COMPENDIUM ON GROUND WATER POTENTIAL AND RECHARGING THROUGH STRUCTURAL AND NON-STRUCTURAL MEASURES

A thesis submitted towards partial fulfilment of the requirements for the degree of

Master of Engineering in
Water Resources and Hydraulic Engineering
Course affiliated to Faculty of Engineering & Technology
Jadavpur University

Submitted by

ABHIK CHAKRABORTI

EXAMINATION ROLL NO.: M6WRP19002

Under the guidance of

Prof. (Dr.) PANKAJ KUMAR ROY
Professor
School Of Water Resources Engineering,
Jadavpur University

School of Water Resources Engineering
M.E. (Water Resources & Hydraulic Engineering) Course affiliated to
Faculty of Engineering and Technology
Jadavpur University
Kolkata-700032
India

2019

M.E. (Water Resources & Hydraulic Engineering) Course affiliated to
Faculty of Engineering and Technology
Jadavpur University
Kolkata, India

CERTIFICATE OF RECOMMENDATION

This is to certify that the thesis entitled **"Compendium on Ground Water Potential and Recharging through Structural and Non-Structural Measures"** is bonafide work carried out by **ABHIK CHAKRABORTI** under our supervision and guidance for partial fulfilment of the requirement for Post Graduate Degree of Master of Engineering in Water Resources & Hydraulic Engineering during the academic session 2018-2019.

THESIS ADVISOR
Prof. (Dr.) Pankaj Kumar Roy
School of Water Resources Engineering
Jadavpur University, Kolkata- 700032

DIRECTOR
Prof. (Dr.) Asis Mazumdar
School of Water Resources Engineering
Jadavpur University, Kolkata- 700032

DEAN

Prof. (Dr.) Pankaj Kumar Roy

Faculty of Interdisciplinary Studies, Law & Management
Jadavpur University, Kolkata- 700032

M.E. (Water Resources & Hydraulic Engineering) Course Affiliated to
Faculty of Engineering and Technology
Jadavpur University
Kolkata, India

CERTIFICATE OF APPROVAL **

This foregoing thesis is hereby approved as a credible study of an engineering subject carried out and presented in a manner satisfactorily to warranty its acceptance as a pre-requisite to the degree for which it has been submitted. It is understood that by this approval the undersigned do not endorse or approve any statement made or opinion expressed or conclusion drawn therein but approve the thesis only for purpose for which it has been submitted.

Committee

Final Examination
for the evaluation of the thesis

**** Only in case the thesis is approved.**

Declaration of Originality and Compliance of Academic Ethics

I hereby declare that this thesis contains literature survey and original research work by the undersigned candidate, as a part of my Master of Water Resources & Hydraulic Engineering degree during academic session 2018-2019.

All information in this document has been obtained and presented in accordance with academic rules and ethical conduct.

I also declare that, as required by this rules and conduct, I have fully cited and referred all material and results that are not original to this work.

Name:	**ABHIK CHAKRABORTI**
Exam. Roll No. :	**M6WRP19002**
Thesis Title:	**Compendium on Ground Water Potential and Recharging through Structural and Non-Structural Measures**

Signature:

Date:

ACKNOWLEDGEMENT

I express my sincere gratitude to my Thesis Advisor **Prof. (Dr.) Pankaj Kumar Roy** under whose valuable guidance this work has been carried out. It would have been impossible to carry out this thesis work with confidence without his wholehearted involvement, advice, support and constant encouragement throughout. He has not only helped me to complete my thesis work but also have given valuable advice to proceed further in my life.

I also express my sincere gratitude to all the faculty members **Prof. (Dr.) Asis Mazumdar, Director, Prof. (Dr.) Arunabha Majumder, Dr. Rajib Das & Dr. Subhasis Das** of School of Water Resources Engineering for their valuable suggestion.

I also express my thankfulness to **Dr. Gourab Banerjee,** Assistant Professor, of School of Water Resources Engineering, Jadavpur University for his hard work and support throughout the study.

Thanks are also due to all staff of School of Water Resources Engineering and the Regional Centre, NAEB, Jadavpur University for their help and support.

Date : May, 2019

Place : Jadavpur University, **ABHIK CHAKRABORTI**

Kolkata **(Exam. Roll No. M6WRP19002)**

ABSTRACT

Ground water is an essential and vital component of our life support system. The ground water resources are being utilized for drinking, irrigation and industrial purposes. There is growing concern on deterioration of ground water quality due to geogenic and anthropogenic activities. The quality of ground water has undergone a change to an extent that the use of such water could be hazardous. Increase in overall salinity of the ground water and/or presence of high concentrations of fluoride, nitrate, iron, arsenic, total hardness and few toxic metal ions have been noticed in large areas in several states of India.

The 85 % of rural population of the country uses ground water for drinking and domestic purposes. Arsenic and fluoride contamination is found in many places in India and as well as in West Bengal also. In West Bengal the arsenic concentration in drinking water is about 60 to 3700 $\mu g/l$ and about 40 million people are affected from it. There are lots of promising technologies available for arsenic and fluoride removal but considering all the technologies, it was found that using Electro-coagulation and activated alumina are convenient and suitable for removal. In West Bengal Baruipur is a place where both arsenic and fluoride is found. So, adopting appropriate technology can remove both arsenic and fluoride at same time. Further experimental analysis needs to be done for both the cases laboratory and field based.

The problem of high fluoride concentration in groundwater resources has become one of the most important toxicological and geo-environmental issues in India. About 20 states of India, including 225 villages in 43 blocks of 7 districts were found to contain fluoride in ground water beyond permissible limit of West Bengal (Including 7 districts Birbaum, Bankura, Malda, Purulia, South 24 Parganas, Dakshin Dinajpur, Uttar Dinajpur), were identified as endemic for fluorosis and people in these regions are at risk of fluoride contamination. Mitigation of groundwater arsenic problems has involved a range of options including survey and monitoring for low-arsenic groundwater sources, use of alternative (Pleistocene) aquifers, treatment of arsenic-contaminated water at the surface, and on-site methods. Other non-groundwater options include rainwater harvesting, provision of treated surface water at community scale (pond sand filter) or piped surface-water supply.

Hazardous Waste, bulk of which is generated by the industries, can cause environmental pollution and adverse health effects if not handled and managed properly. Its effective management, with emphasis on minimization of generation and recycling/ reuse, taking into account economic aspects, is therefore essential. Various actions have been taken for environmentally sound management of hazardous wastes in the country. These include establishing regulatory and institutional framework, preparation of technical guidelines, development of individual & common facilities for recycle/recovery/reuse, treatment and disposal of hazardous wastes, inventory of hazardous wastes generation, identification & assessment of dump sites for the purpose of preparing remediation plans, and creating awareness amongst various stakeholders. However, these activities need to be expanded, reinforced and strengthened.

Introduction

Groundwater is the water present beneath Earth's surface in soil pore spaces and in the fractures of rock formations. A unit of rock or an unconsolidated deposit is called an aquifer when it can yield a usable quantity of water. The depth at which soil pore spaces or fractures and voids in rock become completely saturated with water is called the water table. Groundwater is recharged from and eventually flows to the surface naturally; natural discharge often occurs at springs and seeps, and can form oases or wetlands. Groundwater is also often withdrawn for agricultural, municipal, and industrial use by constructing and operating extraction wells. The study of the distribution and movement of groundwater is hydrogeology, also called groundwater hydrology.

The importance of groundwater for the existence of human society cannot be overemphasized. Groundwater is the major source of drinking water in both urban and rural India. Besides, it is an important source of water for the agricultural and the industrial sector. Being an important and integral part of the hydrological cycle, its availability depends on the rainfall and recharge conditions. Till recently it had been considered a dependable source of uncontaminated water.

But nowadays there is growing concern on deterioration of ground water quality due to geogenic and anthropogenic activities. The quality of ground water has undergone a change to an extent that the use of such water could be hazardous. Increase in overall salinity of the ground water and/or presence of high concentrations of fluoride, nitrate, iron, arsenic, total hardness and few toxic metal ions have been noticed in large areas in several states of India.The problem of high fluoride concentration in groundwater resources has become one of the most important toxicological and geo-environmental issues in India. About 20 states of India were found to contain fluoride in ground water beyond permissible limit endemic for fluorosis and people in these regions are at risk of fluoride contamination.

In addition, with that, hazardous waste is generated by the industries, causing environmental pollution and adverse health effects. Often this is not handled and managed properly. Its effective management, with emphasis on minimization of generation and recycling/ reuse, taking into account economic aspects, is therefore essential. Various actions have been taken for environmentally sound management of hazardous wastes in the country. In this thesis scenario of Ground water condition of West Bengal compared to other states of India has been discussed. As well as the Ground Water Treatment Methodologies for Arsenic, Fluoride etc. has been discussed. Also, a detailed discussion over Hazardous Waste Management is added. Finally, the adaptation strategies are discussed to mitigate the problem of contamination of ground water due to geogenic and anthropogenic activities.

Index of Thesis

CONTENTS

✪✪✪

CHAPTER-1

Literature Review on Ground Water

Emerging Scarcity of Ground Water Resources

- **Source of GroundWater-Hydrological Cycle**

1. Most of the earth's water sources gets water supplies from precipitation, which may fall in various forms, like, rain, snow, hail, dew etc. Rains no doubt, form the principal and major part of the resultant supplies. When rain starts falling, it is first of all intercepted by buildings and other objects. When the rainfall rate exceeds the interception rate, water starts reaching the ground and infiltration starts. This is the source of ground water storage.

2. The average annual rainfall in our country is 1170 mm, which corresponds to annual precipitation, including snowfall of 4000 billion m^3 (BCM). Out of this volume of precipitation, only 1869 BCM appears as average annual potential flow in rivers. Due to various constraints, only 1123 BCM is assessed as average annual utilisable water – 690 BCM from surface water and 433 BCM from ground water.

3. The present total water use is 634 BCM of which 83% is for irrigation. This is projected to grow to 813 BCM by 2010, 1093 BCM by 2025 and 1447 BCM by 2050, against utilisable quantum of 1123 BCM. Thus, the demand will outstrip availability in another 35 to 40 years. The Central Ground Water Board has estimated the present annual ground water draft as 230.6 BCM.

4. Ground water is essentially a dynamic resource which with both passive and active recharge zones. The annual replenishable groundwater resource (433 BCM) is the recharge to the active recharge zone / dynamic zone (unconfined aquifer where recharge takes place annually from rainfall and other sources, infiltrating directly to the water table). The static fresh ground water resources lies beyond the dynamic zone and is called the passive recharge zone.

5. The overall stage of the ground water development in the country is 58%, indicative of a comfortable situation at the aggregate level. This however masks the high degree of variability in availability of water and development throughout the country. It can be seen that in Indo- Gangetic and Brahmaputra plains, ground water potential is very high and such areas can support large scale development. In peninsular India and hilly states, however, groundwater potential is relatively much lower.

6. As regards use, the extent of extraction has been increased significantly over the years, as indicated by the growth in the number of wells and also tube wells served by ground water. It is estimated that there are currently 19 million wells in the country, out of which 16 million are in use and are drawing about 231 BCM of water—213 BCM for irrigation and 18 BCM for domestic and industrial use—out of net annual ground water availability of 399 BCM. It can be seen that there is a high degree of variability in annual groundwater draft vis-à-vis net availability across states. Another important point to note is that by the year 2025, the demand for domestic and industrial uses is projected to rise to 29 BCM from the current level of 18 BCM.

➢ ***Static GroundWater***

Aside from the aquifers of the active recharge zone which get charged every year and which constitute the dynamic fresh ground water resources, there are deeper aquifers below the zone of water level fluctuations. These deeper aquifers of passive recharge zone contain vast quantity of water. The water in these aquifers has accumulated over many years. This water is often called 'static' water though in reality it is also flows but very slowly. In the alluvial areas, these resources are renewable and get replenished over long period from recharge areas flanking in the mountains. However, in some cases like the "Lathi aquifers" in Rajasthan the in-storage resources comprise fossil water, which is of non-renewable nature. The tentative estimate of in-storage fresh groundwater in the country is about 10,800 BCM.

➢ **Over-exploitation: Extent, Causes and Consequences**

✓**Extent of Over-exploitation**

According to the report on ***3rd Census of Minor Irrigation Schemes* (2005)**, the ultimate irrigation potential from the ground water source is 64.05 m.ha., as compared to 46 m.ha. of land currently under ground water irrigation, indicating the further scope for developing ground water in some areas (such as the eastern and north-eastern parts of the country). The report (reference year 2000-01) has however revealed that in many states, irrigation potential created has exceeded the ultimate potential, showing that mining of ground water, that is exploitation beyond the dynamic resource, is already taking place.

The degree of exploitation has varied widely across the country. Some states have a large number of semi critical, critical and overexploit assessment units. Out of the 5723 assessment units assessed jointly by State Ground Water Departments and CGWB in the country, 4078 are safe (71%), 550 are semi critical (10%), 226 are critical (4%) and 839 are over- exploited(15%). Just the six states [Gujarat, Haryana, Maharashtra, Punjab, Rajasthan and Tamil Nadu] comprising 1413 assessment units, have 762 assessment units which are semi critical, critical or overexploited (54% against national average of 29%).

✓ Causes of Over-Exploitation

In most parts of the over-exploited area, the prime cause of over-exploitation is the rising demand for groundwater from agriculture. In some parts, it is growing urbanisation and industrialisation. Further, in many groundwater irrigated areas, decisions on cropping pattern and cropping intensity, which are the predominant determinant of agricultural demand for groundwater, are being taken largely independent of the ease of ground water availability. Thus, water intensive crops have tended to be grown even in the face of scarcity of the groundwater, if these crops are perceived to be relatively remunerative. Such distortions occur partly due to the legal/ regulatory regime governing groundwater and partly to the minimum support price policy and agricultural trade policy currently being followed.

✓ Consequences of Over-Exploitation

Overexploitation leads to (i) increase in pumping depths, reduction in well or tube well yields and rise in the cost of pumping ground water and (ii) widespread and acute scarcity of ground water in summer months for irrigation or drinking uses. This forces farmers to deepen their wells and install larger pumps. Rich farmers may cope with this challenge relatively easily, but small and marginal farmers, many of the whose wells are supported by shallow aquifers, often find it difficult.

Another fallout of ground water over-exploitation has been contamination of the ground water due to the geogenic factors (i.e. because of particular geological formation at deeper levels), resulting in the increasing levels of fluoride, arsenic and iron. Ground water in some parts of **West Bengal** and Gujarat, which are contaminated by arsenic and fluoride now, were safe at the time of independence. Since 85% of rural water supply programmes depends on ground water as the source, effects on health of rural population due to such contamination is a matter meriting serious attention. Further, overexploitation in coastal areas leads to salinity ingress, which eventually results in fresh water turning saline. Environmental impact of overexploitation occurs in other ways too. It can, for example, potentially lead to the reductions in essential base flow torivers and streams, and diminished spring flows.

On both counts stated above (i.e., reduced quantity and lower quality) agricultural sustainability suffer. It may be observed that over-exploitation has been occurred in agriculturally crucial states, such as Punjab, Haryana, Gujarat, Maharashtra and Andhra Pradesh. Further, to the extent the depletion of groundwater raises demand for electricity, it undermines the viability of the power sector, as power for agricultural use is highly subsidised.

Legal Position Regarding GroundWater

The Indian legal system in respect of the groundwater has two important characteristics. First, the system is 'mixed' or 'pluralistic' and includes statutory provisions, precedential court decisions, doctrines and principles deriving from the British common law system, international agreements, religious (personal) law and customary law and practices. This scenario, in no sense unique to India, contribute often to dispensable complexity. Secondly, different parts of the system are not well integrated with each other, resulting in overlapping regulations in many areas. Methods for the legal interpretation have to be adjusted accordingly.

- ✓ **Individuals Right to Use Ground Water**

The right to groundwater in India is as in many other legal cultures, seen as following the right to lands. The source usually referred to in support of this is the Indian Easements Act 1882. An 'easement' is mostly agreed upon between two neighbours and an easement so created leads, according to Section 7(a) of the Act, to restrictions of certain basic rights. One such is the exclusive right of every real property owner (in civil law countries known as immovable property) to enjoy and dispose of this, and of all the products thereof. As real property chiefly denominates the land, and the groundwater legally is seen as a naturally inherent part of land, groundwater must hence be termed as real property. This and other relevant provisions of the Act build upon common law principles establishing a rule of 'absolute ownership' over all there is below the surface of the earth of each landowner. This doctrine, settled in England in the nineteenth century and in turn drawing from ancient Roman law, makes a distinction between water flowing in 'defined channels' underground and percolating water. The landowners are perceived to have an unlimited right to appropriate whole of the latter.

The Indian Easement Act, 1882 links groundwater ownership to land ownership and the legal position has remained intact since then. In the Act 'easement' is defined *as a right which the owner or occupier of certain land possesses, as such, for the beneficial enjoyment of that land to do and continue to do something, or to prevent and continue to prevent something from being done, in or upon or in respect of certain other land not his own*.

The Hon'ble High Court of Kerala in the matter of Perumatty Grama Panchayat vs. State of Kerala also known as the landmark "Coca- Cola Case" decided on the issue of the excessive exploitation of ground water. Certain extracts of the judgement delivered by the Hon'ble High Court are reiterated below:

"Ground water is a national wealth and it belongs to the entire society. It is a nectar, sustaining life on earth. Without water the earth would be a desert… Our legal system – based on English common law – includes the public trust doctrine as part of its jurisprudence. The State is the trustee of all natural resources which are by nature meant for public use and enjoyment. Public at large is the beneficiary of the sea, shore, running waters, air, forests and ecologically fragile lands. The State as a trustee is under a legal duty to protect the natural resources. These resources meant for public use cannot be converted into private ownership (emphasis supplied)…In view of the above authoritative statement of the Hon'ble Supreme Court, it can be safely concluded that the underground water belongs to the public. The State and its instrumentalities should act as trustees of this great wealth. The State has got a duty to protect ground water against excessive exploitation and the inaction of the State in this regard will tantamount to infringement of the right to life of the people guaranteed under Art. 21 of the Constitution of India. The Apex Court has repeatedly held that the right to clean air and unpolluted water forms part of the right to life under Art. 21 of the Constitution… the Panchayat and the State are bound to protect ground water from excessive exploitation".

This judgement clearly lays down that the State has a right and obligation to restrain use of groundwater if it causes harm to others.

- ✓ **Centre's Obligations :Constitution of the Central Groundwater Authority (CGWA)**

As regards groundwater regulation, specifically depletion, the Supreme Court of India has passed several orders in 1996, where under it has issued directions to the Government of India for setting up of Central Ground Water Authority (CGWA) under the Environment (Protection) Act, 1986 and to declare it as an authority under the Environment Protection Act and delegate powers under the said Act to the CGWA for the purposes of regulation and control of groundwater development. The Hon'ble Court further directed that the CGWA should regulate indiscriminate boring and withdrawal of groundwater in the country and issue necessary directions with a view to preserving and protecting the groundwater.

A view was taken by the Hon'ble Supreme Court of the India in the matter of Indian Council for Enviro Legal Action vs. Union of India where it was held that Sections 3 and 5 of the Environment Protection Act empowers the Central Government to give directions and take measures for giving effect to the appropriate environmental protection agency.

CGWA has been granted the powers to, amongst others, regulate and control, manage and develop groundwater in the entire country and to issue necessary directions for this purpose.

The areas of activities of the Central Ground Water Authority:

i) Notification of areas for regulation of ground water development in severely over- exploited areas in the country.

ii) Regulation of ground water abstraction by industries in over exploited/critical areas in the country.

iii) Registration of drilling agencies for assessment of pace of development of ground water and regulation of well drilling activities.

iv) Representation in the national coastal zone management authority and other expert committees of the ministry of environment & forests.

v) Undertaking country-wide mass awareness programmes and training in rain water harvesting for ground recharge.

- **National Environment Policy**

Since the Centre's power to legislate on the groundwater is based on environmental grounds, the National Environment Policy has suggested the following action points in relation to ground water:

- take explicit account of impacts on ground water tables of electricity tariffs and pricing of diesel.
- promote efficient water use techniques, such as sprinkler or drip irrigation among farmers. Provide necessary pricing, inputs and extension support to feasible and remunerative alternative crops for efficient water use.
- support practices of contour bunding and revival of traditional methods for enhancing ground water recharge.
- mandate water harvesting in all new constructions in relevant urban areas as well as design techniques for road surfaces and infrastructure to enhance ground water recharge.
- support R&D in most effective techniques suitable for rural water projects for removal of arsenic and mainstream their adoption in rural drinking water schemes in relevant areas.

- **National Water Policy**

The Ministry of the Water Resources, Government of India ("Ministry") is responsible for laying down policy guidelines and programmes for the development and regulation of country's water resources. Amongst others the Ministry has been allocated the function of "overall planning for the development of groundwater resources, establishment of utilisable resource and formulation of policies of exploitation, overseeing of and support to State level activities in groundwater development."

The Revised National Water Policy (2002) has the following recommendations relating to ground water.

- exploitation of ground water resources should be so regulated as not to exceed the recharging possibilities, as also to ensure social equity. The detrimental environmental consequences of over exploitation of ground water needs to be effectively prevented by the Central and State governments. Ground water recharge projects should be developed and implemented for improving both the quality and availability of ground water resource.
- integrated and coordinated development of surface water and ground water resources and their conjunctive use should be envisaged right from the project planning stage and should form an integral part of the project implementation.
- over exploitation of ground water should be avoided especially near the coast to prevent ingress of sea water into sweet water aquifers.

The recommendations in the National Water Policy and the National Environment Policy should be the cornerstone of the ground water development and regulation policy in the country. However, the above policy statements are neither supported by institutional infrastructure and mechanisms nor by enabling legislation nor by supporting economic incentive structure.

As individual's right to use groundwater is limited by the need to contain environmental consequences, such as lowering of the water table, of such use, the Central Government has the obligation to see that groundwater use does not lead to environmental degradation.

The State Governments have the right to legislate on water including groundwater.

As the depletion of Ground Water may lead to environmental hazard, people's participation along with awareness is required. The people's participation is required in regulator mechanism through more pro-active approach. Also that State Governments need to monitor the Ground Water levels through scientific methods.

- **Changes and Enactment Required**

As has been indicated that as per the Indian Easement Act, 1882 the ownership of the ground water will be governed by the ownership of the land to the extent the uses (exploitation) of ground water is not causing depletion in the ground water levels so the similar rights of the adjoining land owners and public at large are not encroached upon as this natural resource is meant for public use and it should not be allowed to be exploited beyond replenishable level. Therefore, there is a need of an "Act" at the State level to monitor the ground water levels through scientific methods by piezometers under the advisory guidance of Central Ground Water Board (MoWR).

The State Government will also ensure that ground water levels never fall below the replenishable level and accordingly will take necessary measures for regulation/restriction of the ground water uses in the area.

Some States Approach to and Experience with Groundwater Regulation

Some state governments have enacted the ground water legislation (See below). An attempt has been made in this Chapter to examine some individual states' approach to and experience with groundwater regulation.

- **Kerala**

The net annual ground water availability in the State has been assessed as 6.23 BCM. The present annual draft for irrigation is 1.82 BCM and 1.10 BCM for the domestic and industrial uses (total 2.92 BCM). The stage of development is assessed as 47%.

The Kerala Ground Water (Control and Regulation) Act, 2002 came into effect in December 2003 and the Kerala Ground Water Authority was constituted a month later. As per Section 6(1) of the Act, the Authority can recommend to the Government to notify any area within the State for the purpose of regulating groundwater extraction in that area in public interest

- **TamilNadu**

The predominant source of water for the state is rainfall from both the South West and North East monsoons. The average rainfall in the state in a water year (June to May) is 961.8 mm. The annual replenishable ground water resources in the state is 23.07 BCM. The state has a gross irrigated area of about 3.1 m.ha., 38 percent of which is from ground water (open wells and tube wells). The stage of groundwater development in the state is 85%. On the basis of the revised norms of groundwater estimation, as of March 2004, out of a total of 385 assessed blocks, the state had 142 overexploited, 33 critical and 57 semi-critical blocks. Clearly, groundwater situation in the state is among the worst in the country and is a matter of concern.

The Tamil Nadu Groundwater (Development and Management) Act 2003 extends to the whole state of Tamil Nadu except the areas covered under the Chennai Metropolitan Area Groundwater (Regulation) Act 1987 and is to be implemented by the TN Groundwater Authority. Like the Chennai Metropolitan Area Ground Water (Regulation) Act, 1987, this Act is generally prohibitive in nature and relies heavily on permit system. An important feature of this Act is that it does not gives permission the supply of electrical energy from the Tamil Nadu Electricity Board (TNEB) for energising wells sunk in contravention of the provisions of the Act.

- **Punjab**

Punjab is a predominantly agrarian state having 85% of its geographical area under cultivation with an cropping intensity of 188%. The water demand for the kind of agricultural practices followed in the state is very high and a large part of it is for groundwater. Out of the 137 blocks in the state, only 25 are safe; 103 are over exploited, 5 critical and 4 semi- critical.

Punjab is not in favour of ground water legislation as it apprehends that such a step will cause hardship to farmers. Instead, to tackle ground water over exploitation, the State is in favor of the following initiatives.

i) Crop diversification – extending minimum support price to other crops to wean away farmers from paddy cultivation, which is water intensive. Contract farming for sowing alternative crop of chick-pea has been successfully tried.

ii) Large scale artificial recharge – through construction of check dams, use of drainage water and roof top rain water harvesting.

iii) Electricity supply – controlled, regulated and metered supply in critical areas.

iv) Micro irrigation – promotion of drip & sprinkler to conserve water.

v) Alteration in crop calendar – encouraging late sowing of paddy after 16th June to decrease evapotranspiration.

vi) Encouraging industries.

- **Andhra Pradesh**

Out of the 1231 assessment units (mandals) in the state, 219 are over exploited, 175 are semi critical and 77 critical. The stage of ground water development is 45%.

The A.P. Water, Land and Trees Act (WALTA), enacted in the year 2002, aims inter alia at controlling and regulating the use of ground water and propagating tree-plantation on farm. The

State Government has designated the Commissioner, Rural Development as the Administrator for the purpose of the Act. Some of the critical provisions in the area of Ground Water management are:

- Registration of all the borewells with concerned Revenue Authorities at the Mandal level.
- Prior permission for digging of new borewells from Revenue Authorities.
- Registration of all the rigs with the Government.
- Prohibition of water pumping in certain area.

➢ Gujarat

Out of the 223 blocks in the state, only 97 are safe while 69 are semi critical, 12 are critical and 31 over exploited. The per capita availability in north Gujarat and Saurashtra- Kutch is very low (130 m^3 to 424 m^3), putting tremendous pressure on the ground water. The maximum fall of ground water level that has been observed in the monitoring wells of CGWB in the over exploited blocks is around 3m per year. At some places the piezometric surface of the deeper confined aquifer has gone down to 130 m.

The life of tube-well is also much less in Gujarat. While it costs Rs.10 lakhs to drill a tubewell, its life is only 10 years against a normal 30. Ground water is saline as also fluoride contaminated.

To ensure sustainability, however, the State has taken a wide range of conservation initiatives.

➢ Maharashtra

Maharashtra is mainly an agricultural state with 82% of the rural population relying on agriculture. Earlier, the use of groundwater was insignificant. Subsequent to 1972, occurrence of frequent droughts, development of cheap drilling devices and availability of relatively low cost institutional finance, and energisation led to proliferation in irrigation dugwells. The number of such wells rose from about 7 lakhs in 1974 to 15.6 lakhs in 2004 and the area under well irrigation increased from about 10 lakh ha. to 29 lakh ha. during the same period. Out of the 318 blocks in the state, 287 are safe while 23 are semi critical, 1 is critical and 7 over exploited. The stage of ground water development is 48%.

The motivation for ground water legislation came from the specific need to protect drinking water supply sources. It was however found that public drinking water supply sources in many parts of Maharashtra was getting affected due to sinking of wells in the close vicinity and high density and unregulated extraction of water from such wells. This situation made it difficult for authorities to provide minimum prescribed drinking water to the local population. To overcome this situation, increasing and repetitive measures had to be taken to provide dependable and adequate supply of the water to many villages, which ultimately led to huge financial burden on the state government. In view of these developments, the Government of Maharashtra enacted and enforced "Maharashtra Ground Water (Regulation for drinking water purposes) Act, 1993", for the limited purpose of protecting the availability of drinking water supply.

- **GROUND WATER RESOURCES WEST BENGAL DISTRICT WISE STATUS**

  - ✓ **The West Bengal ground water resources management, control and regulation act (2005)**

Water Investigation and Development Department (Government of West Bengal)

The act aims to manage, control and regulate the indiscriminate extraction of groundwater in West Bengal and to provide solutions to matter related to it

The act aims to manage, control and regulate indiscriminate extraction of groundwater in West Bengal and to provide against its widespread contamination with arsenic, fluoride, chloride, iron, other heavy metals or metalloids, organic and inorganic pesticides, fungicides, and rodenticides. It provides for the setting up of a State Level Authority which shall be under the administrative control of the Water Investigation and Development Department, Government of the West Bengal and shall be the apex body of all the District Level Authorities and the Corporation Level Authority.

- **Ground Water Scenario of West Bengal**

Area (Sq.km)	88,752
Rainfall (mm)	2074
Total Districts / Blocks	18 districts / 341 Blocks

- **Hydrogeology**

The state can be divided into two hydrogeological unit namely, fissured hard rocks & porous alluvial formations. Fissured formation includes crystalline, metasedimentary and volcanic rocks.

The yield of wells tapping fractured zones varies from 10-20 m3/hr. Two third of the State is underlain by alluvial sediments mainly deposited by Ganga & Brahmaputra rivers. Based on the yield of wells tapping these alluvial sediments, aquifers of the alluvial area can be divided into three zones. 1. Yielding about 150m3/hr, occurs from Jalpaiguri to Kochbihar in north to Medinipur& 24 Parganas in South. 2. Yielding about 50-150 m3/hr, occurs in parts of Malda, Dinanjpur and western part of Murshidabad districts. 3. Yielding less than 50m3/hr, occurs as Marginal alluvial tract in parts of Birbhum, Burdawan, Bankura and Murshidabad districts.

Critical	1 Block
Semi- critical	37 Blocks
Ground Water User Maps	18 districts
Artificial Recharge to Ground Water (AR)	• Area identified for AR: 7500 sq km • Quantity of Surface Water to be Recharged: 2664 MCM • Feasible AR structures: 11200 percolation tanks with shafts, 3606 gabion structures, 1054 nala bund/ cement plug, 1680 re excavation of tanks, 500 desiltation of village pond, 1000 spring development, 70 sub surface dykes, 1500 RTRWH for Kolkata & Darjeeling.
	AR schemes completed during VIII Plan: 2 AR schemes completed during IX Plan: 5
Ground Water Quality Problems	
Contaminants	**Districts affected (in part)**
Salinity (EC > 3000 µS/cm at 25 ° C)	Haora, Medinipur, S- 24 Parganas,
Fluoride (>1.5 mg/l)	Bankura, Bardhaman, Birbhum, Dakhindinajpur, Malda, Nadia, Purulia, Uttardinajpur
Chloride (> 1000 mg/l)	S-24 Parganas, Haora
Iron (>1.0 mg/l)	Bankura, Bardhaman, Birbhum, Dakhindinajpur, E. Midnapur, Howrah, Hugli, Jalpaiguri, Kolkata, Murshidabad, N-24praganna, Nadia, S-24 Parganas, Uttar Dinajpur, West Midnapur
Nitrate (>45 mg/l)	Bankura, Bardhaman
Arsenic (>0.05 mg/l)	Bardhaman, Hooghly, Howrah, Malda, Murshidabad, Nadia, North 24 Praganas, South 24 Parganas

Periodical Monitoring of Ground Water levels –

- The ground water is a dynamic resource, which replenishes periodically by with precipitation every year. To have a watch on the behaviour of ground water, there is a system of periodical monitoring of ground water level in four scheduled periods **(Jan./Apr./Aug./Nov.)** In a year through 2000 odd Permanent Hydrograph Stations (PHS) scattered over different parts of the State. On the basis of such data, the periodical reports were compiled and circulated to aware the developmental agencies and masses as a whole. This data is very helpful in predicting the ground water situation in different regions as well as long term prospective planning.

- During the financial year 2011-2012 both the wing of Engineering and Geological completed all the works in scheduled periods.

Overall Assessment of States Approach and Experience

Despite repeated circulation of Model Groundwater Bill by the Central Government, states have generally exhibited lethargy in legislating on groundwater. So far, only a few states—particularly those that have been severely affected by the groundwater extraction—have opted for legislation. In this regard, Punjab has been a notable exception. The State believes that legislation could cause hardship to farmers and has hence favoured alternative strategies focusing mainly on conservation. Commonalities among state legislation include:

- Excessive reliance is on state imposed control mechanisms and very little emphasis on cooperative management.

  Sanctions are over limited area and over limited period of time. Penalties are coercive, heavy-handed and in the nature of criminal sanctions.

- Typically, the process involves licensing procedures to regulate digging of wells (number of wells, depth of wells).

Some states have unique features. For example, Tamil Nadu has a separate legislation for Chennai and its surrounding areas, as distinct from the one for the rest of the state. The 1993 Act of Maharashtra focused primarily on drinking water, while other states had a more balanced approach. Maharashtra is also the only state to introduce a regulatory authority, separate from the Government. Gujarat made a successful experiment in electricity supply that had a strong bearing on ground water management without resort to any dedicated legislation.

CHAPTER-2

ENVIRONMENTAL REGULATIONS IN INDIA & ITS IMPLEMENTATION

□ ENVIRONMENT:

The environment is something you are very familiar with. It's everything that makes up our surroundings and affects our ability to live on the earth, the air we breathe, the water that covers most of the earth's surface, the plants and animals around us, and much more.

In recent years, scientists have carefully examining the ways that people affect the environment. They have found that we are causing air pollution, deforestation, acid rain, and other problems that are dangerous both to the earth and to ourselves. These days, when you hear people talk about “the environment”, they are often referring to the overall condition of our planet, or how healthy it is.

□ TYPES OF ENVIRONMENT:

Following are main types of environmental pollution that we must be careful:

1. **Air Pollution**
2. **Water Pollution**
3. **Land Pollution**
4. **Noise Pollution**
5. **Radiation Pollution**
6. **Thermal Pollution, etc**

Water Pollution

One of the most common types of environmental pollution is water pollution. Generally, water pollution is the contagion of any body of water including lakes, groundwater, sea, oceans, etc. A few examples of water pollution include raw sewage running into the lake or streams; Industrial waste drips polluting groundwater, the illicit putting of the stuff or items within bodies of water, etc. The most explicit kind of water pollution affects surface waters including oceans, lakes, and rivers. Sewage, Nutrients, Chemical waste, radioactive waste, etc. can make the water polluted. Water pollution kills pollutants kill organisms and fish, crabs, birds; seagulls, dolphins, etc.

Air Pollution

Air Pollution is another main environmental pollution faced by our world today. Air pollution takes place when damaging stuff including particulates and biological molecules are dumped into Earth's atmosphere. It results in diseases, allergies or premature death in humans. Air pollution can bring harm to the other living organisms such as animals and food crops that we eat. In general, air pollution is the pollution of air by smoke and dangerous gases, chiefly oxides of carbon, sulfur, and nitrogen. Exhausting fumes from vehicles, the burning of fossil fuels, Radiation spills or nuclear accidents, destructive off-gassing from things such as paint, plastic production, and so on can cause air pollution.

Soil Pollution

Soil Pollution is severe environmental pollution that our world is facing now. Soil pollution takes place when the existence of toxic chemicals, pollutants or impurities in the soil is in high. It presents a high risk to plants, wildlife, humans and indeed, the soil itself. The surplus, escalating the use of chemicals such as the pesticides, herbicides, insecticides, and fertilizers is one of the main features causing soil pollution. The primary cause why the soil becomes impure is on account of the presence of human-made waste. Human-made waste products are full of bad chemicals, and it can lead to soil pollution. Industrial activity, agricultural activities, waste disposal, accidental oil spills, acid rain, etc. are the main reasons for soil pollution. Effects of soil pollution include the effect on the health of humans, effect on the growth of plants, decreased soil fertility, toxic dust, changes in soil structure, etc.

Noise Pollution

Noise pollution has become more of an environmental issue since the industrial age. It is disturbing or extreme noise that can make harm to the activity or balance of human as well as animal life. The cause of most outdoor noise globally is primarily originated from machines and transportation systems, motor vehicles engines, factory machine sounds, aircraft, and trains. Noise pollution can result from machines, construction activities, and music performances. Noise pollution can cause tinnitus, hearing loss, sleep disturbances, hypertension, high-stress levels, and other destructive effects on humans. It causes uneasiness and damage to living being's mental and physical health.

Some other Main types of environmental pollution that we must be careful include:

- **Light pollution:** It is a broad term that denotes many problems that are caused by the useless, ugly, and pointless use of artificial light. Specific types of light pollution consist of light trespass, over-illumination, glare, light clutter, and sky glow.
- **Thermal pollution**. It denotes the sudden increase or drops off in the hotness of a natural body of water which may be ocean, lake, river, sea or pond by human influence. A general reason of thermal pollution is the use of water as a coolant by power plants and business firms.
- **Radioactive pollution:** It can happen because of the release of radioactive stuff or high-energy elements into the air, water, or soil on account of excessive human activity, either by mistake or intentionally.

IMPLEMENT ENVIRONMENTAL LAWS IN INDIA

The concern for environmental protection has received a status of fundamental law of the land in India. The Indian constitution provides the basic human right of every individual to live in pollution free environment. We have constitutional provisions and other statutory provisions for the environment protection which follows the approach of sustainable development. Though we do not have 'environment' explicitly mentioned in the constitution, Article 21 provides the right for the protection of life and personal liberty and Article 47 of the Constitution imposes the primary duty on the State to provide public with improved health and good nutrition which leads us to an improved standard of living. Please read more on the development of Environmental Jurisprudence in India here.

Learning from the national capital Declaration, the Supreme Court of India has set down the "Precautionary principle" and therefore the "Polluter Pays Principle" as essential options of "sustainable development". In India, the legislative framework for the protection of atmosphere is provided by Constitutional provisions, General laws (IPC, CrPC), Special acts (more than three hundred acts like IFA, WPA, EPA, Air Act, Water Act, FCA, National inexperienced court 2009, etc.) and Policies (National atmosphere Policy 2006, National Forest Policy, National Agriculture Policy). Please browse additional on Some necessary court petitions and judgments and Central and state acts for the protection of the atmosphere here.

This shows that there is no dearth of legislation for environmental protection in India, however despite all these laws, it is increasingly evident that we have dramatically changed the ecosystem, started to exhaust the already restricted natural resources, and contaminated the atmosphere that makes tough for all living organisms to measure quality life in their scheme.

Air pollution in Asian nation is worsening and has become a national drawback that's killing 1.2 million Indians Associate in Nursingnum once a year each year and cost accounting the economy a calculable three-D of GDP. Recently, New Delhi's air quality became very harmful and also the PM2.5 levels reached over twenty times the safe limit. Pollution could be a major problem with concerning seventieth of India's surface water resources and a growing variety of its groundwater reserves are contaminated with harmful pollutants. Municipal Solid Waste (MSW) and Industrial venturous waste disposal ashore pits is another major concern. The disreputable case of atomic number 92 poisoning in geographic area is clear of land contamination with harmful pollutants that brought severe abnormalities in youngsters within the region. Our forests are degrading at an horrifying rate with increasing phylogeny deforestation. Overall, the condition in Asian nation is degrading and creating it tough to measure a high-quality life in an exceedingly healthier and safer setting.

Though we have significant Environmental protection laws in India, we have not been very successful in fulfilling the requirements of environmental protection, mainly due to the absence of political will and public awareness. Another reason may be because most of our environmental laws are human-centric i.e. primarily focussing on the protection of humans and benefit them and not explicitly meant for the protection of the environment in which humans live. The possible reason behind this is the fact that almost all environmental laws consider the superiority of humans over nature and ecosystem. On the other hand, the ecosystem is a complex system which is closely integrated and self-regulating. It works best when left alone by human interventions whereas our laws are particularly concerned with enhancing the economic welfare of human beings.

Ignorance towards environmental issues will not help. Public awareness and seriousness towards tackling the issues of environmental pollution should be our utmost priority. Having an RO water purifier or Air purifier at our homes is not a demonstration of progress mankind has made but indeed it's a sign that we are on the verge of destroying our home and in the process- our beloved earth. Therefore, environmental legislations are not enough. We need a positive attitude on the part of each citizen which is essential for effective and efficient enforcement of these legislations. To achieve this, we need public awareness as no law works best unless the interaction is voluntary.

The National Green Tribunal Act, 2010

The National Green Tribunal Act, 2010 (No. 19 of 2010) (NGT Act) has been enacted with the objectives to provide for establishment of a National Green Tribunal (NGT) for the effective and expeditious disposal of cases relating to environment protection and conservation of forests and other natural resources including enforcement of any legal right relating to environment and giving relief and compensation for damages to persons and property and for matters connected therewith or incidental thereto.

The Act received the assent of the President of India on June 2, 2010, and was enforced by the Central Government *vide* Notification no. S.O. 2569(E) dated October 18, 2010, with effect from October 18, 2010. The Act envisages establishment of NGT in order to deal with all environmental laws relating to air and water pollution, the Environment Protection Act, the Forest Conservation Act and the Biodiversity Act as have been set out in Schedule I of the NGT Act.

