	87.82	7	2.14	0.71	9.64	98.94
1036			Sripur S Sadan FP	97	32	9.80	3.27	44.08	96.94	8	2.45	0.82	11.02	98.86
1037			Subhasini B S FP	471	38	11.63	3.88	52.35	96.46	4	1.22	0.41	5.51	99.18
1038			Sumodhpur FP	59	221	67.65	22.55	304.44	81.82	58	17.76	5.92	79.90	94.86
1039			Tegharia JB	70	130	39.80	13.27	179.08	89.1	6	1.84	0.61	8.27	99.02
1040			Tetulberia Balia Manik Ghoshal FP	35	47	14.39	4.80	64.74	95.74	6	1.84	0.61	8.27	99.02
1041			Tetulberia N Kana FP	54	205	62.76	20.92	282.40	83.1	8	2.45	0.82	11.02	98.86
1042			Ukila JB	54	282	86.33	28.78	388.47	76.94	7	2.14	0.71	9.64	98.94
1043			Vidyasagar FP	32	240	73.47	24.49	330.61	80.3	5	1.53	0.51	6.89	99.1
1044			Vivekananda Adarsha FP	121	230	70.41	23.47	316.84	81.1	31	9.49	3.16	42.70	97.02

Annexure III

Nature of the curve and projected population in 2022 in the blocks

Estimation of installation cost of deep tubewell

Bhangar I

Cost associated with	**Cost in INR**
Labour for boring tubewell	78,510
Mobilization and transportation of all machinery set, development of tubewells, supply and packing of coarse sand, chemical tests for water sampling including arsenic test, construction of masonary platform, installation of India Mark II hand pump, colour photograph of the completed tubewell	30,644
Supply of PVC pipes and fittings, reducing sockets, PVC strainer	87,861
Supply and delivery of India Mark-II DWP hand pump set	13,624
Total	2,10,459
After addding GST, cost of Civil Work, contingency total cost	2,45,015

Sonarpur

Cost associated with	**Cost in INR**
Labour for boring tubewell	64,470
Mobilization and transportation of all machinery set, development of tubewells, supply and packing of coarse sand, chemical tests for water sampling including arsenic test, construction of masonary platform, installation of India Mark II hand pump, colour photograph of the completed tubewell	30,644
Supply of PVC pipes and fittings, reducing sockets, PVC strainer	76,401
Supply and delivery of India Mark-II DWP hand pump set	13,624
Total	1,85,139
After addding GST, cost of Civil Work, contingency total cost	2,15,522

Canning II

Cost associated with	**Cost in INR**
Labour for boring tubewell	1,03,080
Mobilization and transportation of all machinery set, development of tubewells, supply and packing of coarse sand, chemical tests for water sampling including arsenic test, construction of masonary platform, installation of India Mark II hand pump, colour photograph of the completed tubewell	30,644
Supply of PVC pipes and fittings, reducing sockets, PVC strainer	1,07,421
Supply and delivery of India Mark-II DWP hand pump set	13,624
Total	2,54,769
After addding GST, cost of Civil Work, contingency total cost	2,96,627

Jaynagar II

Cost associated with	**Cost in INR**
Labour for boring tubewell	85,530
Mobilization and transportation of all machinery set, development of tubewells, supply and packing of coarse sand, chemical tests for water sampling including arsenic test, construction of masonary platform, installation of India Mark II hand pump, colour photograph of the completed tubewell	30,644
Supply of PVC pipes and fittings, reducing sockets, PVC strainer	93,321
Supply and delivery of India Mark-II DWP hand pump set	13,624
Total	2,23,119
After addding GST, cost of Civil Work, contingency total cost	2,59,761

Paramita Chaudhuri