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Study of Cause of Groundwater Arsenic in Rural Area of Eastern Uttar Pradesh, India

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ABSTRACT: Access to pure water either for drinking or agricultural purpose is a first goal and a key target for every nation. But due to some natural and anthropogenic reason it's still challenge for many countries. The pollution of soil and water with Arsenic(As) is one of the most important environmental problems globally. Natural as well as anthropogenic activities are the main reason for a coverlet of arsenic contamination in ground water and soil. These contaminated ground water and soil are the major source of arsenic in food chain and other food trophic level. Presence of Arsenic considered as one of the hazardous elements in the environment and exposure of it causes serious health issues arise like cardiovascular, neurological, hematological, renal, and respiratory problems. Groundwater Arsenic contamination in Eastern Gangetic River Basin reported worldwide in recent studies which causes many adverse effects not only for drinking but also for irrigation purpose. Accumulation of arsenic in soil through contaminated ground water during irrigation, which is uptake by many edible parts of plants and subsequently transferred in other food chain. Uttar Pradesh and Bihar situated in the middle and upper Gangetic belt. According to surveyed reports on the in the Ganga–Meghna– Brahmaputra (GMB) region, a large population nearly 500 million people are facing arsenic problem having in area approx 500,000km². The conversion of arsenic oxidation state and their presence in ground water or soil depends upon various environmental conditions. It can be recognized in three forms: Inorganic, organic, and arsine gas. Arsenic presents as in trivalent (+3) oxidation state (like arsenic trioxide, sodium arsenite, and arsenic trichloride) and in pentavalent (+5) state (like arsenates, arsenic pentoxide and arsenic acid). Interconversion of Arsenate form (+5) into arsenite form (+3) conditionally in oxidized and reduced condition, which is the most toxic form of arsenic. The conversion of more toxic inorganic form to less toxic organoarsenic compound such as disodiummethylarsenate (DSMA) and monosodium methylarsenate (MSMA) formation via organism known as Biomethylation .

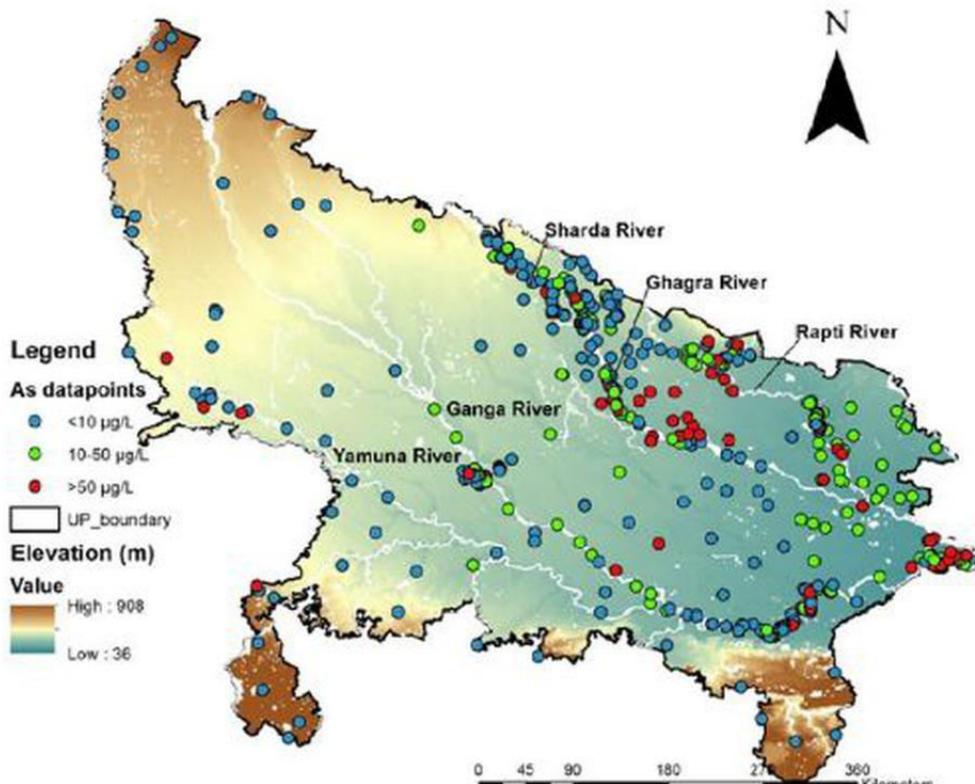
KEYWORDS: groundwater, arsenic, eastern UP, rural, accumulation, health, soil, toxic, food chain, contamination

