Risk assessment of chronic arsenic exposure to human and domestic animals and possible remedial strategies: Study in selected endemic areas of West Bengal, India

Synopsis of the Thesis submitted by

Antara Das, M.Sc.

Doctor of Philosophy

School of Environmental Studies

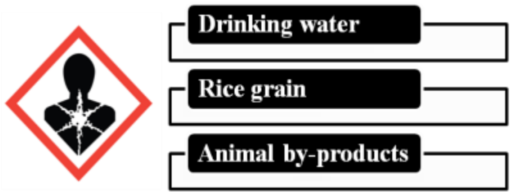
Faculty of Interdisciplinary Studies, Law and Management
JADAVPUR UNIVERSITY

KOLKATA- 700032

INDIA

2022

SYNOPSIS



The present research work is a multi-dimensional approach of the effect of arsenic (As) exposure in human, livestock and environment. It is a naturally occurring toxic metalloid, globally classified as a group I human carcinogen. Groundwater As contamination is a natural calamity exhumed from its sediments and ruling the world's largest delta Ganga-Meghna-Brahmaputra delta for past 30–40 years. Contamination of As is not only limited to groundwater, with time it has spread into the food chain. In many of the remote villages of West Bengal, India like Eithbhata, Mathpara of North 24 Parganas district and Kadomtola, Raninagar of Murshidabad, As kills people slowly and silently. Nine districts of West Bengal covering around 6 million people are severely suffering from groundwater As contamination. The work firstly comprises the evaluation of twenty physico-chemical parameters in 110 groundwater samples from 17 blocks of Nadia district located in West Bengal, for its overall quality assessment. A Water Quality Index (WQI) modelling has been done further where about 66% of water sample are not recommended for use. The mean anionic concentration range in groundwater seems to be in the order of bicarbonate (HCO_3^-) > chloride (Cl^-) > carbonate (CO_3^{2-}) > sulphate (SO_4^{2-}) > nitrate (NO_3^-) > phosphate (PO_4^{3-}) which signifies the water quality of Nadia district is allover alkaline and it is mainly because of HCO_3^- alkalinity. Hardness is determined by Ca^{2+} and Mg^{2+} ions where Ca^{2+} ion concentration (mean: 53.7 mg/L, range: 4–156 mg/L) overrules Mg^{2+} one (mean: 44.9 mg/L, range: 0.18–114 mg/L). Groundwater in all the blocks is As contaminated and maximum As concentration is found to be 206 μg/L in Chakdah. Few ground water samples have been identified with presence of elevated level of NO_3^- (45–57.6 mg/L), particularly from four blocks (Krishnanagar-I, Nabadwip, Kaliganj and Chapra) in the district. No sample has been identified with uranium (U) concentration (range: 0.21–20.9 μg/L) beyond its permissible limit (30 μg/L, recommended by WHO). Presence of high concentrations of Cl^{-}, NO_3^{-} and especially HCO_3^{-} ions in groundwater and their positive interdependence with each other may magnify U contamination in future through dissolution of U as they are good carrier of U. The F^{-} concentration has been observed within its recommended value in drinking water. There is a strong possibility for cancer risk through As and U in drinking water as the mean cancer risk value (1.2×10^{-3} and 2.48×10^{-3}) goes beyond their respective acceptance level. Apparently there is no health risk from F^{-} but in few cases NO_3^{-} poses non carcinogenic health hazards in future. Secondly, As contamination scenario in groundwater and treated drinking water sources from all the 9 gram panchayats under Raninagar-II block, Murshidabad has been studied. Approximately 54.6% of groundwater samples from the domestic and community tube-wells (n = 366) are with As concentration above the permissible limit in drinking water (10 μg/L); while 37.3 % of groundwater samples from agricultural tube-wells (n = 67) are As-contaminated above its recommended value in irrigational water (100 μg/L). Arsenic–Iron pollution index assessment and ecological risk analysis state that the groundwater of the study area is sternly polluted. About 12.5 tonnes of As is withdrawn every year through irrigational water in the entire block. Bio-accumulation of As in rice grain (1.78) and paddy whole grain (2.67) shows the potential of hyper-accumulation. The concentrations of two essential micro-nutrients in groundwater (Selenium and Zinc) are low (mean: 0.57 and 84.5 μg/L, respectively) which encourages the poor health of the local inhabitants.