Consequent to enforcement of the National Green Tribunal Act, 2010, the National Environment Tribunal Act, 1995 and the National Environment Appellate Authority Act, 1997 stand repealed. The National Environment Appellate Authority established under s 3(1) of the National Environment Appellate Authority Act, 1997stands dissolved, in view of the establishment of the National Green Tribunal under the National Green Tribunal Act, 2010 *vide* Notification no. S.O. 2570(E) dated October 18, 2010.

The Air (Prevention and Control of Pollution) Act, 1981

The Air (Prevention and Control of Pollution) Act, 1981 (the "Air Act") is an act to provide for the prevention, control and abatement of air pollution and for the establishment of Boards at the Central and State levels with a view to carrying out the aforesaid purposes.

To counter the problems associated with air pollution, ambient air quality standards were established under the Air Act. The Air Act seeks to combat air pollution by prohibiting the use of polluting fuels and substances, as well as by regulating appliances that give rise to air pollution. The Air Act empowers the State Government, after consultation with the SPCBs, to declare any area or areas within the Sate as air pollution control area or areas. Under the Act, establishing or operating any industrial plant in the pollution control area requires consent from SPCBs. SPCBs are also expected to test the air in air pollution control areas, inspect pollution control equipment, and manufacturing processes.

The Water (Prevention and Control of Pollution) Act, 1974

The Water Prevention and Control of Pollution Act, 1974 (the "Water Act") has been enacted to provide for the prevention and control of water pollution and to maintain or restore wholesomeness of water in the country. It further provides for the establishment of Boards for the prevention and control of water pollution with a view to carry out the aforesaid purposes. The Water Act prohibits the discharge of pollutants into water bodies beyond a given standard, and lays down penalties for non-compliance. At the Centre, the Water Act has set up the CPCB which lays down standards for the prevention and control of water pollution. At the State level, SPCBs function under the direction of the CPCB and the State Government.

Further, the Water (Prevention and Control of Pollution) Cess Act was enacted in 1977 to provide for the levy and collection of a cess on water consumed by persons operating and carrying on certain types of industrial activities. This cess is collected with a view to augment the resources of the Central Board and the State Boards for the prevention and control of water pollution constituted under the Water (Prevention and Control of Pollution) Act, 1974. The Act was last amended in 2003.

The Environment Protection Act, 1986

The Environment Protection Act, 1986 (the "Environment Act") provides for the protection and improvement of environment. The Environment Protection Act establishes the framework for studying, planning and implementing long-term requirements of environmental safety and laying down a system of speedy and adequate response to situations threatening the environment. It is an umbrella legislation designed to provide a framework for the coordination of central and state authorities established under the Water Act, 1974 and the Air Act. The term "environment" is understood in a very wide term under s 2(a) of the Environment Act. It includes water, air and land as well as the interrelationship which exists between water, air and land, and human beings, other living creatures, plants, micro-organisms and property.

Under the Environment Act, the Central Government is empowered to take measures necessary to protect and improve the quality of environment by setting standards for emissions and discharges of pollution in the atmosphere by any person carrying on an industry or activity; regulating the location of industries; management of hazardous wastes, and protection of public health and welfare. From time to time, the Central Government issues notifications under the Environment Act for the protection of ecologically-sensitive areas or issues guidelines for matters under the Environment Act.

In case of any non-compliance or contravention of the Environment Act, or of the rules or directions under the said Act, the violator will be punishable with imprisonment up to five years or with fine up to Rs 1,00,000, or with both. In case of continuation of such violation, an additional fine of up to Rs 5,000 for every day during which such failure or contravention continues after the conviction for the first such failure or contravention, will be levied. Further, if the violation continues beyond a period of one year after the date of conviction, the offender shall be punishable with imprisonment for a term which may extend to seven years.

Hazardous Wastes Management Regulations

Hazardous waste means any waste which, by reason of any of its physical, chemical, reactive, toxic, flammable, explosive or corrosive characteristics, causes danger or is likely to cause danger to health or environment, whether alone or when in contact with other wastes or substances.

There are several legislations that directly or indirectly deal with hazardous waste management. The relevant legislations are the Factories Act, 1948, the Public Liability Insurance Act, 1991, the National Environment Tribunal Act, 1995 and rules and notifications under the Environmental Act. Some of the rules dealing with hazardous waste management are discussed below:

- **Hazardous Wastes (Management, Handling and Transboundary) Rules, 2008**, brought out a guide for manufacture, storage and import of hazardous chemicals and for management of hazardous wastes.
- **Biomedical Waste (Management and Handling) Rules, 1998**, were formulated along parallel lines, for proper disposal, segregation, transport, etc, of infectious wastes.

- **Municipal Solid Wastes (Management and Handling) Rules, 2000**, aim at enabling municipalities to dispose municipal solid waste in a scientific manner.

Natural resource and its implementation

Natural resources are resources that exist without actions of humankind. This includes all valued characteristics such as magnetic, gravitational, electrical properties and forces etc. On earth it includes: sunlight, atmosphere, water, land (includes all minerals) along with all vegetation, crops and animal life that naturally subsists upon or within the heretofore identified characteristics and substances.

Particular areas such as the rainforest in Fatu-Hiva are often characterized by the biodiversity and geodiversity existent in their ecosystems. Natural resources may be further classified in different ways. Natural resources are materials and components (something that can be used) that can be found within the environment. Every man-made product is composed of natural resources (at its fundamental level). A **natural resource** may exist as a separate entity such as fresh water, air, and as well as a living organism such as a fish, or it may exist in an alternate form that must be processed to obtain the resource such as metal ores, rare earth metals, petroleum, and most forms of energy.

Here are various methods of categorizing natural resources, these include source of origin, stage of development, and by their renewability.

On the basis of origin, natural resources may be divided into two types:

- ***Biotic*** — Biotic resources are obtained from the biosphere (living and organic material), such as forests and animals, and the materials that can be obtained from them. Fossil fuels such as coal and petroleum are also included in this category because they are formed from decayed organic matter.

- ***Abiotic*** – Abiotic resources are those that come from non-living, non-organic material. Examples of abiotic resources include land, fresh water, air, rare earth metals and heavy metals including ores such as gold, iron, copper, silver, etc.

Considering their stage of development, natural resources may be referred to in the following ways:

Potential resources — Potential resources are those that may be used in the future—for example, petroleum in sedimentary rocks that, until drilled out and put to use remains a *potential* resource.

Actual resources— Those resources that have been surveyed, quantified and qualified and, are currently used—development, such as wood processing, depends on technology and cost.

Reserve resources — The part of an actual resource that can be developed profitably in the future.

Stock resources — Those that have been surveyed, but cannot be used due to lack of technology—for example, hydrogen.

Many natural resources can be categorized as either renewable or non-renewable:

Renewable resources— Renewable resources can be replenished naturally. Some of these resources, like sunlight, air, wind, water, etc., are continuously available and their quantity is not noticeably affected by human consumption. Though many renewable resources do not have such a rapid recovery rate, these resources are susceptible to depletion by over-use. Resources from a human use perspective are classified as renewable so long as the rate of replenishment/recovery exceeds that of the rate of consumption. They replenish easily compared to Non-renewable resources.

Non-renewable resources – Non-renewable resources either form slowly or do not naturally form in the environment. Minerals are the most common resource included in this category. By the human perspective, resources are non-renewable when their rate of consumption exceeds the rate of replenishment/recovery; a good example of this are fossil fuels, which are in this category because their rate of formation is extremely slow (potentially millions of years), meaning they are considered non-renewable. Some resources actually naturally deplete in amount without human interference, the most notable of these being radio-active elements such as uranium, which naturally decay into heavy metals. Of these, the metallic minerals can be re-used by recycling them, but coal and petroleum cannot be recycled. Once they are completely used they take millions of years to replenish.

Environment Law :

Environmental law has a series of treaties, regulations, representations, and common law that allsystematically intertwine andwork together. These series of doctrines broadly identify the reaction ofhumanity and the rest of the natural environment. Its purpose is to control the impact of human activity onthe natural environment, as well as the impact of human activity onhumanity itself. Environmental laws are ideally separated into two major areas regarding pollution and environmental remedies, as well as the management and conservation of natural resources. Many environmental laws regarding pollution concentrate on a single element, such as air or water pollution, discussing theliabilities for those responsible for exceeding what is allowable by law aswell as the responsibility for clean up.Other environmental laws regarding theconservation of resources often focus on one resource per law, such as forests, animal species, mineral deposits, and other abstract resources such as scenic areas or sightsof value to archaeological research.Environmental laws are usually influenced by principles of philosophy and social concerns of environmentalconservation, as well as improving the state of the environment. Pollution control laws areimplemented to protect overall human health and to preserve the naturalenvironment.

With the Constitution being the oldest document thatapplies to American practices today, many note that its durability is anextension of its capability to adapt. As Americans, we presented major social and economic changes thatremodeled the way we live, create, and work. Environmental protection concernshave presented significant changes in the way our Government is run. There has been theimplementation of more administrative agencies, as well as national regulatory programs.

Below are a list some regulations applied toprovide environmental protection in USA :

- The Clean Air Act (CAA)1970- A Federal law that regulates air emissions. It also authorizes the EPA (Environmental Protection Agency) to establish quality standards protecting the society and regulate hazardous air pollutants.

- The Clean Water Act (CWA) 1972- Developed a basic structure to dischargepollutants andregulate quality in surface waters.

- The United States EnvironmentalProtection Agency (EPA)- Protects human health and the naturalenvironment. Congress gave the EPA authorization to write regulationsexplaining what is needed to improve and implement environmental laws.

- Energy Policy Act (EPA)- Addresses the issues concerning the production of energy in the US including all aspects of energy efficiency, renewable energy, oil and gas, coal, vehicles and motor fuels, hydro power, geothermal energy, and climate change technology.

- Food Quality Protection Act(1996) – This Act was created to evaluate the levels of pesticideresidues in foods to meet the standard of public health protection.

- Safe Drinking Water Act (1974)- This Act establishes the standards for safe drinking tap water requiring rules for ground water protection. Last amended in 1996 with funds established to pay for water system upgrades.

The current environmental laws that addressenvironmental protection present a foundation for the conditions and changesbrought on by American advances of technology. Many people argue, however, that theenvironmental laws need to be examined and intensified to be able to encompassthe capacity in the way technology uses resources today.

The National Environment Policy

National Environment Policy 2006 is a response to India's national commitment to a clean environment, mandated in the Constitution in Articles 48 A and 51 A (g), (DPSP) strengthened by judicial interpretation of Article 21. It is recognized that the maintenance of the Healthy environment is not the responsibility of the state alone. It is the responsibility of every Citizen and thus a spirit of partnership is to be realized through the environment Management of the country.

Objectives and Strategies of New National Environment Policy (2006) of India

There are different policies for forests, water and environmental pollution. But the experience in implementing these policies over the years has brought out the need for a comprehensive policy approach to the management of the environment in the country. Therefore, a new national environment policy was announced in 2006.

Objectives of National Environment Policy (2006):

The following are the objectives of the National Environment Policy:

1. Conservation of Critical Environmental Resources:

To protect and conserve critical environmental resources and invaluable natural and man- made heritage which are essential for life-supporting livelihoods and welfare of the society.

2. Inter-generational Equity:

To ensure judicious use of environmental resources to meet the needs and aspirations of present and future generations.

3. Efficiency in Environmental Resources Use:

To ensure efficient use of environmental resources in the sense of reduction in their use per unit of economic output and to minimize adverse environmental impacts on society.

4. Environmental Governance in the Management of Resources:

To apply the principles of resources. To apply the principles of good governance (i.e. transparency, rationality, accountability, reduction in costs and time, and public participation) to the management of environmental resources.

5. Enhancement of Resources:

Appropriate technology and traditional knowledge, managerial skills, and social capital will be used for conservation and enhancement of resources.

6. Livelihood Security for the Poor:

To ensure equitable access to environmental resources for poor tribal community, which are most dependent on environmental resources for their livelihood.

7. Integration of Environmental Concerns for Socio-economic

Development; to integrate environmental concerns into policies, plans, programmes and projects for socio-economic development.

(B) Strategy for Conservation of Environmental Resources

The following strategy will be adopted for conservation of environmental resources in India:

1. Land Degradation:

The following steps will be taken to reduce land degradation:

(i) Encourage adoption of science based and traditional sustainable land use practices through research and development.

(ii) Pilot scale demonstrations and farmers' training.

(iii) Promote reclamation of wasteland and degraded forest land through formulation and adoption of multi-stakeholder partnerships involving the land owning agency, local communities and investors.

(iv) To reduce desertification through action plans.

2. Forests:

The following strategy for conservation of forests will be followed:

(i) To formulate an innovative strategy for increase of forest and tree cover from the present level of 23 percent of the country's land area, to 33 percent in 2012 through afforestation of degraded forest land, wasteland and tree cover on private or revenue land.

Key elements of the strategy would include:

(a) The implementation of multi-stakeholder partnerships involving the forest department, local communities and investors, with clearly defined obligations and entitlements for each partner, following good governance principles, to derive environmental livelihood, and financial benefits.

(b) Rationalisation of restrictions on cultivation of forest species outside notified forest areas.

(c) Enabling farmers to undertake social and farm forestry where their returns are more favourable than cropping.

(d) Universalization of the Joint Forestry Management System throughout the country.

(e) Formulating an appropriate methodology for reckoning and restoring the environmental values of forests which are unavoidably diverted to other uses.

(f) Giving legal recognition of the traditional rights of forest dwelling tribes and provide long-term incentives to the tribal's to conserve the forests.

3. Wildlife:

In respect of wildlife conservation, the following steps would be pursued:

(i) Expanding the Protected Area Network of the country. It must be ensured that the overall area of the network in each biogeographic zone would increase in the process.

(ii) Paralleling multi-stakeholder partnerships for afforestation. Further, formulating and implementing similar partnerships for enhancement of wildlife habit in conservation and community reserves.

(iii) Encouraging eco-tourism at wildlife sites.

(iv) Implementing measures for captive breeding and release into the wild identified endangered species.

4. Biodiversity:

According to the National Environment Policy, a large- scale exercise has been already completed for providing inputs towards a National Biodiversity Action Plan. However, following measures would be taken to protect biodiversity at national level.

(i) Strengthen the protection of biodiversity hot spots.

(ii) Pay attention to the potential impacts of development projects on biodiversity resources and natural heritage.

(iii) Genetic material of threatened species of flora and fauna must be conserved on priority.

(iv) Conferring intellectual property rights for traditional knowledge.

5. Wetlands:

Wetlands, natural and man-made, freshwater or brackish, provide numerous ecological services. They provide habitat to aquatic flora and fauna. But now wetlands are under threat from drainage and conversion for agriculture and human settlements, besides pollution.

The key strategy for action will include the following steps:

(i) To set up a legally enforceable regulatory mechanism for identified valuable wetlands to prevent their degradation and enhance their conservation.

(ii) To formulate and implement sustainable tourism strategies for identified wetlands thorough multi-stakeholder partnerships involving public agencies, and local communities.

(iii) To take explicit account of impacts on wetlands of significant development projects during environmental appraisal of such projects.

6. Conservation of Man-made Heritage:

Man-made heritage reflects the pre-history, ways of living and culture of people. In the case of India, such heritage is at the core of our national identity. At the same time, considerable economic value, and livelihoods may be derived from conservation of man- made heritage and their sustainable use.

The following action plans would be required for their sustainable use.

(i) In setting ambient environmental standards, especially for air quality, the potential impacts on designated heritage sites must be taken into account.

(ii) Integrated regional development plans should be drawn up with participation of the local community with respect to shifting polluting activities and waste far away from sites.

(iii) Impacts on designated heritage sites must be considered at the stage of developing the terms of reference for environmental impact assessments of the projects.

7. Environmentally Sensitive Zones:

Environmentally sensitive zones may be defined as areas with identified environmental resources with incomparable values, which require special attention for their conservation. In order to conserve and enhance these resources, without impeding legitimate socio-economic development of these areas, the following actions will be taken.

(i) Identify and give legal status to Environmentally Sensitive Zones in the country.

(ii) Formulate area development plans for these zones on a scientific basis with adequate participation by the local communities.

(iii) Create local institutions for the environmental management of such areas.

8. Strategy for Sustainable Mountain Development:

Mountain ecosystems play a key role in providing forest cover, feeding perennial river systems, conserving genetic diversity and providing an immense resources base for livelihoods through sustainable tourism.

There has been significant adverse impact on mountain ecosystems by way of deforestation, submergence of river valleys, pollution of freshwater resources, despoiling of landscapes, degradation of human habitat, loss of genetic diversity, retreat of glaciers, and pollution.

Keeping in view, the following action plan for sustainable mountain development would be taken up:

(i) Adopting best practice norms for infrastructure construction in mountain regions to avoid or minimize damage to sensitive ecosystems and despoiling of landscapes.

(ii) Encouraging cultivation of traditional varieties of crops and horticulture by promotion of organic farming and enabling farmers to realize a price premium.

(iii) Promoting sustainable tourism through adoption of best practice norms for tourism facilities and access to ecological resources.

(iv) Developing strategies for particular unique mountains capes.

9. Strategy for Sustainable Coastal Resources:

Coastal environmental resources provide habitats for marine species, which in turn comprise the resource base for large numbers of fisher folk, protection from extreme weather events, a resource base for sustainable tourism, agricultural and urban livelihoods.

In recent years, there has been significant degradation of coastal resources, for which the proximate causes include poorly planned human settlements, improper location of industries and infrastructure, pollution from industries, and settlements, and over exploitation of living natural resources.

In keeping with these adverse effects on coastal resources, the following measures would be taken:

(i) To mainstream the sustainable management of mangroves into the forestry sector regulatory regime, ensuring that they continue to provide livelihoods to local communities.

(ii) To disseminate available techniques for regeneration of coral reefs, and support activities based on application of such techniques.

(iii) To embody considerations of sea-level rise in coastal management plans.

(iv) India has passed Coastal Regulation Zone (CRZ) notification in February 1991 and Integrated Coastal Zone Management (ICZM) to ensure protection to coastal environmental in India. Their rules and regulations are firmly founded on scientific principles. Specific projects should be consistent with the approval of ICZM plans.

10. Strategy for Conservation of Freshwater Resources:

The fresh water resources comprise the river systems, groundwater and wetlands. Each of these has a unique role and characteristic linkage to other environmental entities.

(A) River Management:

The following comprise elements of an action plan for river management:

(i) Promoting integrated approaches to management of river basins by the concerned river authorities, considering upstream and downstream inflows and withdrawals by reason.

(ii) Monitoring authorities will check pollution loads and natural regeneration capacities to ensure adequate flows and adherence to water quality standards.

(iii) To consider and mitigate the impacts on river flora and fauna.

(iv) To consider mandating the installation of water saving closets and taps in the building byelaws of urban centres.

(B) Groundwater:

Groundwater is present in underground aquifers in many parts of the country. The water table has been falling rapidly in many areas of the country in recent years. This is largely due to withdrawal for agricultural, industrial and urban use in excess of annual recharge.

In urban areas, apart from withdrawals for domestic and industrial use, housing and infrastructure such as roads prevent sufficient recharge. In addition, some pollution of groundwater occurs due to leaching of stored hazardous waste and use of agricultural chemicals in particular pesticides.

The following action plans are required in this direction:

(i) The efficient use of groundwater would accordingly, require that the practice of non-metering of electricity supply to farmers be discontinued.

(ii) To promote efficient water use techniques such as sprinkler or drip irrigation among farmers.

(iii) To support practices of contour bunding and revival of traditional methods for enhancing groundwater recharge.

(iv) To mandate water (rainwater) harvesting in all new constructions in relevant urban areas to enhance groundwater recharge.

(v) To support research and development in cost effective techniques suitable for rural drinking water projects.

(C) Policy for Pollution Abatement:

The following measures will be adopted to control the pollution at local and national level:

1. Water Pollution:

The following measures will be adopted to control water pollution:

(i) To enhance reuse of treated sewage and industrial waste water before final discharge to water bodies.

(ii) To set up common effluent treatment plants on cost recovery basis.

(iii) To take explicit account of groundwater pollution in pricing policies of pesticides and fertilizers.

(iv) To develop a strategy for strengthening regulation regarding the impact of ship breaking on marine resources.

(v) To promote research and development in the field of low cost technologies for sewage treatment.

(vi) To develop public-private partnership for setting up effluent and sewage treatment plants.

2. Air Pollution:

The following are elements of an action plan for air pollution:

To accelerate the national programmes of dissemination of improved fuel wood stoves, and solar cookers for rural women. To provide incentive based instruments for controlling air pollution

Toprovide adequate investments in low pollution mass transport systems with the help of public and private partnership. To give greater legal standing to local community and NGOs to undertake monitoring of environmental compliance, to promote reclamation of wastelands by energy plantations.

3. Noise Pollution:

The following would comprise elements of an action plan on abatement of Noise Pollution:

(i) Make appropriate distinctions between different environments in terms of setting ambient noise standards, e.g. rural versus urban , educational and hospital establishments versus other areas, daytime versus night time in residential areas; areas in the vicinity of rail, road and airport infrastructure etc.

(ii) Distinguish between noise standards and protection measures the context of occupational exposure, and environmental exposure to third parties.

(iii) Formulate noise emissions norms i.e. loudspeakers, automobile horns and fireworks ratings appropriate to various activities o ensure that exposure levels to third parties who are not participants in the activity do not exceed prescribed ambient standards.

Encourage dialogue between state/local authorities and religious/ community representatives on the adoption of enforceable specific durations, timings for use of loudspeakers or fireworks.

4. Soil Pollution:

The following are elements of an action plan on soil pollution:

(i) Develop and implement strategies for cleanup of pre-existing toxic and hazardous waste dumps, in particular, in industrial area and reclamation of such lands for sustainable use.

(ii) Strengthen the capacities of local bodies for segregation, recycling and reuse of municipal solid wastes.

(iii) Develop and implement strategies for recycle, reuse and final environmentally benign disposal of plastics wastes, including through promotion of relevant technologies, and use of incentive based instruments.

(iv) Promote organic farming of traditional crop varieties through research.

(v) Develop transparent, voluntary and science-based eco-labelling schemes.

List of Legislations on Environment and Ecology in India

Environmental laws	Year of legislation	Brief Description
Easement Act	1882	This law allows private rights to use a resource that is, groundwater, by viewing it as an attachment to the land. It also states that all surface water belongs to the state and is a state property.
Indian Fisheries Act	1897	This law establishes two sets of penal offences whereby the government can sue any person who uses dynamite or other explosive substance in any way (whether coastal or inland) with intent to catch or destroy any fish or poisonous fish in order to kill.
Factories Act	1948 and amended in 1987	It was the first to express concern for the working environment of the workers. The amendment of 1987 has sharpened its environmental focus and expanded its application to hazardous processes.
River Boards Act	1956	This law enables the states to enroll the central government in setting up an Advisory River Board to resolve issues in inter-state cooperation.

Merchant Shipping Act	1970	It aims to deal with waste arising from ships along the coastal areas within a specified radius.
Wildlife Protection Act	1972-73 and Amendment in 1991	It provides for the protection of birds and animals and for all matters that are connected to it whether it be their habitat or the waterhole or the forests that sustain them.
Water (Prevention and Control of Pollution) Act	1974	It establishes an institutional structure for preventing and abating water pollution. It establishes standards for water quality and effluent. Polluting industries must seek permission to discharge waste into effluent bodies. The CPCB (Central Pollution Control Board) was constituted under this act.
Water (Prevention and Control of Pollution) Cess Act	1977	It provides for the levy and collection of cess or fees on water consuming industries and local authorities.
Water (Prevention and Control of Pollution) Cess Rules	1978	This law contains the standard definitions and indicate the kind of and location of meters that every consumer of water is required to affix.
Forest (Conservation) Act and Rules	1980-81	It provides for the protection of and the conservation of the forests.
Air (Prevention and Control of Pollution) Act	1981	It provides for the control and abatement of air pollution. It entrusts the power of enforcing this act to the CPCB.
Air (Prevention and Control of Pollution) Rules	1982	This law defines the procedures of the meetings of the Boards and the powers entrusted to them.

Environment (Protection) Act	1986	It authorizes the central government to protect and improve environmental quality, control and reduce pollution from all sources, and prohibit or restrict the setting and /or operation of any industrial facility on environmental grounds.
Environment (Protection) Rules	1986	It lay down procedures for setting standards of emission or discharge of environmental pollutants.
Air (Prevention and Control of Pollution) Amendment Act	1987	This law empowers the central and state pollution control boards to meet with grave emergencies of air pollution.
Objective of Hazardous Waste (Management and Handling) Rules	1989	To control the generation, collection, treatment, import, storage, and handling of hazardous waste.
Manufacture, Storage, and Import of Hazardous Rules	1989	It defines the terms used in this context, and sets up an authority to inspect, once a year, the industrial activity connected with hazardous chemicals and isolated storage facilities.
Manufacture, Use, Import, Export, and Storage of hazardous Micro-organisms/ Genetically Engineered Organisms or Cells Rules	1989	It was introduced with a view to protect the environment, nature, and health, in connection with the application of gene technology and micro-organisms.
Coastal Regulation Zone Notification	1991	This law puts regulations on various activities, including construction, are regulated. It gives some protection to the backwaters and estuaries.
Public Liability Insurance Act and Rules	1991 and Amendment in 1992	It was drawn up to provide for public liability insurance for the purpose of providing immediate relief to the persons affected by

		accident while handling any hazardous substance.
National Environmental Tribunal Act	1995	This has been created to award compensation for damages to persons, property, and the environment arising from any activity involving hazardous substances.
National Environment Appellate Authority Act	1997	This has been created to hear appeals with respect to restrictions of areas in which classes of industries etc. are carried out or prescribed subject to certain safeguards under the EPA.
Biomedical waste (Management and Handling) Rules	1998	It is a legal binding on the health care institutions to streamline the process of proper handling of hospital waste such as segregation, disposal, collection, and treatment.
Environment (Siting for Industrial Projects) Rules	1999	It lay down detailed provisions relating to areas to be avoided for siting of industries, precautionary measures to be taken for site selecting as also the aspects of environmental protection which should have been incorporated during the implementation of the industrial development projects.
Municipal Solid Wastes (Management and Handling) Rules	2000	This law apply to every municipal authority responsible for the collection, segregation, storage, transportation, processing, and disposal of municipal solid wastes.
Ozone Depleting Substances (Regulation and Control) Rules	2000	This has been laid down for the regulation of production and consumption of ozone depleting substances.

Batteries (Management and Handling) Rules	2001	This law shall apply to every manufacturer, importer, re-conditioner, assembler, dealer, auctioneer, consumer, and bulk consumer involved in the manufacture, processing, sale, purchase, and use of batteries or components so as to regulate and ensure the environmentally safe disposal of used batteries.
Noise Pollution (Regulation and Control) (Amendment) Rules	2002	It lay down such terms and conditions as are necessary to reduce noise pollution, permit use of loud speakers or public address systems during night hours (between 10:00 p.m. to 12:00 midnight) on or during any cultural or religious festive occasion.
Biological Diversity Act	2002	It is an act to provide for the conservation of biological diversity, sustainable use of its components, and fair and equitable sharing of the benefits arising out of the use of biological resources and knowledge associated with it.

Laboratory facilities of the Board

Environmental monitoring describes the processes and activities that need to take place to characterise and monitor the quality of the environment. Environmental monitoring is used in the preparation of environmental impact assessments, as well as in many circumstances in which human activities carry a risk of harmful effects on the natural environment. All monitoring strategies and programmes have reasons and justifications which are often designed to establish the current status of an environment or to establish trends in environmental parameters. In all cases the results of monitoring will be reviewed, analysed statistically and published. The design of a monitoring programme must therefore have regard to the final use of the data before monitoring starts.

Air sampling

Passive or "diffusive" air sampling depends on meteorological conditions such as wind to diffuse air pollutants to a sorbent medium. Passive samplers have the advantage of typically being small, quiet, and easy to deploy, and they are particularly useful in air quality studies that determine key areas for future continuous monitoring.

Air pollution can also be assessed by biomonitoring with organisms that bioaccumulate air pollutants, such as lichens, mosses, fungi, and other biomass. One of the benefits of this type of sampling is how quantitative information can be obtained via measurements of accumulated compounds, representative of the environment from which they came. However, careful considerations must be made in choosing the particular organism, how it's dispersed, and relevance to the pollutant.

Soil monitoring

Soil monitoring involves the collection and/or analysis of soil and it's associated quality, constituents, and physical status to determine or guarantee its fitness for use. Soil faces many threats, including compaction, contamination, organic material loss, biodiversity loss, slope stability issues, erosion, salinization, and acidification. Soil monitoring helps characterize these and other potential risks to the soil, surrounding environments, animal health, and human health.

Assessing these and other risks to soil can be challenging due to a variety of factors, including soil's heterogeneity and complexity, scarcity of toxicity data, lack of understanding of a contaminant's fate, and variability in levels of soil screening.[18] This requires a risk assessment approach and analysis techniques that prioritize environmental protection, risk reduction, and, if necessary, remediation methods. Soil monitoring plays a significant role in that risk assessment, not only aiding in the identification of at-risk and affected areas but also in the establishment of base background values of soil.

Soil monitoring has historically focused on more classical conditions and contaminants, including toxic elements (e.g., mercury, lead, and arsenic) and persistent organic pollutants (POPs).Historically, testing for these and other aspects of soil, however, has had its own set of challenges, as sampling in most cases is of a destructive in nature, requiring multiple samples over time. Additionally, procedural and analytical errors may be introduced due to variability among references and methods, particularly over time. However, as analytical techniques evolve and new knowledge about ecological processes and contaminant effects disseminate, the focus of monitoring will likely broaden over time and the quality of monitoring will continue to improve.

Soil sampling

The two primary types of soil sampling are grab sampling and composite sampling. Grab sampling involves the collection of an individual sample at a specific time and place, while composite sampling involves the collection of a homogenized mixture of multiple individual samples at either a specific place over different times or multiple locations at a specific time.Soil sampling may occur both at shallow ground levels or deep in the ground, with collection methods varying by level collected from. Scoops, augers, core barrel and solid-tube samplers, and other tools are used shallow, whereas split-tube, solid-tube, or hydraulic methods may be used in deep ground.

Monitoring programs

Soil contamination monitoring

Soil contamination monitoring helps researchers identify patterns and trends in contaminant deposition, movement, and effect. Human-based pressures such as tourism, industrial activity, urban sprawl, construction work, and inadequate agriculture/forestry practices can contribute to and make worse soil contamination and lead to the soil becoming unfit for its intended use. Both inorganic and organic pollutants may make their way to the soil, having a wide variety of detrimental effects. Soil contamination monitoring is therefore important to identify risk areas, set baselines, and identify contaminated zones for remediation. Monitoring efforts may range from local farms to nationwide efforts, such as those made by China in the late 2000s, providing details such as the nature of contaminants, their quantity, effects, concentration patterns, and remediation feasibility. Monitoring and analytical equipment will ideally will have high response times, high levels of resolution and automation, and a certain degree of self-sufficiency. Chemical techniques may be used to measure toxic elements and POPs using chromatography and spectrometry, geophysical techniques may assess physical properties of large terrains, and biological techniques may use specific organisms to gauge not only contaminant level but also by-products of contaminant biodegradation. These techniques and others are increasingly becoming more efficient, and laboratory instrumentation is becoming more precise, resulting in more meaningful monitoring outcomes.

Soil erosion monitoring

Soil erosion monitoring helps researchers identify patterns and trends in soil and sediment movement. Monitoring programs have varied over the years, from long-term academic research on university plots to reconnaissance-based surveys of biogeoclimatic areas. In most methods, however, the general focus is on identifying and measuring all the dominant erosion processes in a given area. Additionally, soil erosion monitoring may attempt to quantify the effects of erosion on crop productivity, though challenging "because of the many complexities in the relationship between soils and plants and their management under a variable climate.

Soil salinity monitoring

Soil salinity monitoring helps researchers identify patterns and trends in soil salt content. Both the natural process of seawater intrusion and the human-induced processes of inappropriate soil and water management can lead to salinity problems in soil, with up to one billion hectares of land affected globally (as of 2013). Salinity monitoring at the local level may look closely at the root zone to gauge salinity impact and develop management options, where at the regional and national level salinity monitoring may help with identifying areas at-risk and aiding policymakers in tackling the issue before it spreads.The monitoring process itself may be performed using technologies such as remote sensing and geographic information systems (GIS) to identify salinity via greenness, brightness, and whiteness at the surface level. Direct analysis of soil up close, including the use of electromagnetic induction techniques, may also be used to monitor soil salinity.

Water quality monitoring

Design of environmental monitoring programmes

Water quality monitoring is of little use without a clear and unambiguous definition of the reasons for the monitoring and the objectives that it will satisfy. Almost all monitoring (except perhaps remote sensing) is in some part invasive of the environment under study and extensive and poorly planned monitoring carries a risk of damage to the environment. This may be a critical consideration in wilderness areas or when monitoring very rare organisms or those that are averse to human presence. Some monitoring techniques, such as gill nettingfish to estimate populations, can be very damaging, at least to the local population and can also degrade public trust in scientists carrying out the monitoring.

Almost all mainstream environmentalism monitoring projects form part of an overall monitoring strategy or research field, and these field and strategies are themselves derived from the high levels objectives or aspirations of an organisation. Unless individual monitoring projects fit into a wider strategic framework, the results are unlikely to be published and the environmental understanding produced by the monitoring will be lost.

Surface Water Quality Monitoring

Water pollution is a major environmental problem in the United States. To improve the surface water quality of the 2,493 ha (6,160 ac) Coulee Baton watershed in Louisiana, a collaborative nonpoint source pollution control study was initiated in 2004. Conservation measures and best management practices (BMPs) including cross-fencing of pasturelands (726.9 m [2,385 ft]), irrigation land leveling (12.9 ha [32 ac]), grade stabilization structures (two), irrigation water pipeline (975.4 m [3,200 ft]), and a livestock well covering a total of 92.7 ha (229 ac) of agricultural land, and repair or replacement of 80 septic systems in the watershed were voluntarily implemented by landowners and homeowners. Water samples were collected from seven monitoring sites for 66 rain events from September 24, 2009, to August 9, 2011. Laboratory determinations of water samples included total suspended solids (TSS), total dissolved solids (TDS), total solids (TS), five-day biological oxygen demand (BOD_5), nitrate/nitrite-nitrogen (NO_3/NO_2-N), soluble reactive phosphate (SRP), total phosphorus (TP), total Kjeldahl N (TKN), chloride (Cl), fluoride (Fl), sulfate (SO_4), and fecal coliform counts.

Surface water temperature, dissolved oxygen (DO), turbidity, conductivity, and pH were determined in the field using YSI Sonde (YSI Incorporated, Yellow Springs, Ohio). For the watershed, DO, BOD_5, and TS concentrations and fecal coliform count ranged, respectively, between 1.2 and 14.1 mg L^{-1} (ppm), 2 and 40.1 mg L^{-1}, 35 and 5,719 mg L^{-1}, and 400×10^6 and 17×10^6 most probable number (MPN) per 100 mL. The months of March, April, June, and September showed, on average, higher concentrations of TS and TDS, fecal coliform count, NO_3/NO_2-N, and SRP and TP, respectively. As compared to the ongoing BMPs, the post-BMPs, TSS, NO_3/NO_2-N, SRP, and BOD_5 concentrations, on average, were lower by 56.2%, 23.1%, 82.5%, and 27.4%, respectively. Developed land use types and the failed septic systems were identified as major sources of fecal coliform pollution. These results suggest comprehensive strategies are necessary for effective nonpoint source pollution control in agricultural watersheds.

Use-based Classification of Surface Waters

Use based Classification of Surface Waters in India

Designated-best-Use/ Beneficial Use	**Classification of water**	**Criteria**
Drinking water source without conventional treatment but after disinfection	A	1. Total Coliforms Organism MPN/100 ml shall be 50 or less 2. pH between 6.5 and 8.5 3. Dissolved Oxygen 6 mg/l or more 4. Biochemical Oxygen Demand 5 days 20 °C 2 mg/l or less
Outdoor bathing (organised)	B	1. Total Coliforms Organism MPN/100 ml shall be 500 or less 2. pH between 6.5 and 8.5 3. Dissolved Oxygen 5 mg/l or more 4. Biochemical Oxygen Demand 5 days 20 °C 3 mg/l or less
Drinking water source after conventional treatmen and disinfection	C	1. Total Coliforms Organism MPN/100 ml shall be 5000 or less 2. pH between 6 and 9 3. Dissolved Oxygen 4 mg/l or more 4. Biochemical Oxygen Demand 5 days 20 °C 3 mg/l or less
Propagation of wild life and fisheries	D	1. pH between 6.5 and 8.5 2. Dissolved Oxygen 4 mg/l or more

Use based Classification of Surface Waters in India

Designated-best-Use/ Beneficial Use	Classification of water	Criteria
		3. Free Ammonia (as N) 1.2 mg/l or less
Irrigation, industrial cooling, controlled waste disposal	E	1. pH between 6.0 and 8.5 2. Electrical Conductivity at 25 ^{o}C micro mhos/cm maximum 2250 3. Sodium absorption ratio maximum 26 4. Boron maximum 2 mg/l

Discharge standards for Treated Sewage revised

Parameter	Standard	Scope
1) **pH**	6.5-9	Everywhere in the country
2) **Bio-Chemical Oxygen Demand (BOD)**	Not to exceed 20	For metro areas and all state capitals barring Himachal Pradesh, Uttarakhand, Jammu and Kashmir and Union territory of Andaman and Nicobar Islands, Dadar and Nagar Haveli Daman and Diu and Lakshadweep
	Not to exceed 30	Other areas
3) **Total Suspended Solids**	Less than 50	For metro areas and all state capitals barring Himachal Pradesh, Uttarakhand, Jammu and Kashmir and Union territory of Andaman and Nicobar Islands, Dadar and Nagar Haveli Daman and Diu and Lakshadweep
	Less than 100	Other areas
4) **Fecal Coliform (FC)**	Less than 1000	Everywhere in the country

Industries in West Bengal

West Bengal has the sixth largest economy in India with ₹10.49 lakh crore (US$150 billion). It is primarily dependent on agriculture and medium-sized industry, although services and heavy industries play an increasingly significant role in the economy of the state.[4] Years after independence, West Bengal was still dependent on the central government for meeting its demands for food as production remained stagnant and the Green Revolution bypassed the state. However, there has been a significant spurt in food production since the 1980s. The state is now one of the few with a surplus, producing nearly 20% of the rice and 33% of the potato yield in 2004, despite accounting for only 7.55% of the population of India.[4] The state's total financial debt stood at ₹1,918 billion (US$27 billion) as of 2011.

Net State Domestic Product at Factor Cost at Current Prices (2004–05 Base Figures in crores of Indian Rupees	
Year	**Net State Domestic Product**
2004–2005	190,073
2005–2006	209,642
2006–2007	238,625
2007–2008	272,166
2008–2009	309,799
2009–2010	366,318

District-wise Economic Indicators

The following is a list of basic economic data for the districts of West Bengal as of 2013-2014, the latest year for which data is available.

District	**Gross District Domestic Product as of 2013-14,**	**at Constant (2004–05) Prices)**
Bardhaman	₹38,923.07 crore (equivalent to ₹940 billion or US$14 billion in 2017)	₹40,634.07 (equivalent to ₹98,000 or US$1,500 in 2017)
Birbhum	₹10,291 crore (equivalent to ₹250 billion or US$3.8 billion in 2017)	₹25,426.29 (equivalent to ₹62,000 or US$940 in 2017)
Bankura	₹11,729.33 crore (equivalent to ₹280 billion or US$4.3 billion in 2017)	₹28,345.12 (equivalent to ₹69,000 or US$1,100 in 2017)

PurbaMedinipur	₹26,978.96 crore (equivalent to ₹650 billion or US$10 billion in 2017)	₹44,654.60 (equivalent to ₹110,000 or US$1,700 in 2017)
Paschim Medinipur	₹18,930.11 crore (equivalent to ₹460 billion or US$7.0 billion in 2017)	₹27,575.49 (equivalent to ₹67,000 or US$1,000 in 2017)
Howrah	₹22,817.15 crore (equivalent to ₹550 billion or US$8.5 billion in 2017)	₹39,313.99 (equivalent to ₹95,000 or US$1,500 in 2017)
Hooghly	₹24,371.33 crore (equivalent to ₹590 billion or US$9.0 billion in 2017)	₹35,920.65 (equivalent to ₹87,000 or US$1,300 in 2017)
Uttar 24 Parganas	₹48,035.5 crore (equivalent to ₹1.2 trillion or US$18 billion in 2017)	₹37,010.24 (equivalent to ₹90,000 or US$1,400 in 2017)
Dakshin 24 Parganas	₹29,238.58 crore (equivalent to ₹710 billion or US$11 billion in 2017)	₹29,745.60 (equivalent to ₹72,000 or US$1,100 in 2017)
Kolkata	₹36,031.93 crore (equivalent to ₹870 billion or US$13 billion in 2017)	₹67,993.29 (equivalent to ₹160,000 or US$2,500 in 2017)
Nadia	₹18,205.56 crore (equivalent to ₹440 billion or US$6.7 billion in 2017)	₹29,006.54 (equivalent to ₹70,000 or US$1,100 in 2017)
Murshidabad	₹21,280.12 crore (equivalent to ₹510 billion or US$7.9 billion in 2017)	₹25,416.46 (equivalent to ₹61,000 or US$940 in 2017)
Uttar Dinajpur	₹6,843 crore (equivalent to ₹170 billion or US$2.5 billion in 2017)	₹18,836.95 (equivalent to ₹46,000 or US$700 in 2017)
Dakshin Dinajpur	₹4,955.3 crore (equivalent to ₹120 billion or US$1.8 billion in 2017)	₹23,599.48 (equivalent to ₹57,000 or US$870 in 2017)
Malda	₹12,023.94 crore (equivalent to ₹290 billion or US$4.5 billion in 2017)	₹25,412.24 (equivalent to ₹61,000 or US$940 in 2017)
Jalpaiguri	₹14,240.17 crore (equivalent to ₹340 billion or US$5.3 billion in 2017)	₹29,692.58 (equivalent to ₹72,000 or US$1,100 in 2017)
Darjeeling	₹10,664.32 crore (equivalent to ₹260 billion or US$4.0 billion in 2017)	₹45,808.78 (equivalent to ₹110,000 or US$1,700 in 2017)
Cooch Behar	₹7,895.18 crore (equivalent to ₹190 billion or US$2.9 billion in 2017)	₹24,973.51 (equivalent to ₹60,000 or US$930 in 2017)
Purulia	₹8,340.2 crore (equivalent to ₹200 billion or US$3.1 billion in 2017)	₹24,749.26 (equivalent to ₹60,000 or US$920 in 2017)
West Bengal	**₹371,795.04 crore (equivalent to ₹9.0 trillion or US$140 billion in 2017)**	**₹36,293.33 (equivalent to ₹88,000 or US$1,300 in 2017)**

Large industries

- Thermal power plants
- Paper & pulp
- Fertiliser
- Textile
- Paints
- Oil Refinery
- Petrochemicals

- Integrated Iron & Steel
- Bulk Drug
- Distillery
- Sponge Iron

Small industries

- Foundry
- Rolling mill
- Secondary Lead Smelting
- Galvanising
- Rubber
- Dyeing bleaching
- Ceramic
- Ferro alloy
- Tanneries
- Plastic product manufacturing

Introduction of New Strategies /Tools to control pollution

---

1. Waste water charge program (WCP):

Like most countries, Sri Lanka adopts a traditional command and control (CAC) approach to industrial pollution control. The Environmental Protection License (EPL) is the main instrument through which the pollution is controlled. The standards for discharge of waste including wastewater are stipulated by the CEA. The list of industries has also been prescribed for which an EPL has to be obtained for operation.