I. INTRODUCTION

Arsenic groundwater contamination has far-reaching consequences including its ingestion through food chain, which are in the form of social disorders, health hazards and socioeconomic dissolution besides its sprawling with movement, and exploitation of groundwater. The food crops grown using arsenic contaminated water are sold off to other places, including uncontaminated regions where the inhabitants may consume arsenic from the contaminated food. This may give rise to a new danger.[1]

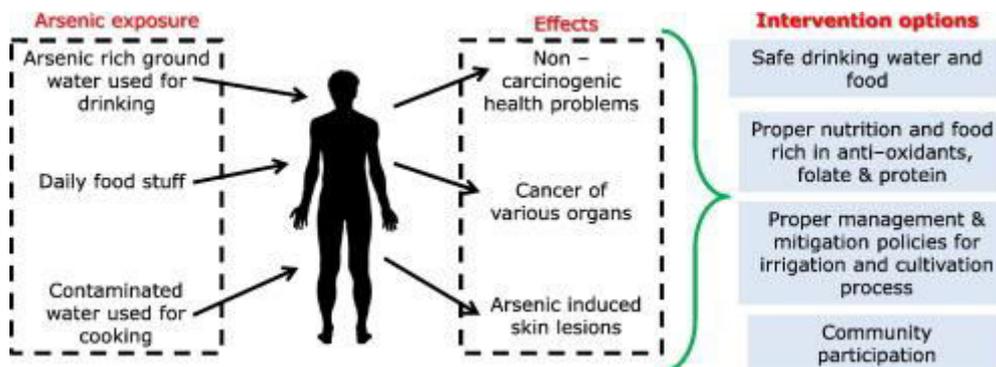
During the last three decades, substantial amount of R & D work has been done to enrich knowledge in respect of the following:

- The source and cause of Arsenic contamination in groundwater.
- Extent and magnitude of the contamination in groundwater.
- Mechanism of dissolution of Arsenic from soil to groundwater.
- Impact on Community Health: Diagnosis of sickness and symptoms.
- Development of technologies for removal of arsenic from groundwater.
- Analytical techniques for detecting arsenic from groundwater.



Arsenic concentration in groundwater of UP shown by blue, red and green circles

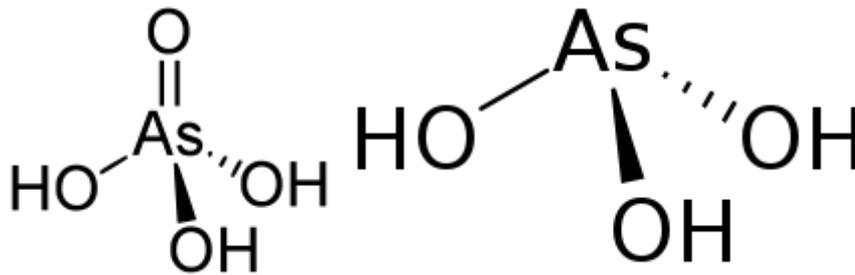
Gorakhpur (Latitude 26° 13' N and 27° 29' N and Longitude 83°05' E and 83°56' E) is one of the eastern district of Uttar Pradesh, India has geographical area 3,483.8 sq. km with average temperature ranging from 20 0C to 31 0C and an annual average rainfall is between 1016 mm to 1207 mm. Rapti river is the major river of the district originating from Nepal that sometimes caused severe floods. The Rapti is interconnected through many other small rivers following meandering courses across the Gangetic plain. The geology of the district exposes nothing beyond ordinary river borne alluvium which is not old. The mineral products are few and unimportant. Brick clay is abundant everywhere and bricks are made all over the district. The soil in the district is light sandy or dense clay of yellowish brown colour. The sand found in the rivers is medium to coarse grained, greyish white to brownish in colour and is suitable for construction. In addition to above findings, it is believed that the over exploitation of ground water leading to fast depletion of groundwater table may be the main cause behind the release of arsenic from deep strata leading, thereby, to the spreading of arsenic problem in groundwater in Gorakhpur district over a period of past several years.[2,3]