The populations suffer from serious cancer and non-cancer risk through contaminated drinking water where the studied adult males face higher risk than the females. Hence, the role of the key factors (As intake, age and sex) regulating As toxicity is aimed to evaluate in a severely exposed population from Murshidabad. The mean As concentrations in drinking water supplied through tube well, Sajaldhara treatment plant and pipeline in Raninagar II block were observed as 208, 27 and 54 µg/l, respectively. Urinary As concentration was found as < 3–42.1, < 3–56.2 and < 3–80 µg/l in children, teenagers and adults, respectively. The mean As concentrations in hair and nail were found to be 0.84 and 2.38 mg/kg; 3.07 and 6.18 mg/kg; and 4.41 and 9.07 mg/kg, respectively, for the studied age-groups. Arsenic concentration in drinking water was appeared to be associated with that in hair and nail ($r = 0.57$ and 0.60), more than urine ($r = 0.37$). Deposition of As in biomarkers appeared to be dependent on age; however, independent of sex. A principal component analysis showed a direct relationship between dietary intake of As and deposition in chronic biomarkers. Nail was proved as the most fitted biomarker of As toxicity by Dunn's post hoc test. Monte Carlo sensitivity analysis and cluster analysis showed that the most significant factor regulating health risk is 'concentration of As' than 'exposure duration', 'body weight' and 'intake rate'. The contribution of As concentration towards calculated health risk was highest in teenagers (45.5–61.2%), followed by adults (47.8–49%) and children (21–27.6%). Besides sub-clinical toxicity, different types of skin lesions were observed among the affected inhabitants such as 'raindrop pigmentation' in the dorsal part of the hand, feet or whole body, 'spotted and diffused keratosis', 'melanosis', even 'bowens'. Regular and sufficient access to As-safe drinking water is an immediate need for the affected population.

Arsenic toxicity in the domestic livestock and the possible risk for human and environment caused by them has also been investigated in the present research. Daily dietary As intake of an exposed adult cow or bull is nearly 4.56 times higher than control populace and about 3.65 times higher than exposed goats. Arsenic toxicity is well exhibited in all the biomarkers through different statistical interpretations. Arsenic bio-concentration is faster through water compared to paddy straw and mostly manifested in faeces and tail hair in cattle. Cow dung and tail hair are the most pronounced pathways of As biotransformation into environment. A considerable amount of As has been observed in animal proteins such as cow milk, boiled egg yolk, albumen, liver and meat from the exposed livestock. Cow milk As is mostly accumulated in casein (83%) due to the presence of phosphoserine units. SAMOE–risk thermometer, calculated for the most regularly consumed foodstuffs in the area, shows the human health risk in a distinct order: drinking water > rice grain > cow milk > chicken > egg > mutton ranging from class 5 to 1. USEPA health risk assessment model reveals more risk in adults than in children, subsisting severe cancer risk from the foodstuffs where the edible animal proteins cannot be ignored.

This research focused on investigation of the performance efficiencies of the mitigation measures made by the government and non-governmental organizations. It observed that in some areas, the pipeline supplied water and the treated water from the arsenic-iron removal plants (AIRP) contain adequate arsenic to cause health risk. The present work found annual average As removal efficiency of the studied 12 AIRPs in Gaighata, North 24 Parganas is 61.2 % (range: 35.2 to 82.6 %) and the annual average iron removal efficiency of the AIRPs is 81.4% (range: 35.7 to 97.3 %). Trace element study shows presence of Al and Mn in 30 and 50 % treated samples respectively. WQI study revealed that 25% treated water samples are of ‘poor’ quality; 16.7% treated water samples are of ‘high’ heavy metal evaluation index value. Therefore, besides insufficient access to safe water, in many areas, people still use the contaminated tube wells in the name of ‘treated water’. In my study period of one year, two plant also got closed due to lack of manpower or poor performance. Henceforth, it is clear that the plants are not maintained properly and regularly. This depicted the failed scenario of the arsenic mitigation plans by the concerned authorities. The Reverse Osmosis (R.O.) and Sajaldhara water treatment plants in

Raninagar II, Murshidabad showed 77.6 and 74.4 % of As removal efficiency. Among all kinds of alternate drinking water sources, dug wells seemed to be the safest in regards to As contamination with a natural Fe/As ratio of 66.1 and account for lowest health risk according to Severity Adjusted Margin of Exposure (SAMOE). However, the water quality of few dug wells is quite hard in nature, which can be reduced through boiling. The dug wells must be covered properly to protect from bacteriological contamination along with other types of nuisances. Lastly, domestically a solar oxidation process is promoted through my research for removal of As from contaminated water (removal efficiency ~ 50%) with application of amla at minor dose.

The suggestion is to increase the use of dug wells in the villages at both domestic and community level along with the usage of surface water bodies. On this note, the initiative taken by the neighboring state Bihar to restore 82,000 dug wells for providing security about unpolluted drinking water is appreciated which will ensure good health as well as lessen water scarcity during dry summer. Domestic livestock too should be fed with surface water instead of groundwater. People of the affected areas are suggested to actively take part in 'rainwater harvesting' following the governmental campaign of this year named 'Jal Shakti Abhiyan - Catch the Rain' for spontaneous and healthy living. Moreover, prohibition in exploitation of groundwater is the utmost need of this hour to build a sustainable future on this earth.