In spite of the control of wastewater discharge through the EPL scheme, the quality of many water bodies continue to deteriorate in many regions of Sri Lanka. This is because the standards stipulated are concentration based and no consideration has been given to the pollution load discharged into the environment.

2. Promotion of Cleaner Production and Waste Minimization Technologies

Cleaner Production (CP) is a process through which industries could reduce the amount of waste generated thereby reduces the cost of end of pipe treatment costs. Adoption of Cleaner Production techniques is a win-win situation as the industry could meet the regulatory requirements of the CEA while increasing profits.

Unfortunately the concept of Cleaner Production hasn't been reached to a large number of industries in Sri Lanka. Therefore the Central Environmental Authority has taken steps to awaken the industrialists include the Cleaner Production Concept in their process.

CP will assist industrialists to reduce waste generation in a cost effective manner. There is the added that the pollution load to the environment will be reduced through the adoption of cleaner production technologies. Therefore adopting the CP is beneficial to industrialists in order to reduce the pollution load.

3. National Green Awards

The Concept

“The Environmental Protection License (EPL) is the existing main legal tool for control of industrial waste to the environment according to the provisions of the NEA. It is implemented as a command and control method. On the other hand Environmental Impact Assessment (EIA) is the legal tool to protect and manage the natural Environment from the development projects. In addition to the two legal enforcement procedures, the CEA is implementing environmental Education and Awareness Programmes among all schools in the island.

However the above three systems are not adequate to achieve the CEA target in control of polluting substances to the environment. Also CEA is facing many practical difficulties in implementing the above systems in the field. Therefore it is very important and necessary to apply other administrative tools together with existing legal tools to minimize pollution from the different type of activities.

In the context, the CEA has identified the National Green Award Scheme as a strategy for environmental pollution control and management to implement among the activities which discharge or emit pollutants to the environment. The Green Award scheme makes a competitive forum among different sectors to apply the best practices in the pollution abatement and greening the environment, thereby improving the quality of environment in Sri Lanka.

Awards are considered as a recognition to their endeavors in industrial process, commitment, coordination and communication to keep the environment green and clean. And it is a platform to discover, discuss, disseminate the best options adopted by the winners while appreciating their attempts in respective industrial processes and activities as a whole. And it is one of the best ways to encourage entrepreneurs and service providers to keep the environment green and clean.

Target and Objectives

Industrial award scheme has following goals and targets as it proceeds.

1. Granting government recognition to industries/institutions which have advanced environment practices in Sri Lanka.
2. Promotion of self monitoring based pollution control and environmental management system to compliance with standards, regulations and to maintain the sustainability of the environment.
3. Enhance interest among the working group on clean and green environment within the premises.
4. Development and adoption of novel strategy to encounter the improvement of the quality of the environment.
5. Enhance environmental consensus of the industrialists by the market acceptance of their industrial products which are made by environment friendly processes.

Classification of Industries & Siting Policy

Red - having high pollution potential
Classification of Industries & Siting Policy
- permitted outside municipal areas of KMA
- eg. Thermal Power Plants, Heavy Engineering etc.

Orange-- having less pollution potential

- permitted outside KMC & HMC areas & Industrial Estates of KMC & HMC areas
- eg. Bakery, confectionery (>1 TPD), Building, construction projects >20,000 m^2 built up area (discharge less than 100KLD).

Green-- having least pollution potential

- permitted in all areas but Consent of Board required
- eg. Leather foot wear and leather products, Ready mix cement concrete.

White - having no pollution potential
Exempted - permitted in all areas & Consent of Board not required- eg. Fly ash bricks / block manufacturing, Auto Emission Testing Centres.

Few water intensive polluting categories of industries not permitted within an area of 10km. radius of the Kolkata Leather Complex at Bantala

Recent Initiatives of WBPCB

- **Implementation of World Bank funded CBIPMP (Capacity Building for Industrial Pollution Management Project) – remediation of old MSW dumpsite at Dhapa.**
- **Setting up of CETP for Small Scale Textile industries**
- **Extension of Air Quality Monitoring Network at Kolkata.**
- **Real Time Ambient Noise Monitoring.**
- **On-line Monitoring of Water & Air Pollution in major industries.**
- **On-line Consent Management in line with Ease of Doing Business.**
- **Installation of Solar Photovoltaic Cell in school and health centers in different district of the State.**
- **Installation of Rain Water harvesting structure in different school in different district of the State.**

On Environment: 2018's Most Impactful Environmental Regulatory and Deregulatory Actions:

The close of every year elicits reflection on the months past and anticipation of new adventures ahead. As we conclude 2018, we reflect on the regulatory and deregulatory actions that have taken place in the United States and we anticipate new challenges, new adventures, and new opportunities to evolve in the future.

I started thinking about the most impactful environmental regulatory and deregulatory actions from this past year; a tough year for environmentalists and regulated industry alike. Environmental groups were busy fighting regulatory rollbacks and regulated industry had to content with unstable regulatory targets. With this in mind, here are my Top 3 most impactful actions and why I chose them.

NUMBER 1

The Affordable Clean Energy (ACE) Proposed Rule (August 21, 2018)

The ACE Rule is the Environmental Protection Agency (EPA)'s Clean Power Plan (CPP) replacement. After repealing the CPP, reasoning that EPA exceeded its statutory authority under the Clean Air Act Section 111, the EPA proposed the ACE rule to establish a new regulatory framework for carbon dioxide emissions from existing power plants.

Without going into the legal analysis of how Section 111 of the Clean Air Act is designed to function, this proposed ACE rule includes significant changes in how existing coal fired power plants will be regulated. In general, there are less stringent regulations for existing plants than for new or modified plants (111(b) and 111(d)).

When we say "regulated" it means requirements such as the installation of emission reducing technology according to the "best system of emission reduction (BSER)." Power plants that are newly built, or that are modified, must also comply with permit requirements under New Source Review (NSR). The ACE rule redefines BSER for existing power plants such that power plants are looked at individually, instead of as part of a larger energy grid, thereby reducing applicable technologies that plants may employ to decrease emissions. In addition, the ACE Rule changes the threshold for what "triggers" NSR. This is not a comprehensive summary of the ACE Rule, but it is representative of the types of change in both regulatory action and overall policy that is at issue here.

So, why is this impactful?

1. The ACE Rule represents a major policy shift. The ACE Rule and the repeal of the CPP exemplify the difference in regulatory interpretation and in the approach to US policy obligations.

2. This issue isn't going away. There are a lot of existing power plants still out there. The U.S. Energy Information Administration provides information on the 8,652 power plants on record (by varied fuel type). This problem isn't going away and the necessity in regulating a predominant source of energy generation in the US will be an ongoing point of contention between environmentalists and the coal lobby.The comment period for the ACE Rule ended October 30th 2018. My prediction – this fight isn't over. Regulated industry should continue to follow this rulemaking into the new year.

NUMBER 2

Litigation over the Keystone XL Pipeline

There has been much consternation over this highly disputed pipeline designed to bring oil from Alberta, Canada all the way to Nebraska, USA. Most recently, a judge in Montana effectively pressed the pause button on moving forward with the international pipeline. The litigation centered on the State Department's approval of the Presidential Permit, following the 2014 Final Supplemental Environmental Impact Statement (EIS) required under the National Environmental Policy Act. This is a significant ruling because, not only does it stop the pipeline right now, it will likely impact future progress as the issue (most likely) enters the appeals process. The LA Times presents a nice summary of the findings in the Judge's order.

So, why is this impactful?

Although this isn't a regulatory action, this pipeline would affect multiple provinces and states, impact different environmental ecosystems, and transport a truly significant amount of oil. In addition, Keystone has become a highly politicized issue that has the potential to cause deep riffsamong those who support and those who contest the pipeline. Finally, the fight over Keystone XL is more than just about this particular project. The fight highlights the tension between stakeholders of traditional verses renewable forms of energy.

NUMBER 3

The Bureau of Land Management's Waste Prevention, Production Subject to Royalties, and Resource Conservation; Rescission or Revision of Certain Requirements

We first wrote about the original Waste Prevention Rule in Compliance Strategies – Like an uncharted race to a finish line back in April. There we emphasized how difficult it is for industry to track changes to specific provisions of a rule. The Rescission/Revision of the Waste Prevention Rule is now final, with an effective date of November 27, 2018. With it are rescissions pertaining to leak detection and repair (LDAR) among other requirements.

So, why is this impactful?

The history of this rulemaking emphasizes the point that complying with environmental regulations requires preparation, situational awareness, and the ability to pivot at, what seems like, a moment's notice. The rule also reminds us that environmental regulation is not just about the EPA. Other agencies play a vital role in business operational requirements. The action item for the remainder of 2018 and for 2019 for regulated industry will be to figure out what this new final rule means for you and your business.

A STUDY ON LAW RELATING TO GROUNDWATER RECHARGE IN INDIA

INTRODUCTION

Groundwater is the most extracted resource on the earth. The groundwater depletion and pollution has initiated political and legal controversies in recent times. The past ten years have witnessed the discussions on various options to overcome the difficulties posed by groundwater depletion. The 'artificial recharge methods' and 'rainwater harvesting' are the ideas usually found in these discussions. This paper addresses the law and policy issues relating to groundwater recharge, but it has used a term (Managed Aquifer Recharge) which is not often used in the legal discussions. 'Managed Aquifer Recharge (MAR)', is emerging as a holistic approach to various groundwater recharge philosophies and the paper explains the rational for choosing this term.

The gap between the policy and law started widening ever since the legislation relating to environmental protection is made in India. The depletion of groundwater, the state expenditure relating to drinking water supply, climate change issues, groundwater extraction by electric power, and mechanism to extract water from deep bore wells has initiated policy and law making initiatives. These initiatives include various groundwater recharge policies, programmes and laws. The paper surveys and identifies the gaps in law and policy relating to groundwater recharge as they seem to be not harmonious.

MANAGED AQUIFER RECHARGE: AN APPROACH FOR FUTURE

Any discussion on groundwater governance, policy and law includes a deliberation on the groundwater recharge. The terms used to denote groundwater recharge processes includes artificial and natural recharge, aquifer recharge and rainwater harvesting. This term is widely used in water polices and official papers of the state in recent times. A brief introduction to MAR will explain the reasons for preferring this term in this paper.

MAR describes intentional storage and treatment of water in aquifers, this term is preferred over 'artificial recharge" as the later creates an adverse connotation of artificial in a society where community participation in water resources management is becoming more prevalent[v]. MAR includes a management proposal for all intentional and incidental recharge to groundwater, thereby proposing to regulate all sorts of groundwater recharge programmes under one umbrella concept. MAR has also been called as enhanced or augmented recharge, water banking and sustained underground storage. The common reasons to use MAR includes securing and enhancing water supplies, improving groundwater quality, preventing salt water from intruding into coastal aquifers, reducing evaporation of stored water, maintaining environmental flows and groundwater.

CONSTITUTIONAL BASICS FOR MAR

From central government to NGO's, largest polluting corporate to farmers relying on subsistence agriculture, groundwater sustainability is considered as an important aspect in their work plan. This requires a Constitutional understanding on MAR in India to explain the rights of all stake holders including policy and law making powers, institutional structure and jurisdictional conflicts amongst various authorities.

Water, primarily a State subject under the Constitution of India was not considered as a significant subject to be regulated at the time of making the Constitution. This is reflected by the fact that 'groundwater' was not in the discussions of constituent assembly. Further, the Constituent assembly discussions relating to the most important subject of inter-state water disputes were also not very significant. At the time of independence, the water scarcity is not felt to this extend and the technology was not developed to transport and store water. Naturally, groundwater was one of the underutilized resources at the time of independence. Now it is one of the most extracted natural resource on the earth. At the time of providing a constitutional mechanism for Panchayat Raj institutions, these facts were considered and provisions relating to the management of groundwater and recharge were made implicitly.

The fundamental right to water and its manifestations have attained significant developments in recent times. The recognition has come from both international and national understanding on the requirement of a right based approach for water entitlements. The right to water extends to drinking water, environmental dimensions and other aspects including groundwater. One could bring an argument linking the fundamental right to water and the obligation to protect water resources, concluding a positive duty on the state to protect groundwater resources by taking appropriate measures including MAR.

The utilization and management of material resources of the State are best guided by the Directive Principles of State Policy (DPSP). It is to be made clear that groundwater is a material resource and the State is expected to secure the ownership and control of these resources to distribute for serving the common good[xiv]. Further, it is the obligation of the State to protect and improve the environment and to safeguard the forests and wild life of the country. This may be inferred to protect the water bodies in general and groundwater resources in particular. On the other hand a duty is imposed on the individuals to protect the environment and natural resources of the country.

NATIONAL AND STATE WATER POLICIES

The recent version of the National Water Policy and its adoption is an example of the politics and controversies surrounded by water. The Union attempting to usurp the powers of the States and the States were opposed to the idea of uniformity of any kind emanating from Union mandate. The Union on the other hand did not make any sincere attempt to fulfill the constitutional obligation entrusted with the parliament to resolve inter-state water disputes as well as managing inter-state rivers. The inability to manage inter-state waters not only reflects the unwilling Union, but provides an opportunity to speculate on the intention of the Union to take larger regulatory role over water resources. The Union's intention to regulate water in general and groundwater in particular, emerges from various constraints including financial dimensions of Union sponsored projects and the projects funded by international agencies as they reach the states with conditionality. The role of Supreme Court is significant regarding two aspects connected to groundwater. Firstly, the Supreme Court is liberal in its approach to declare right to water as a fundamental. Secondly, the groundwater depletion and pollution are increasingly receiving the attention of court. This has compelled the Union to revise the Water Policy. The newly adopted water policy was not welcomed by all States and one cannot be sure of realizing this policy as it may not be supported by the existing legal regime. Therefore, the water policy proposes a framework water law which will be adopted by States under Article 252 of Indian Constitution.

The proposed water framework law will be an umbrella statement of general principles of law guiding all the State agencies in their water related agenda. The groundwater to be treated as a community resource held by the state under public trust doctrine, and the existing groundwater laws to be modified. Though the Supreme Court has held that groundwater to be governed by public trust doctrine, the groundwater legislation which is to be discussed later in this paper, did not consider groundwater as public trust, but consider groundwater as a state controlled resource. Even these legislation are not enforced properly anywhere, for instance, the Tamil Nadu Groundwater Act of 2003 is yet to be notified in spite of High Court directions.

The policy recognizes the declining groundwater levels in over-exploited areas and addresses the technological measures to arrest such a trend. Artificial recharge programmes are to be placed to ensure the extraction-recharge balance of groundwater. The policy reiterates the need for aquifers to maintain the base flows to surface system and maintain ecology, it recognizes the importance of groundwater in the interstate dispute settlement, and it declares the importance of aquifer mapping and the need to update the maps in future. The policy addresses several quality and quality orientated issues relating to groundwater, recycle and reuse of water, groundwater depletion due to various projects and the need and impact of small water harvesting structures.

Considering water as a state subject, the federal units should have come with water policies consistently. But we find that only few states have got their water policy, these policies also reflect the National Water Polices with few changes. For instance, the Orissa Water Policy calls for groundwater recharge programmes by roof top method and watershed programmes. It lays down a water utilization priority. The Tamil Nadu Water Policy, 1994 emphasis the importance of groundwater protection and enhancement of water information infrastructure. Thus an effective governance system is missing from the State's perspective; this encourages the Union to take liberty in making laws to govern various aspects of groundwater. If States have come up with a groundwater authority by their legislation, Supreme Court might not have ordered to constitute an authority through a legislation which was enacted to give effect for international obligations.

MODEL LAWS

Union has continuously evolved model groundwater laws for the past two decades for the adoption of States; number of States also enacted groundwater laws having these drafts as models. But the benefits out of these model laws or the implementation of the groundwater legislation are matter of great concern. It has not benefited the poor public in dealing with groundwater depletion. The Madras High court refused to intervene the state's scheme to provide drinking water to Chennai city while ignoring the groundwater related rights of farmers. The court decision would have been different if the State groundwater legislation has been brought into force. Similarly, *Plachimada* groundwater pollution might have been resolved properly if the State groundwater law is properly enforced.

The model bills are in the making, the process continues with the Draft Water Framework Law released by the government of India. The proposed law claims to bring more economic value to the water by linking groundwater with electricity tariff, it further dwells into various groundwater recharge programmes and schemes. It is relevant to look at the portion of the draft relating to the groundwater recharge,

"… (6)The appropriate Government shall demarcate groundwater recharge zones by identifying critical natural recharge areas of an aquifer and those areas that require special attention with regard to the recharge of groundwater and including areas that are affected by contaminants and saline Water ingress.

(7)The groundwater recharge zones ...shall be accorded the highest priority in terms of groundwater protection and regulation and the appropriate government shall take all possible measures to conserve and protect such groundwater recharge zones".

The electricity-groundwater nexus is a difficult one to be compromised in many States where electricity for agriculture is free or highly subsidized. The importance given to the economic value of groundwater may be subjected to criticism.

UNION LEGISLATION

The Easement Act, 1882 provides an absolute right of groundwater for the owner of the land, this illustration forms the basis for absolute ownership theory quoted often from an illustration to explain the exclusive rights of an owner,

"The right of every owner of land to collect and dispose within his own limits of all water under the land which does not pass in a defined channel and all water on its surface which does not pass in a defined channel."

In *M/s Nila Sea Foods Private Limited*,Justice K. Venaktaraman has observed that the land owners have the right to draw the water from their land and absolutely there is no prohibition for tapping water even by an enactment of law by the appropriate government. A similar view has been expressed by the High court in *Era SoundaraPandian -Vs- Mrs. Lakshmi*, the respondent used to take water from the well for drinking and domestic purpose by using motor pump sets. The Corporation entered into the property of the respondents and removed the motor from the premises under the Tamil Nadu Ground Water (Development and Management) Act, 2003, later the corporation changed its version and they claimed to have entered under some other law. Though this contradiction was not accepted by the Court, it was observed that there is no need to initiate criminal proceedings against erred officials. In another significant case, it was contended that without notifying the Act, the authorities are not having right to take steps under the provisions of the Act. This was accepted and the court directed the government to take steps to notify the Act. The Court made an order to State, not to issue any groundwater withdrawal permission till the Act is notified. The above mentioned cases reflect the conflict in enforcing the groundwater laws, thereby maintaining the validity of the provisions of Easement Act.

The Water Act, 1974 is enacted not only to maintain and restore the wholesomeness of water but also to establish appropriate institutions with a view in carrying the objectives of the Act. The Pollution Control Boards (PCBs) were set up both at the Central and State level (including Joint Boards) for the effective implementation of the Act. The PCB's promote cleanliness of streams and wells in different areas of the state. The PCBs also can enter the premises of any industry and take samples, if the water contaminated, the PCBs can issue order for closures of industry. This is to ensure the quality and quantity of groundwater, the industries will be indirectly forced to maintain the groundwater levels by recharging.

The Environmental Protection Act was enacted to protect the environment which includes groundwater resources. The Act empowers the Central Government as the sole authority to exercise its powers to give directions for the stoppage or regulation of the supply of water for any other service. Further, the Central Ground Water Board established under this Act serves as a monitoring agency for groundwater situation, the board provides various standards and provide technical and information assistance to States. The objectives of the board include "enhancing ground water sustainability through artificial recharge and rainwater harvesting as a measure for checking the depleting trend of ground water".

STATE LEGISLATION

Water, as a State subject is to be analyzed from the State's perspective. The provisions relating to MAR is expressed in various local laws, the Tamil Nadu laws are the first of its kind to provide compulsory rainwater harvesting structure in every establishment and household. It is pertinent that these laws come into effect at difficult water situations and enforced vigorously for a particular period of time[xlii]. One has not come across any recent studies to know the effectiveness of this law.

Over the last two decades, numbers of states have enacted their own groundwater laws. This has led to major reforms in the legal regime governing groundwater in India. This State legislation broadly aims to redefine the rights, duties and roles of the government, as well as those of individuals, *vis-a-vis* groundwater resources. These laws have also resulted in institutional reforms and have also attempted to incorporate into groundwater regulation important norms of environmental law such as conservation and sustainable use. Evolving groundwater laws seek to vest in the concerned state government the power to regulate and control the use of groundwater by private individuals. Various state Acts have adopted the licensing system as a regulatory tool (i.e., a permit or registration-based system). A systematic analysis of this legislation would help us to understand the scope for MAR under these laws.

ANDHRA PRADESH WATER, LAND AND TREES ACT, 2002

The title of the Andhra Pradesh state legislation on groundwater indicates the emphasis on protection and conservation. The extent of regulation could range from mere monitoring of groundwater use through the registration process to complete prohibition or closing down of wells. The nature and extent of regulation depends upon the quality and quantity of groundwater in a particular area. For instance, there could be a complete prohibition on new wells in areas designated as 'over-exploited'. One of the important features of the evolving regulatory framework is the priority given to drinking water, particularly the special protection given to public drinking water sources. This prioritization is sometimes manifested in the form of provisions prescribing the distance required to be maintained by new wells from public drinking water sources. The Act specifically prohibits ground water contamination in any manner by anyone and prohibits direct disposal of waste waters into the aquifers. With a view to improve the groundwater resources by methods of harvesting and recharge the Act stipulates that the Authority may issue guidelines for constructing appropriate rainwater harvesting structures in all residential, commercial and other premises and open spaces. The statute has a built in institutional framework for setting up of groundwater authorities at the state level. The state groundwater authority shall perform the specific functions of promotion of water conservation and regulate the exploitation of ground and surface water in the State.

TAMIL NADU GROUND WATER (DEVELOPMENT AND MANAGEMENT) ACT, 2003

The state legislation apart from the protection of groundwater resources *interalia* attempts to provide safeguards against hazards of over exploitation and to ensure planned development and proper management of this vital and limited resource. This Act applies to the whole of Tamil Nadu except the city of Chennai and the legal provisions relating to extraction and use of groundwater in Chennai is governed by a separate legislation. The Act empowers the State Ground water Authority to develop, control, regulate and administer the groundwater and to direct and regulate the development and management of groundwater resources in the State consistent with conserving it and ensuring its optimal and efficient utilization. The Authority for the purpose of maximizing the feasible, conjunctive use of surface-water and ground-water may identify and notify 'suitable areas' to stabilize the existing use or to improve or increase the use of water. The Act further confers power upon the Authority to lay down or adopt standards for quality of water depending on the kinds of water use by having regard to the standards evolved by the institutions either statutorily empowered or technically competent to do so. The Authority has the power to direct, regulate and control the development, extraction and utilization of groundwater in the notified area. To make suitable modification of groundwater regime due to mining activities, the Authority if satisfied may direct the disposal of mine water in a manner that it may be directly used by the farmers and its recharge, if feasible to augment groundwater storage. As a regulatory mechanism, the Act also prohibits the transportation of groundwater by means of lorry, trailer or any other motor vehicle from any notified area for any purpose without obtaining a permit under the provisions of the Act. Any person desiring to transport groundwater from any notified area for any purpose, by means of lorry, trailer or any other motor vehicle shall apply to the authority for the grant of a permit.[lx]

KERALA GROUND WATER (CONTROL AND REGULATION) ACT, 2002

The important legal change is the incorporation of objectives of conservation and development of the resource. Most of the evolving groundwater legislation emphasizes conservation and development as major objectives. The Act recognizes the need for conservation in its preamble. The Act envisages the classification of areas on the basis of the condition of the groundwater. Further the permit may be denied if it is likely to endanger the existing use of groundwater in that area. This regulatory framework also provides scope for subsequent alterations in the conditions specified in the permit or certificate of registration. The regulatory framework provided under the Act is generally applicable to the 'notified areas'. The power to notify an area vests with the state government and therefore the power of the groundwater authority in this regard is merely advisory in nature. The Kerala Government accorded priority to public drinking water use under the Act and it mandates for the maintenance of quality of groundwater as a criterion required to be considered while granting permit or certificate of registration.

HIMACHAL PRADESH GROUND WATER (REGULATION AND CONTROL OF DEVELOPMENT AND MANAGEMENT) ACT, 2005

The Act applies to certain notified areas and permit or registration system is put in place in such notified areas. The Act empowers the Authority for the purpose of improving the groundwater situation to identify the areas of groundwater recharge and to issue guidelines for adoption of rain water harvesting for groundwater recharge in such areas. The Act requires all users in such notified areas to register their wells. Potential users are required to seek prior permission. The control over groundwater use is sought to be effectuated by imposing conditions specified in the permit or certificate of registration. The Act accords first priority to drinking water usage over other needs while granting permit or registration. The need to prioritize drinking water has been expressly recognized by the judiciary in a couple of cases. The norm of according priority to drinking water is the prima facie objective of ground water laws. While granting permit the Authority has to consider the maintenance of quality of groundwater and its usage.

WEST BENGAL GROUND WATER RESOURCES (MANAGEMENT, CONTROL AND REGULATION) ACT, 2005

The Act aims to manage, control and regulate indiscriminate extraction of ground water in the state. Groundwater authorities are vested with the responsibility of enforcing the regulatory tools provided by the relevant statutes to ensure sustainable use. By and large, the institutional mechanisms provided under various state groundwater laws follow a similar structure and perform similar functions. However, there are some variations across states. For example, West Bengal has put in place a decentralized structure by providing three levels of groundwater authorities – state level, district level and corporation level. The decentralized institutional mechanism emphasise on preparation of district-wide groundwater profile periodically. The Act in its preamble stated that maintenance of quality of groundwater as an objective and this mandate is to be considered while granting permit or certificate of registration. While granting certificate of registration the Authority shall consider the groundwater balance, the quality and quantity of groundwater available in the locality. The Act also imposes a legal obligation on the District or Corporation Level Authority to keep a regular vigil on the quality and quantity of water available from the ground water resources in the district or the corporation, as the case may be, and promptly bring to the notice of the State Level Authority any sudden deterioration in ground water resources or contamination of ground water resources with poisonous metals or chemicals or otherwise.

CHHATTISGARH GROUND WATER (REGULATION AND CONTROL OF DEVELOPMENT AND MANAGEMENT) ACT, 2012

The Act regulates and controls the Development and Management of Ground Water. The Act mandates the Authority, after consultation with various expert bodies, including Central Ground Water Authority (CGWA) to control and or to regulate the extraction or the use or both of ground water in any form in any area, to advise the State Government to declare any such area to be a notified area. For the purpose of groundwater recharge the Act explicitly contains a provision under which the Authority may identify the recharge worthy areas in the State and issue necessary guidelines for adoption of rain water harvesting for ground water recharge in these areas. In rural areas, watershed management to facilitate ground water recharge may be encouraged through community participation. This legal provision *inter alia* emphasized the over-exploitation of ground water due to ever increasing population and other development activities that have led to fall in ground water table, drying up of wells, reduced sustainability of tube wells, environmental degradation etc. in many parts of the State. The Act underlines the need for groundwater recharge and rain water harvesting since it is essential to improve the ground water situation in critical areas. The Act prohibits contamination of groundwater by anybody including industrial, local bodies. It also prohibits direct disposal of waste waters into the aquifers.

CONCLUSION

The following observations emerge from the discussion on MAR, groundwater laws and policy,

1. The laws and policies are inconsistent; such an inconsistency is not absolutely bad. But the criticism is that they cannot operate together in the present situation because of this inconsistency. If the state prefers to give primacy for policy, it leaves the laws not to be notified, authorities and rules are not to be made, ensuring that the state actions are not condemned by law and Courts. This kind of inconsistency defeats the purpose of both law and policy.

2. The Union and States conflict with each other on various issues relating to groundwater, specifically on the primacy of the States to enact laws, enforcement of schemes and funding. These conflicts must end and the States may progressively make laws and policies ensuring their jurisdiction.
3. Managed Aquifer Recharge is a natural development of scientific studies; the Union and States must progressively use the scientific advancements relating to groundwater resources and incorporate them into the legal and policy framework.

- **GROUND WATER RESOURCES WEST BENGAL DISTRICT WISE STATUS**

The West Bengal ground water resources management, control and regulation act (2005)

Authored By :

Water Investigation and Development Department (Government of West Bengal)

The act aims to manage, control and regulate indiscriminate extraction of groundwater in West Bengal and to provide solutions to matter related to it.

The act aims to manage, control and regulate indiscriminate extraction of groundwater in West Bengal and to provide against its widespread contamination with arsenic, fluoride, chloride, iron, other heavy metals or metalloids, organic and inorganic pesticides, fungicides, and rodenticides. It provides for the setting up of a State Level Authority which shall be under the administrative control of the Water Investigation and Development Department, Government of West Bengal and shall be the apex body of all the District Level Authorities and the Corporation Level Authority.

The power and duties of the State Level Authority are -

- take into consideration every aspect to manage the ground water resources in West Bengal including issuing of certificate of registration or permit in accordance with the provision of the Act;
- initiate a policy to conserve the ground water resources by way of recharging, replenishing, recycling or reusing, in a co-ordinated manner;
- create mass awareness and encourage interaction between modern technologies and age-old practices of ground water conservation and management by harnessing traditional

knowledge in sustainable water management and dovetailing such traditional knowledge with modern technologies;

- organise people's participation and involvement in planning and actual management of ground water resources;
- keep under constant review area-specific ground water levels and publishing the revised data periodically for wide circulation for mass awareness and for devising and implementing plans and programmes of use such water;
- continuously analyse, study and review the physical, chemical, bacteriological, and virological qualities of ground water and devise and implement pragmatic strategies;
- promote and implement modern and traditional water harvesting technologies to ensure minimum extraction of ground water;
- maintain separate registers for issuing permit or certificate of registration granted by it in the manner as may be prescribed.

- **Ground Water Scenario of West Bengal**

Area (Sq.km)	88,752
Rainfall (mm)	2074
Total Districts / Blocks	18 districts / 341 Blocks

- **Hydrogeology**

The state can be divided into two hydrogeological unit namely fissured hard rocks & porous alluvial formations. Fissured formation includes crystalline, metasedimentary and volcanic rocks. The yield of wells tapping fractured zones varies from 10-20 m3/hr. Two third of the State is underlain by alluvial sediments mainly deposited by Ganga & Brahmaputra rivers. Based on the yield of wells tapping these alluvial sediments, aquifers of the alluvial area can be divided into three zones. 1. Yielding about 150m3/hr, occurs from Jalpaiguri to Kochbihar in north to Medinipur& 24 Parganas in South. 2. Yielding about 50-150 m3/hr, occurs in parts of Malda, Dinanjpur and western part of Murshidabad districts. 3. Yielding less than 50m3/hr, occurs as Marginal alluvial tract in parts of Birbhum, Burdawan, Bankura and Murshidabad districts.

Critical	1 Block
Semi- critical	37 Blocks
Ground Water User Maps	18 districts
Artificial Recharge to Ground Water (AR)	• Area identified for AR: 7500 sq km • Quantity of Surface Water to be Recharged: 2664 MCM • Feasible AR structures: 11200 percolation tanks with shafts, 3606 gabion structures, 1054 nala bund/ cement plug, 1680 re excavation of tanks, 500 desiltation of village pond, 1000 spring development, 70 sub surface dykes, 1500 RTRWH for Kolkata & Darjeeling.
	AR schemes completed during VIII Plan: 2 AR schemes completed during IX Plan: 5
Ground Water Quality Problems	
Contaminants	Districts affected (in part)
Salinity (EC > 3000 µS/cm at 25 ° C)	Haora, Medinipur, S- 24 Parganas,
Fluoride (>1.5 mg/l)	Bankura, Bardhaman, Birbhum, Dakhin Dinajpur, Malda, Nadia, Purulia, Uttar Dinajpur
Chloride (> 1000 mg/l)	S-24 Parganas, Haora
Iron (>1.0 mg/l)	Bankura, Bardhaman, Birbhum, Dakhindinajpur, E. Midnapur, Howrah, Hugli, Jalpaiguri, Kolkatta, Murshidabad, N-24praganna, Nadia, S-24 Parganas, Uttar Dinajpur, West Midnapur
Nitrate (>45 mg/l)	Bankura, Bardhaman
Arsenic (>0.05 mg/l)	Bardhaman, Hooghly, Howrah, Malda, Murshidabad, Nadia, North 24 Parganas, South 24 Parganas

Periodical Monitoring of Ground Water levels –

- Ground water is a dynamic resource, which replenishes periodically by with precipitation every year. To have a watch on the behaviour of ground water, there is a system of periodical monitoring of ground water level in four scheduled periods (Jan./Apr./Aug./Nov.) In a year through 2000 odd Permanent Hydrograph Stations (PHS) scattered over different parts of the State. On the basis of such data, the periodical reports were compiled and circulated to aware the developmental agencies and masses as a whole. This data is very helpful in predicting the ground water situation in different regions as well as long term prospective planning.

- During the financial year 2011-2012 both the wing of Engineering and Geological completed all the works in scheduled periods.

District wise distribution of Permanent Hydrograph Station is given below:-		
Sl No	District	Number of Permanent Hydrograph Station
1	Pascim Medinipur	216
2	Purba Medinipur	232
3	Bankura	238
4	Purulia	133
5	Howrah	87
6	Birbhum	82
7	Burdwan	203
8	Kolkata	65
9	Hoogli	129
10	North 24 Parganas	125
11	South 24 Parganas	79
12	Nadia	191
13	Murshidabad	114
14	Malda	43
15	Uttar And Dakshin Dinajpur	42+36
16	Darjeeling	49
17	Jalpaiguri	70
18	Coochbehar	54
Total		**2188**

NOTE:

A comprehensive study can be made if a record of fluctuations of ground water levels is obtained along with the records of rainfall. For such purpose, an instrument named “Automatic Water Level Recorder” have already been installed at 6 districts at

I. Burdwan Agri-Irrigation Bunglow Campus, Burdwan,

II. Chinsurah Agri-Mechanical Bunglow Campus, Hooghly,

III. Suri Agri-Irrigation Bunglow Campus, Birbhum,

IV. Domjur Block Office Campus, Howrah,

V. Administrative Building of W.R.I.D&D, Jalpaiguri

VI. Administrative Building of W.R.I.D&D, Coochbehar.

This instrument gives a continuous record of fluctuations of the groundwater levels.

NATIONAL Laws and Policy

NEW DELHI

- The Central Ground Water Authority (CGWA) has directed Group Housing Societies/Institutions/Schools/Hotels/Industrial establishments/Farm Houses in South and South West Districts and group housing societies located outside notified areas of NCT of Delhi where ground water levels are more than 8 meters below the ground surface to adopt Roof Top Rain Water Harvesting systems in their premises.

- Ministry of Urban Development and Poverty Alleviation, Govt. of India has made modifications to the building bye laws that requires Water Harvesting through storing of water runoff including rain water in all new buildings on plots of 100 sq. meters and above will be mandatory.

- Building plans are not sanctioned unless such provision is provided. DDA/MCD representatives undertake a site inspection before issue of Completion Certificate to the building and ensure that the RWH is made as per plan.

- Buildings with plots of 200 sq. meters or above that extract ground water through tube wells, bore wells, etc need to implement Rain water harvesting.

- Financial assistance is given to a maximum of 50% of total cost of the Rain Water Harvesting structure or Rs. 1,00,000 whichever is less.

TAMIL NADU

The Government of Tamil Nadu has made rainwater harvesting mandatory for all the buildings, both public and private, in the state. It made it mandatory for Chennai Metropolitan Development Authority, all MCs, Municipalities, etc to sanction building plans only after implementation of RWH. Water and sewer connection would not be given to new buildings without RWH. RWH has been made mandatory in three storied buildings irrespective of the size of rooftop area.

BANGALORE

Every owner or occupier of a building with site area 2400 sq. feet or above or every owner who proposes to construct a building with site area more than 1200 sq. feet shall provide rain water harvesting structures in such a manner as provided in the regulations.

MUMBAI

The State Government has made rainwater harvesting mandatory for all buildings that are being constructed on plots that are more than 1,000 sq m in size.

SURAT

Surat Municipal Corporation has made Rain water harvesting mandatory for new buildings with plot size of 4000 sq. meters or more. 50 % subsidy maximum amount up to Rs. 2000/- is given to the citizens to encourage the noble cause of rainwater recharging.

KANPUR (UTTAR PRADESH)

Rainwater harvesting has been made mandatory in all new buildings with an area of 500 sq meters or more.

NAGPUR

As per the regulation, all layouts of open spaces, amenity spaces of housing societies and new constructions of area equal to or more than 300 sq. m. shall have one or more rainwater harvesting structures such as an open well or bore well, or underground storage tank or percolation pits.

In the case of noncompliance with the aforementioned rules, the Nagpur Municipal Corporation would levy a fine of up to Rs.1000 per annum per 100 sq. m. of built-up area.

INDORE (MADHYA PRADESH)

- Rainwater harvesting has been made mandatory in all new buildings with an area of 250 sq m or more. Under Madhya Pradesh Bhumi Vikas Rules, 1984, Rooftop Rainwater Harvesting has been enforced in Municipalities for buildings more than 250 sq.m. RWH has been made mandatory for G + 3 structures.

- A rebate of 6 per cent on property tax has been offered as an incentive for implementing rainwater harvesting systems.

HYDERABAD (ANDHRA PRADESH)

Rainwater harvesting has been made mandatory in all new buildings with an area of 300 sq m or more irrespective of the roof area. It has been made mandatory to provide RWH in all Group Housing and Commercial Complexes.

KERALA

Government of Kerala included rainwater harvesting structures in new constructions. Exemption from this is granted for cases where water logging is common or in areas with impermeable subsoil conditions to considerable depths.

RAJASTHAN

The State Government has made rainwater harvesting mandatory for all public

Establishments and all properties in plots covering more than 500 sq m in urban areas. If completion certificate for RWH is not submitted to PHED, water supply connection can be terminated.

GUJARAT

Under the Gujarat Development Control Regulations, buildings with area between 500 and 1500 sq. meters, the owner or developer shall have to undertake Rainwater Harvesting as per the Authority Specifications. For buildings with area between 1500 to 4000 sq meters, owner/developer has to provide percolation wells with rain water harvesting system at one percolating well for every 4000 sq. meters or part thereof of building unit. The state Roads and Buildings Department has made rainwater harvesting mandatory for all government buildings.

HARYANA

Haryana Urban Development Authority (HUDA) has made rainwater harvesting mandatory in all new buildings irrespective of roof area. The CGWA has also banned drilling of tubewells in notified areas.

CHANDIGARH

Chandigarh has made it mandatory for all new buildings to implement Rain water harvesting irrespective of size of plot or roof.

HIMACHAL PRADESH

Installation of rainwater harvesting system has been made mandatory for all buildings to be constructed in urban areas of the state and no building plan without rainwater harvesting system can be approved. Construction of rainwater harvesting system has also been made mandatory for all schools, govt. buildings and rest houses, upcoming industries& bus stands.

DAMAN & DIU

Administration of Daman & Diu has issued instructions to the local PWD for construction of roof top rainwater harvesting structures and accordingly, PWD has initiated action.

GOA

PWD has been asked to take up rainwater harvesting structure for Government buildings. The PWD is studying various designs of roof top rain water harvesting for taking up other existing large Government buildings and for any new coming Government buildings under construction.

LAKSJHADWEEP

Lakshadweep Administration has already taken up construction of rainwater harvesting structures in different islands.

MEGHALAYA

The State Government of Meghalaya has instructed the concerned Department to provide funds under their respective annual plans for construction of roof top rainwater harvesting structures in the Govt. buildings.

NAGALAND

The State Government has made provision for roof top rainwater compulsory for all new Government buildings.

PONDICHERRY

Approvals are issued to new constructions subject to the provision of rainwater harvesting in building designs. PWD has started constructing roof top rainwater harvesting structures in the Government buildings since 2002.

WEST BENGAL

West Bengal Municipal (Building) Rules, 2007, installation of rainwater harvesting system has been made mandatory.

ARUNACHAL PRADESH

Building By-laws are being framed keeping provision for rain water harvesting as mandatory in Government Buildings.