The proposition is found on the fact that intermittent incidents of arsenic contamination in groundwater can arise both naturally and industrially. The natural occurrence of arsenic in groundwater is directly related to the arsenic complexes

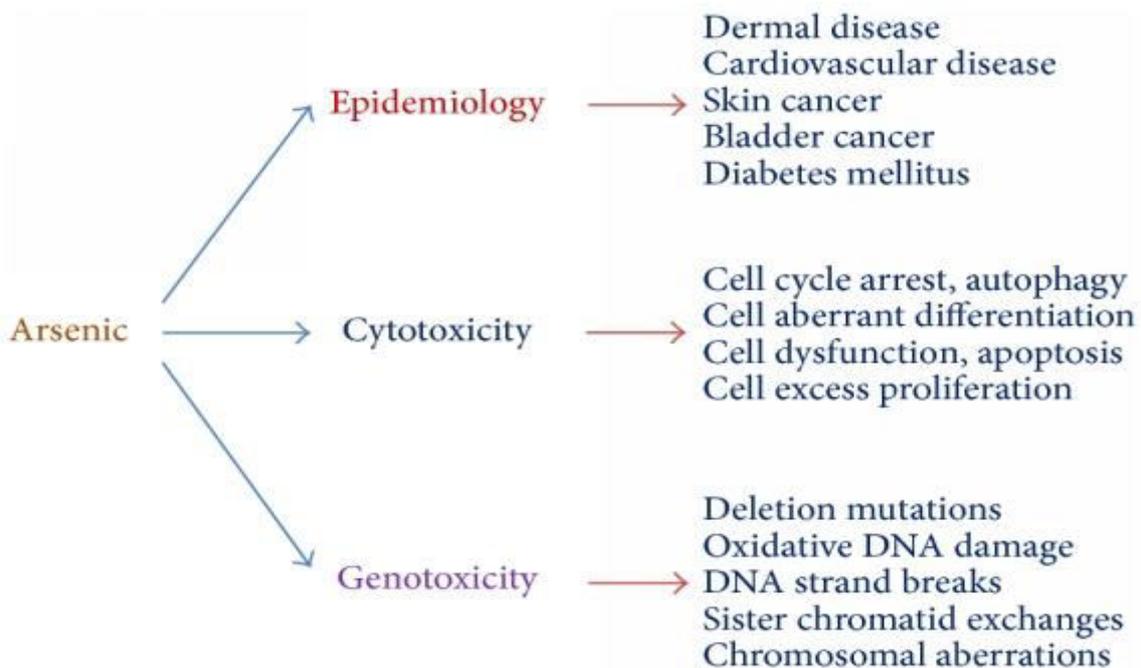


present in soils. Arsenic can liberate from these complexes under some circumstances. Since arsenic in soils is highly mobile, once it is liberated, it results in possible groundwater contamination. The researchers also inferred that, although arsenic is occurring in the alluvial sediments, the ultimate origin of arsenic is perhaps in the outcrops of hard rock’s higher up the Ganges catchment.



Arsenic acid (H3AsO4), arsenous acid (H3AsO3) and their derivatives are typically encountered in arsenic contaminated ground water.

It is well known that consumption of arsenic contaminated ground water leads to chronic health effects. The early symptoms of arsenic drinking water include the presence of arsenic in nail, hair, urine and skin. The serious issues concerning arsenic epidemics are keratosis, anemia, skin pigmentation, pulmonary and neurological problems . Moreover, serious concerns are the occurrence of lung, skin and prostate cancers . These clinical symptoms, especially dermal lesions (the most commonly observed symptom) occur after some years of consumption of arsenic contaminated drinking water.[4,5] GIS is becoming a valuable scientific tool since its inception in 1960s. It is designed for storing, querying, analyzing as well as for displaying data and/or information with spatial characteristics. Its application spans is to cover a wide range from simple inventory and management to sophisticated analysis and modeling of spatial data. It is also widely used in the environmental sciences. The application of GIS on arsenic problems has been of more concerns. GIS was used in groundwater arsenic mitigation program. It tackled many aspects of arsenic problems, including analysis of present groundwater conditions, assessment of exposure and potential health subsequences, planning and implementation of emergency and long term sanitation .



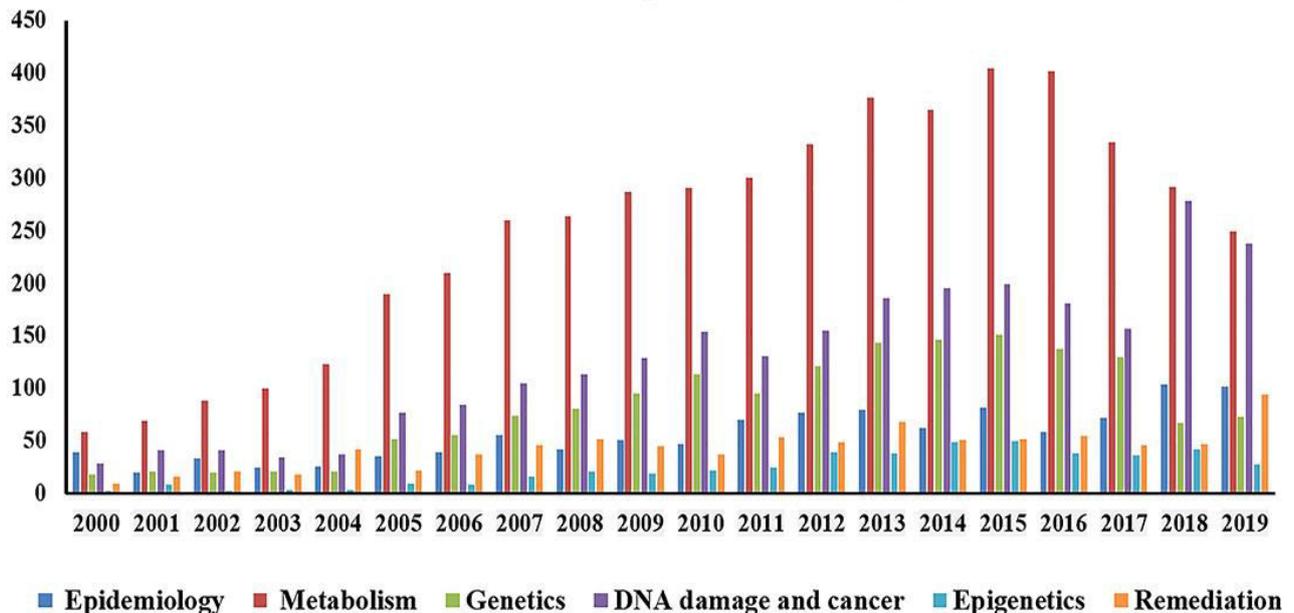


Therefore, it is very important to study the mitigation of arsenic in the ground water. The ground water of Ballia District was selected as a model for studying the mitigation of arsenic. The present paper describes the behavior of arsenic movement in the ground water by using chemical analytical values of arsenic in pre- and post monsoon seasons. Besides, GIS and Remote sensing approaches were also used to study the arsenic mitigations in the ground water of Ballia District in eastern UP.[6,7]

Arsenic contamination in Kanpur, Unnao and Allahabad, district: Chakraborti et al. revealed ground water contaminated with in the district of Kanpur (Gangaghat, Sikandarpur Sarosi Sikandarpur, Achalagan blocks), Unnao (Kanpur urban comes in unnao distric) and Allahabad (Kunda, Nababganj and Kariahara block) district where the level of arsenic exceed from the value of 50 mg/l. Tripathi et al. found the presence of arsenic in drinking water supplies ,hair and nails at Kanpur in five divisions (Vajidpur, Panki block C, J.K. colony, Dadanagar and Motinagar) and reported the level of contamination in water, hair and nail were 2.4331, 0.5332 and 0.40604 ppm respectively.[8]

A new study has found that as many as 2.34 crore people in rural areas of Uttar Pradesh are exposed to high levels of arsenic in groundwater.