ANDAMAN & NICOBAR

Building Byelaws are being amended to incorporate mandatory provision of rainwater harvesting.

ORISSA

Formulation of a comprehensive Water Law is under active consideration by the competent authorities.

RAJKOT

The Rajkot Municipal Corporation amended the byelaws of general development control regulations through the regulation No.17.18 to make it mandatory to undertake rainwater harvesting in buildings having built up area of 80 sq m or more. However, in case of existing buildings more than 1000 sq. meters of built-up area a moratorium of five years shall be given within which the above requirements of the Development Regulations shall be complied with.

GWALIOR

By order dated 27th January 2006 rainwater harvesting has been made mandatory for buildings having an area more than 250 sq m. The engineer in charge of the area has been authorized to impose a penalty of Rs.7000 in case of non-compliance. A rebate of 6 % in property tax in the year in which the construction of rrainwater harvesting facility has been completed will be provided for the owner of the building as an incentive.

JABALPUR

Rainwater harvesting has been made mandatory in all new buildings with an area of 250 sq m or more from 1 April 2005. A rebate of 6 per cent on property tax has been offered as an incentive for implementing rainwater- harvesting systems in the building

RANCHI

The Ranchi Regional Development Authority has included rainwater harvesting in its byelaws.

MUSSOORIE

The Mussoorie Dehradun Development Authority has made provision for installation of rainwater harvesting system in its building byelaws.

RAINWATER HARVESTING IN WEST BENGAL : Rapid urbanization and industrialization has led to incessant withdrawal of groundwater in recent times, without paying much heed to the hydro-geological characteristics of the area, thereby depleting the groundwater level at a fast rate. West Bengal receives a fair amount of rainfall in almost all parts during monsoon. However, in absence of any structured strategy for harvesting the rainwater excepting some piecemeal approaches Most part of the rainwater finds its way to drains/nullahs as runoff. In view of uncontrolled groundwater abstraction, there is not only significant lowering of aquifer level, in many areas of the state including Kolkata, Haldia, etc., such abstraction is also resulting in intrusion of saline water as also arsenic in the aquifer, besides subsidence of land in specific areas. For reasons stated above, it is high time to start harvesting rainwater, specially in urban cities and drought-prone districts of the state. The rainwater during the rainy seasons can easily be collected from the rooftop (even in thatched huts). The collected rainwater may either be recharged into the groundwater aquifers or storied for direct use after very simple pre-treatment. Advantages of Rainwater Harvesting ➔ Helps in meeting the ever increasing demand for water;

➔ Helps in conserving ground water and supplement surface water resources; ➔ Rain water is bacteriologically pure, free from organic matter and soft; ➔ Helps in utilization of the runoff going into drains; and ➔ Reduces soil erosion, flood hazard, etc. Rainwater harvesting techniques Harvesting rainwater is very simple. When it rains we have to collect this water and not allow it to run away. Broadly, rainwater can be harvested by three main techniques: a) Storage of rainwater for direct use; b) Recharging groundwater aquifers for future use; and c) Diversion of run off into existing surface water bodies. Rain Water Open Space Harvesting Ground Water Recharge Rooftop Harvesting Direct use after Filtering Direct Storage Surplus water A typical rooftop rainwater harvesting system comprises of following: ● Catchment; ● Gutters; ● Down pipe and first flush pipe; ● Filter unit; ● Storage tank; and ● Collection pit. Tentative cost for rooftop rainwater harvesting per 100 sq.m. roof-area Type of Utilisation Tentative cost per 100 sq.m. of roofarea Storage of rainwater Rs. 2 lakhs Recharge of rainwater Rs. 7 lakhs Ground water recharge Rainwater may be charged into the groundwater aquifers through any suitable structures like: ● Recharging of dug wells and abandoned tube wells; ● Settlement tank; ● Recharging of service tube wells; ● Soak aways / Percolation pit; ● Recharge trenches; ● Recharge troughs; ● Modified injection well; and ● Spreading techniques. Initiatives taken by the West Bengal Pollution Control Board (WBPCB) ● The WBPCB advocates the matter of rainwater harvesting in West Bengal. The Board does not permit groundwater recharge within industrial areas. ● Rain water harvesting system has been installed in 50 schools and one college (13 schools in Birbhum, 12 in Bankura, 16 in Purulia and 10 in Darjeeling districts) in collaboration with various government and non-government agencies and funded by the WBPCB. ● The Board has played a promotional role for installation of rainwater harvesting structures in another 32 schools (Five each in Darjeeling, Bankura, Purulia, Murshidabad and Nadia, four in Birbhum, and three in Kolkata). ● The execution of the above-stated projects has been done by the Institute of Environmental Studies & Wetland Management, Action for Food Production, Centre for Ground Water Studies, PaschimBangaVigyan Mancha, and Institute for Motivating Self Employment. Organisations/Persons involved.

Guidelines for Rainwater Harvesting for large construction projects with built up area equal or more than 20,000 sqmt. Introduction The numbers of water stressed regions at various part of the country are increasing due to the rapid growth rate of real estate. The urban areas are facing twin challenges of water scarcity and inadequate capacity of wastewater disposal systems. The rapid growth of urban population leads to escalation of water demand. Meeting these increasing water demand with a geographically constrained water supply system is often a very difficult task. Large construction projects are also being taken up at areas where municipal water supply is yet to be made available. The developers are frequently exploring and abstracting groundwater to ensure the basic amenities at their housing projects. Conservation of ground water is important because it takes years to be replenished. In areas where ground water is used, care must be taken to minimize the quantity of water withdrawn and bring it on per with quantity of water being replenished. The State Expert Appraisal Committee (SEAC), has been constituted by Ministry of Environment & Forests (MoEF), Government of India as per the notification SO1533 dated 14 th September 2006 on Environmental Clearance (EC) procedure in April 2007. The SEAC has taken note of the seriousness of the situation. It has been decided to make rainwater-harvesting mandatory in new large construction projects and to prevent the future imbalance in the hydrology of the development zones. The Modern Methods The modern methods of rainwater harvesting can be broadly categorized under two - (a) Collection and storage of rainwater for direct use, and (b) Groundwater recharging. A combination of these two are also practiced, where rainwater is collected and stored in containers for direct use while the collected rainwater in excess of the storage capacity is charged into ground (groundwater recharging). The underlying principle of the rainwater harvesting is to “collect the rainwater when it rains and don't allow rainwater to run away” (runoff). It requires arrangements for collection (usually through gutters and drop down pipelines) of rainwater falling on rooftop and storage of collected rainwater for direct use and/or for groundwater recharge. This method is commonly known as Rooftop Rainwater Harvesting. Rainwater falling on the open spaces around the building (other than rooftop) is also used for rainwater harvesting generally by means of groundwater recharging. In urban areas, rainwater available from rooftop of buildings, paved areas are drained out. This water can be stored or recharged to aquifer and can be utilized gainfully at the time of need. In urban area, rainwater-harvesting system are designed in a way that it does not occupy large space for collection and recharge system. A few of the techniques of roof top rainwater harvesting in urban areas for recharging of groundwater aquifer are - (a) roof top rainwater harvesting through recharge pit, (b) roof top rainwater harvesting through recharge trench, (c) roof top rainwater harvesting through existing tube wells and (d) roof top rainwater harvesting through trench with recharge well. Rainwater collected from terraces of a cluster of building may be led into nearby ponds (with previous top layer) or in a storage tank. Runoff water can also be diverted into such ponds. The storage -recharge guideline. Except the upland at north and dry land at western part the West Bengal has significant ground water reserve. However considering the increased rate of abstraction from agriculture and development projects the SEAC has decided to formulate a rainwater harvesting guideline, which will economically viable and will lead to conservation as well as better utilization of water. The rainwater harvesting system has three components: • the catchments • the collection System • the utilization It has been decided that the rooftop catchments shall be used for the rainwater harvesting. The collection system shall be designed for storage/recharge system as applicable. The water shall be recommended for utilization in car washing, landscaping, fire fighting etc. Different percentage of storage and recharge has been proposed for different stories of building to keep the cost escalation rate as well as rainwater harvested equitable irrespective of buildings heights. The proponent must follow Guidelines for HARVESTING RAINWATER in large building projects with total built up area equal to more than twenty thousand square meter in the State of West Bengal SL No. Category of Building Minimum percentage of rain water which should harvested by Surface Storage Sub-surface Recharge * 1 10 to 15 storied Buildings & Above 40% 60% 2 6 to 10 storied Buildings 35% 45% 3 3 to 5 storied Buildings 25% 15% (recharge or Additional Storage) 4 Less than three storied Buildings 10% 10% Note 1. While suggesting the guidelines, RWH potential in 1000 sqm Roof Area was considered to be 7, 68, 000 litres annually based on the rainfall characteristics. Uniform utilization of harvested rainwater throughout the year from created Storage Tank was also considered. Based on the above consideration, the storage facility to be created from 1000 sqm Roof area for SL No. 1, 2, 3 were thought to be 3 lakh litres, 2.5 lakh litres and 1.5 lakh litres respectively. 2. * The sub surface recharge proposal including the design of recharge structure and location of recharge structure should be submitted before the State Expert Appraisal Committee for consideration. The total quantity of the rain water which would be harvested by the proponent should also be mentioned in the proposal. 3. However, depending upon the characteristics of soil and ground water regime of a particular site, the percentage of surface storage and sub-surface recharge may vary keeping the total percentage of harvested rain water unchanged. The State Expert Appraisal Committee shall approve such proposal only after review and scrutiny on case to case basis.

CHAPTER-3

GROUND WATER QUALITY SCENERIO OF INDIA AND TREATMENT METHODOLOGY

GROUND WATER QUALITY FEATURES

INTRODUCTION:

Ground water is very essential and vital component of our life support system. The ground water resources are being utilized for drinking, irrigation and industrial purposes. There is growing concern on deterioration of ground water quality due to geogenic and anthropogenic activities.

The quality of ground water has undergone a change to an extent that the use of such water could be hazardous. Increase in overall salinity of the ground water and/or presence of high concentrations of fluoride, nitrate, iron, arsenic, total hardness and few toxic metal ions have been noticed in large areas in several states of India.

Ground water contains a lot of varieties of dissolved inorganic chemical constituents in various concentrations as a result of chemical and biochemical interactions between water and the geological materials through which it flows and to a lesser extent because of the contribution from the atmosphere and surface water bodies.

Porous formations

Porous formations are further subdivided into Unconsolidated and Semi – consolidated formations. The areas covered by alluvial sediments of river basins, coastal and deltaic tracts constitute the unconsolidated formations. These are by far the most significant ground water reservoirs for large scale and extensive development. The hydrogeological environment and ground water regime in the Indo-Ganga-Brahmaputra basin indicate the existence of potential aquifers having enormous fresh ground water resources.

The semi-consolidated formation occurs mostly in the narrow valleys or structurally faulted basins. The Gondwanas, Lathis, Tipams, Cuddalore sandstones and their equivalents are the most extensive productive aquifers. Under favourable situations, these formations give rise to free flowing wells. In select tracts of northeastern sides of India, these water-bearing formations are quite productive. The Upper Gondwanas, which are generally arenaceous, constitute prolific aquifers.

Fissured formations

The Fissured or consolidated formations occupies almost two-thirds of the country. Consolidateformations other than vesicular volcanic rocks have negligible primary porosity. From the hydrogeological point of view, fissured rocks are broadly classified into four types viz. Igneous and metamorphic rocks excluding volcanic and carbonate rocks, volcanic rocks, consolidated sedimentary rocks excluding carbonate rocks and Carbonate rocks.

i) The Igneous and metamorphic rocks excluding volcanic and carbonate rocks: -The most common rock types are granites, gneisses, charnockites, khondalites, quartzites, schists and associated phyllites, slates, etc. These rocks possess negligible primary porosity but attain porosity and permeability due to fracturing and weathering. Ground water yield depends on rock type and possibly on the grade of metamorphism.

ii) Volcanic rocks:-The predominant types of the volcanic rocks are the basaltic lava flows of Deccan Plateau. Water bearing properties of different flow units control ground water occurrence and movement in Deccan Traps. The Deccan Traps have usually poor to moderate permeabilities depending on the presence of primary and secondary pore spaces including vescicles/fractures.

iii) Consolidated sedimentary rocks excluding carbonate rocks:-Consolidated sedimentary rocks occur in Cuddapahs, Vindhyans and their equivalents. These formations consist of conglomerates, sandstones, shales, slates and quartzites. The presence of bedding planes, joints, contact zones and fractures controls the ground water occurrence, movement and yield potential of aquifers.

iv) Carbonate rocks:- Limestones in the Cuddapah, Vindhyan and Bijawar groups of rocks dominates the carbonate rocks other than the marbles and dolomites. In carbonate rocks, the circulation of water creates solution cavities thereby increasing the permeability of the aquifers. Solution activity leads to widely contrasting permeability within short distances in such rocks

Hydrochemistry:-

Hydrochemistry is an interdisciplinary science that deals with the chemistry of water in the natural environment. Professional fields such as chemical hydrology, aqueous chemistry, hydrochemistry, water chemistry and hydro-geochemistry are all more or less synonyms. The classical use of chemical characteristics in chemical hydrology is to provide information about the regional distribution of water qualities. At the same time, hydrochemistry has a potential use for tracing the origin and history of water. The hydrochemistry can also be of immense help in yielding information about the environment through which water has circulated. Hydrochemistry can be helpful in knowing about residence times, flow paths and aquifer characteristics as the chemical reactions are time and space dependent. It is essential to study the entire system like atmospheric water (rainwater), surface water and ground water simultaneously in evaluating their hydrochemistry and pollution effect.

CHEMISTRY OF GROUND WATER:-

The downward percolating water is not inactive, and it is enriched in CO_2 .It can also act as a strong weathering agent apart from general solution effect. Consequently, the chemical composition of ground water will vary depending upon several factors like frequency of rain, which will leach out the salts, time of stay of rain water in the root-zone and intermediate zone, presence of organic matter etc. It may also be pointed out that the water front does not move in a uniform manner as the soil strata are generally quite heterogeneous. The movement of percolating water through larger pores is much more rapid than through the finer pores. The overall effect of all these factors is that the composition of ground water varies from time to time and from place to place.

Before reaching the saturated zone, percolating water is charged with oxygen and carbon dioxide and is most aggressive in the initial stages. This water gradually loses its aggressiveness, as free CO_2 associated with the percolating water gets gradually exhausted through interaction of water with minerals.

$$CO_2 + H_2O \quad H_2CO_3 \quad H^+ + HCO_3^-$$

H^+ + Feldspar + H_2O Clay + H_4SiO_4 + Cation

The oxygen present in this water is used for the oxidation of organic matter that subsequently generates CO2 to form H2CO3. This process goes on until oxygen is fully consumed.

$$CH_2O + O_2 = CO_2 + H_2O$$

(Organic matter)

Apart from these reactions, there are several other reactions including microbiological mediated reactions, which tend to alter the chemical composition of the percolating water. For example, the bicarbonate present in most waters is derived mostly from CO2 that has been extracted from the air and liberated in the soil through biochemical activity. Some rocks serve as sources of chloride and sulphate through direct solution. The circulation of sulphur, however, may be greatly influenced by biologically mediated oxidation and reduction reactions. Chloride circulation may be a significant factor influencing the anion content in natural water.

SUITABILITY OF GROUND WATER FOR DRINKING

One of the main objectives of the ground water quality monitoring is to assess the suitability of ground water for drinking purposes. The physical and chemical quality of ground water is important in deciding its suitability for drinking purposes. As such the suitability of ground water for potable uses with regard to its chemical quality has to be deciphered and defined on the basis of the some vital characteristics of the water. Bureau of Indian Standards (BIS) formally known as Indian Standard Institute (ISI) vide its document IS: 10500:1991, Edition 2.2 (2003-09) has recommended the quality standards for drinking water and these have been used for finding the suitability of ground water. On this basis of classification, the natural ground water of India has been categorized as desirable, permissible and unfit for human consumption.

Ground Water Quality in India

Ground water in shallow aquifers is generally suitable for use for different purposes and is mainly of Calcium bicarbonate and mixed type. However, other types of water are also available including Sodium -Chloride water. The quality in deeper aquifers also varies from place to place is generally found suitable for common uses. Only in some cases, ground water has been found unsuitable for specific use due to various contaminations mainly because of geogenic reasons. The main ground water quality problems in India are as follows.

Inland Salinity:-

Inland salinity in ground water is prevalent mainly in the arid and semi arid regions of Rajasthan, Haryana, Punjab and Gujarat and to a lesser extent in Uttar Pradesh, Delhi, Madhya Pradesh Maharashtra, Karnataka , Bihar and Tamil Nadu. About 2 lakh sq.km area has been estimated to be affected by saline water of Electrical Conductivity in excess of 4000 μS/cm. There are several places in Rajasthan and southern Haryana where EC values of ground water is greater than 10000 μS /cm making water non-potable.

Inland salinity is also caused due to practice of surface water irrigation without consideration of ground water status. The gradual rise of ground water levels with time has resulted in water logging and heavy evaporation in semi arid regions lead to salinity problem in command areas. As per recent assessment about 2.46 m ha of the area under surface water irrigation projects is water logged or threatened by water logging.

Coastal Salinity:-

Coastal areas represent zones where land and sea meet and comprises variety of complex environments including deltas, estuaries, bays, marshes, dunes and beaches. Coastal aquifers have boundaries in contact with seawater and are always under dynamic equilibrium with it. Withdrawal of fresh ground water from these aquifers may result in inequilibrium resulting in intrusion of saline water in coastal aquifers.

The Indian subcontinent has a dynamic coast line of about 7500 km length. It stretches from Rann of Kutch in Gujarat to Konkan and Malabar coast to Kanyakumari in the south to northwards along the Coromandal coast to Sunderbans in West Bengal .The western coast is characterized by wide continental shelf and is marked by backwaters and mud flats while the eastern coast has a narrow continental shelf and is characterized by deltaic and estuarine land forms. Ground water in coastal areas occurs under unconfined to confined conditions in a wide range of unconsolidated and consolidated formations.

Normally, saline water bodies owe their origin to entrapped sea water (connate water), sea water ingress, leachates from navigation canals constructed along the coast, leachates from salt pans etc. In general, the following situations are encountered in coastal areas

i. Saline water overlying fresh water aquifer

ii. Fresh water overlying saline water

iii. Alternating sequence of fresh water and saline water aquifers

In India, salinity problems have been observed in a number of places in coastal areas of the country. Problem of salinity ingress has been noticed in Minjur area of Tamil Nadu and Mangrol – Chorwad- Porbander belt along the Saurashtra coast. In Orissa in an 8-10 km. wide belt of Subarnrekha, Salandi, Brahamani outfall regions in the proximity of the coast, the upper aquifers contain saline horizons decreasing landwards. Salinity ingress is also reported in Pondicherry region, east of Neyveli Lignite Mines.

FLUORIDE

Fluorine is a fairly common element but it does not occur in the elemental state in nature because of its high reactivity. Fluorine is the most electronegative and reactive of all elements that occur naturally within many type of rock. It exists in the form of fluorides in a number of minerals of which fluorspar, cryolite, fluorite and fluorapatite are the most common. Fluorite (CaF2) is a common fluoride mineral.

Most of the fluoride found in groundwater is naturally occurring from the breakdown of rocks and soils or weathering and deposition of atmospheric particles. Most of the fluorides are sparingly soluble and are present in ground water in small amounts. The occurrence of fluoride in natural water is affected by the type of rocks, climatic conditions, nature of hydrogeological strata and time of contact between rock and the circulating ground water. Presence of other ions, particularly bicarbonate and calcium ions also affects the concentration of fluoride in ground water.

It is well known that small amounts of fluoride (less than 1.0 mg/l) have proven to be beneficial in reducing tooth decay. Community water supplies commonly are treated with NaF or fluorosilicates to maintain fluoride levels ranging from 0.8 to 1.2 ppm to reduce the incidence of dental carries. However, high concentrations such as 1.5 mg/l of F and above have resulted in staining of tooth enamel while at still higher levels of fluoride ranging between 5.0 and 10 mg/l, further pathological changes such as stiffness of the back and difficulty in performing natural movements may take place.

BIS has recommended an upper desirable limit of 1.0 mg/l of F- as desirable concentration of fluoride in drinking water, which can be extended to 1.5 mg/l of F in case no alternative source of water is available. Water having fluoride concentration of more than 1.5 mg/l are not suitable for drinking purposes.

The fluoride content in ground water from observation wells in a major part of the country is found to be less than 1.0 mg/l. The distribution of ground water samples with fluoride concentration more than 1.5 mg/l have been depicted on the map (Plate III). It is observed that there are several locations in the States of Andhra Pradesh, Gujarat, Karnataka, Madhya Pradesh, Rajasthan, Chattisgarh, Haryana, Orissa, Punjab, Haryana, Uttar Pradesh West Bengal, Bihar, Delhi, Jharkahnd, Maharashtra, and Assam where the fluoride in ground water exceeds 1.5 mg/l. These locations are marked with serial numbers indicating specific details like District, Location and fluoride content of observation well in the State (Annexure-I). The list of districts showing localized occurrence of fluoride in ground water in excess of 1.5mg/l is given in table 4.

Sl. No	**State**	**Parts of Districts having F > 1.5mg/litre**
1	Andhra Pradesh	Adilabad, Anantpur, Chittoor, Guntur, Hyderabad, Karimnagar, Khammam, Krishna, Kurnool, Mahbubnagar, Medak, Nalgonda, Nellore, Prakasam, Ranga Reddy, Vizianagaram, Warangal, West Godavari
2	Assam	Goalpara, Kamrup, KarbiAnglong, Nagaon,

3	Bihar	Aurangabad, Banka, Buxar, Jamui, Kaimur(Bhabua), Nawada, Rohtas, Supaul
4	Chhattisgarh	Bastar, Bilaspur, Dantewada, Janjgir-Champa, Jashpur, Kanker, Korba, Koriya, Mahasamund, Raipur, Rajnandgaon, Surguja
5	Delhi	East Delhi, North West Delhi, South Delhi, South West Delhi, West Delhi
6	Gujarat	Ahmadabad, Amreli, Anand, Banaskantha, Bharuch, Bhavnagar, Dohad, Junagadh, Kachchh, Mehsana, Narmada, Panchmahals, Patan, Rajkot, Sabarkantha, Surat, Surendranagar, Vadodara,
7	Haryana	Bhiwani, Faridabad, Gurgaon, Hissar, Jhajjar, Jind, Kaithal, Kurushetra, Mahendragarh, Panipat, Rewari, Rohtak, Sirsa, Sonepat
8	Jammu & Kashmir	Rajauri, Udhamur
9	Jharkhand	Bokaro, Giridih, Godda, Gumla, Palamu, Ranchi
10	Karnataka	Bagalkot, Bangalore, Belgaun, Bellary, Bidar, Chamarajanagar, Chikmagalur, Chitradurga, Davangere, Dharwad, Gadag, Gulburga, Haveri, Kolar, Koppal, Mandya, Mysore, Raichur, Tumkur
11	Kerala	Palakkad
12	Maharashtra	Amravati, Chandrapur, Dhule, Gadchiroli, Gondia, Jalna, Nagpur, Nanded

13	Madhya Pradesh	Bhind, Chhatarpur, Chhindwara, Datia, Dewas, Dhar, Guna, Gwalior, Harda, Jabalpur, Jhabua, Khargaon, Mandsaur, Rajgarh, Satna,Seoni,Shajapur,Sheopur, Sidhi
14	Orissa	Angul, Balasore, Bargarh, Bhadrak, Bandh, Cuttack, Deogarh, Dhenkanal, Jajpur, Keonjhar,, Sonapur
15	Punjab	Amritsar, Bhatinda, Faridkot, fatehgarh Sahib, Firozepur, Gurdaspur, Mansa, Moga, Muktsar, Patiala, Sangrur
16	Rajasthan	Ajmer, Alwar, Banaswara, Barmer, Bharatpur, Bhilwara, Bikaner, Bundi, Chittaurgarh, Churu, Dausa, Dhaulpur, Dungarpur, Ganganagar, Hanumangarh, Jaipur, Jaisalmer, Jalor, Jhunjhunun,
		Jodhpur, Karauli, Kota, Nagaur, Pali, Rajsamand, Sirohi, Sikar, SawaiMadhopur, Tonk, Udaipur
17	Tamil Nadu	Coimbatore, Dharmapuri, Dindigul, Erode, Karur, Krishnagiri, Namakkal, Perambalur, Puddukotai, Ramanathapuram, Salem, Virudhunagar
18	Tamil Nadu	Coimbatore, Dharmapuri, Dindigul, Erode, Karur, Krishnagiri, Namakkal, Perambalur, Puddukotai, Ramanathapuram, Salem, Virudhunagar
19	Uttar Pradesh	Agra, Aligarh, Etah, Firozabad, Jaunpur, Kannauj, Mahamaya Nagar, Mainpuri, Mathura, Mau
20	West Bengal	Bankura, Bardhaman, Birbhum, Dakshindinajpur, Malda, Nadia, Purulia, Uttardinajpur

ARSENIC

Arsenic is a naturally occurring trace element found in rocks, soils and the water in contact with them. Arsenic has been recognized as a toxic element and is considered a human health hazard.

As per the BIS Standard for drinking water (BIS 1991 and subsequent modifications), the maximum permissible limit of Arsenic concentration in ground water is 0.01 mg/l. The occurrences of Arsenic in ground water beyond permissible limit (> 0.05 mg/l) has been shown on the maps as water quality hot spots as the task force set up in West Bengal has recommended 0.05 mg/l as permissible limit based on earlier BIS Standard.

The occurrence of Arsenic in ground water was first reported in 1980 in West Bengal in India. In West Bengal, 79 blocks in 8 districts have Arsenic beyond the permissible limit of 0.05 mg/l. The most affected areas are on the eastern side of Bhagirathi river in the districts of Malda, Murshidabad, Nadia, North 24 Parganas and South 24 Parganas and western side of the districts of Howrah, Hugli and Bardhman. The occurrence of Arsenic in ground water is mainly in the aquifers upto 100 m depth. The deeper aquifers are free from Arsenic contamination.

Apart from West Bengal, Arsenic contamination in ground water has been found in the states of Bihar, Uttar Pradesh, Assam & Chhattisgarh. Arsenic in ground water has been reported in parts of 15 districts in Bihar, 9 districts in Uttar Pradesh and one district each in Chhattisgarh & Assam. The occurrence of Arsenic in the states of Bihar, West Bengal and Uttar Pradesh is in alluvial formations but in the state of Chhattisgarh, it is in the volcanic rocks exclusively confined to N-S trending Dongargarh-Kotri ancient rift zone. It has also been reported in Dhemaji district of Assam The map showing distribution of Arsenic in ground water of India (Plate-V) has been generated from the data on arsenic concentration in water samples mostly collected from the groundwater observation wells/ hand pumps. Arsenic contamination in West Bengal & Bihar states show the affected blocks based on the findings of Task Force/ State Government agencies. Uttar Pradesh, Assam & Chhattisgarh States have not declared blocks affected by Arsenic (Unlike Bihar & West Bengal), and hence Arsenic contaminated areas have been shown as points based on findings of Central Ground Water Board and State Ground Water Departments. The details of the locations are given in Annexure-III A & III B. The point sources are plotted on the map (Plate-V). Each spot shows the serial number indicating the specific details (district, block, location, concentration). Table-6 shows the list of districts from which Arsenic in excess of 0.05mg/l has been reported.

Table 6: Districts Having Arsenic (>0.05mg/litre) in Ground Water in Different States of India

Sl. No.	**State**	**Parts of Districts having As> 0.05mg/litre**
1.	Assam	Dhemaji
2.	Bihar*	Begusarai, Bhagalpur, Bhojpur, Buxar, Darbhanga, Katihar, Khagaria, Kishanganj, Lakhiserai,Munger, Patna, Purnea, Samastipur, Saran, Vaishali
3.	Chhattisgarh	Rajnandgaon
4.	Uttar Pradesh	Agra, Aligarh, Balia, Balrampur, Gonda, Gorakhpur, Lakhimpur Kheri*, Mathura, Muradabad

IRON

Iron is a common constituent in soil and ground water. It is present in water either as soluble ferrous iron or the insoluble ferric iron. Water containing ferrous iron is clear and colorless because the iron is completely dissolved. When exposed to air, the water turns cloudy due to oxidation of ferrous iron into reddish brown ferric oxide.

The concentration of iron in natural water is controlled by both physico chemical and microbiological factors. It is contributed to ground water mainly from weathering of ferruginous minerals of igneous rocks such as hematite, magnetite and sulphide ores of sedimentary and metamorphic rocks.

The permissible Iron concentration in ground water is less than 1.0 mg/litre as per the BIS Standard for drinking water. The occurrences of iron in ground water beyond permissible limit (> 1.0 mg /litre) have been shown on the maps as point sources (Plate-IV). Each spot shows the serial number indicating the specific details (district, block, location, and concentration) water quality hot spots. These are observed in several pockets of the country. It is based on the chemical analysis of water samples mostly collected from the groundwater observation wells/ springs/ hand pumps. The details of the sampling sources are given in Annexure-II.

On perusal of Plate-IV, it is observed that high concentration of Iron (>1.0 mg/l) in ground water has been found in the states of Andhra Pradesh, Assam, Bihar, Chhattisgarh, Goa, Gujarat, Haryana, Jharkhand, Karnataka, Kerala, Madhya Pradesh, Maharashtra, Manipur, Meghalaya, Orissa, Punjab, Rajasthan, Tamil Nadu, Tripura, Uttar Pradesh, West Bengal & Andaman & Nicobar. The summary list of districts in which iron in ground water is found to exceed the permissible limits for drinking water in localized areas is shown in table 5.

Table 5: Districts Having Localized Occurrence of Iron (>1.0 mg/litre) in Ground Water in India

Sl. No	**State**	**Parts of Districts having Fe> 1.0 mg/litre**
1	Andaman & Nicobar Island	Andaman
2	Andhra Pradesh	Adilabad, Chittoor, Cuddapah, Guntur, Hyderabad, Karimnagar, Krishna, Kurnool, Mahbubnagar, Medak, Nalgonda, Nellore, Nizamabad, Ranga Reddy, Visakhapatnam,
3	Assam	Cachar, Darrang, Dhemaji, Dhubri, Goalpapra, Golaghat, Hailakandi, Jorhat, Kamrup, KarbiAnglong ,Karimganj, Kokrajhar, Lakhimpur, Morigaon, Nagaon, Nalbari, Sibsagar, Sonitpur

4	Bihar	Gopalganj, Katihar,Khagaria,Kishanganj,Lakhiserai,Madhepur Muzaffarpur, Nawada, Rohtas, Saharsa, Samastipur, Siwan, Supaul, West Champaran.
5	Chhattisgarh	Bastar, Dantewada, Kanker, Koriya,
6	Goa	North Goa, South Goa
7	Gujarat	Ahmadabad Banaskantha, Bhavnagar, Kachchh, Narmada,
8	Haryana	Ambala, Bhiwani, Faridabad, Fatehabad, Gurgaon, Hissar, Jhajjar, Jind, Kaithal, Karnal, Kurukshetra, Mahendragarh, Panipat, Rohtak, Sirsa, Sonepat, Yamuna Nagar
9	Jammu & Kashmir	Baramulla, Budgam, Kathua, Kupwara, Pulwama, Srinagar
10	Jharkhand	Chatra, Deoghar, East Singhbhum, Giridih, Ranchi, West Singhbhum
11	Karnataka	Chikmagalr, Chitradurga, Dakshina Kannada, Davangere, Gulburga, Hassan, Haveri, Kodagu, Kolar, Koppal, Mysore, Raichur, Shimoga, Tumkur, Udupi, Uttara Kannada
12	Kerala	Alappuzha, Ernakulam, Idukki, Kannur, Kasaragod, Kollam, Wayanad, Thiruvananthapuram,Thrissur,
13	Maharashtra	Ahmednagar, Amravati, Beed, Buldana, Chandrapur, Dhule, Gadchiroli, Jalna, Kohlapur, Latur, Nandurbar ,Nashik, Osmanabad, Parbhani, Ratnagiri, Satara, Thane, Wardha,
14	Manipur	Bishnupur, Thoubal
15	Madhya	Balaghat, Betul, Bhind, Chhatarpur, Chhindwara, Guna, Gwalior,

	Pradesh	Hoshangabad, Narsinghpur, Panna, Raisen, Rajgarh, Rewa, Sagar, Satna, Sehore, Seoni, Shahdol, Shajapur, Sidhi, Ujjain, Umaria, Vidisha, Dindori, EastNimar
16	Meghalaya	East Garo Hills, East Khasi Hill, Jaintia Hills
17	Orissa	Balasore, Bargarh, Bhadrak, Cuttack, Deogarh, J.Singhpur, Jajpur, Jharsuguda, Kalahandi, Kandmahal, Keonjhar, Kendrapara, Khurda, Koraput, Mayurbhanj, Nayagarh, Puri, Rayagada, Sambalpur, Sundergarh, Sonapur
18	Punjab	Bhathinda, Faridkot, Fatehgarh Sahib, Firozepur, Gurdaspur, Hoshiarpur, Mansa, Rupnagar, Sangrur
19	Rajasthan	Ajmer, Alwar, Banswara, Baran, Bharatpur, Bhilwara, Bikaner, Chittaurgarh, Churu, Dausa, Dhaulpur, Dungarpur, Ganganagar, Hanumangarh,Jaipur,Jaisalmer,Jhalawar,Jhunjhunun,Jodhpu,Karauli, Kota, Nagaur, Pali, Rajsamand, Sikar, Sawai Madhopur, Tonk, Udaipur
20	Tamil Nadu	Namakkal, Salem
21	Tripura	Dhalai, North Tripura, South Tripura, West Tripura
22	Uttar Pradesh	Azamgarh, Balia, Balrampur, Etawah, Fatehpur, Gazipur, Gonda, Hardoi, Kanpur Dehat, Kanpur Nagar, Lakhimpur, Lalitpur, Mau, Siddharthnagar, Unnao Siddharthnagar, Unnao
23	West Bengal	Bankura, Bardhaman, Birbhum, Dakhindinajpur, E. Midnapur, Howrah, Hugli, Jalpaiguri, Kolkatta, Murshidabad , N-24praganna, Nadia, S-24pragannas, Uttardinajpur, West Midnapur

GROUND WATER QUALITY HOT SPOTS IN UNCONFINED AQUIFERS OF INDIA

Unconfined aquifers are extensively tapped for water supply across the country therefore; its quality is of paramount importance. The chemical parameters like TDS, Chloride, Fluoride, Iron, Arsenic and Nitrate etc are main constituents defining the quality of ground water in unconfined aquifers. Therefore, presence of these parameters in ground water beyond the permissible limit in the absence of alternate source has been considered as ground water quality hotspots.

Ground water quality hot spot maps of the country have been prepared depicting six main parameters based on their distribution shown on the separate maps. These maps depict the areal distribution of the following constituents in ground water tapping the unconfined aquifers.

I. Electrical Conductivity

II. Chloride

III. Fluoride (>1.5 mg/litre)

IV. Iron (>1.0 mg/litre)

V. Arsenic (>0.05 mg/litre)

VI. Nitrate (>45 mg/litre)

Maps depicting distribution of electrical conductance (salinity) and chloride are regional in nature and have contours, whereas fluoride, iron, & nitrate are depicted as hot spots/ locations having concentrations exceeding the permissible limit prescribed by Bureau of Indian Standards for drinking water.

In case of West Bengal & Bihar, Arsenic affected blocks have been identified based on the findings of Task Force/ State Government agencies. They have adopted the permissible limit as 0.05 mg/litre based on originally published standard (1983) of BIS. Uttar Pradesh, Assam & Chhattisgarh States have not declared blocks affected by Arsenic (Unlike Bihar & West Bengal).Hence, Arsenic concentrations in excess of 0.05mg/l have been shown as affected blocks on the map (West Bengal and Bihar states) and point values for other states (Uttar Pradesh, Assam & Chhattisgarh) based on findings of Central Ground Water Board and State agencies.

CHLORIDE

Chloride is present in all natural waters, mostly at low concentrations. It is highly soluble in water and moves freely with water through soil and rock. In ground water the chloride content is mostly below 250 mg/l except in cases where inland salinity is prevalent and in coastal areas.

BIS (Bureau of Indian Standard) have recommended a desirable limit of 250 mg /l of chloride in drinking water; this concentration limit can be extended to 1000 mg/l of chloride in case no alternative source of water with desirable concentration is available. However ground water having concentration of chloride more than 1000 mg /l are not suitable for drinking purposes.

In plate 2, the concentration of chloride (in mg/litre) in ground water from observation wells have been used to show distribution patterns of chloride in different ranges of suitability. It is apparent from the map that majority of the samples having chloride values less than 250 mg/litre are found mostly in the states of J & K, Himachal Pradesh, Uttarakhand, Uttar Pradesh, Bihar, Jharkhand, Chhattisgarh, Orissa, M.P, Kerala, Maharashtra, West Bengal, North- Punjab, Sikkim & North-Eastern states.

Water with chloride ranging between 250 and 1000 mg/l falling under ‘permissible’ range are confined mostly to parts of Maharashtra, Western M.P, Southern Punjab, Southern West Bengal, Karnataka, Andhra Pradesh and Western Uttar Pradesh.

Relatively high values of Chloride (>1000 mg/litre) are observed in few parts of the country. Table 3 shows the statewise list of districts affected by high chloride water (>1000 mg/litre) and these areas are water quality hot spots from point of view of chloride.

Table-3: Districts Having Chloride Concentration more than 1000 mg/litre in Ground Water in India

Sl. No	**State**	**Parts of district having Chloride > 1000 mg/litre**
1	Andhra Pradesh	E-Godavari, Prakasam , Nellore, Guntur, Mahbubnagar, Nalgonda, Kadappa, Krishna, Khammam, Kurnool, Medak, Warangal, Srikakulam

2	Delhi	North West, West, South West
3	Gujarat	Ahmadabad, Amreli, Anand, Bharuch, Bhavnagar, Banaskantha, Dohad, Porbandar, Jamnagar, Junagadh, Kachchh, Mehsana, Patan,Panchmahals, Rajkot, Sabarkantha, Surendranagar, Surat, Vadodara,
4	Haryana	Bhiwani, Gurgaon,Jhajjar,Mahendragarh, Rohtak, Sirsa, Sonipat
5	Karnataka	Bagalkot, Belgaum, Bellary, Dharwar, Gadag, Gulbarga, Raichur
6	Madhya Pradesh	Bhind, Ujjain
7	Maharasthra	Ahmadnagar*, Chandrapur, Jalna, Nagpur, Satara
8	Orissa	Jagatsinghpur
9	Punjab	Firozepur
10	Rajasthan	Barmer, Bharatpur, Bikaner, Bundi*, Churu, Chittaurgarh, Dausa, Ganganagar, Hanumangarh, Jaipur, Jaisalmer, Jalor, Jhunjhununn, Jodhpur, Karauli, Nagaur, Pali, Sirohi, Sawaimadhopur, Nagaur, Sikar, Tonk, Udaipur
11	Tamil Nadu	Chennai,Cuddalore,Coimbatore, Karur, Pudukkottai, Thoothukkudi, Ramanathapuram, Namakkal,Shivaganga, Salem, Thirunamalai, Tirunelveli, Tiruvarur*,Thanjavur, Vellore, Virudhanagar,
12	Uttar Pradesh	Aligarh, Agra, Hathras, Mathura
13	West Bengal	Haroa, N-24 Parganas, S-24 Parganas

Salinity:-

Health Hazard

High concentrations of salts can damage crops, affect plant growth, degrade drinking water quality, and damage industrial equipment. Most salts do not naturally degrade, and can remain in groundwater for decades. High concentrations of chloride (a major constituent of total dissolved solids) can make water unfit for human consumption and for many industrial uses, but the human health-related problems have not been critically observed yet. However, high concentrations of sodium ion can contribute to certain heart disease or high blood pressure, particularly in susceptible individuals Excessive concentration of chlorine has bad effects on the environment as well: it can produce leaf burn and even defoliation in sensitive crops; in lakes can increase the presence of metals in waters and prevent the distribution of oxygen and nutrients and thus harm aquatic life.

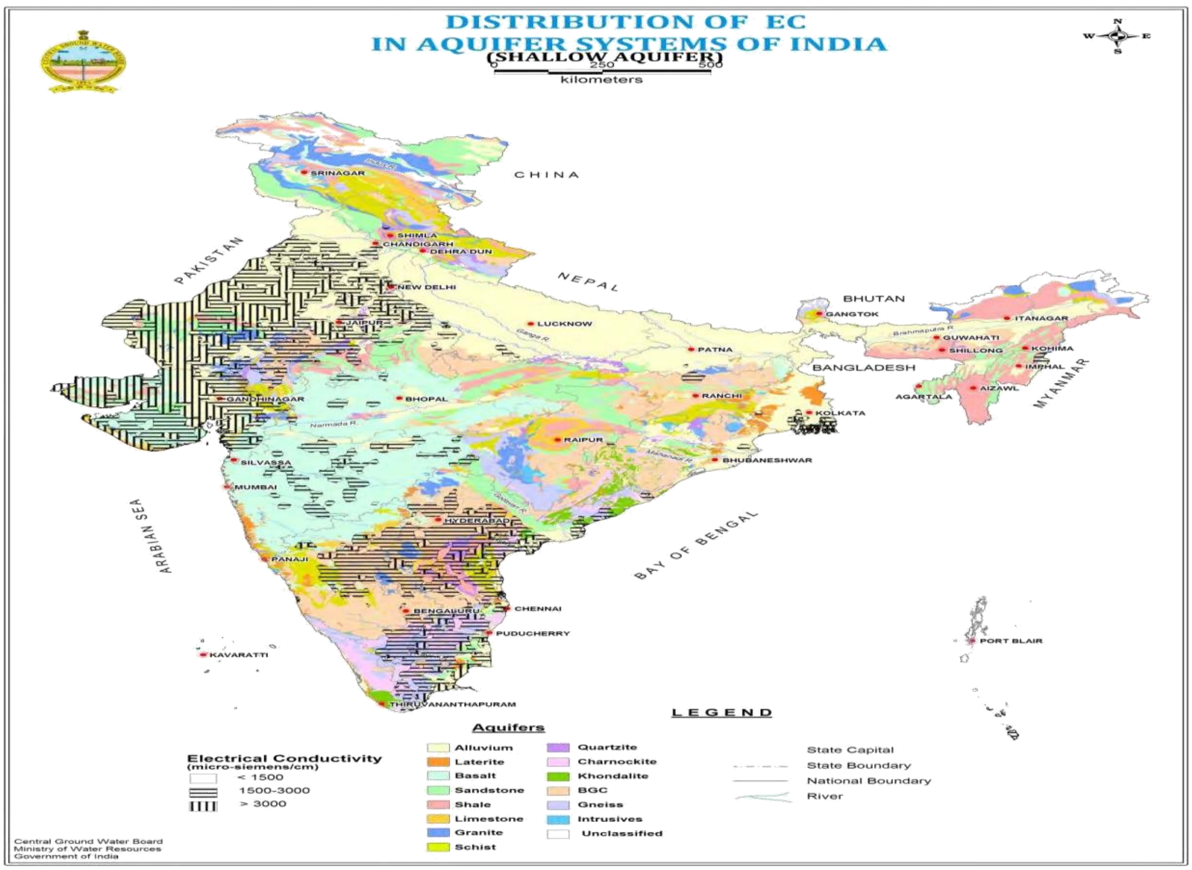


Fig 15 The distribution of EC in different Principal Aquifer Systems of India

FLUORIDE

Health Hazard

Low level fluoride is required by human system as it is helpful in preventing dental carries, while consumption of high concentrations of fluoride can lead to serious health issues. The long exposures and use of ground water having high fluoride in excess of 1.5 mg/l results in *Fluorosis,* The types of fluorosis are dental, skeletal as well as non-skeletal type.

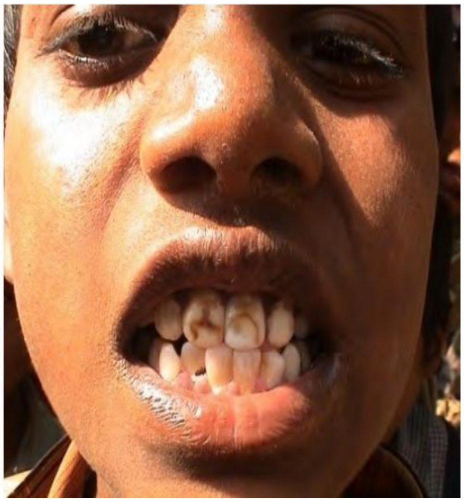


Fig 10 Symptoms of Fluorosis mottled teeth and knocking knees

The dental fluorosis is the loss of luster and shine of the dental enamel. The discoloration starts from white, yellow, brown to black. It affects both the inner and outer surfaces of the teeth. Skeletal fluorosis is due to excessive quantity of fluoride deposited in the skeleton, which is more in cancellous bones compared to cortical bones. The disease is generally diagnosed at a developed stage. Fluoride poisoning leads to severe pain associated with rigidity and restricted movements of cervical and lumber spine, knee and pelvic joints as well as shoulder joints. Crippling deformity is associated with rigidity of joints and includes Kyphosis, Scoliosis, flexion deformity of knee joints, Paraplegia and Quadriplegia. Skeletal fluorosis affects both young children as well as adults. Non-skeletal type of Fluorosis includes ill effects on skeletal muscle, Erythrocytes, Gastro-Intestinal system, ligaments or combination of all. Fluorosis is irreversible and no tratment exists for it.

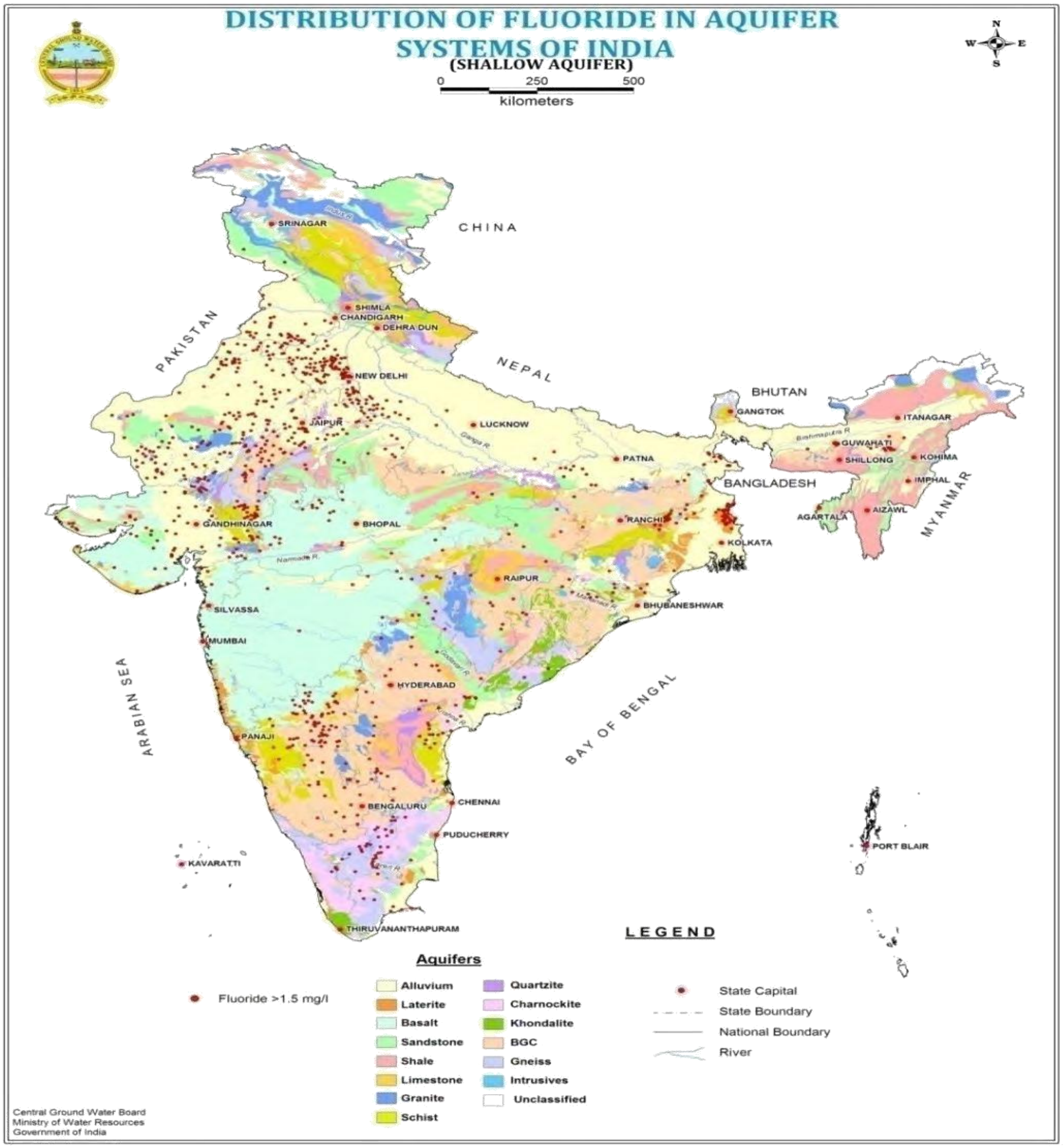


Fig 11 The distribution of fluoride in Principal Aquifer Systems of India

ARSENIC

Health Hazard

Human system is sensitive to arsenic. Animals are not as sensitive to arsenic as humans, owing to differences in gastrointestinal absorption. The excess arsenic may cause sufficient damage to human health and these may be respiratory distress due to irritation of mucous membranes, resulting into laryngitis, bronchitis or rhinitis, myocardial depolarization and cardiac arrhythmias that may lead to heart failure, gastrointestinal effects like burning lips, painful swallowing, thirst, nausea and abdominal colic. Anaemia and leucopenia are other common effects of arsenic poisoning. Ingestion of inorganic arsenic can also result in neural injury, having such symptoms like headache, lethargy, mental confusion, hallucinating, seizures and coma Skin disorders caused by long term arsenic ingestion have been commonly reported. It includes generalized hyperkeratosis, warts or corns on the palms and soles and areas of hyperpigmentation interspersed with small areas of hypopigmentation in the face, neck and back. Inorganic arsenic increases the risk of lung cancer when exposure occurs through inhalation. Ingestion of inorganic arsenic also increases the risk of skin cancer.

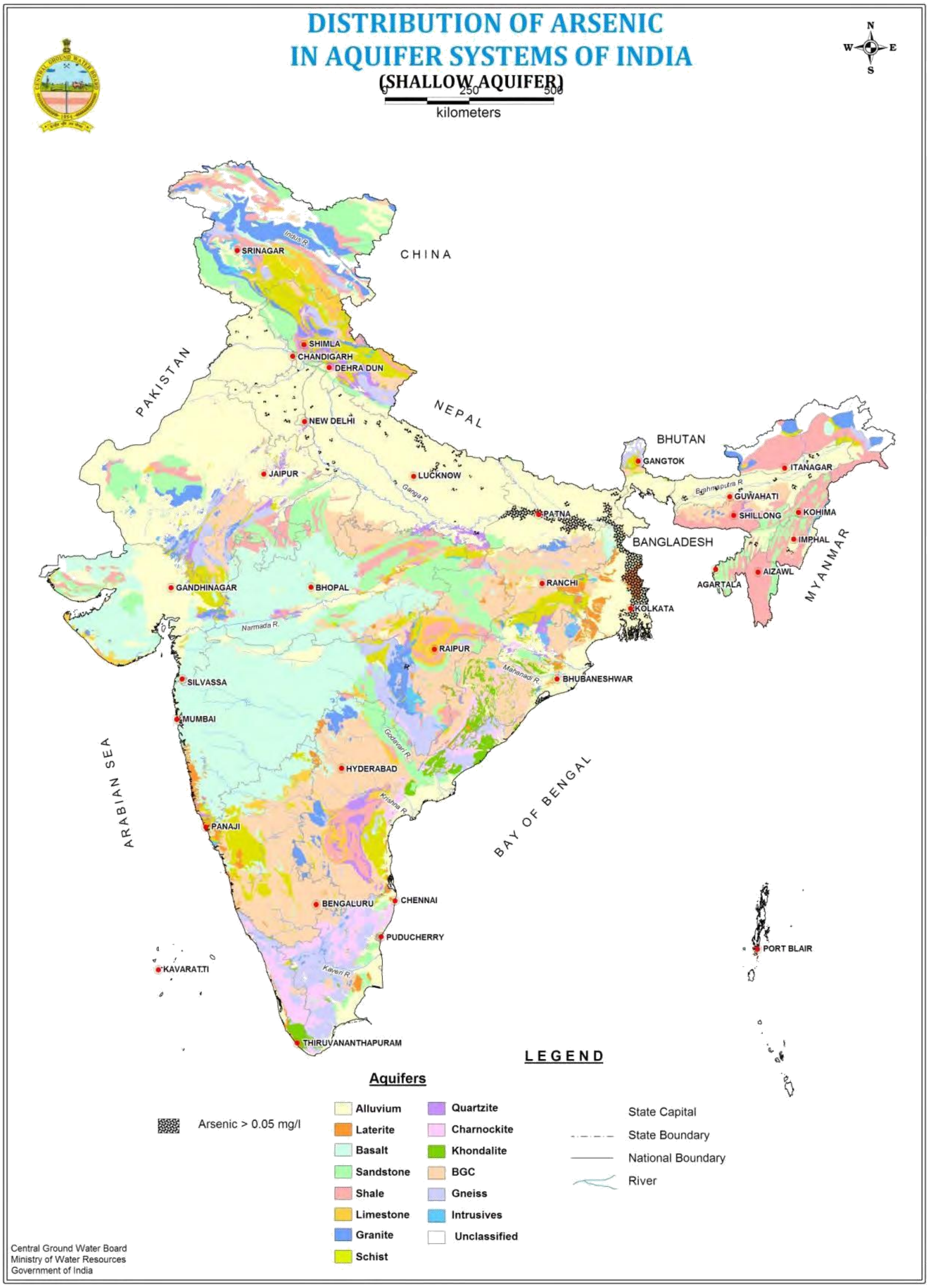


Fig 1: Distribution of Arsenic in Principal Aquifer Systems of India

IRON

Health Hazard

High iron makes the water water taste astringent. The water may appear brownish due to the precipitation of ferric hydroxide. It may stain utensils, laundry and equipment. The EPA cautions that although iron in drinking water is safe to ingest, but the iron sediments may contain trace impurities or harbor bacteria that can be harmful.

The most well-known role that iron plays in human nutrition is in the formation of the protein haemoglobin, which transports oxygen to all cells of the body. Iron is also used in cellular metabolism and is found in many of the body's enzymes. Low iron stores in the body can lead to iron deficiency, anaemia and fatigue. The immune system is also affected. In young children this negatively affects mental development, leads to irritability and causes concentration disorder.

Chronically consuming excess amounts of iron can lead to a condition known as iron overload. This condition is usually the result of a gene mutation. Left untreated, iron overload can lead to haemochromatosis, a severe disease that can damage the body's organs. Early symptoms include fatigue, weight loss, and joint pain, but if haemochromatosis is not treated, it can lead to heart disease, liver problems and diabetes.

Manganese

Manganese is considered to be the 12th most abundant element in the biosphere. Although manganese is one of the most abundant metallic elements, there is only about $1/5^{th}$ as much manganese in the earth's crust as there is iron. The chemistry of manganese is somewhat similar to that of iron as both metals participate in redox processes in weathering environment. Many igneous and metamorphic rocks contain manganese as a minor constituent but in basalt it is a significant constituent. Lateritic weathering process produces manganese oxide accumulation in economic proportion. It is widely distributed in soil, sediment, water and in biological materials. Although manganese is essential for humans and other species of the animal kingdom as well as for plants, at higher level it is toxic.

The levels of manganese in groundwater from natural leaching processes can vary widely depending upon the types of minerals present at the aquifer. Manganese is not an essential constituent of any of the common silicate rock minerals, but it can substitute for iron, magnesium, or calcium in silicate structures. Manganese can form a wide variety of mixed-valence oxides and has three possible valence states in such environments rather than two (2+, 3+, and 4+) but the 3+ species are unstable. Many igneous and metamorphic minerals contain divalent manganese as a minor constituent. It is a significant constituent of basalt as it is present in minerals such as olivine, pyroxene and amphibole. Small amounts are commonly present in dolomite and limestone, substituting for calcium. Manganese are more commonly found in deeper wells where the water generally remains in contact with rock for a longer time. In coal mining regions this metal may also be presented as a consequence of both deep and surface mining activities. Manganese often occurs together with iron in groundwater but it usually occurs in much lower concentrations than iron. It is present in soil as a result of mineral weathering and atmospheric deposition, originating from both natural and anthropogenic sources. The divalent ion is the only form that is stable in soil solution, while Mn(III) and Mn(IV) are only stable in the solid phase of soil. Manganese mobility in soil is extremely sensitive to soil conditions such as acidity, wetness, organic matter content, biological activity etc. The solubility of soil manganese is thus controlled by redox potential and soil pH, where low pH or low redox potential favour the reduction of insoluble manganese oxides resulting in increased manganese mobility. At soil pH above 6, manganese forms bonds with organic matter, oxides and silicates thereby its solubility decreases. Manganese availability and solubility is thus generally low at high pH and high organic matter content, while in acid soils with low organic matter content its availability is high. The solubility of manganese is also high in anaerobic conditions at pH above 6, as well as in aerobic conditions at pH below 5.5.

Health Hazard

Manganese is easily concentrated in the brain, especially in the basal ganglia, and can cause an irreversible neurological syndrome similar to Parkinson's disease. Relatively high doses of manganese affect DNA replication and causes mutations in microorganism and mammalian cells. In mammalian cells, manganese causes DNA damage and chromosome aberrations. Large amounts of manganese affect fertility in mammals and are toxic to the embryo and foetus. The risk of damage to the central nervous system is of greater importance

Arsenic and Fluoride Problems of Groundwater in West Bengal

India is a subcontinent country with large amount of resources, though many places in India people uses Ground water as only source for drinking and domestic purpose. But ground water is not safe in most of the places. Arsenic and Fluoride can be taken care of major concern of ground water pollution in these days. Arsenic and fluoride contamination is found in many places in India and as well as in West Bengal also. There are lots of promising technologies available for arsenic and fluoride removal but considering all the technologies it was found that using Electro-coagulation and activated alumina are convenient and suitable for removal. In West Bengal Baruipur is a place where both arsenic and fluoride is found. So adopting appropriate technology can remove both arsenic and fluoride at same time. Further experimental analysis need to be done for both the cases laboratory and field based.

The 85 % of rural population of the country uses ground water for drinking and domestic purposes. In West Bengal the arsenic concentration in drinking water is about 60 to 3700 μg/l and about 40 million people are affected from it. In middle Ganga plain, Bihar, 206 tube wells (95% of total) were analyzed for arsenic content and showed that 56.8% tube wells have exceeded arsenic concentration of 50 μg/l and 19.9% have more than 300 μg/l. In exposer of the arsenic level about 750 to 800 μg/l, which caused several skin and lung disease and arsenic concentration in well water used for drinking purpose were 10-1800 μg/l and a peripheral vascular disease called "Black foot disease" is a common disease among the living population due to arsenicism. High concentration of fluoride in ground water beyond the permissible limit of 1.5 mg/l poses the health problem. World Health Organization (WHO) guideline value and the permissible limit of fluoride as per Bureau of Indian Standard (BIS) is 1.5 mg/L. Excessive fluoride in drinking water causes dental and skeletal fluorosis, which is encountered in endemic proportions in several parts of the world. In small doses it has remarkable influence on the dental system by inhibiting dental caries, while in higher doses, it causes dental and skeletal fluorosis. In India 62 million people including 6 million children are affected with fluoride related health diseases.

Arsenic-Affected Districts of West Bengal

Table 2 indicates a total of 8,066 habitations with 10.9 million people impacted by arsenic in West Bengal. Worst-affected districts are Malda, Murshidabad, Nadia, and North 24 Parganas. These all lie to the east of the Ganga (Hooghly) River. Numbers of affected blocks in each district are given in Table 3.

Table 2. Habitations in Arsenic-Affected Districts of West Bengal

District	No. habitations	Population	Affected habitation	Affected population	% of district population affected
Bankura	6,638	3,403,362	1	3,115	0.1
Bardhaman	5,386	5,271,056	142	291,224	5.5
Hooghly	11,762	3,975,186	178	98,050	2.5
Howrah	2,130	3,116,331	1	2,876	0.1
Maldah	7,787	5,717,269	836	1,156,620	20.2
Murshidabad	3,105	6,790,427	1,439	3,895,605	57.4
Nadia	3,944	4,248,441	2,448	3,030,716	71.3
North 24 Parganas	7,334	5,184,365	2,699	2,196,158	42.4
South24 Parganas	9,039	7,405,677	322	252,114	3.4
Total	57,125	45,112,114	8,066	10,926,478	24.2

Growing awareness of the arsenic crisis in West Bengal groundwater led the Government of West Bengal to set up a working group in December 1983 to address the problem. The group confirmed exceedances of arsenic beyond the maximum drinking-water limit on an unprecedented scale. In 1988, the government set up a state-level investigation, funded by the Technology Mission of the Government of India, and initiated a state-level Arsenic Task Force in 1993. The Task Force tested some 132,000 public hand-pumped tube wells in the arsenic-affected areas, and those deemed safe were painted blue to identify them. It also initiated awareness campaigns. In 1996, the Task Force made recommendations for surface-water supply schemes. Figure 1 shows the main arsenic affected areas of West Bengal.

The state government instigated a comprehensive Arsenic Master Plan with assistance from the Government of India to provide arsenic-free drinking water for the rural population. The master plan identified short-, medium-, and long-term measures for mitigation, ranging from rainwater harvesting to piped supplies.

According to the website of the Public Health Engineering Department (PHED) of the Government of West Bengal, as of May 2017, 61.4% of the rural population of 4,304,314 (total 10,111,442) in North 24 Parganas were served by piped water supplies, in 21 blocks.[7]

As of January 2017, 48.9% of the rural population of 5,703,115 (total population 7,103,807) in Murshidabad was served by piped water supplies, in 26 blocks. However, ‘piped water’ by PHED in rural areas means water supply through public stand-posts

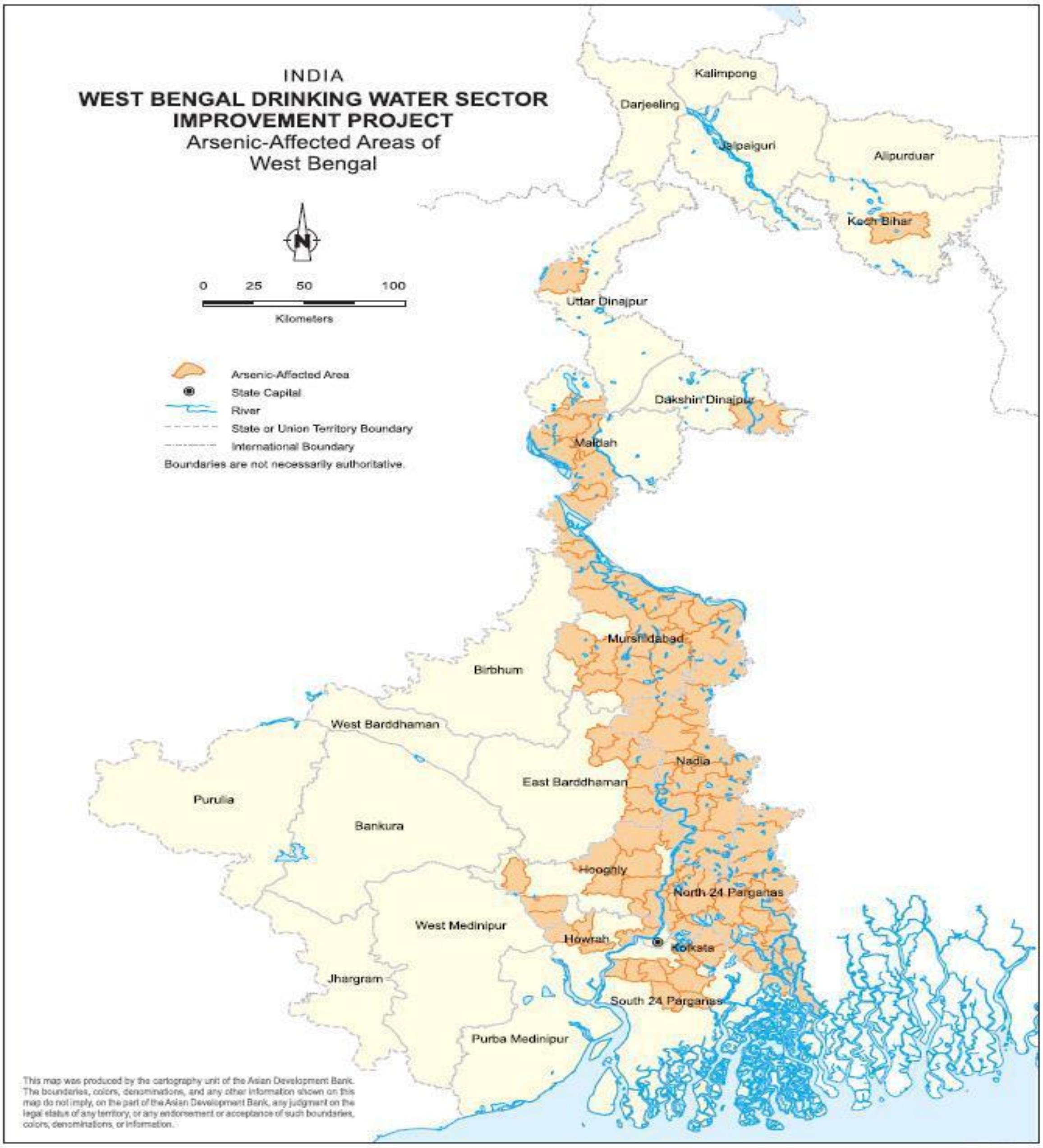


Figure 1. Arsenic-Affected Areas of West Bengal

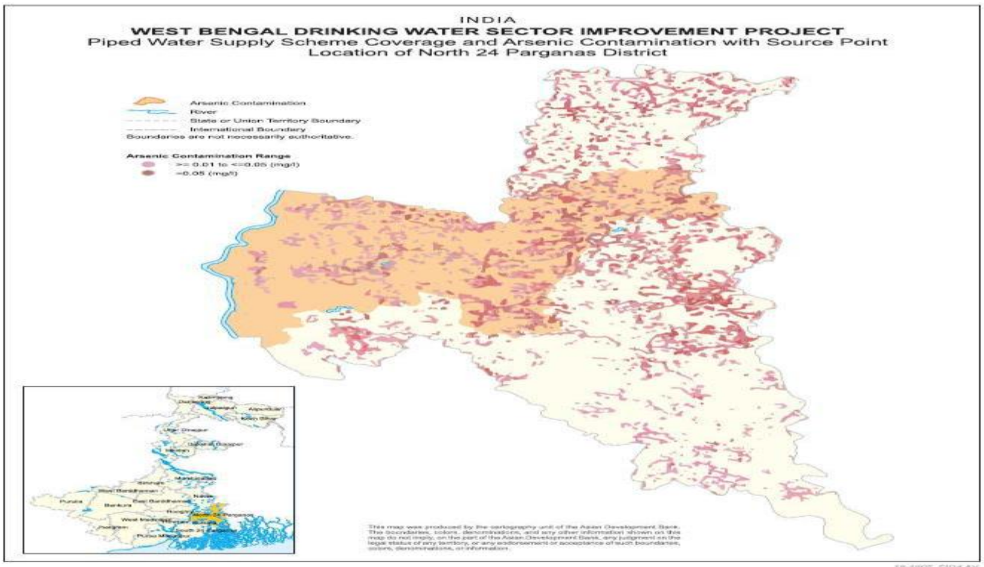
DISTRIBUTIONS IN NORTH 24 PARGANAS DISTRICT

The Government of India, Ministry of Drinking Water and Sanitation, integrated management information system (IMIS) groundwater data for the 3 years, 2014–2017, indicate that out of 47,062 water samples tested from 22 blocks in North 24 Parganas, 8,609 (18.3%) exceeded 10 µg/L (Table 4).[8] More than 30% of the tested samples in Baduria, Basirhat I, Gaighata, Habra I, and Swarupnagar had arsenic concentrations above the 10 µg/L limit. Distributions of the arsenic exceedances in the district are shown in Figure 2. Details of sample design are not known, but the distribution of arsenic concentrations is assumed to be representative of the distribution in the groundwater of the district.

Table 4. Summary of Arsenic Distributions in North 24 Parganas District

Blocks	No. habitations affected by **arsenic** (>10 µg/L)	No. samples tested	No. samples with arsenic >10 µg/L	% samples with arsenic >10 µg/L
Amdanga	58	2,676	205	7.66
Baduria	155	4,537	1,366	30.1
Bagda	140	2,312	434	18.8
Barasat I	106	2,461	194	7.88
Barasat II	135	2,251	510	22.7
Barrackpur I	30	1,168	51	4.37
Barrackpur II	2	946	3	0.32
Basirhat I	234	2,762	1,157	41.9
Basirhat II	88	1,894	160	8.45
Bongaon	167	2,082	583	28.0
Deganga	181	2,354	599	25.5
Gaighata	174	2,113	805	38.1
Habra I	198	2,337	714	30.5
Habra II	192	2,044	414	20.3
Haroa	61	2,170	123	5.67
Hasnabad	78	2,460	210	8.54
Hingalganj	9	1,447	13	0.90
Minakhan	10	2,340	21	0.90
Rajarhat	87	1,844	175	9.49
Sandeshkhali I	1	709	1	0.14
Sandeshkhali II	4	1,627	4	0.25
Swarupnagar	205	2,528	867	34.3
Total	**2,315**	**47,062**	**8,609**	**18.3**

Figure 2. Spatial Distribution of Arsenic in North 24 Parganas District, West Bengal



Data from the Ministry of Drinking Water & Sanitation, Government of India, IMIS database (2014–2017) indicate that 2,315 habitations (33.3%) have sources with arsenic concentrations above 10 µg /L. The block-wise categorization of distributions is summarised in Table 5.

According to longer-term IMIS groundwater data, least-affected areas of North 24 Parganas occur mainly in the coastal areas.

Table 5.Percentage Distribution of Arsenic-Affected Habitations in North 24 Parganas

% habitations affected by arsenic (>10µg /L)	**Block**	**No. blocks**
<50%	Bagda, Barasat I, Barrackpur I, Barrackpur II, Basirhat II, Bongaon, Gaighata, Haroa, Hasnabad, Hingalganj, Minakhan, Rajarhat, Sandeshkhali I, Sandeshkhali II	16
50–75%	Barasat II, Deganga, Habra I, Habra II, Swarupnagar	5
>75%	Basirhat I	1

µg = microgram, no. = number, < = less than, > = more than.

Source. Ministry of Drinking Water & Sanitation. Government of India, Integrated Management Information System (IMIS), 2014–2017 data. https://mdws.gov.in/.

DISTRIBUTIONS IN MURSHIDABAD DISTRICT

A study of arsenic in groundwater in Murshidabad by Rahman, et al. (2005) reported analyses from 29,612 hand-pumped tube wells across the district, of which 26% were found to have arsenic concentrations above 50 µg/L and 53.8% above 10 µg/L. Of the 26 blocks in Murshidabad, 24 were found to have some occurrences of arsenic >50 µg/L. The investigation estimated that 2.5 million people were exposed to drinking water with more than 10 µg/L with 1.2 million people exposed to more than 50 µg/L. The total population of the district was estimated at 5.3 million and the total number of tube wells at 0.2 million.

According to PHED (2006) data, using population statistics from the 2001 Census and a threshold of 50 µg/L, a total of 4 million people in Murshidabad inhabit 19 blocks affected by high-arsenic drinking water (Table 6). These affected blocks are located mainly to the east of the Bhagirathi River.

Table 6. Population of Arsenic-Affected Blocks in Murshidabad District

Arsenic-affected block (>50 µg/L)	Population of block
Beldanda I	259,000
Beldanga II	210,000
Berhampur	379,000
Bhagwangola I	163,000
Bhagwangola II	130,000
Farakka	220,000
Hariharpara	222,000
Jalangi	216,000
Lalgola	268,000
Murshidabad-jiaganj	200,000
Nawda	196,000
Raghunathganj I	154,000
Raghunathganj II	193,000
Raninagar I	155,000
Raninagar II	156,000
Samserganj	212,000
Suti I	139,000
Suti II	213,000

Fluoride

Fluoride-contaminated groundwater was first detected in West Bengal in 1997. Exceedances were noted in the Nasipur area of Nalhati I block in the district of Birbhum, after which the government took rapid action to provide an alternative water supply based on river-bed tube wells from River Tripita.

The Geological Survey of India (GSI) undertook a follow-up study during 1999–2000 covering an area of some 600 sq. km of West Bengal in order to determine the scale and cause of contamination. Fluoride problems were found to be mostly associated with tube wells abstracting from basaltic rocks of the Rajmahal Traps (http://www.wbphed.gov.in). Shear zones in Precambrian rocks were also found to be associated with high-fluoride groundwater in parts of Purulia and Bankura districts. Dug wells, ponds, and shallow tube wells tapping alluvium had low fluoride concentrations (<1.5 mg/L).

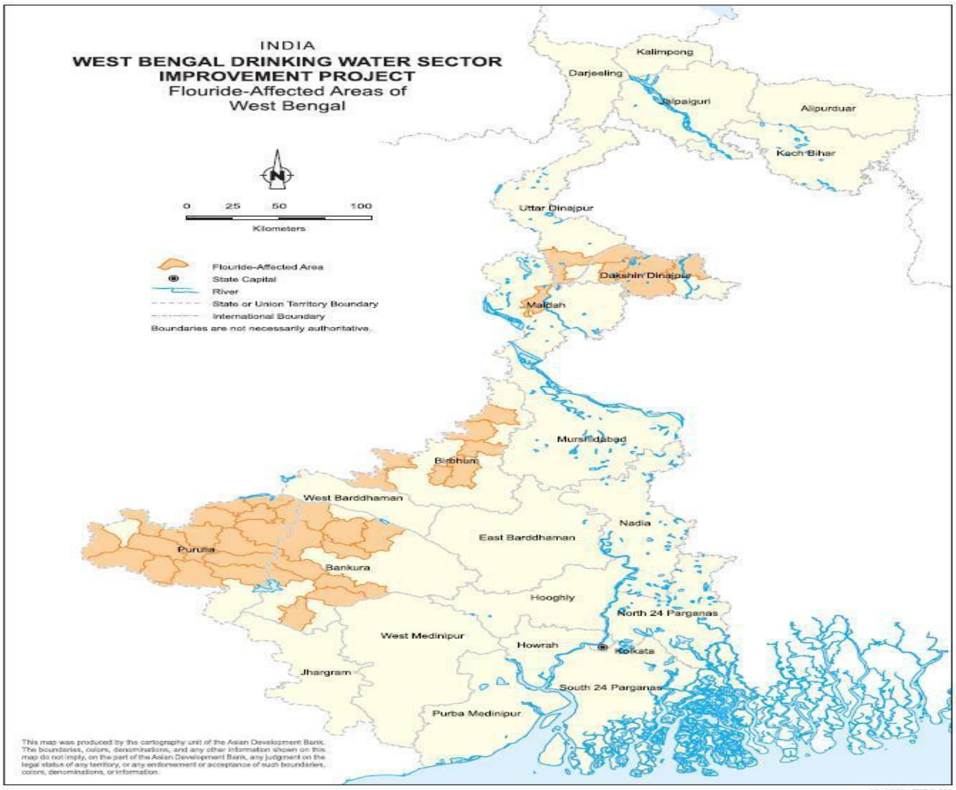
A fluoride committee constituted by PHED with the involvement of several organizations, instigated a rapid assessment of fluoride in groundwater sources across West Bengal in 2003.

The survey covered 107 blocks in 12 districts and found fluoride concentrations exceeding 1.5 mg/L in groundwater from 43 blocks in seven districts (Table 10) (PHED, 2013). Subsequent testing of all hand-pumped tube wells in the 43 blocks found 3.88% exceeding the acceptable government standard.

Table 10. Blocks in West Bengal Affected by Fluoride at Concentrations >1.5 mg/L

District	Fluoride-affected blocks	No. blocks
Bankura	Bankura II, Barjora, Chhatna, Gangajalghati, Hirbandh, Indpur, Raipur,Saltora, Simlapal, Taldangra	10
Birbhum	Khoyrasol, MayureswarI,Nalhati I, Rajnagar, Rampurhat I, Sainthia, Suri II	7
Dakshin Dinajpur	Bansihari, Gangarampur, Kumarganj, Kushmundi, Tapan	5
Malda	Bamangola, Ratua II	2
Purulia	Arsha, Bagmundi, Balarampur, Barabazar, Hura, Jaipur, Jhalda I, Kashipur, Manbazar I, Neturia, Para, Puncha, Purulia I, Purulia II, Raghunathpur I, Raghunathpur II, Santuri	17
S 24 Parganas	Baruipur	1
Uttar Dinajpur	Itahar	1
Total		**43**

Figure 3. Map of Fluoride-Affected Areas in West Bengal



Data from the PHED shows that as of August 2016, an estimated 615,000 people in the state were affected by fluoride >1.5 mg/L (Table 11).[19]

Interventions by PHED to reduce fluoride exposure in the affected districts have resulted in the provision of piped water supplies in Birbhum, Dakshin Dinajpur, and Purulia.

Table 11. Fluoride-Affected Habitations in West Bengal

District	No. habitations	Total population	Affected habitation	Affected population	% population affected
Bankura	6,638	3,403,362	43	30,570	0.90
Birbhum	4,335	3,416,742	51	55,671	1.60
Dakshin Dinajpur	4,788	1,480,800	701	251,917	17.00
Maldah	7,787	5,717,269	4	2,110	<0.05
Purulia	4,363	2,802,601	229	245,900	8.80
Uttar Dinajpur	3,687	2,672,341	18	28,985	1.10
Total	**31,598**	**19,493,115**	**1046**	**615,153**	**3.20**

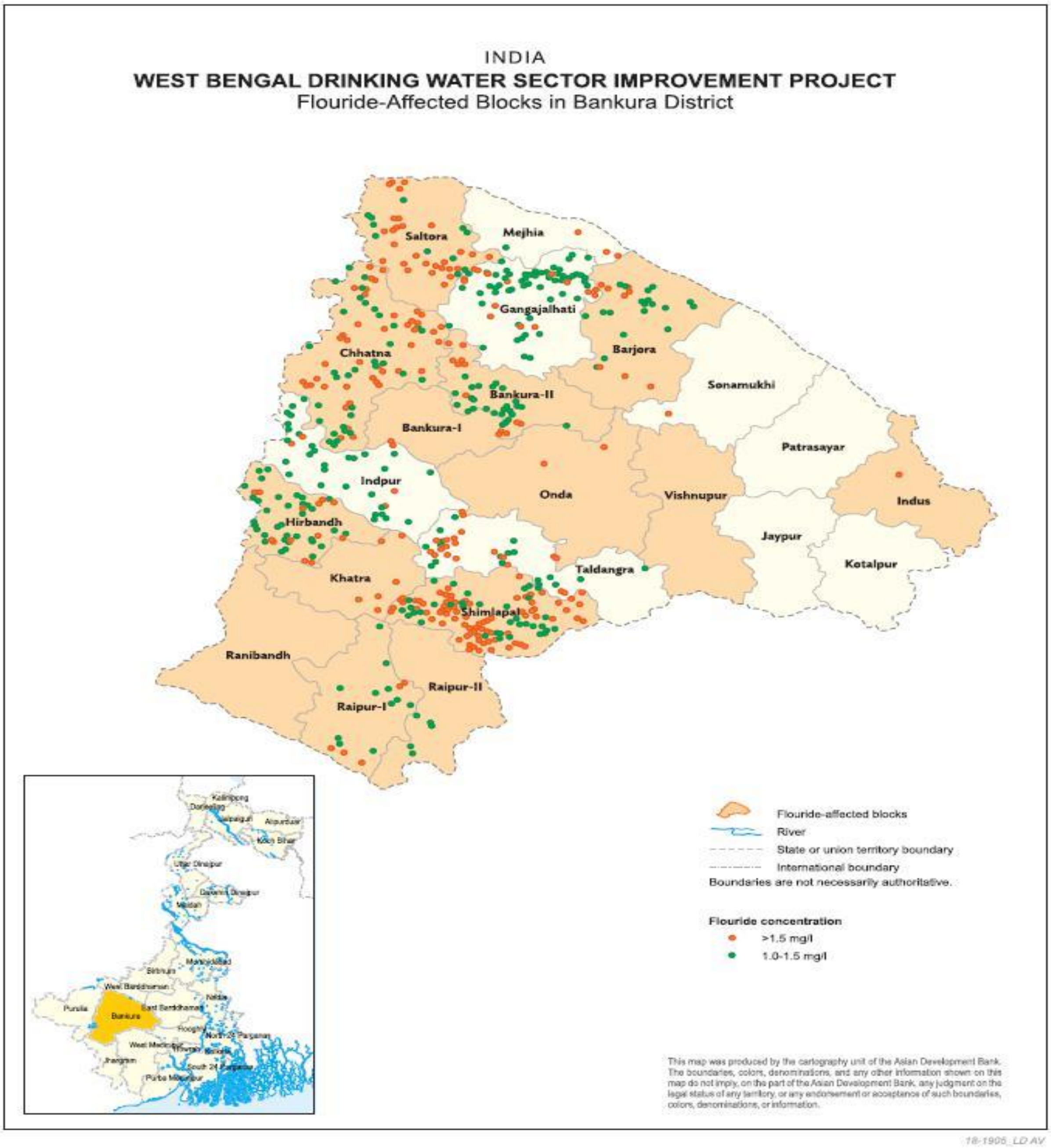
Source: Government of West Bengal, Public Health Engineering Department. Integrated Management Information System (IMIS). August 2016 data.

DISTRIBUTIONS IN BANKURA DISTRICT

According to the Central Ground Water Board of Government of India (CGWB), high fluoride concentrations in 10 blocks of the Bankura district are associated with fractured granite or older alluvium in tube wells at 40–50 meters depth.

The distribution of fluoride exceedances according to the water quality monitoring and surveillance system adopted by the PHED is shown in Figure 4. Green dots denote fluoride concentrations of 1.0–1.5 mg/L; orange dots greater than 1.5 mg/L.

Figure 4. Map Showing Distributions of Fluoride-Affected Blocks in Bankura District



Government of India, Ministry of Drinking Water & Sanitation. Integrated Management Information System (IMIS). 2013–2017 data for fluoride in groundwater for the years 2013–2017 are summarized in Table 12. The data reveal that 275 habitations were affected by high-fluoride groundwater. Of 52,834 samples tested across 21 blocks, 413 samples (0.78%) exceeded 1.5 mg/L. Most of these were from tube wells. The 1,046 samples (1.98%) had concentrations between 1.0 and 1.5 mg/L.

Table 12. Fluoride-Affected Blocks in Bankura District

Name of block	Samples tested	Fluoride >1.5 mg/L		Fluoride 1.0–1.5 mg/L		Habitations	
		No.	%	No.	%	>1.5 mg/L	1.0–1.5 mg/L
Bankura I	1854	2	0.11	29	1.56	2	18
Bankura II	2657	25	0.94	95	3.58	19	53
Barjura	2751	18	0.65	35	1.27	13	20
Bishnupur	2368	0	0.00	3	0.13	0	3
Chhatna	5,250	67	1.28	198	3.77	47	137
Ganjagalghati	5,007	26	0.52	259	5.17	20	107
Hirabandh	1,684	10	0.59	53	3.15	10	41
Indpur	2,651	7	0.26	36	1.36	7	27
Indus	2,077	2	0.10	2	0.10	2	2
Jaypur	2,054	0	0.00	0	0.00	0	0
Khatra	1,842	6	0.33	4	0.22	5	4
Kotulpur	1,737	0	0.00	2	0.12	0	2
Mejia	867	4	0.46	61	7.04	4	23
Onda	3,378	1	0.03	1	0.03	1	1
Patrasayer	1,704	0	0.00	0	0.00	0	0
Raipur	2,462	11	0.45	29	1.18	5	22
Ranibundh	2,104	0	0.00	6	0.29	0	5
Saltora	1,969	43	2.18	131	6.65	31	59
Sarenga	1,425	2	0.14	0	0.00	2	0
Simlipal	2,149	167	7.77	68	3.16	95	57
Sonamukhi	1,704	1	0.06	0	0.00	1	0
Taldangra	3,140	21	0.67	33	1.05	12	19
Total	**52,834**	**413**	**0.78**	**1,046**	**1.98**	**276**	**600**

Ten blocks were found to have groundwater sources with more than 0.4% fluoride exceedance, five were found to have <0.4% exceedances, and five more had no exceedances (Table 12). Simlipal is the worst-affected block with 95 habitations recording fluoride concentrations >1.5 mg/L.

An independent analysis carried out with updated data sourced from PHED indicated that habitations were affected by fluoride in 17 blocks of Bankura district (Table 13).

Table 13. Fluoride-Affected Blocks in Bankura District

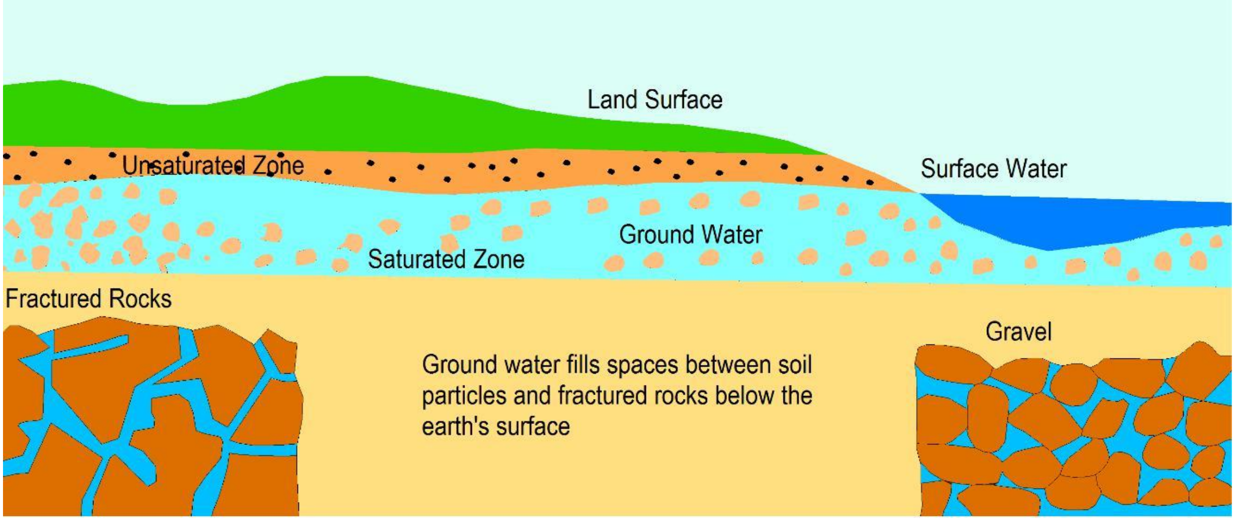
Name of block	Fluoride-affected habitations (>1.5 mg/L)
Bankura I	5
Bankura II	27
Chhatna	52
Ganjagalghati	19
Hirabandh	10
Indpur	7
Indus	1
Khatra	8
Mejia	4
Onda	2
Raipur	6
Saltora	28
Sarenga	2
Simlipal	100
Sonamukhi	1
Taldangra	12

Quantitative Overview of Ground water in India

Introduction

Ground water is the water that seeps through rocks and soil and is stored below the ground. The rocks in which ground water is stored are called aquifers. Aquifers are typically made up of gravel, sand, sandstone or limestone. Water moves through these rocks because they have large connected spaces that make them permeable. The area where water fills the aquifer is called the saturated zone. The depth from the surface at which ground water is found is called the water table. The water table can be as shallow as a foot below the ground or it can be a few hundred meters deep. Heavy rains can cause the water table to rise and conversely, continuous extraction of ground water can cause the level to fall. Figure 1 illustrates the major definitions used in the context of groundwater.

Figure 1: Graphical representation of ground water and associated terms



The underground (hydrogeological) setting of ground water defines the potential of this resource and its vulnerability to irreversible degradation.[1] This setting in India can be divided into following categories, which are described below:

- **Hard-rock aquifers of peninsular India:** These aquifers represent around 65% of India's overallaquifer surface area. Most of them are found in central peninsular India, where land is typically underlain by hard-rock formations. These rocks give rise to a complex and extensive low-storage aquifer system, where in the water level tends to drop very rapidly once the water table falls by more than 2-6 meters. Additionally, these aquifers have poor permeability[*] which limits their recharge through rainfall. This implies that water in these aquifers is non-replenishable and will eventually dry out due to continuous usage

Alluvial aquifers of the Indo-Gangetic plains: These aquifers, found in the Gangetic and Indusplains in Northern India have significant storage spaces, and hence are a valuable source of fresh water supply. However, due to excessive ground water extraction and low recharge rates, these aquifers are at the risk of irreversible overexploitation.

Ground water availability

As of April 2015, the water resource potential or annual water availability of the country in terms of natural runoff (flow) in rivers is about 1,869 Billion Cubic Meter (BCM)/year.[2] However, the usable water resources of the country have been estimated as 1,123 BCM/year. This is due to constraints of topography and uneven distribution of the resource in various river basins, which makes it difficult to extract the entire available 1,869 BCM/year.

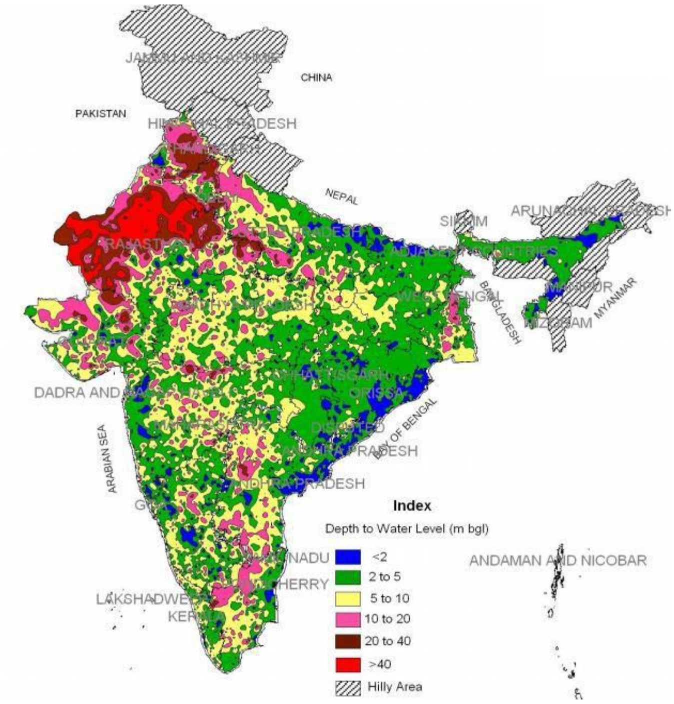
Out of the 1,123 BCM/year, the share of surface water and ground water is 690 BCM/year and 433 BCM/year respectively. Setting aside 35 BCM for natural discharge[*], the net annual ground water availability for the entire country is 398 BCM. The overall contribution of rainfall to the country's annual ground water resource is 68% and the share of other resources, such as canal seepage, return flow from irrigation, recharge from tanks, ponds and water conservation structures taken together is 32%.[4] Due to the increasing population in the country, the national per capita annual availability of water has reduced from 1,816 cubic metre in 2001 to 1,544 cubic metre in 2011.[2]This is a reduction of 15%

Table 1: Statistics regarding water resources in India

Parameter	Unit (Billion Cubic Meter/Year)
Annual water availability	1,869
Usable water	1,123
Surface water	690
Ground water	433

Sources: Water and Related Statistics, April 2015, Central Water Commission; PRS

Figure 2: Depth to water level (pre-monsoon, 2014)



The figure indicates that ground water is available at a lower level in the north-western region of the country. There are other significant pockets across the country where the depth of the water level is more than 10 metres. This implies that one has to dig deeper to reach the water table in these regions. When the ground water level crosses 10 metres, sophisticated equipment is required to extract it.

Note: m bgl denotes meters below ground level.

Sources: Central Ground Water Board; PRS.

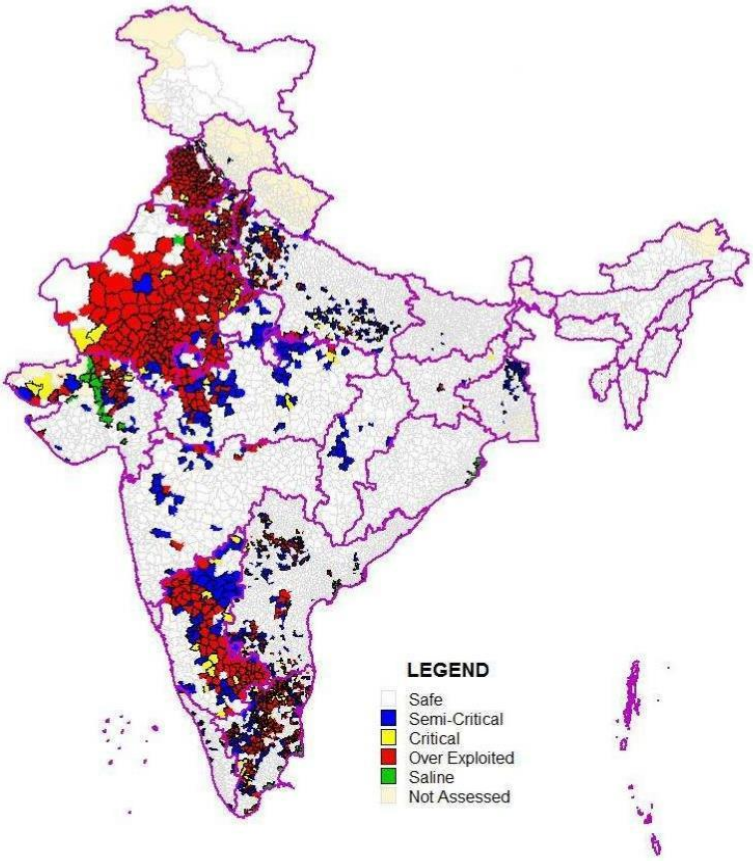
Ground water resources in the country are assessed at different scales within districts, such as blocks/mandals/talukas/watersheds. Ground water development is a ratio of the annual ground water extraction to the net annual ground water availability. It indicates the quantity of ground water available for use. Table 2 below compares the level of ground water development in the country over the past two decades.

Table 2: Comparative status of level of ground water development in India in the past 20 years

Level of ground water development	Explanation	% of districts in 1995	% of districts in 2004	% of districts in 2009	% of districts in 2011
0-70% (Safe)	Areas which have ground water potential for development	92	73	72	71
70-90% (Semi-critical)	Areas where cautious ground water development is recommended	4	9	10	10
90-100% (Critical)	Areas which need intensive monitoring and evaluation for ground water development	1	4	4	4
>100% (Over-exploited)	Areas where future ground water development is linked with water conservation measures	3	14	14	15

Sources: Central Ground Water Board; PR

Figure 3: Categorization of ground water assessment units



Note: Data as of 2011

Sources: Ground water scenario in India, November 2014, Central Ground Water Board; PRS

State	Ground water development in 2011 (%)
Andhra Pradesh	37
Arunachal Pradesh	0
Assam	14
Bihar	44
Chhattisgarh	35
Delhi	137
Goa	28
Gujarat	67
Haryana	133
Himachal Pradesh	71
Jammu & Kashmir	21
Jharkhand	32
Karnataka	64
Kerala	47
Madhya Pradesh	57
Maharashtra	53
Manipur	1
Meghalaya	0
Mizoram	3
Nagaland	6
Odisha	28
Puducherry	90
Punjab	172
Rajasthan	137
Sikkim	26
Tamil Nadu	77
Telangana	55
Tripura	7
Uttar Pradesh	74
Uttarakhand	57
West Bengal	40
Total *	62

Note: *Total includes union territories.

The level of ground water development is very high in the states of Delhi, Haryana, Punjab and Rajasthan, where ground water development is more than 100%. This implies that in these states, the annual ground water consumption is more than annual ground water recharge. In the states of Himachal Pradesh, Tamil Nadu and Uttar Pradesh and the Union Territory of Puducherry, the level of ground water development is 70% and above. In rest of the states, the level of ground water development is below 70%. Over the years, usage of ground water has increased in areas where the resource was readily available.[2]This has resulted in an increase in overall ground water development from 58% in 2004 to 62% in 2011, as illustrated in Figure

CHAPTER-4

☐ Arsenic and Fluoride Problems of Groundwater in West Bengal and Available Technologies for Remediation

India is a subcontinent country with large amount of resources, though many places in India people uses Ground water as only source for drinking and domestic purpose. But ground water is not safe in most of the places. Arsenic and Fluoride can be taken care of major concern of ground water pollution in these days. Arsenic and fluoride contamination is found in many places in India and as well as in West Bengal also. There are lots of promising technologies available for arsenic and fluoride removal but considering all the technologies it was found that using Electro-coagulation and activated alumina are convenient and suitable for removal. In West Bengal Baruipur is a place where both arsenic and fluoride is found. So, adopting appropriate technology can remove both arsenic and fluoride at same time. Further experimental analysis needs to be done for both the cases laboratory and field based.

The 85 % of rural population of the country uses ground water for drinking and domestic purposes. In West Bengal the arsenic concentration in drinking water is about 60 to 3700 μg/l and about 40 million people are affected from it. In middle Ganga plain, Bihar, 206 tube wells (95% of total) were analyzed for arsenic content and showed that 56.8% tube wells have exceeded arsenic concentration of 50 μg/l and 19.9% have more than 300 μg/l. In exposer of the arsenic level about 750 to 800 μg/l, which caused several skin and lung disease and arsenic concentration in well water used for drinking purpose were 10-1800 μg/l and a peripheral vascular disease called “Black foot disease” is a common disease among the living population due to arsenicism. High concentration of fluoride in ground water beyond the permissible limit of 1.5 mg/l poses the health problem. World Health Organization (WHO) guideline value and the permissible limit of fluoride as per Bureau of Indian Standard (BIS) is 1.5 mg/L. Excessive fluoride in drinking water causes dental and skeletal fluorosis, which is encountered in endemic proportions in several parts of the world. In small doses it has remarkable influence on the dental system by inhibiting dental caries, while in higher doses, it causes dental and skeletal fluorosis. In India 62 million people including 6 million children are affected with fluoride related health diseases.

☐ BACKGROUND

In West Bengal groundwater in 79 blocks (out of 341 blocks in the state) in the district of Malda (7 out of 15 blocks), Murshidabad (19 out of 26 blocks), Nadia (17 out of 17 blocks), North 24-Parganas (19 out of 22 blocks), South 24-Parganas (9 out of 29 blocks), Howrah(2 out of 14 blocks), Hooghly (1 out of 18 blocks) and Barddhaman (5 out of 31 blocks) is under the risk of Arsenic contamination. The problem of high fluoride concentration in groundwater resources has become one of the most important toxicological and geo-environmental issues in India. About 20 states of India, including 225 villages in 43 blocks of 7 districts were found to contain fluoride in ground water beyond permissible limit of West Bengal (Including 7 districts Birbaum, Bankura, Malda, Purulia, 24 South Parganas, Dakshin Dinajpur, Uttar Dinajpur), were identified as endemic for fluorosis and people in these regions are at risk of fluoride contamination.

☐ METHODOLOGY FOR ARSENIC REMOVAL

Many of ARP (Arsenic Removal Process) technologies can be reduced in scale and conveniently applied at household and community level, for the removal of arsenic from groundwater. For arsenic removal technics conventionally distinguished into:

(i) SMALL-SCALE WATER TREATMENT:

a. A simpler and less expensive form of arsenic removal is known as the Sono arsenic filter, using 3 pitchers containing cast iron turnings and sand in the first pitcher and wood activated carbon and sand in the second. Plastic buckets can also be used as filter containers.
b. In the United States small "under the sink" units have been used to remove arsenic from drinking water. This option is called "point of use" treatment. The most common types of domestic treatment use the technologies of adsorption (using media such as Bayoxide E33, GFH, or titanium dioxide) or reverse osmosis. Ion exchange and activated alumina have been considered but not commonly used.
c. Using black colored tablet contains Fe3+ salt, an oxidizing agent and activated charcoal. After addition of the tablet to the arsenic contaminated water, water turns black due to presence of carbon and after filtration it is easy to know whether there is any leakage from the filter.

(ii) LARGE-SCALE WATER TREATMENT:

Some large utilities with multiple water supply wells could shut down those wells with high arsenic concentrations, and produce only from wells or surface water sources that meet the arsenic standard. Other utilities, however, especially small utilities with only a few wells, may have no available water supply that meets the arsenic standard.

a. **Oxidation and filtration:** Oxidation of As (III) to As (V) by adding suitable oxidizing agent followed by coagulation, sedimentation and filtration. Oxidation and filtration normally refer to the processes that are designed to remove naturally occurring iron and manganese from water. If arsenic is present in the water, it is removed via two primary mechanisms: adsorption and co-precipitation. First, soluble iron and As (III) are oxidized. The As (V) then adsorbs onto the iron hydroxide precipitation that are ultimately filtered from solution. In general, the Fe: As mass ratio should be at least 20:1. These conditions customarily result in an arsenic removal efficiency of 80-95%.

b. **Co-precipitation:** The effectiveness of arsenic co-precipitation, with iron, is relatively independent of source water pH, in the range 5.5 to 8.5. This technology can typically reduce arsenic concentrations to less than 50 μg/L and in some cases below 10 μg/L. In order to remove arsenic by co-precipitation, coagulant is to be added. Water treatment with coagulants, such as alum [$Al_2(SO_4)_3.18H_2O$], ferric chloride [$FeCl_3$] and ferric sulfate [$Fe_2(SO_4)_3.7H_2O$], are effective in removing arsenic from water. Ferric salts have been found to be more effective in removing arsenic than alum on a weight basis and effect over a wider range of pH. In both cases, pentavalent arsenic can be more effectively removed than trivalent arsenic.

c. **Adsorption:** Activated Alumina, Iron filings (zero valent iron) and hydrated iron oxide. The technology can reduce arsenic concentrations to less than 50 μg/L in general and in some cases even below 10 μg/L. Its effectiveness is sensitive to a variety of untreated water contaminants and characteristics.

d. **Iron oxide adsorption** filters the water through a granular medium containing ferric oxide. Ferric oxide has a high affinity for adsorbing dissolved metals such as arsenic. The iron oxide medium eventually becomes saturated, and must be replaced.

e. **Ion Exchange** has long been used as a water-softening process, although usually on a single-home basis. It can also be effective in removing arsenic with a net ionic charge. (Note that arsenic oxide, As2O3, is a common form of arsenic in groundwater that is soluble, but has no net charge.)

f. **Both Reverse** osmosis and electro dialysis (also called electrodialysis reversal) can remove arsenic with a net ionic charge. (Note that arsenic oxide, As2O3, is a common form of arsenic in groundwater that is soluble, but has no net charge.) Some utilities presently use one of these methods to reduce total dissolved solids and therefore improve taste. A problem with both methods is the production of high-salinity waste water, called brine, or concentrate, which then must be disposed of.

☐ EMERGING METHODS

Besides the conventional methods mentioned above several new methods have been studied recently. Some interesting methods are shortly described below.

a. **Fe-Mn-Oxidation:** Conventional iron and manganese removal can result in significant arsenic removal, through coprecipitation and sorption onto ferric or manganic hydroxides. Most low-cost methods for arsenic and manganese removal rely on aeration and filtration through porous media such as sand and gravel. Any method that effectively removes iron and manganese could be evaluated to see if arsenic is also removed effectively.

b. **Green sand filtration:** Greensand is a granular material composed of the mineral glaucite, which has been coated with manganese oxide. It is a natural zeolite (microporous mineral), and has strong ion exchange properties, and will remove iron, manganese, arsenic, sulphide, and many other anions (Water & Wastes, 2003).Like manganese dioxide coated sand, greensand surface is strongly oxidizing, and is thus able to remove both arsenite and arsenate. This method is especially interesting to utilities where Fe and Mn are already being removed using a manganese greensand filter. It is possible that a small pH adjustment from 8+ to 6.5 may be all that is required to bring the facility into compliance.

c. **Coagulation assisted Microfiltration:** In coagulation assisted microfiltration technology, microfiltration is used in a manner similar to a conventional gravity filter. The advantages of MF over conventional filtration are a more effective microorganism barrier, removal of smaller floc sizes and an increased plant capacity (EPA, 2000). The microfiltration membrane system works to remove arsenic from water by the addition of an iron-based coagulant, such as ferric chloride, to the water. The arsenic is adsorbed onto positively charged ferric hydroxide particles, which are then removed by micro-filtration. In pilot studies, the removal of arsenic to below 2 μg/l is reported in waters with a pH between 6 and 7.

d. **In situ (sub-surface) arsenic immobilization:** When arsenic is mobilized in groundwater under reducing conditions, it is also possible to immobilize the arsenic by creating oxidized conditions in the subsurface. In Germany, in order to remediate an aquifer containing high arsenite, high ferrous iron, low-pH groundwater, potassium permanganate was injected directly into contaminated wells, oxidizing arsenite, which coprecipated with ferric oxides as ferric arsenate. Arsenic concentrations were reduced by over 99%, from 13,600 to 60 μg/l.

e. **Enhanced coagulation (aka electrocoagulation, electroflotation):** With enhanced coagulation, aka electrocoagulation or electroflotation, soluble anodes made from iron or aluminum are used. Reported advantages mentioned in laboratory studies are the in-situ oxidation of As (III) tot As (V), and better removal efficiencies than with classical coagulation. Also organic arsenic, fluoride and dissolved metals are removed by this method. Final As concentrations in groundwater are below 10 μg/l, even with high initial concentrations. An additional advantage of enhanced coagulation is the reported removal of natural organic matter (NOM).

f. **Biological arsenic removal:** Arsenic in water can be removed by microbiological processes (Rahman and Ravenscroft, 2003). Two main types of metal-microbe interactions can be potentially used for the removal of arsenic from ground water. They are (a) microbial oxidation of arsenic (III) to arsenic (V) to facilitate its removal by conventional arsenic removal processes, and (b) bioaccumulation of arsenic by microbial biomass.

g. **Phytoremediation:** Some aquatic plants have capacity to accumulate arsenic. Among these aquatic plants, Azolla and Spirodella (duckweed) species have the highest efficiency of arsenic absorption. In study it was revealed that

Sirodellapolyrhiza species was found to absorb arsenic very efficiently. The results indicated that a complete cover of Spirodellapolyrhiza could accumulate about 175 g of arsenic from a pond of one hectare area per day.

h. **Electrokinetic treatment:** Electrokinetic treatment is an emerging remediation method designed to remove heavy metal contaminants from soil and groundwater. The method is most applicable to soil with small particle sizes, such as clay. A current passed between electrodes is intended to cause water, ions, and particulates to move through the soil, waste, and water. Components arriving at the electrodes can be removed by means of electroplating or electrode position, precipitation or coprecipitation, adsorption, complexing with ion exchange resins, or by pumping of water (or other fluid) near the electrode (EPA, 2002).

i. **IOCS (iron oxide coated sand) &Memstill:** UNESCO-IHE developed an arsenic removal method based on adsorption on iron oxide coated sand (IOCS). IOCS is a by-product from groundwater treatment plants and consequently very cheap. The Netherlands Organization of Applied Scientific Research (TNO) has developed a membrane based distillation concept which radically improves the economy and ecology of existing desalination technology for seawater and brackish water. This so-called "Memstill technology" combines multistage flash and multi-effect distillation modes into one membrane module.

j. **Water Pyramid:** Aqua-Aero Water Systems has developed the Water Pyramid concept for tropical, rural areas (Aqua-Aero Water systems, 2007). The Water Pyramid makes use of simple method to process clean drinking water out of salt, brackish or polluted water. One of the pollutants could be fluoride. Most of the energy needed to clean the water is derived from the sun.

k. **Solar Dew Collector:** Solar Dew purifies water uses a new porous membrane to purify water using solar energy (Solar Dew, 2007). The technique is similar to the Water Pyramid. Water sweats through the membrane, evaporates on the membrane's surface and increases the air humidity in the evaporation chamber. Based on a temperature difference, pure water condenses on the cooler surfaces of the system.

☐ In-situ (sub-surface) arsenic treatment

In-situ remediation refers to all such techniques that make arsenic immobilization possible within the aquifer itself. As arsenic is mobilized in groundwater under reducing conditions, it is also possible to immobilize the arsenic by creating oxidized conditions in the subsurface.

a) Use of atmospheric O2 for iron and arsenic rich water In-situ treatment for the removal of arsenic, iron, manganese, or combination thereof, has been successfully applied to water wells. In the United States, in-situ remediation of other trace-elements, such as chromium, is gaining regulatory acceptance. In-situ remediation is generally thought to be less expensive than above-ground treatment.

   The concept of in-situ remediation of Fe (II) has been practiced in Europe for decades where concentrations are lowered through introduction of atmospheric O2 to Fe (II)-rich water. The process is commonly cyclic, with a period of injection followed by a period of pumping. Beside Fe (II), Mn and As conc. have also been reduced. The efficiency of removal has been noted to increase after continued cycles. In addition, even after operation of such systems for decades, clogging of wells or aquifer materials has not been reported.

b) Use of atmospheric O2 and ferrous chloride for low Iron and Arsenic rich waterThis removal technique has been demonstrated successfully from alkaline water (pH>8) with low iron load at Carson valley, USA. The low dissolved Fe content limits development of significant Fe oxide and the high pH limits As adsorption onto Fe oxide. In this case, dissolved O2, Fe (II), and HCl are added to water and injected into the aquifer to form Fe-oxide and lower the pH to remove As.

   The SAR (Sub-terranean Arsenic Removal) Technology developed by a consortium of European & Indian scientists & demonstrated at a location near Kolkata during 2005-06 is a demonstration of in-situ technology. This technology was subsequently replicated successfully in arsenic affected areas in West Bengal through World Bank Development Marketplace 2006 programme.

In this technique (Fig 7), the aerated water is stored in feed water tanks and released back into the aquifers through the tube well by opening a valve in a pipe connecting the water tank to the tube well pipe under the pump head. A number of different physical, chemical and biological processes are intensified in the surrounding area of the well screen section, the so called oxidation zone. Because of the input of oxygen, the redox potential of the water is increased. The dissolved oxygen in aerated water oxidizes arsenite to less-mobile arsenate, the ferrous iron to ferric iron and Manganese(II) to Manganese(III), followed by adsorption of arsenate on Fe(III) and manganese(III) resulting in a reduction of the arsenic content in tube well water

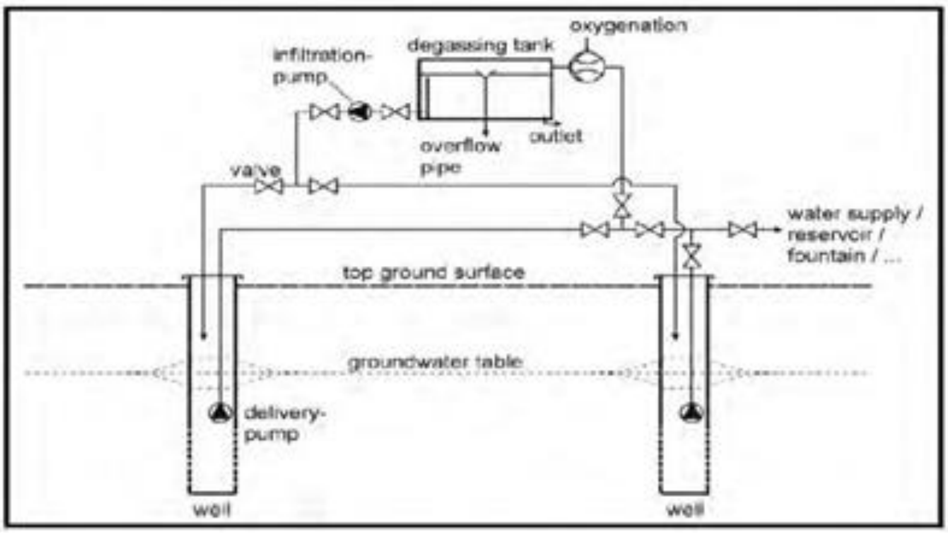


Fig: Borehole and other equipment set up in the SAR technology for in-situ arsenic remediation

Permeable Reactive Barriers (PRB) Technology In this in-situ technique, walls containing reactive media are installed across the path of a contaminated groundwater plume to intercept the plume. The barrier allows water to pass through the media which removes the components by precipitation, degradation, adsorption, or ion-exchange. This method is reported to have lower operation and maintenance costs than ex-situ (pump and treat) methods. PRBs are already commercially available and are being used to treat groundwater containing arsenic at a full scale at two sites in the USA, although arsenic is not the primary target (EPA, 2002). Four types of materials have been used in the construction of permeable reactive barriers (PRB) used in the treatment of arsenic contaminated groundwater: zero valent iron (ZVI), furnace slag, sorbents and composite materials (organic + ZVI or a sorbent). It has been observed that iron Based Sorbents (IBS) can remove efficiently both the As (III), As (V) and their mixtures. As (V) is removed easier than As (III). Some of the Iron Based Sorbents (IBS) available in the market are; Adsorpas (Technical University of Berlin), ARM 300 (BASF), G2 (ADI International), SMI III (SMI), GEH 102 (GEH Wasserchemie GmbH & Co. KG) and Bayoxide E33 (Bayer AG). Iron oxide-bearing minerals (iron-oxide coated sand) have long been recognized as an effective reactive media for arsenic-contaminated groundwater remediation. Based on it, technique has been developed to facilitate in situ oxidative precipitation of Fe^{3+} in a soil (sand) media for generating a reactive barrier that could immobilize arsenic (As) and other dissolved metals in groundwater.

c) Electrokinetic treatment:-Electrokinetic treatment is an emerging insitu remediation method designed to remove heavy metal contaminants from soil and groundwater. The method is most applicable to soil with small particle sizes, such as clay. However, its applications for treating arsenic contaminated groundwater are not of practical interest as treatment is limited by the depth to which the electrodes can be placed.

Of the various in-situ remediation techniques, in India, only the SAR technology as described above has been demonstrated successfully in parts of West Bengal. Even though, in-situ immobilization has the great advantage of not producing any wastes that must be disposed of, however, experience is limited, and the technique should be

The Biological Activated Carbon (BAC) system: In this system a granular activated carbon (GAC) filter is used, which are continuously aerated to enhance the growth of biological activity within the filter media. This system has been used in rural Saskatchewan province of Canada on experimental basis for seven years with consistent arsenic removal exceeding 90% (Pokhrel et al., 2005).In addition to the techniques mentioned above, researches have been conducted on Phytoremediation, which uses aquatic plants to accumulate arsenic and thus removing arsenic from groundwater. Azolla and Spirodella (duckweed) species have the highest efficiency. A study on duckweed was carried out in Bangladesh (Rahman and Ravenscroft, 2003) and found to be efficient. The results indicated that a complete cover of plant could accumulate about 175 g of arsenic from a pond of one hectare area per day.

☐ METHODOLOGY FOR FLUORIDE REMOVAL:

There are few technologies available for fluoride removal. The unique potentiality of these different technological methodology is unique from one another.

a. **Nalgonda Technique:** In the Nalgonda Technique two chemicals (Dahi et al. 1996), alum (aluminum sulphate or kalium aluminum sulphate) and lime (calcium oxide) are added to and rapidly mixed with the fluoride contaminated water. Induced by a subsequent gentle stirring, flocs develop (aluminum hydroxides) and are subject to removal by simple settling. The main contents of the fluoride is removed along with the flocs, due to a combination of sorption and ion exchange with some of the produced hydroxide groups.

b. **Precipitation methods:** Fluoride removal by alum (Culp et al., 1958), a method studied for application alum dose. 225 ppm of alum in increments during rapid mixing and flocculation followed by settling and rapid sand filtration was verified .It was desired to reduce the raw water fluoride concentration from 3.6 to 1.0 ppm. Boruff's (1934) investigation, aluminum sulfate dosages of 8.5 ppm (0.5 gram) to 171 ppm (10 grams) per gallon were added to 2.5 liters of raw water containing known quantities of fluorides.

c. **Activated alumina:** Activated alumina is a granular, highly porous material consisting essentially of aluminum trihydrate. The use of activated alumina in a continuous flow fluidized system is an economical and efficient method for defluoridating (Kubli et. al. (1947), Ghorai et al. 2004) water supplies. The process could reduce the fluoride levels down to 0.1 mg/L. The operational, control and maintenance problems, mainly clogging of bed, may be averted in this method.

d. **Electro coagulation (Electrochemical methods):** Electro coagulation process with aluminum bipolar electrodes was used for defluoridation process. The influence of parameters such as inter-electrode distance, fluoride concentration, temperature and pH of the solution were investigated and optimized with synthetic water in batch mode.

   The basic principle (N. Mameri, et el. 1997) of the process is the adsorption of fluoride with freshly precipitated aluminum hydroxide, which is generated by the anodic dissolution of aluminum or its alloys, in an electrochemical cell. Constraints in the above technology: Electricity is the main raw material and hence wherever electricity is not available a suitable polar panel can be installed.

e. **Bone Char:** Bone char is simply ground animal bones charred to remove all organics. It consists essentially of tricalcium phosphate and carbon. It has been utilized by Scott et al. (1937) and Sorg et. al. (1978) in full scale defluoridation plants .This material initially developed for decoloring cane syrup is more economical than bone. The ability to be regenerated by washing with caustic soda made bone char useful in fluoride removal processes.

f. **Contact Precipitation:** It is a technique by which fluoride is removed from the water through the addition of calcium and phosphate compounds and then bringing the water in contact with an already saturated bone charcoal medium.

g. **Degreased and alkali treated bones :** Degreased and alkali treated bones are effective in the removal of fluoride from initial fluoride concentration ranging from 3.5 mg fluoride/L to 10 mg fluoride/L to less than 0.2 mg fluoride/L.

h. **Synthetic tri-calcium phosphate:** The product is prepared by reacting phosphoric acid with lime. The medium is regenerated with 1% NaOH solution followed by a mild acid rinse. It has a capacity to remove 700 mg fluoride/L

i. **Florex:** A mixture of tri-calcium phosphate and Hydroxy -apatite, commercially called Florex, showed a fluoride removal capacity of 600 mg of fluoride per liter and is regenerated with 1.5% sodium hydroxide solution.

j. **Activated Carbon & Lime:** Most of the carbons prepared from different carbonaceous sources showed fluoride removal capacity after alum impregnation. High Fluoride removal capacities of various types of activated carbons had been reported. Scott et al (1937) and others showed that the decrease in fluoride concentration was a function of the amount of magnesium removed during the softening process. Upon a routine examination of raw and treated municipal water supplies, it was (Scott et al. 1937) reported that fluoride concentration in the effluents from lime softening plants showed a substantial reduction when compared to the fluoride in the raw water.

k. **Ion Exchange Resins:** Strong base exchange resins remove fluorides (Meenakshi et al. 2007). Cation exchange resins impregnable with alum solution have been found to act as defluoridation agents.

l. **Magnesia & Serpentine:** Investigations were conducted to study the usefulness of magnesia in fluoride removal. Crystalline magnesium hydroxide was obtained by reacting a magnesium salt with milk of lime. Serpentine is a mineral name, formula Mg6Si4O10 (OH). The material is green or yellow and is available in Andhra Pradesh. To test the capacity of serpentine to remove fluorides from waters (Chidambaram et al. 2003), the green and yellow varieties were studied for their defluoridation capacity.

m. **Lime stone,** special soils and clay etc.: Recently limestone and heat-treated soil were tried for fluoride removal. Limestone was used in a two-column continuous flow system (limestone reactor) to reduce fluoride concentrations from wastewaters to below the MCL (Maximum contaminant level) of 4 mg/L. On the basis of experimental data a plausible mechanism of fluoride sorption by clay minerals is suggested. Removal of fluoride by adsorption on to low-cost materials like kaolinite, bentonite, charfines, and lignite seeds was investigated.

n. **Fly Ash and natural minerals:** The removal of fluoride was attempted using natural materials such as red soil, charcoal, brick, and fly-ash. The study reveals that red soil has good fluoride removal capacity followed by brick, fly-ash and charcoal.

In the report of "Fluoride in groundwater: Overview and evaluation of removal methods" & "Arsenic in groundwater: Overview and evaluation of removal methods" by International Groundwater Resources Assessment Centre (2008) based on available information. A promising emerging technique is Enhanced Coagulation (EC). With this technique a very efficient removal of As (III) and As (V) is possible to below the recommended WHO-value of 10 μg/l. With EC also the removal of fluoride, humic substances and other harmful or toxic matters is realized (metal hydroxides). For groundwater with high iron content, also conventional iron removal techniques, like aeration and filtration, can be used to remove arsenic at low costs. However the efficiency of these techniques for As-removal is not very high. The Nalgonda process, Bone charcoal and Calcined clay are low costs methods for domestic use. On a community scale, the Nalgonda process is also a low cost option. If a high fluoride removal is necessary then activated alumina, reverse osmosis and electrodialysis are preferred methods. For brackish water only reverse osmosis, electrodialysis and the Water Pyramid/Solar Dew method can be used.

☐ In-Situ Treatment Fluoride Removal

This in situ/ex vivo study investigated the effect of CO_2 laser irradiation and acidulated phosphate fluoride gel (APF) application, separately and in combination, on enamel resistance to erosion.

Material and Methods

During 2 experimental 5-day crossover phases, 8 volunteers wore intraoral appliances containing bovine enamel blocks which were submitted to four groups: 1st phase - control, untreated and CO_2 laser irradiation, 2nd phase - fluoride application and fluoride application before CO_2 laser irradiation. Laser irradiation was performed at 10.6 µm wavelength, 5 µs pulse duration and 50 Hz frequency, with average power input and output of 2.3 W and 2.0 W, respectively (28.6 J/cm^2). APF gel (1.23%F, pH 3.5) was applied on enamel surface with a microbrush and left on for 4 minutes. Then, the enamel blocks were fixed at the intraoral appliance level. The erosion was performed extraorally 4 times daily for 5 min in 150 mL of cola drink. Enamel loss was measured profilometrically after treatment and after the in situ phase. The data were tested using one-way Repeated Measures Anova and Tukey's test ($p<0.05$).

Results:

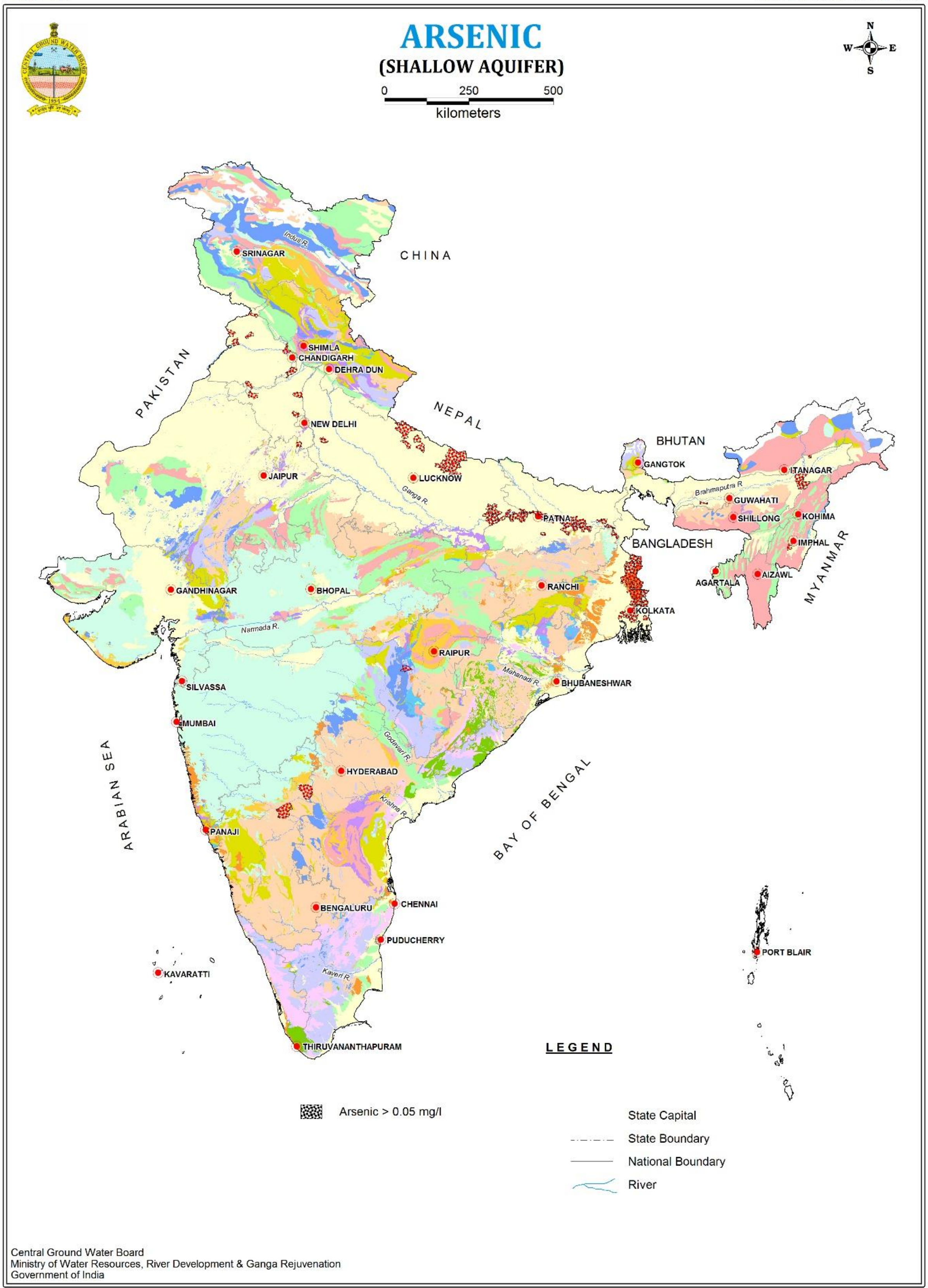
CO_2 laser alone (2.00±0.39 µm) did not show any significantly preventive effect against enamel erosion when compared with the control group (2.41±1.20 µm). Fluoride treated enamel, associated (1.50±0.30 µm) or not (1.47±0.63 µm) with laser irradiation, significantly differed from the control.

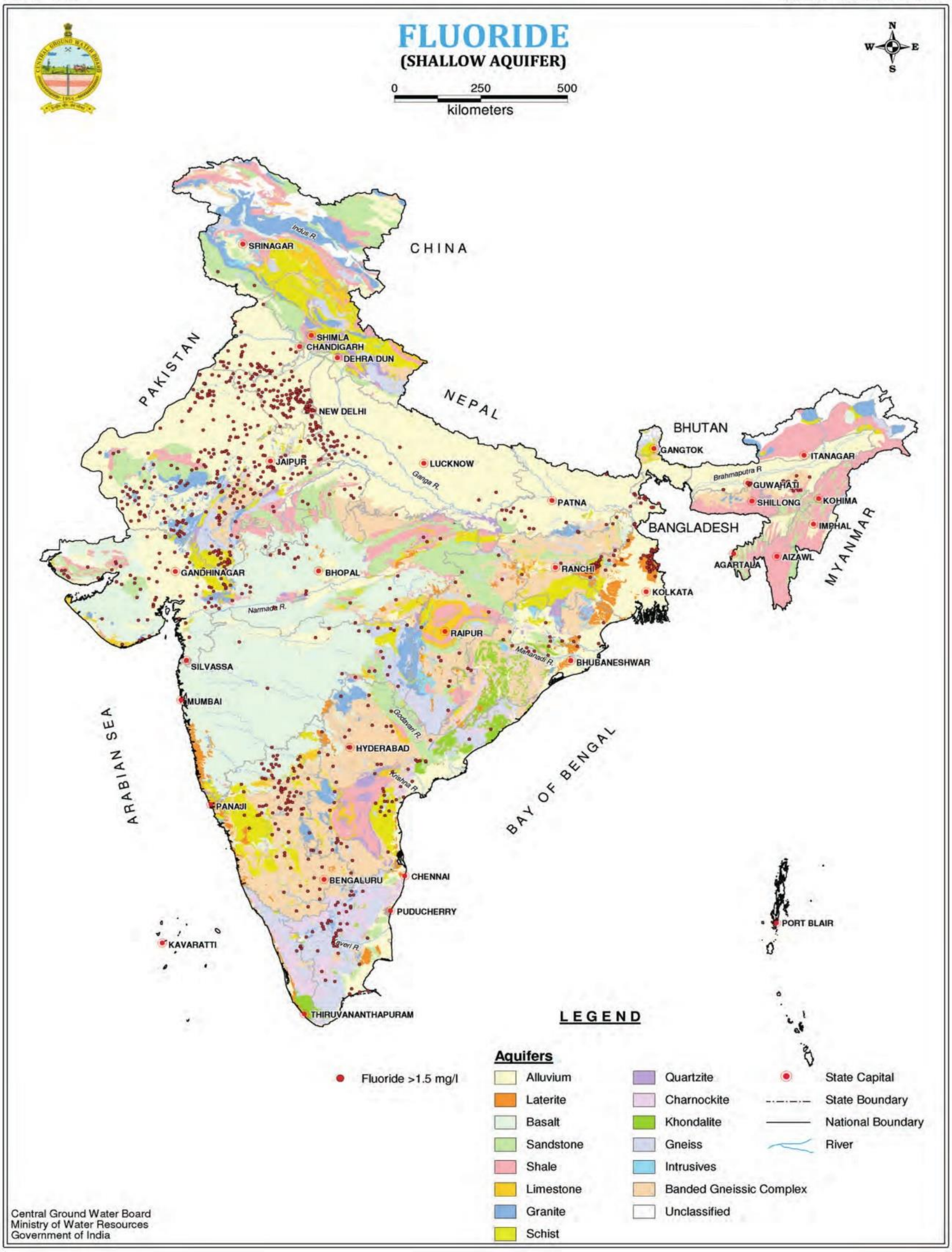
☐ Some Treatment Plant in West Bengal

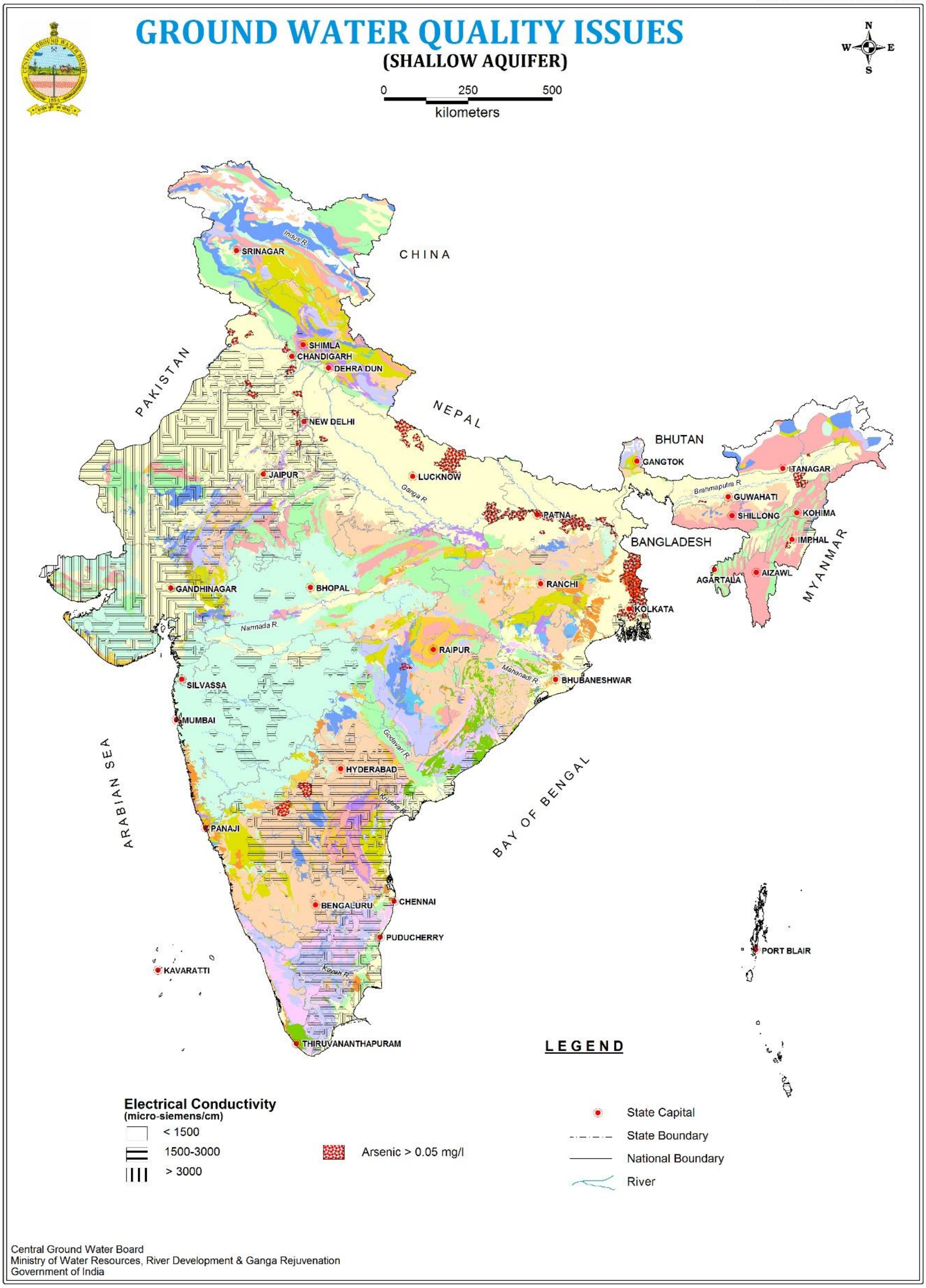
1. Techpro India | RO Water Treatment Plant Kolkata | Iron Removal Plants Kolkata
   Address: 4, Suri Lane, Ground Floor Near Neel Ratan Sarkar Medical College, Kolkata, West Bengal 700014

2. Priti International - Turnkey Project Consultants & Consultant of Water Treatment Plant
   Address: 47b, Balaram Bose 1st Ln, Jadubabur Bazar, Bhowanipore, Kolkata, West Bengal 700020

3. New Town Water Treatment Plant
   Address: Street No 51, Action Area 1A, Newtown, Kolkata, West Bengal 700156
   Phone: 094324 96157


ARSENIC
(SHALLOW AQUIFER)
0 250 500
kilometers
N
W E
S
CHINA
PAKISTAN
NEPAL
BHUTAN
BANGLADESH
MYANMAR
ARABIAN SEA
BAY OF BENGAL
SRINAGAR
SHIMLA
CHANDIGARH
DEHRA DUN
NEW DELHI
JAIPUR
LUCKNOW
PATNA
GANGTOK
ITANAGAR
GUWAHATI
SHILLONG
KOHIMA
IMPHAL
AGARTALA
AIZAWL
KOLKATA
RANCHI
GANDHINAGAR
BHOPAL
RAIPUR
BHUBANESHWAR
SILVASSA
MUMBAI
HYDERABAD
PANAJI
CHENNAI
BENGALURU
PUDUCHERRY
KAVARATTI
PORT BLAIR
THIRUVANANTHAPURAM
Indus R.
Ganga R.
Brahmaputra R.
Narmada R.
Mahanadi R.
Godavari R.
Krishna R.
Kaveri R.
LEGEND
Arsenic > 0.05 mg/l
State Capital
State Boundary
National Boundary
River
Central Ground Water Board
Ministry of Water Resources, River Development & Ganga Rejuvenation
Government of India


FLUORIDE
(SHALLOW AQUIFER)
0
250
500
kilometers
N
S
E
W
CHINA
PAKISTAN
NEPAL
BHUTAN
BANGLADESH
MYANMAR
ARABIAN SEA
BAY OF BENGAL
SRINAGAR
SHIMLA
CHANDIGARH
DEHRA DUN
NEW DELHI
JAIPUR
LUCKNOW
PATNA
GANGTOK
ITANAGAR
GUWAHATI
SHILLONG
KOHIMA
IMPHAL
AIZAWL
AGARTALA
RANCHI
KOLKATA
GANDHINAGAR
BHOPAL
RAIPUR
BHUBANESHWAR
SILVASSA
MUMBAI
HYDERABAD
PANAJI
BENGALURU
CHENNAI
PUDUCHERRY
KAVARATTI
PORT BLAIR
THIRUVANANTHAPURAM
Indus R.
Ganga R.
Brahmaputra R.
Narmada R.
Mahanadi R.
Godavari R.
Krishna R.
LEGEND
Aquifers
Fluoride >1.5 mg/l
Alluvium
Laterite
Basalt
Sandstone
Shale
Limestone
Granite
Schist
Quartzite
Charnockite
Khondalite
Gneiss
Intrusives
Banded Gneissic Complex
Unclassified
State Capital
State Boundary
National Boundary
River
Central Ground Water Board
Ministry of Water Resources
Government of India


GROUND WATER QUALITY ISSUES
(SHALLOW AQUIFER)
0 250 500
kilometers
N
W
E
S
CHINA
PAKISTAN
NEPAL
BHUTAN
BANGLADESH
MYANMAR
ARABIAN SEA
BAY OF BENGAL
Indus R.
Ganga R.
Brahmaputra R.
Narmada R.
Mahanadi R.
Godavari R.
Krishna R.
Kaveri R.
SRINAGAR
SHIMLA
CHANDIGARH
DEHRA DUN
NEW DELHI
JAIPUR
LUCKNOW
PATNA
GANGTOK
ITANAGAR
GUWAHATI
SHILLONG
KOHIMA
IMPHAL
AGARTALA
AIZAWL
KOLKATA
RANCHI
GANDHINAGAR
BHOPAL
RAIPUR
BHUBANESHWAR
SILVASSA
MUMBAI
HYDERABAD
PANAJI
CHENNAI
BENGALURU
PUDUCHERRY
KAVARATTI
PORT BLAIR
THIRUVANANTHAPURAM
LEGEND
Electrical Conductivity
(micro-siemens/cm)
< 1500
1500-3000
> 3000
Arsenic > 0.05 mg/l
State Capital
State Boundary
National Boundary
River
Central Ground Water Board
Ministry of Water Resources, River Development & Ganga Rejuvenation
Government of India

CHAPTER-5

REJECT WAST MANAGEMENT (HAZARDOUS WASTE)

☐ Introduction

Hazardous Waste, bulk of which is generated by the industries, can cause environmental pollution and adverse health effects if not handled and managed properly. Its effective management, with emphasis on minimization of generation and recycling/ reuse, taking into account economic aspects, is therefore essential. With this objective, it is felt necessary to have an appropriate strategy for the regulatory bodies, generators of waste, recyclers and operators of the facilities to minimize, recycle, treat and dispose of hazardous waste in an environmentally sound manner.

Various actions have been taken for environmentally sound management of hazardous wastes in the country. These include establishing regulatory and institutional framework, preparation of technical guidelines, development of individual & common facilities for recycle/recovery/reuse, treatment and disposal of hazardous wastes, inventory of hazardous wastes generation, identification & assessment of dump sites for the purpose of preparing remediation plans, and creating awareness amongst various stakeholders. However, these activities need to be expanded, reinforced and strengthened.

The overarching objective of this strategy is to reach the goal of “Zero Disposal of Hazardous Waste”, adopting a holistic approach encompassing reduction at source, reuse , recycle and recovery- in that order- through infusion of cost-effective innovative technologies, processes, and practices .

Further, the management of ‘end of life’ consumer products, having hazardous constituents, such as used lead acid batteries, waste electrical & electronic equipment etc., must give primacy to reuse , recycling and recovery.

Hazardous waste which is not amenable to reuse , recycling and recovery has to be subjected to physico-chemical/ biological treatment, incineration or disposal in the secured landfill.

The Strategy also addresses the issue of import of recyclable, recoverable or reusable hazardous waste not only to meet the growing needs of certain materials like non-ferrous metals but also to reduce negative environmental footprints. Import of hazardous waste from any country to India for disposal shall not be permitted.The hazardous waste management strategy incorporates the essence of the 'National Environmental Policy 2006', relevant multilateral environmental agreements like Basel Convention and the National Regulations.

☐ National Environment Policy

The "National Environment Policy 2006" has brought out management aspects of hazardous wastes in the form of an action plan which includes:

1. Develop and implement viable models of public-private partnerships for setting up and operating secure landfills, incinerators and other appropriate techniques for the treatment and disposal of toxic and hazardous waste, both industrial and bio-medical, on payment by users, taking the concerns of local communities into account.
2. Develop and implement strategies for cleanup of toxic and hazardous waste dump legacies, in particular in industrial areas and abandoned mines, and reclamation of such lands for future sustainable use.
3. Survey and develop a national inventory of toxic and hazardous waste dumps and an online monitoring system for movement of hazardous wastes. Strengthen capacities of institutions responsible for monitoring and enforcement in respect of toxic and hazardous wastes.
4. Strengthen the legal arrangements and response measures for addressing emergencies arising out of transportation, handling and disposal of hazardous wastes, as part of the chemical accident's regime.
5. Give legal recognition to, and strengthen the informal sector systems of collection and recycling of various materials. In particular enhance their access to institutional finance and relevant technologies.
6. Develop and enforce regulations and guidelines for management of e-waste, as part of hazardous waste regime.

☐ Basel Convention

India, being a Party to the Basel Convention on trans-boundary movement of hazardous wastes, is required to fulfil its objectives regarding control and reduce trans-boundary movements of hazardous wastes. Other objectives of the Convention include prevention and minimization of generation of such wastes , their environmentally sound management and active promotion of the transfer and use of cleaner technologies.

☐ Regulatory Frame Work

To regulate management of Hazardous Waste generated within the country as well as export/import of such waste, the Hazardous Wastes (Management and Handling) Rules, 1989 were notified under the Environment (Protection) Act, 1986. Any waste, which by virtue of any of its physical, chemical, reactive, toxic, flammable, explosive or corrosive characteristics causes danger or is likely to cause danger to health or environment, whether alone or when in contact with other wastes or substances has been defined as hazardous. These rules were amended in 2008 to bring greater clarity to classification of hazardous wastes by linking generation of waste streams to specific industrial processes. Simultaneously, threshold levels for concentration of specified hazardous constituents in wastes were laid down to distinguish between hazardous and other wastes. For regulating imports and exports, wastes had been classified as either 'banned' or 'restricted'. The procedure for registration of recyclers/re-processors with environmentally sound management facilities for processing waste categories, such as used lead acid batteries, non-ferrous metals waste and used/waste oil, has also been laid down

The new Rules titled 'Hazardous Waste (Management, Handling and Transboundary Movement) Rules, 2008' have been notified superseding the earlier regulation. Recycling of e-waste has also been addressed under these Rules.

The management and handling of Bio-medical wastes as well as used lead acid batteries are regulated under separate Rules made for the purpose.

☐ Categories of Hazardous Waste:

This strategy encompasses the following categories of hazardous waste:

a) Industrial wastes (hazardous) generated during production such as rejects/process residues, spent chemicals/solvents, spent catalysts, hazardous dust collected from air pollution control devices, sludge arising from waste water treatment plants etc.,
b) Date-expired products such as obsolete pesticides and medicines,
c) Discarded products such as fluorescent bulbs and tubes containing mercury, used batteries etc.,
d) E-waste
e) Hazardous waste from demolition including ship breaking activities,
f) Used oil/waste oil, and
g) Used Lead Acid Batteries.

Other types of hazardous waste, not included in this strategy, are radio-active waste and bio-medical/infectious waste which are covered under separate relevant regulations.

The high-volume low effect wastes such as fly ash, phosphogypsum, red mud, slags from pyrometallurgical operations, mine tailings and ore beneficiation rejects are excluded from the category of hazardous waste. However, management of these wastes shall be as per the guidelines issued by regulatory authorities from time to time. These guidelines should emphasize utilization of these wastes to the maximum extent.

☐ Hazardous Waste Generation

The inventory of hazardous waste generating industries and hazardous waste generated has been prepared out by the State Pollution Control Boards (SPCBs) in the States and Pollution Control Committee (PCCs) in the respective Union Territories (UTs). Currently, there are around 30,000 industries generating hazardous waste of the order of 6 Million Tonnes per annum.The terms inventory has of recyclable, also brought out detailed information on quantum of waste reusable, in landfillable and incinerable components. Such information facilitates better planning of common facilities for treatment and disposal.

The experience of industrially developed nations indicates that 1 % increase in the Gross Domestic Product (GDP) leads to 1 to 3 % increase in generation of hazardous waste. Given the fact that the GDP growth in India is rapidly accelerating, it can be reasonably projected that the hazardous waste generation in the country would increase. This strategy, therefore, acquires even more significance in the context of efforts to reduce hazardous waste generation.

Since the industries do change their products, processes, or capacity of production and as new industries get established, there is a need to periodically update inventories by the SPCBs/PCCs. Besides, it should be made mandatory on the part of industries to report changes / additions in hazardous waste generation and the steps taken by them to reduce generation of waste per unit of production.

As per the Hazardous Waste Rules, industries have to store hazardous waste properly, and in accordance with authorization issued by SPCBs/PCCs. The waste recycled either has to be reused or disposed in captive or common Treatment, Storage and Disposal Facility (TSDF) if available in the State, or incinerated in a captive incinerator of its own, or in a common TSDF having incineration facility, based on type of waste.

So far as the 'end of life' consumer products are concerned, no detailed inventory has been prepared, except for some rough estimates in respect of the e-waste. These are bound to increase in volume as the economy grows.

☐ Components of Hazardous Waste Management Strategy:

a) Waste Avoidance and Waste Minimization at Source:

In the hierarchy of waste management, waste avoidance and waste minimization have to be attempted first. This requires a close look at the processes generating hazardous waste was to incorporate feasible modification in processes, technologies and plant practices.

Dissemination of information on technological options for waste avoidance and minimization should, therefore, be a continuing exercise. Whenever switch-over to cleaner processes involves substantial investments and import of machinery/ technology, suitable financial incentives in the form of rebate in customs duty, etc need to be considered.

In the chemical industry, in particular, assessment of cleaner technologies needs to be taken up in major segments such as pesticides, dyes and bulk drugs, and their intermediates. In all such industries, wherever laboratory scale trials have been completed, setting-up of pilot/demonstration plants needs to be encouraged through suitable incentives. This would enable speedier adoption of cleaner technologies by the industry.

In cases, where techno-economic feasibility of cleaner production process has been well-established and these have been already adopted by some industrial units, such as cyanide free electroplating, a dialogue should be initiated by the concerned agencies of Central/State Governments with the industry associations for switch over to cleaner production options within a specified time period.

In the petrochemicals, bulk drug, pesticides and dye & dye intermediates sectors, product-wise opportunities available for recovery of resources, such as solvents, other reagents and by-products as well as re-generation of spent catalysts, have been well documented and need to be implemented within a specified time frame. The time frame may be fixed by the regulatory authorities in consultation with the concerned industry associations.

In order to assess the current technological status in different industrial categories and preparing action plans for phasing in cleaner production processes/technologies, MoEF may constitute dedicated Task Forces comprising of experts in the concerned field.

b) Reuse, Recovery and Recycling of Hazardous Waste:

Second in the hierarchy of waste management is reuse, recycle and recovery of useful resources from wastes, in that order. MoEF may, therefore, consider constituting dedicated waste specific Task Forces so as to explore options/opportunities of reusing, recovery and recycling of the hazardous wastes in an environmentally sound manner.

Further, to promote reuse, recovery and recycling of hazardous wastes, establishment of 'waste exchange banks/centres' should be encouraged jointly and severally by MoEF and State Governments with financial assistance. These banks/centres should not only provide information on wastes but also promote reuse, recovery and recycling technologies which up-cycle the quality of resource recovery rather than down-cycle it.

For example, recycling of non-ferrous metal wastes (zinc dross, brass dross, used lead acid batteries, copper oxide mill scale etc) offers attractive options for resource recovery. Current gap between demand and supply of lead, zinc and copper as well as the projected widening of the gap due to rapid increase in demand arising from growth in the various sectors, serves as incentive for recycling of such wastes. As compared to primary production of metals, recycling is energy efficient and environment friendly and hence, needs to be promoted. The recycling of used lubricating oil is another example of resource conservation.

At present, there are about 800 recyclers of non-ferrous metal wastes/used oil/ waste oil registered under the Hazardous Waste (Management, Handling & Transboundary Movement) Rules, 2008. The capacity registered for re-refining/ recycling of used oil & waste oil is about 1.2 Million KLA; that for non-ferrous metal wastes other than lead is 1.3 Million Tonnes per annum and for lead based waste is about 0.75 Million Tonnes per annum. Registrations have been granted to units based on their processing facilities for environmentally sound re-processing technologies. Barring a few large facilities, recycling takes place essentially in the small-scale sector. As such, there are limitations on technology up-gradation necessary to ensure re-processing in an efficient manner.

In order to promote technology up gradation, it would be necessary to incentivize re-processors with state-of-the-art facilities which not only meet the CPCB guidelines but go beyond. One such incentive could be the preferential access to imports of non-ferrous metal wastes and other wastes requiring MoEF permission to only those recyclers employing state-of-the-art facilities. To examine the cases of preferential access to import, MoEF may assign the task to the 'Technical Review Committee' comprising of experts.

Despite the registration scheme for recyclers, recycling in the unorganized sector with all its attendant environmental and health hazards is reported to continue. This underscores the importance of channelization of wastes generated. While the Battery (Management and Handling) Rules 2001, mandate return of used lead acid batteries, compliance remains unsatisfactory. It would be necessary to extend the corporate responsibility concept to the producers, for instance,in the form of a buyback scheme.

At present, there are no environmentally sound re- processing facilities in the country to recover toxic metals such as mercury from thermometers, fluorescent tube-lights etc, and cadmium from batteries. Considering the potential for serious health impacts posed by co-disposal of such hazardous wastes with municipal solid wastes, development of a system for channelization of such wastes and setting up of facilities for their re-processing deserves to be accorded high priority.

c) E-Waste (Electrical and Electronic Equipments/Assemblies)

The recycling of e-waste such as components of waste electrical and electronic assemblies comprising accumulators and other batteries, mercury- switches, activated

glass cullets from cathode- ray tubes and other activated glass and PCB capacitors etc. is also required to be regulated due to the presence of hazardous constituents. The guidelines in this regard have already been issued so as to ensure environmentally sound recycling of e-waste. The producers of electronic equipment may be required to have a centralized facility for e-waste of their brand as extended producer responsibility. In such cases, the import and export of e- waste would become necessary and should be allowed if the facility has environmentally sound processing technology. Even in case of a facility created for indigenous e-waste, a minimum scale of operation for environmentally sound processing technology is essential thereby requiring sufficient e- waste for processing. For such facilities, import of e-waste may be considered. The export of e-waste may be allowed in the event of non-availability of environmentally sound recycling facilities. The State Governments should encourage e-waste recycling projects under the public-private-partnership mode.

d) Safe disposal of hazardous waste:

Waste which cannot be reused or recycled has to be disposed of in an environmentally sound manner. Depending on the waste category, physico-chemical/bio-logical treatment, secured land disposal, incineration or any other mode of safe and environmentally sound disposal should be adopted. Design and operational norms of such facilities, either captive or common should strictly adhere to the guidelines framed by the Central pollution Control Board. Supervision of such facilities during construction stage would be necessary to ensure quality of the construction of the disposal facilities as per guidelines of Central Pollution Control Board. Post-closure monitoring of the disposal facilities would also be necessary. A separate escrow fund needs to be created for this purpose. Common facilities shall invariably be equipped with laboratory facilities to verify waste characteristics so as to decide upon treatment and disposal options including secured land filling or incineration.

☐ Setting-up of the Common Treatment, Storage and Disposal Facilities:

Currently there are 25 Common Hazardous Waste Treatment, Storage and Disposal Facilities in operation in 12 States. In addition to this, 64 sites have been identified and 35 sites have been notified for setting up of the disposal facilities. The notified sites are at different stages of development. The annual capacities of the TSDFs range from 10,000 T/annum to 1.2 lakhs T/annum with an operating life span of 15-30 years.

Common facilities including integrated facilities have to be planned following the polluter-pays principle although, at the initial stages, a certain level of assistance from the State Governments could significantly accelerate the process of setting up of these facilities and also ensure their viability in the initial years which is vital. Several State Governments have made available land at concessional rates for setting up of these facilities, which form part of the State's industrial infra-structure. The State Governments may also consider providing financial support matching the Central subsidy. For economic viability of such common facilities, the quantum of waste to be disposed of is undoubtedly the single most important factor. Considering the urgency to set up common facilities and also the imperative to make them viable, scientific planning backed by sound economic rationale is called for.

Transportation could account for a significant portion of disposal cost in the case of landfillable wastes. Location of TSDFs should therefore be close to the sources of generation. In view of the difficulties encounterd in identifying suitable sites, setting –up of TSDFs should be considered within the industrial estates.

The capacity of an integrated waste management facility should be decided based on availability of hazardous waste in the State/in nearby area. Such a facility should comprise a secured landfill, arrangements for treatment, incinerator, a laboratory capable of comprehensive analysis, and arrangement for transportation and handling of wastes including supporting infrastructure. Such a facility could also have arrangement for recovery/recycle/reprocessing.

During operation and for a stipulated period of post closure, liability for any damage caused shall rest with the TSDF operator. A separate Escrow fund should be created by the facility operator for post-closure monitoring and a liability insurance be taken to deal with liability arising due to mishaps, calamities etc.

The TSDFs should cater to meticulously delineated hazardous waste catchment areas taking into consideration their distance from the generators and availability of wastes based on the principle of hazardous waste disposal as close to the hazardous waste generation. The State

Pollution Control Boards/Pollution Control Committees should ensure that in a given hazardous waste catchment area, there are no multiple operating TSDFs.

☐ Interstate transportation of hazardous waste

Interstate movement of hazardous wastes will be required when (a) landfillable waste generated by a State is less than 10,000 tonnes per annum (TPA), (b) a company with units located in several States proposes to incinerate wastes at one facility, and (c) incinerable waste generation in a State is less than 5000 tonnes per annum at which level an incineration facility becomes financially viable. Based on mutual consultations and agreement between the State Governments, interstate movement of hazardous wastes should be permitted, in particular, to take care of the difficulties faced by some States for development of TSDFs. Subject to the above, facilities for landfilling / incineration should be set-up within two years. In any case, there should be no restriction on interstate transportation of recyclable/reusable of hazardous waste.

In case of some States/UTs, particularly the north-eastern States, combined facilities with neighboring States involving interstate movement appears to be a preferable option due to factors such as land availability and the amount of waste generated in each Sate for landfilling/incineration

For proper tracking of HW disposal in an environmentally sound manner by the State Pollution Control Boards (SPCBs)/ Pollution Control Committees (PCCs) the Manifest System of movement of hazardous waste shall be followed as per the hazardous waste regulations.

The SPCB/PCC should develop on-line tracking system for movement of hazardous waste from generation to the disposal/recovery/recycle stage.

Use of cement kilns for Hazardous Waste Incineration

Subject to implementation of suitable safeguards, incineration of high calorific value hazardous wastes in cement kilns is one of the safe alternatives to conventional incineration. The spread of cement industry in the country across the States makes this option particularly attractive.

Sludge from petrochemical industry, oil refinery and paint industry as well as spent solvents/solvent recovery residues from pesticide and Bulk drug industries are particularly suitable for this purpose in view of their high calorific value. In the cement kilns, the high flame temperature of around 2,000 oC, high material temperature of around 1,400 oC and large residence time of around 4-5 seconds ensure complete combustion of all organic compounds. Acid gases formed during combustion are neutralized by the alkaline raw material. The non-combustible residue including heavy metals gets trapped / embedded into the clinker in an irreversible manner. However, it may become necessary to carry out some blending and processing of the wastes before they are suitable for use in the cement kiln.

The Central Pollution Control Board has conducted field trials for different waste categories and also arranged to carry out monitoring of all hazardous air pollutants. As the field trials have indicated, compliance of notified emission norms for hazardous waste incinerators, use of hazardous wastes (such as ETP Sludge from dyes & dye intermediates, Tyre Chips, paint sludge, TDI Tar Residue and Refinery Sludge) as supplementary fuels in Cement Kilns need to be promoted. In view of this, the respective State Boards may issue authorizations and necessary approvals. Use of incinerable waste for energy recovery in other industries may also be explored by CPCB. In case of paint sludge, successful use after reconditioning as a primer / coating has been in practice in some of the automobile manufacturing industries. Such reuse of hazardous waste is a preferable option over co-incineration and should be encouraged.

☐ Illegal dump sites and remediation

In the absence of common facilities, illegal and clandestine dumping of hazardous waste is reported in several States. Even after waste disposal facilities have become operational in some States, the problem persists. Surveillance, both by enforcement agencies and the industry associations, needs to be stepped up to avoid illegal dumping.

Remediation / rehabilitation of dumpsites should be based on scientific assessment of contamination of soil and groundwater, and based on modeling the projected future damage. The approach for site remediation, would vary modeling of from site to site depending on the nature of pollutants, future damage potential, remediation cost etc. The remediation strategy would include excavation of waste at site and shifting it to the nearest TSDF or establishing a dedicated secured landfill. Site remediation measures may be taken up to prevent further spread of contamination through containment measures. In any case, the ‘polluter pays principle’ has to be strictly enforced which means that the polluter has to reinstate or restore the damaged or destroyed elements of the environment at his cost. To take care of cases of remediation where the polluters are not traceable, a dedicated fund should be created by the SPCB/PCC.

☐ Strengthening of Infrastructure of Regulatory Bodies

The mantle of hazardous waste management regulation is primarily on the State Pollution Control Boards at the field level. For effective discharge of their responsibility, the Boards have to be strengthened in terms of manpower, equipment, instruments and other infrastructure facilities. The Central and State Governments may support the Boards by adequate funding for effective implementation of the HW (M, H & TM) Rules, 2008. Further, training and awareness programmes for the Boards staff need to be organized periodically.

The Customs Department plays an important role in regulating import of hazardous wastes into the country. Cases of illegal imports of hazardous wastes indicate the need to plug existing loopholes. Priority areas for action include harmonization of EXIM Regulations with the provisions of HW (Management, Handling & Transboundary Movement) Rules, training of Customs Department Personnel engaged in inspection and sampling and also up-gradation of Customs Department laboratories.

Appraisers carrying out inspection of hazardous waste received need to be trained to pick up representative samples. In addition to sampling techniques, appraisers should be made aware of current hazardous wastes regulations, documentation requirements, etc. Equally important is the need to upgrade laboratory facilities at all major ports of entry. Difficulties faced by Customs authorities in distinguishing between used oil and waste oil serves as a case in point to identify the gaps. Lack of laboratory facilities for analysis of trace organics, such as PCBs, could either result in holding up of supplies for long periods of time merely on grounds of suspicion or lead to illegal imports of waste oil under the garb of furnace oil/fuel oil. Trained man-power and equipment for analysis of all important heavy metals and trace organics should be taken up and a time-bound plan prepared for their up gradation. Till such time all the ports are upgraded both in terms of equipment and training of laboratory personnel, outsourcing of laboratory related work to laboratories recognized under the Environment (Protection) Act may be considered.

☐ Disposal of date-expired drugs and pesticides

There are significant quantities of date –expired drugs and pesticides lying in various States, which need to be disposed of. The options available are (i) to have these reprocessed wherever possible by the industry which supplied them (ii) to appropriately incinerate them either through dedicated incinerators of individual industries or through incinerators available with common facilities (TSDF). In order to deal with such hazardous wastes, interstate transportation as well as its disposal in a facility as per above-stated options should be permitted by the concerned State Governments.

☐ Handling and management of hazardous waste during ship dismantling

Various materials/wastes containing hazardous constituents are handled during ship dismantling. These include used oil, waste oil, asbestos containing panels/tiles, damaged asbestos containing material, paint chips and unused chemicals like acids etc. Some of these materials can be used directly such as asbestos panels, unusedchemicals etc., some can be sold to recyclers and others need to be disposed of in TSDFs. Adequate safety systems and procedures need to be adopted during dismantling and handling of these materials/wastes. This activity is required to be regulated through State Maritime Boards, SPCBs and Factory Inspectorates, as per the comprehensive code of the Ministry of Steel.

CHAPTER-6

GROUNDWATER ARSENIC MITIGATION

INTRODUCTON

Mitigation of groundwater arsenic problems has involved a range of options including survey and monitoring for low-arsenic groundwater sources, use of alternative (Pleistocene) aquifers, treatment of arsenic-contaminated water at the surface, and on-site methods. Other non-groundwater options include rainwater harvesting, provision of treated surface water at community scale (pond sand filter) or piped surface-water supply (The World Bank, 2005) (Table 7).

Use of the deeper Pleistocene alluvial aquifers has long been a component of arsenic mitigation programmes in the Bengal Basin and other alluvial-deltaic plains of South and Southeast Asia. Careful management of these aquifers is needed, and various internal and external studies have given numerous warnings that their overexploitation risks drawdown of arsenic-rich groundwater (Fendorf et al., 2010; Radloff et al., 2011). Studies have indicated that this process may already have occurred in some heavily stressed aquifers, especially those lacking a robust aquitard layer between the two aquifer units (e.g., Vietnam, Winkel et al., 2011).

Dug wells (large-diameter wells, 'ring' wells) are also commonly observed to have relatively low concentrations of dissolved arsenic, typically below 10 µg/L. This is due to the toxic nature of the shallowest horizons of the Holocene aquifers, close to the piezometric surface.

Dug wells offer some prospects for mitigation of groundwater arsenic problems but suffer the limitations of reduced yields in the dry season when water levels fall and the increased risk of surface-borne pollution. Sustainability of these sources is therefore questionable in some areas.

On-site or in-situ methods for removal of arsenic have been applied on a pilot scale in some western countries (e.g., the United States of America, Paul et al., 2010; Welch, et al., 2008) and in recent years in South and Southeast Asia (Sarkar and Rahman, 2001) (Box 1). In-situ methods rely on one of two basic principles, one based on aeration of the groundwater in the presence of dissolved iron and the other on reducing the groundwater to facilitate sulfate reduction. Both are microbially-mediated. In the first method, aerated (oxidized) water is introduced into the affected aquifer to promote oxidation of the reduced trivalent arsenic to the oxidized pentavalent form. This, in turn, promotes iron oxide precipitation as grain coatings locally around the tube well inlet, with sorption of the pentavalent arsenic onto the oxide mineral surfaces. The aeration approach is based on long-established on-site methods for removal of iron and manganese in groundwater. For example, the in-situ removal method, Vyredox® method (Hallberg and Martinell, 1976), first developed in Finland, is in use in several places in Europe.

In the second method, sulfate and organic carbon with or without zero-valent iron, are introduced to the affected aquifer to promote precipitation of iron sulfide or arsenic sulfide with co-precipitation or sorption of dissolved arsenic (O'Day et al., 2004). The sulfide-reducing method has been tested less widely than the aeration method. Although several laboratory studies of microbial sulfate-reduction methods have been carried out (Xie et al., 2016), few field-based operations have been tested.

One 2009 study of artificial recharge of rainwater collected via a recharge pit into a shallow high-arsenic tube well (16 meters deep) in Ashoknagar, Habra I block, North 24 Parganas, also indicated a reduction in concentrations of arsenic over the period of investigation. An initial concentration of 128 pg/L in the tube well was reduced to 80 pg/L after 1 month and to <1 pg/L after 3 months during the dry season.

Table 7. Pros and Cons of Groundwater Arsenic Mitigation Options, West Bengal

Mitigation measure	**Pros**	**Cons**
Dug well	Inexpensive, many exist already	Not well accepted by the people of West Bengal; prone to urface-borne contamination. Limited supply may dry up in the dry season
Hand-pumped tube well	Inexpensive, simple toinstall. Statistical distributions indicate that many are low in arsenic, even in affected areas.	Needs to be tested for arsenic, identified, and monitored. Involves major testing program.
Rainwater harvesting	High rainfall allows storage	Contamination of water during collection and storage. May be insufficient storage for perennial supply.

Pond sand filter		Untreated water may be contaminated with surface pollutants; requires installation, maintenance, monitoring
Deep tube well	Free from surface-borne contaminants	Needs careful management to counter over-abstraction; needs monitoring; deep aquifer may not exist in all areas; more expensive

Mitigation measure	Pros	Cons
		to install and pump than shallow tube wells
Off-site arsenic removal from Groundwater		High maintenance demands; needs regular monitoring, sludge removal; domestic systems typically small volume and time-consuming; long-term sustainability doubtful
On-site arsenic removal plant	No sludge removal	Pilot schemes: no major uptake of methodology; long-term sustainability questionable; vulnerability to clogging of aquifer
Piped water supply (surface water or groundwater)	Potential for household supply, Improved Water quality and hygiene, convenience. Improved long-term security. Centralised treatment with efficiencies.	High capital cost; requirement for maintenance; requirement for monitoring.

SUB-TERRANEAN ARSENIC REMOVAL

West Bengal, a pilot aeration-based in-situ subterranean arsenic removal (SAR) water treatment plant was set up in Kasimpore, North 24 Parganas, in 2004. The project was funded by the European Union and led by researchers at Queen's University Belfast (Sen Gupta et al., 2009). Subsequent funding by the World Bank led to the installation of six operational plants in 2008 (http://www.insituarsenic.org). The operation involves storage of aerated tube well water in tanks with reintroduction to the aquifer via the abstraction tube well. Some 20% of the water is reintroduced, the remainder provided for use by the community. Water-quality monitoring has been set up to test for arsenic. Initial groundwater arsenic contents of some 100–250 mg/L have been reduced to less than 50 mg/L. Each treatment plant has been delivering 3,000–4,000 liters of low-arsenic, low-iron drinking water per day to the rural community since 2008, without clogging of the aquifer pore spaces. Typical production costs are $1 per 2,000 liters. The plants and technology set up in West Bengal have won a number of innovation awards. On-site plants have also been installed in Bangladesh, Cambodia, Malaysia, and Viet Nam.

The efficacy of the methodology is dependent on factors such as initial concentrations of arsenic and iron. The reduction of the drinking-water standard from 50 µg/L to 10 µg/L poses an additional challenge for remediation. Addition of ferrous iron may improve the efficacy in low-iron groundwater conditions. Pilot schemes with addition of ferrous iron have been tested in the United States of America (Paul et al., 2010; Sheffer, 2010) and the People's Republic of China (Wang, 2017). On-site methods have the advantage of reduced requirement for surface infrastructure and no sludge disposal compared with off-site systems. Areas of uncertainty include site variability (e.g., in the iron/arsenic ratio in the groundwater, reaction times, reductive capacity of the aquifer, porosity, and sustainability). Clogging of aquifer pore spaces over time is a concern.

On-Site Water Treatment Plants Installed in West Bengal by the World Bank-Funded Project Consortium Led by Queen's University Belfast

Location	District
Basirhat, Merudandi	North 24 Parganas
Basirhat, Purbapara	North 24 Parganas
Nilgunj, Rangapur	North 24 Parganas
Chakdah, Ghetugachi, Gotra,	Nadia
Gobardanga, Tepul	North 24 Parganas
Naserkul, Ranaghat	Nadia

MITIGATION EXPERIENCES ELSEWHERE

The earliest observations of arsenic occurrence in drinking water with its resultant health problems were possibly made in Argentina in the early 1900s, subsequently in 1950s in a couple of other countries of South America and East Asia region problems were tackled in these regions by the provision of piped water supplies (treated groundwater in Argentina and Mexico; treated surface water in other countries). In the Lagunera area of Mexico, a 100 km long aqueduct supplied treated water to the affected area, with cost recovery through tariffs (Alaerts and Khouri, 2004). Arsenic problems in these regions are now largely historical.

Discoveries of arsenic contamination in the large alluvial aquifers of South and Southeast Asia are a more recent phenomenon, beginning with West Bengal in 1988. Problems are most commonly associated with Holocene alluvial and deltaic aquifers occupying the major river deltas of the region, originating from the Himalayan highlands.

Arsenic problems were first recognized in Cambodia in 2000 (Feldman et al., 2007). Occurrences have analogies with those of West Bengal, contamination being observed in groundwater from the lower part of the Mekong River Basin. The population at risk in Cambodia is estimated to 100,000 , and installation of arsenic removal plants in tube wells appears to be the most common mitigation option (Sampson et al., 2008). International organizations such as ADB and UNICEF have supported Cambodia in installing small-scale domestic arsenic filters. As of 2012, some 27,000 rural households had been supplied with arsenic filters.

Occurrences in Viet Nam also emerged in 2000 (Berg et al., 2001). High arsenic concentrations are found in groundwater from the Red River and Mekong River deltas. Around 1 million people are estimated to be or have been at risk. Public drinking-water supply is pumped from a deep Pleistocene low-arsenic aquifer at 150–250m depth. Mitigation of rural water supplies has included domestic water treatment and small-scale piped supply schemes.

The country considered to be worst-affected by groundwater arsenic problems is Bangladesh. Problems were first identified in 1993 in the western part of Bangladesh, across the border from West Bengal. Rapid surveys identified the problem as widespread, and estimates of exposure were placed at 57 million people above a concentration of 10 µg/L and 35 million people above 50 µg/L (BGS and DPHE, 2001). The government made a commitment in 2004 to prioritise mitigation through supply of treated surface water, but measures implemented have varied, including well switching and surface treatment (short-term), and longer-term options using deep tube wells, rainwater harvesting, centralised iron removal plants, and pond sand filters in places where piped water supply is not geographically or economically feasible (The World Bank, 2016). Mitigation measures are undertaken with community participation. Arsenic-contaminated tube wells have been painted red, and mitigation efforts include awareness campaigns and arsenic testing. Testing of groundwater for arsenic from 5 million tube wells up to the mid-2000s resulted in the switching of some 29% of the affected population from high- to low-arsenic tube wells. A further 12% of the affected population was served by the construction of deep low-arsenic tube wells (Hug et al., 2008). According to the World Bank-supported Bangladesh Rural Water Supply & Sanitation Project (The World Bank, 2016), rural piped water supply schemes have been set up in 37 villages on a pilot demonstration basis through private–public partnership as of 2016. The project reports that 924,000 people have been supplied with improved water sources, 14,000 tube wells have been constructed or rehabilitated, 100% of new tube wells installed have been tested for arsenic, and 28,000 households have been connected to new piped supplies (The World Bank, 2016). Despite mitigation interventions, however, Human Rights Watch still estimates some 20 million people are exposed to arsenic in drinking water (above 50 μg/L)

(Human Rights Watch, 2016). Although well switching has been responsible for the greatest reduction in arsenic exposure to date, it can only be considered a short-term measure in conditions where the switched well offers a non-sustainable supply (Milton et al., 2012).

The varying operational responses to arsenic contamination of groundwater mentioned in paras. 35–47 indicate the complexities of the problem and the lack of unifying appropriate approach. Responses depend on scale, population and its distribution, hydrographic, geological, and hydrogeological conditions, and socio-economic and institutional factors.

GROUNDWATER FLUORIDE MITIGATION MEASURES

PHED has prepared a comprehensive action plan on fluoride mitigation in West Bengal. This has an estimated cost of $235 million and will be implemented in a phased manner in the 43 fluoride-affected blocks of seven districts (Bankura, Birbhum, Dakshin Dinajpur, Malda, Purulia, South 24 Parganas, and Uttar Dinajpur). Technological options for fluoride treatment are being explored where no alternate surface-water source is available nearby (Table no-14)

Mitigation measure	Pros	Cons
Dug well	Inexpensive, many exist already	Not well accepted by the people of West Bengal; prone To surface-borne contamination. Limited supply. May dry up in the dry season.
Hand-pumped/motorized tube Well	Many are low in fluoride, even in affected areas	Needs to be tested for fluoride and monitored.
Rainwater harvesting	Sufficient rainfall to allow collection	Contamination of water during collection and storage.
Off-site fluoride removal	Household or community scale, various established methods	Requires regular maintenance; may impart taste to treated water; some residues may remain; sludge disposal; requires capacity monitoring; may be limited; sustainability is questionable.
Managed aquifer recharge (MAR) schemes	No sludge removal, various methods applicable for differing settings	May not be effective against fluoride, needs monitoring.
Piped water supply (groundwater or surface water)	Potential for household supply, improved water and quality, hygiene; convenience. Improved long-term security. Centralised treatment with efficiencies	High capital cost, requires maintenance and monitoring.

Table 14. Pros and Cons of Groundwater Fluoride Mitigation Options, West Bengal

A significant number of piped water-supply schemes have already been commissioned in fluoride-affected districts, and others are in progress to supply fluoride-free drinking water in the affected areas of the state (Table 15).

Table 15. Coverage by Piped Supply Schemes in Fluoride-Affected Districts of West Bengal

District	Rural Population	Total population	No. blocks	No. water supply schemes	Scheme Started	% served by piped supplies
Bankura	3,296,901	3,596,674	22	60	May 2017	21.3
Burbhum	3,052,956	3,502,404	19	64	Jun 2017	35.0
Dakshin Dinajpur	1,439,981	1,676,276	8	54	May 2017	33.4
Malda	3,447,185	3,988,845	15	116	May 2017	58.1
Purulia	2,556,801	2,930,115	20	42	May 2017	27.0
South 24 Parganas	6,074,188	8,161,961	29	189	May 2017	46.1
Uttar Dinajpur	2,644,906	3,007,134	9	67	Jun 2017	17.4

Of the recognized fluoride-affected districts, two of the least well-served are Bankura and Uttar Dinajpur (Table 15).

The options for mitigation of fluoride problems are more limited in drought-prone areas, which are typical of fluoride terrains. Mitigation measures include survey and monitoring of tube wells/dug wells to identify groundwater sources with sustainably low concentrations (<1.5 mg/L), rainwater harvesting (possibly for parts of the year), community-scale groundwater or surface-water treatment (Haldar and Ray, 2014), shallow aquifer storage (‘subsurface’ storage), managed aquifer recharge (MAR), or piped supply.

The main objectives of MAR schemes are to increase storage volume in aquifers or to treat water or wastewater via subsurface filtration (Maliva, 2014). MAR is an established technology that has operated successfully over many years in many countries, including India. It has been adopted effectively in arid and semi-arid areas (Tuinhof and Heederik, 2002). MAR schemes have shown a marked expansion in India since the mid-1990s; Chadha (2002) described a national master plan for the development of a total area of 450,000 km2 for MAR to store 36 billion m3 of water, including 37,000 percolation tanks, 110,000 check dams, 48,000 recharge wells, and 26,000 gabion structures.

The MAR schemes tend to be economically viable provided that hydrogeological conditions are favorable and end use is high value (i.e., potable water) (Maliva, 2014). Potential additional benefits include reduced groundwater pumping costs, maintenance of spring flows and alleviation of saline intrusion.

MAR has long been suggested as a means to reduce fluoride concentrations in groundwater, as well as to augment groundwater resources. MAR schemes have been implemented through the construction of check dams, recharge wells, percolation ponds and/or tanks, and infiltration galleries (Box 2). Positive benefits in terms of fluoride concentrations have been demonstrated in water-supply wells locally from the introduction of check dams (Bhagavan and Raghu, 2005; Brindha et al., 2016) and dug recharge wells (Brindha et al., 2016).

Despite these observations, documentation on MAR implementation appears to suggest mixed outcomes for fluoride mitigation (Brindha et al., 2016) as well as for water budgets (Boisson et al., 2015). Some supply wells have shown limited changes, or even increased fluoride concentrations (Bhagavan and Raghu, 2005). Raising the groundwater level can bring previously unsaturated aquifer horizons into the zone of water-level fluctuation, the mineralogy, and texture of which may influence water quality (e.g., Hallett et al., 2015). Raising the groundwater level to a point near the ground surface could also increase concentrations of fluoride and dissolved salts through evaporation. The potential of MAR schemes for fluoride mitigation is therefore significant, but the outcomes are site-specific and require monitoring.

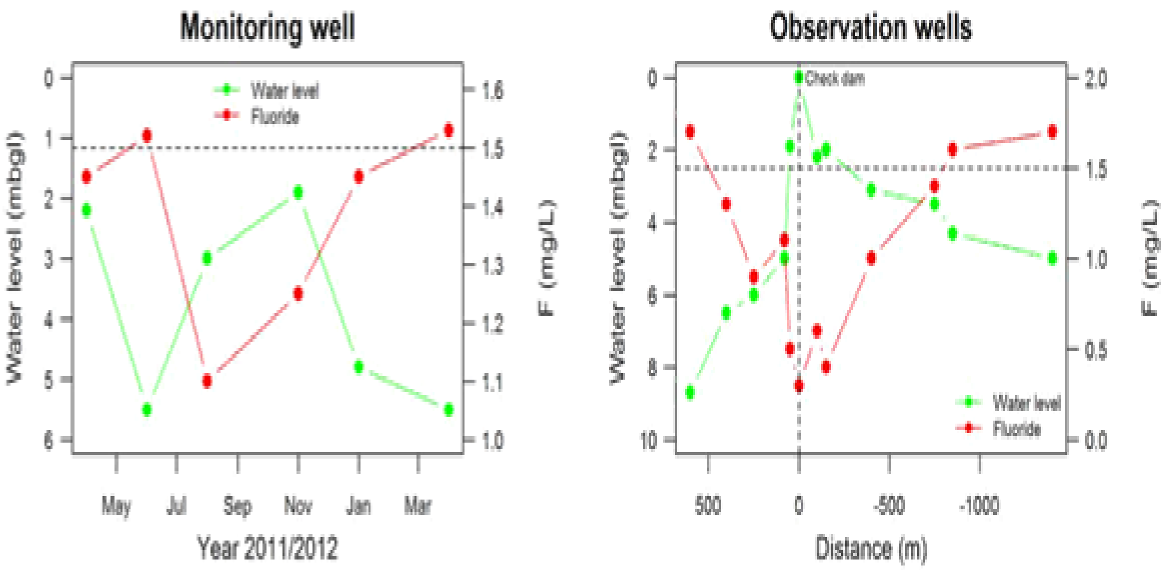
MANAGED AQUIFER RECHARGE FOR FLUORIDE MITIGATION

Enhancing recharge to a shallow aquifer via the introduction of structures such as percolation ponds, check dams, infiltration galleries, and recharge wells can help to mitigate problems with high concentrations of fluoride in groundwater, as well as replenishing stocks of groundwater.

Recharge wells: One pilot project in Dharmapuri-Krishnagiri: Harur Taluk in Tamil Nadu, set up by academics of Anna University, created a 1.5 m wide structure to induce recharge to a nearby well. Concentrations of fluoride in the well were observed to fall from 4 mg/L to 0.2 mg/L over time, which allowed use for potable supply.

Induced recharge structure, Dharmapuri district, Tamil Nadu

Check dams: Check dams have also shown evidence of reducing local groundwater fluoride concentrations (<1 km radius of influence). A pilot in Tamil Nadu also showed a reduction in fluoride concentrations over the area of influence of the recharge (<1 km).



The graphs above show a reduction in fluoride concentration with increased groundwater level in a MAR monitoring well. Observation wells across the area of influence have lower fluoride concentrations close to the check dam across the Pambar River, highlighting the diluting effect of MAR on local groundwater (Brindha et al., 2016). In these cases, dilution has brought concentrations of fluoride down from just above the drinking-water limit within the area of influence.

In other nations, where mitigation efforts have been instigated to reduce fluoride exposure from groundwater, approaches tend to involve surface treatment of varying scales (domestic to municipal and centralized) or installation of piped supplies. Coagulation with alum—a form of the Nalgonda technique—has probably been applied most widely, including in Ethiopia, Kenya, and Tanzania as well as in India. However, frustrations with the efficacy and operation of the Nalgonda technique due to the partial removal of fluoride and production of sludge, have more recently led to a shift towards the use of bone char as a fluoride removal medium in East African countries (Dahi, 2016). This has greater removal efficacy than alum and is usually readily available locally.

In the People's Republic of China, fluoride occurrences have been mitigated most commonly by the provision of piped water supplies, although defluorination methods (e.g., activated alumina or electrodialysis) have also been applied in some areas (Wang et al., 2012).

CONJUNCTIVE WATER USE

The stated aim of the Government of West Bengal's Vision 2020 program is to move away from reliance on groundwater from hand-pumped tube wells for potable supply. This staged transition involves the implementation of piped water supply schemes with household connection where feasible but recognizes the value of the conjunctive use of surface water, good-quality groundwater, and rainwater as part of an integrated water supply strategy for the state.

The strategy includes construction of check dams and tanks or bunds, development and rehabilitation of surface ponds, development of shallow groundwaters and infiltration galleries in stream beds (sub-surface sources), use of collector wells, and development of protected dug wells with hand pumps where feasible. Rainwater harvesting is an additional option that has been little tested in West Bengal but offers some prospects, especially for part of the year. All methodologies have pros and cons, with feasibility dependent in each case on local geological, socio-economic, land use, and climatic factors.

Table 16 provides a list of piped supply schemes implemented or planned by PHED in West Bengal. Schemes include both surface water, groundwater sources, and sub-surface water schemes (riverbed abstraction), instigated for mitigation of arsenic and fluoride.

Table 16. Piped Supply Schemes (Groundwater or Surface Water, Planned or Implemented for Arsenic or Fluoride) in West Bengal

Piped supply scheme	District	Blocks	No. villages to be covered	Population (2011) to benefit	Est. cost (lakh Rs.)	Est. commission date	Water source
Bally Jagacha	Howrah	Bally Jagacha	9	209,504	15,068	2017	River Hooghly
Bally-Jagachha	Howrah	Domjur	19	68,125	4,588.00	2019	River Hooghly
Balupur	Malda	Ratua-I	24	54,390	2,239.76	2007	River Fulhar
Bankura	Bankura	Bankura - I, Bankura - II, Barjora, Bishnupur, Chhatna, Hirbandh, Indus, Khatra, Onda, Raipur, Ranibundh, Saltora, Sarenga, Simlapal	1897	2,141,370	101,122	2016 (partially commissioned)	Surface Water/ Sub-Surface water and Groundwater: River Dwarakeswar, Kangsabati, Damodar
Barasukjora	Paschim	Binpur II	36	16,868	2,136.09	2016	Surface water (Dam)
Beldanga	Murshidabad	Beldanga I	58	754,451	6,708.78	2017	River Bhagirathi
Beldanga	Murshidabad	Beldanga Municipality	4 Wards	72,911	1,279	2003	River Bhagirathi
Beniagram	Murshidabad	Farakka	16	82,967	2,146	2016	River Bhagirathi
Birbhum	Birbhum	Suri-I, Suri-Ii & Sainthia	58	61,569	5,759.53	2018	Sub-surface water of River Mayurakshi
Bolpur–Raghunathpur	Birbhum	Bolpur-Sriniketan	144	316,489	8,797.38	2002	Groundwater
Surface water scheme for Chakdah	Nadia	Chakdah (P)	114	406,103	10,198	2014	River Bhagirathi
Chunakhali	South 24 Parganas	Basanti	5	26,285	1,327.19	2015	Groundwater
Dakshin Dinajpur	Dakshin Dinajpur	Tapan	279	250,504	16,550.05	2018	River Punarbhaba
Darjeeling	Darjeeling	Darjeeling Municipal, en-route villages		134,390	6,618.00	2012	Balason River
Dherua	Paschim Medinipur	Midnapur	96	32,701	2,147.08	2016	RiverBank TW
Dual-use solar pump	Bankura/Purulia/ Paschim Medinipur	Raipur, Sarenga, Ranibandh, Simlapal	161	20,125	5,167.36	2016	Groundwater
Falta-Mathurapur	South 24 Parganas	Kulpi, Diamond Harbour I, II, Falta, Jaynagar	902	2,251,277	133,241	2016	River Hooghly

		II, Kultali, Magrahat I, Mandir Bazar, Mathurapur I, II					
Goubazar Ichhapur	Burdwan	Durgapur-Faridpur	19	21,156	1,699.19	2016	Ajoy River
Gour and Mahadipur	Malda	English Bazar	24	23,187	691.19	2008	River Bhagirathi
Surface water scheme for Haringhata	Nadia	Chakdah (P), Haringhata	137	371,773	11,898	2014	River Bhagirathi
Hingalganj	North 24 Parganas	Hingalganj	7	34,428	2,979.6	2018	Groundwater
Jaigaon	Alipurduar	Kalchini			9,372		River Torsa
Jamgara Jagannathpur	Burdwan	Durgapur-Faridpur	9	14,549	971.72	2016	Ajoy River
Kalabani	Purulia	Hura	20	26,682	1,406.14	2017	Surface water of Futiary Dam
Madandi	Purulia	Neturia	18	13,028	1,668.76	2018	Sub-surface water of River Damodar
Mahayampur	Murshidabad	Beldanga-I	6	53,486	654.31	2008	River Bhagirathi
Malda Phase I	Malda	Manikchak, English Bazar	122	403,542	8,848	2000	River Fulhar
Malda Phase II	Malda	Kaliachak-I, II & III	158	702,722	4,300	2009	River Bhagirathi
Manbazar II	Purulia	Manbazar-II	57	44,591	4,036.46	2016	Surface water (Dam)
Mathurabil	North 24 Parganas	Barrackpur-I	15	61,814	1,192.63	2017	Pond water
Mukutmanipur	Bankura	Khatra	72	73,616	2,171.06	2008	Mukutmanipur Dam
Mukuundobag/ Jiaganj-Azimganj	Murshidabad	Murshidabad Jiaganj (part), Azimganj Municipality	27	46,673	1,677	2016	River Bhagirathi
Murshidabad Central Sector	Murshidabad	Hariharpara, Berhampur (pt)	105	659,684	18,346	2016	River Bhagirathi
Surface water scheme for Murshidabad Central	Murshidabad	Murshidabad-Jiaganj & Berhampore	135	379,692	10,722.4	2014	River Bhagirathi
Surface water scheme for Nadia	Nadia	Nadia/Kaliganj, Nakashipara, Krishnanagar-II (P), Nabadwip (P)	291	910,638	24,594.96	2010	River Bhagirathi
Nayagram	Paschim	Nayagram	192	76,539	7,495.00		River Subarnarekha
North 24 Parganas	North 24 Parganas	Habra-I&II, Gaigahta,Amd Anga (Part), Deganga (Part),	335	11,854	57,772	2018	River Hooghly

North 24 Parganas	North 24 Parganas	Barrackpore Block (Tapas)	6	37,823	6,353.29	2017	Groundwater
Surface water scheme for North 24 Parganas	North 24 Parganas	Barrackpur-I, Barasat-I, Amdanga, Deganga	234	719,555	14,314	2008	River Hooghly
Surface water scheme for South 24 Parganas	South 24 Parganas	Budge Budge-II, Bishnupur-I & II, Bhangar-I, Baruipur, Sonarpur, Mograhat-II, Joynagar-I	688	2,951,000	39,537	2007	River Hooghly
Panskura-II	Purba/ Medinipur	Kolaghat	112	247,000	18,662.52	2017	River Rupnarayan
Pardeonapur	Maldah	Kaliachak III	17	39,324	3,128.08	2017	Surface water
Purbasthali	Bardhaman	Purbasthali-II	62	123,455	3,978	2011	River Bhagirathi
Purulia	Purulia	Purulia-I/II, Pura, Hura, Puncha, Kashipur, Raghunathpur-I, Manbazar-I, Barabazar	1098	1,046,758	117,310	2019	River Kumari, Kangsabati, Dwarakeswar
Raghunathganj	Murshidabad	Raghunathganj – I	63	184,564	5,108	2013	River Bhagirathi
Raghunathpur	Purulia	Neturia, Raghunathpur-I & II	101	110,622	46,822.43	2002	River Utala
Raipur	Bankura	Raipur	26	34,612	2,120	2017	River Kangasabati
RCFA Part I	Bardhaman	Salanpur, Barabani, Asansol (Part), Kulti (Part)	217	1,241,335	365	1973	Surface water of Maithon Reservoir
RCFA Part II	Bardhaman	Jamuria, Asansol, Raniganj,Ondal , Hirapur, Durgapur-Faridpur	119	712,000	5,325	2003	Subsurface flow of River Damodar (collector well)
RCFA Part III	Bardhaman	Durgapur-Faridpur	26	96,176	1,900	2008	Subsurface flow of River Ajoy
Siliguri	Darjeeling	Siliguri Municipal Corporation	47 Wards	509,709	4,617.55	2000	Tista Mahananda Link Canal
Sub-surface fluoride scheme	Dakhin Dinajpur	Gangarampur	203	237,628	14,501.52	2018	River Punarbhaba

Water treatment to remove arsenic or fluoride has been a common practice in affected areas of West Bengal, but these are short-term solutions pending the provision of a more sustainable potable supply. Problems with maintenance, lack of testing, user acceptability, and disposal of arsenic, fluoride concentrated sludge are critical issues, all of which compromise on available treatment systems as sustainable options for arsenic and fluoride mitigation. On-site treatments for arsenic offer more promise on a local scale but are dependent on local factors such as aquifer permeability and initial groundwater chemistry. They also require local maintenance and have not been widely adopted in West Bengal. On-site treatments may constitute a local mitigation option in some areas but are unlikely to be a large-scale and long-term solution. MAR schemes are better established for enhancing recharge and improving overall water quality but still need further evaluation as a sustainable mitigation strategy for fluoride. For both on-site strategies (for either arsenic or fluoride), a proportionate and reliable water-quality testing regime is required.

WATER-QUALITY TESTING

Improved provision has been made for laboratory testing facilities since the Government of India initiated a national rural drinking-water-quality monitoring and surveillance program in 2006. In West Bengal, some 116 testing laboratories are operational, managed by PHED and NGOs. Capabilities include testing for arsenic, fluoride, and salinity. Sanitary surveys are also conducted routinely, and data are georeferenced. Data are entered into a web-based system and stored on the Ministry of Drinking Water and Sanitation integrated management information system (MDWS IMIS) database. Local stakeholder engagement (e.g., at Gram Panchayat level) ensures collaboration in sample collection, sharing of analytical results, awareness campaigns, and demand for monitoring and surveillance services.

Testing of water samples follows protocols in Standard Methods for Examination of Water and Wastewater (APHA). Some 5% of samples are retested in a PHED laboratory. As of 2013, some 130,000 samples for arsenic and 52,000 for fluoride had been tested in West Bengal.20 Data are mapped in a global information system. Some NGOs used field test kits (e.g., for arsenic), but these have not been adopted significantly by government-managed laboratories.

CHAPTER-7

➢ CONCLUSION & RECOMMENDATION

Arsenic and fluoride contamination problems in groundwater are a major concern. Though these two affecting parameters are totally different from each other but critical situations and carcinogenic diseases can occur for both cases. A typical situation like in Baruipur, where arsenic and fluoride can occur alike. Adopting appropriate technology can remove both arsenic and fluoride simultaneously. Further, experimental analysis (laboratory and field based both) need to be done for both the cases.

Around 9–11 million people in West Bengal are estimated to have been drinking water with arsenic concentrations above the BIS limit of 10 μg/L, out of a total of 12.9 million nationally. This makes West Bengal the worst-impacted state of India so far.

Also, some 517,000–615,000 people in West Bengal are estimated to have been drinking water with fluoride concentrations above the BIS limit of 1.5 mg/L, with an estimated 67 million exposed nationwide.

The regional occurrence of high-arsenic and high-fluoride groundwaters across India are distinct, with arsenic problems for the most part being a feature of the large alluvial-deltaic plains of the North-East and fluoride problems a feature of the hard-rock aquifers of central and peninsular India. Exceptions occur where arsenic mobility is associated with metalliferous mineralization, with or without mining activity. In states where both alluvial-deltaic and basement aquifers are represented, problems with both trace elements can result, though not in the same aquifers. Such is the case with West Bengal. Aquifers of the western part of the state are composed of crystalline granite-gneiss complexes, while those of the Eastern and Northern parts comprise Holocene alluvial-deltaic deposits.

Problems with arsenic in West Bengal are usually restricted to the Holocene alluvial/deltaic aquifer where groundwater is anoxic, and arsenic which is mobilized from the unconsolidated sediments. Shallow groundwater from dug wells is toxic and has lower concentrations of arsenic (<10 μg/L). Groundwater from a deeper Pleistocene aquifer also has usually low concentration of arsenic (<10 μg/L) as arsenic is more strongly bound and sediments have been flushed by flowing groundwater for longer periods. Exceptions do occur, however, in both shallow dug wells and deep Pleistocene groundwater. The Pleistocene aquifer is especially vulnerable to contamination from above in the event of aquifer over-pumping and/or completion with poor well seals.

In either arsenic- or fluoride-affected districts, not all tube wells have concentrations of arsenic or fluoride above the respective drinking-water limits, and percentage exceedances vary from region to region. The concentrations of both arsenic and fluoride can show considerable variation over short ranges and use of groundwater for potable supply in at-risk areas need a comprehensive water-quality testing and monitoring program.

Large water testing programs have been implemented to ascertain, map and mitigate the occurrence of arsenic and fluoride in groundwater across affected states. Many groundwater sources remain untested, however, and monitoring is uncommon. Understanding the design of surveys from available databases is difficult and the representativeness of sampling therefore is not always clear.

Many testing laboratories have been set up, often locally, to deal with the major requirement for analytical facilities. Quality assurance information is difficult to obtain, and accreditation of laboratories is little developed.

Where groundwater is unsuitable for use, mitigation options include the use of alternative aquifers, rainwater harvesting, locally treated surface water, or treatment of groundwater above ground or on-site, as well as the supply of piped surface water or groundwater. Feasibility and efficacy of these options is element- and location-specific. Feasibility depends on factors such as local hydrography, geology, aquifer permeability, and groundwater level and/or trend, rainfall, and downstream conditions, as well as socio-economic factors such as governance, ownership, and willingness to pay.

For fluoride, on-site mitigation is feasible in principle in the form of MAR schemes, which are long-established in India for enhancing groundwater storage and improving water quality, albeit not for fluoride mitigation specifically. For arsenic, on-site treatments are available, but applications in developing countries tend to have been on pilot scales. Methods based on arsenic oxidation are more widely tested than reduction methods.

Supply of piped treated water to arsenic- or fluoride-affected areas offer a greater certainty in water quality and water security in the long-term. Decisions depend on prioritization (worst-affected areas), logistics, cost, and feasibility of local alternatives.

➢ REFERENCES

- ✓ Report of the Expert Group on Ground Water Management & Ownership, published in Sept'2007.
- ✓ Arsenic and Fluoride Problems of Groundwater in West Bengal and Available Technologies for Remediation, Arindam Haldar1 , Soumya kanta Ray 2 Research Scholar, Department of Civil Engineering, Bengal Engineering & science University, Shibpur, India1 Assistant Professor, Department of Civil (Environmental) Engineering, MIET, Bandel, Hooghly, India.
- ✓ Namita Soni and Anju Bhatia, Department of Home Science, University of Rajasthan, Jaipur, India, Analysis of Quality of Drinking Water of Private Bore-well and Piped water Supply in Jaipur City, Rajasthan, India.
- ✓ Sabal D., Ashutosh and Khan T.I., Ground Water Fluoride, Content and Water Quality in Amber Tehsil of Jaipur, District, *The Ecoscan*, 2(2), 265-267 (2008)
- ✓ Shri B. M. Jha, Chairman,DrS.C.Dhiman, Member(SML), Shri A. R Bhaisare, Member(SAM) Retd, Shri Subrata Kunar, Member(SAM, Ground Water Quality in Shallow Aquifers of India.
- ✓ West Bengal Drinking Water Sector Improvement Project (RRP IND 49107-006).
- ✓ Central Ground Water Board, Ministry of Water Resources, river Development and Ganga Rejuvenation, Government of India, http://cgwb.gov.in/wqreports.html.
- ✓ Alaerts, G J, and Khouri, N. 2004. Arsenic contamination of groundwater: Mitigation strategies and policies. Hydrogeology Journal, Vol. 12, 103-114.
- ✓ Annapoorna, H, and Janardhana, M R. 2016. Arsenic contamination in groundwater of the areas surrounding Ingaldhal, Chitradurga District, Karnataka State. International Journal of Geology, Earth & Environmental Sciences, Vol. 6, 1-7.
- ✓ Berg, M, Tran, H C, Nguyen, T C, Pham, H V, Schertenleib, R, and Giger, W. 2001. Arsenic contamination of groundwater and drinking water in Vietnam: A human health threat. Environmental Science & Technology, Vol. 35, 2621-2626.
- ✓ BGS, and DPHE. 2001. Arsenic contamination of groundwater in Bangladesh (four volumes).
- ✓ British Geological Survey (see www.bgs.ac.uk/Arsenic/Bangladesh), (Keyworth).
- ✓ Bhagavan, S V B K, and Raghu, V. 2005. Utility of check dams in dilution of fluoride concentration in ground water and the resultant analysis of blood serum and urine of

villagers, Anantapur District, Andhra Pradesh, India. Environmental Geochemistry and Health, Vol. 27, 97-108. 10.1007/s10653-004-0786-4

- ✓ Boisson, A, Villesseche, D, Baisset, M, Perrin, J, Viossanges, M, Kloppmann, W, Chandra, S, Dewandel, B, Picot-Colbeaux, G, Rangarajan, R, Maréchal, J C, and Ahmed, S. 2015. Questioning the impact and sustainability of percolation tanks as aquifer recharge structures in semi-arid crystalline context. Environmental Earth Sciences, Vol. 73, 7711-7721. 10.1007/s12665-014-3229-2
- ✓ Brindha, K, Jagadeshan, G, Kalpana, L, and Elango, L. 2016. Fluoride in weathered rock aquifers of southern India: Managed Aquifer Recharge for mitigation. Environmental Science and Pollution Research, Vol. 23, 8302-8316. 10.1007/s11356-016-6069-7
- ✓ Chadha, D K. 2002. State of the art of artificial recharge applied in village level schemes in India. 19-24 in Management of Aquifer Recharge and Subsurface Storage - Making Better Use of Our Largest Reservoir. Tuinhof, A, and Heederik, J P (editors). NNC-IAH publication No. 4. (Wageningen, The Netherlands: Netherlands National Committee - International Association of Hydrogeologists (NNC-IAH).)
- ✓ Chakraborti, D, Biswas, B K, Chowdhury, T R, Basu, G K, Mandal, B K, Chowdhury, U K, Mukherjee, S C, Gupta, J P, Chowdhury, S R, and Rathore, K C. 1999. Arsenic groundwater contamination and sufferings of people in Rajnandgaon district, Madhya Pradesh, India. Current Science, Vol. 77, 502-504.
- ✓ Chakraborti, D, Das, B, Rahman, M M, Chowdhury, U K, Biswas, B, Goswami, A B, Nayak, B, Pal, A, Sengupta, M K, Ahamed, S, Hossain, A, Basu, G, Roychowdhury, T, and Das, D. 2009. Status of groundwater arsenic contamination in the state of West Bengal, India: A 20-year study report. Molecular Nutrition & Food Research, Vol. 53, 542-551. 10.1002/mnfr.200700517 Chowdhury, U K, Biswas, B K, Chowdhury, T R, Samanta, G, Mandal, B K, Basu, G C, Chanda, C R, Lodh, D, Saha, K C, Mukherjee, S K, Roy, S, Kabir, S, Quamruzzaman, Q, and Chakraborti, D. 2000. Groundwater arsenic contamination in Bangladesh and West Bengal, India. Environmental Health Perspectives, Vol. 108, 393-397.
- ✓ Dahi, E. 2016. Africa's U-turn in defluoridation policy: from the Nalgonda technique to bone char.
- ✓ Fluoride, Vol. 49, 401-416.

- ✓ Das, S, and Nag, S K. 2016. Geochemical appraisal of fluoride-laden groundwater in Suri I and II blocks, Birbhum district, West Bengal. Applied Water Science, 1-12. 10.1007/s13201-016-0452-x
- ✓ Edmunds, W M, and Smedley, P L. 2013. Fluoride in natural waters. Essentials of Medical Geology, Second Edition. Selinus, O, Alloway, B, Centeno, J A, Finkelman, R B, Fuge, R, Lindh, U, and Smedley, P L (editors). (New York: Springer.)
- ✓ Feldman, P R, Rosenboom, J W, Saray, M, Navuth, P, Samnang, C, and Iddings, S. 2007. Assessment of the chemical quality of drinking water in Cambodia. Journal of Water and Health, Vol. 5, 101-116.
- ✓ Fendorf, S, Michael, H A, and van Geen, A. 2010. Spatial and Temporal Variations of Groundwater Arsenic in South and Southeast Asia. Science, Vol. 328, 1123-1127. 10.1126/science.1172974
- ✓ Ghosal, U, Sikdar, P K, and McArthur, J M. 2015. Palaeosol Control of Arsenic Pollution: The Bengal Basin in West Bengal, India. Groundwater, Vol. 53, 588-599. 10.1111/gwat.12251 Ghosh, N C, and Singh, R D. 2008. Groundwater Arsenic Contamination in India: Vulnerability and Scope for Remedy Central Ground Water Board,
- ✓ Haldar, A, and Ray, S K. 2014. Arsenic and fluoride problems of groundwater in West Bengal and available technologies for remediation. International Journal of Innovative Research in Science, Engineering & Technology, Vol. 3, 135-141.
- ✓ Hallberg, R, and Martinell, R. 1976. Vyredox - in situ purification of groundwater. Ground Water, Vol. 14, 88 - 92.
- ✓ Hallett, B M, Dharmagunawardhane, H A, Atal, S, Valsami-Jones, E, Ahmed, S, and Burgess, W G. 2015. Mineralogical sources of groundwater fluoride in Archaen bedrock/regolith aquifers: Mass balances from southern India and north-central Sri Lanka. Journal of Hydrology: Regional Studies, Vol. 4, 111-130. http://dx.doi.org/10.1016/j.ejrh.2014.10.003
- ✓ Harvey, C F, Swartz, C H, Badruzzaman, A B M, Keon-Blute, N, Yu, W, Ali, M A, Jay, J, Beckie, R, Niedan, V, Brabander, D, Oates, P M, Ashfaque, K N, Islam, S, Hemond, H F, and Ahmed, M F. 2002. Arsenic mobility and groundwater extraction in Bangladesh. Science, Vol. 298, 1602-1606. Hug, S J, Leupin, O X, and Berg, M. 2008. Bangladesh and Vietnam: Different Groundwater Compositions Require Different Approaches to Arsenic Mitigation. Environmental Science & Technology, Vol. 42, 6318-6323. 10.1021/es7028284

- ✓ Human Rights Watch. 2016. Nepotism and Neglect: The Failing Response to Arsenic in the Drinking Water of Bangladesh's Rural Poor. (USA), Available from http://www.hrw.org.
- ✓ IMG. 2015. Report of the Inter-Ministerial Group (IMG) for Arsenic Mitigation. Ministry of Water
- ✓ Resources, River Development and Ganga Rejuvenation, Government of India, (Delhi),
- ✓ Islam, F S, Gault, A G, Boothman, C, Polya, D A, Charnock, J M, Chatterjee, D, and Lloyd, J R.
- ✓ 2004. Role of metal-reducing bacteria in arsenic release from Bengal delta sediments. Nature,
- ✓ Vol. 430, 68-71.
- ✓ Maithani, P B, Gurjar, R, Banerjee, R, Balaji, B K, Ramachandran, S, and Singh, R. 1998. Anomalous fluoride in groundwater from western part of Sirohi district, Rajasthan, and its crippling effects on human health. Current Science, Vol. 74, 773-777.
- ✓ Maliva, R G. 2014. Economics of Managed Aquifer Recharge. Water, Vol. 6, 1257-1279. 10.3390/w6051257
- ✓ Milton, A H, Hore, S K, Hossain, M Z, and Rahman, M. 2012. Bangladesh arsenic mitigation programs: lessons from the past. Emerging Health Threats Journal, Vol. 5, 10.3402/ehtj.v3405i3400.7269. 10.3402/ehtj.v5i0.7269
- ✓ Mukherjee, A, and Fryar, A E. 2008. Deeper groundwater chemistry and geochemical modeling of the arsenic affected western Bengal basin, West Bengal, India. Applied Geochemistry, Vol. 23, 863-894. 10.1016/j.apgeochem.2007.07.011
- ✓ Mukherjee, S C, Saha, K C, Pati, S, Dutta, R N, Rahman, M M, Sengupta, M K, Ahamed, S, Lodh, D, Das, B, Hossain, M A, Nayak, B, Mukherjee, A, Chakraborti, D, Dulta, S K, Palit, S K, Kaies, I, Barua, A K, and Asad, K A. 2005. Murshidabad - One of the nine groundwater arsenic-affected districts of West Bengal, India. Part II: Dermatological, neurological, and obstetric findings. Clinical Toxicology, Vol. 43, 835-848.
- ✓ Naujokas, M F, Anderson, B, Ahsan, H, Aposhian, H V, Graziano, J H, Thompson, C, and Suk, W A. 2013. The Broad Scope of Health Effects from Chronic Arsenic Exposure: Update on a

- Worldwide Public Health Problem. Environmental Health Perspectives, Vol. 121, 295-302. 10.1289/ehp.1205875
- O'Day, P A, Vlassopoulos, D, Root, R, and Rivera, N. 2004. The influence of sulfur and iron on dissolved arsenic concentrations in the shallow subsurface under changing redox conditions. Proceedings of the National Academy of Sciences of the United States of America, Vol. 101, 13703-13708.
- Pal, T, Mukherjee, P K, Sengupta, S, Bhattacharyya, A K, and Shome, S. 2002. Arsenic pollution in groundwater of West Bengal, India - An insight into the problem by subsurface sediment analysis. Gondwana Research, Vol. 5, 501-512.
- Paul, A P, Maurer, D K, Stollenwerk, K G, and Welch, A H. 2010. In-Situ Arsenic Remediation in Carson Valley, Douglas County, West-Central Nevada. United States Geological Survey, (Reston, Virginia),
- PHED. 2006. Master Plan to Tackle Arsenic Contamination of Groundwater in West Bengal. Public Health Engineering Department, G o W B, 157 pp. Available from http://www.wbphed.gov.in/main/index.php/component/content/article/95-water-quality/133-master-plan.
- PHED. 2013. A note on fluoride contamination of ground water in West Bengal. Public Health
- Engineering Department, Government of West Bengal.Available at http://www.wbphed.gov.in/main/index.php/component/content/article/95-water-quality/134-fluoride
- Radloff, K A, Zheng, Y, Michael, H A, Stute, M, Bostick, B C, Mihajlov, I, Bounds, M, Huq, M R, Choudhury, I, Rahman, M W, Schlosser, P, Ahmed, K M, and van Geen, A. 2011. Arsenic migration to deep groundwater in Bangladesh influenced by adsorption and water demand. Nature Geoscience, Vol. 4, 793-798. 10.1038/ngeo1283
- Rahman, M M, Sengupta, M K, Ahamed, S, Lodh, D, Das, B, Hossain, M A, Nayak, B, Mukherjee, A, Chakraborti, D, Mukherjee, S C, Pati, S, Saha, K C, Palit, S K, Kaies, I, Barua, A K, and Asad, K A. 2005. Murshidabad - One of the nine groundwater arsenic-affected districts of West Bengal, India. Part I: Magnitude of contamination and population at risk. Clinical Toxicology, Vol. 43, 823-834.
- RGNDWM. 1993. Prevention and Control of Fluorosis in India: Volume II: Water Quality and Defluoridation Techniques. Rajiv Gandhi National Drinking Water Mission, Ministry of Rural Development, (New Delhi)

Thank You