Trends in arsenic related research publications from the year 2000-2019



Forty districts in the state are exposed to high concentration of arsenic in groundwater. The worst-affected:

- Balia
- Barabankhi
- Gorakhpur
- Ghazipur
- Gonda
- Faizabad
- Lakhimpur Kheri

Most of these areas are in the floodplains of Ganga, Rapti and Ghaghara rivers.

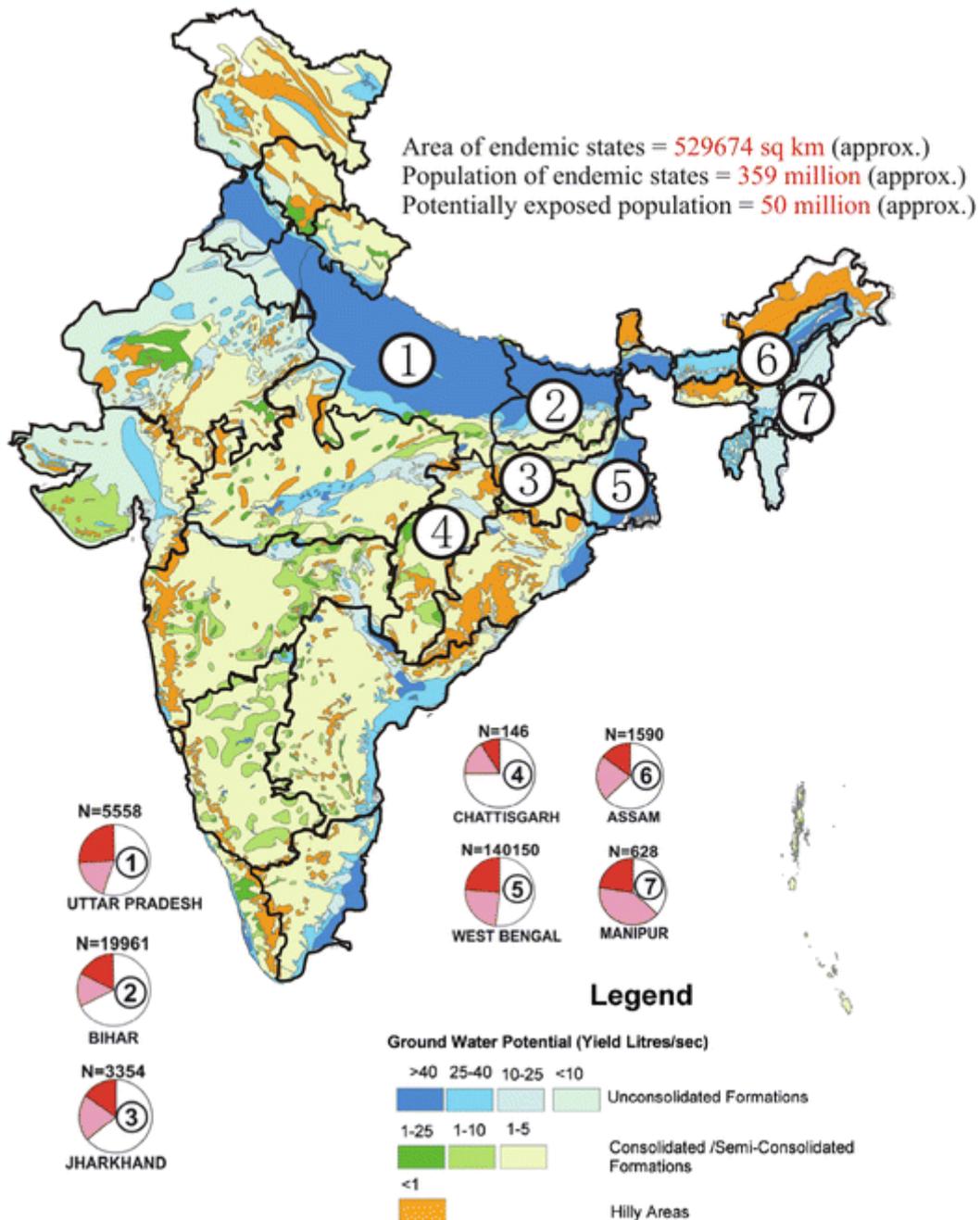
Ten other districts with moderate risk of arsenic contamination are:

- Shahjahanpur
- Unnao
- Chandauli
- Varanasi



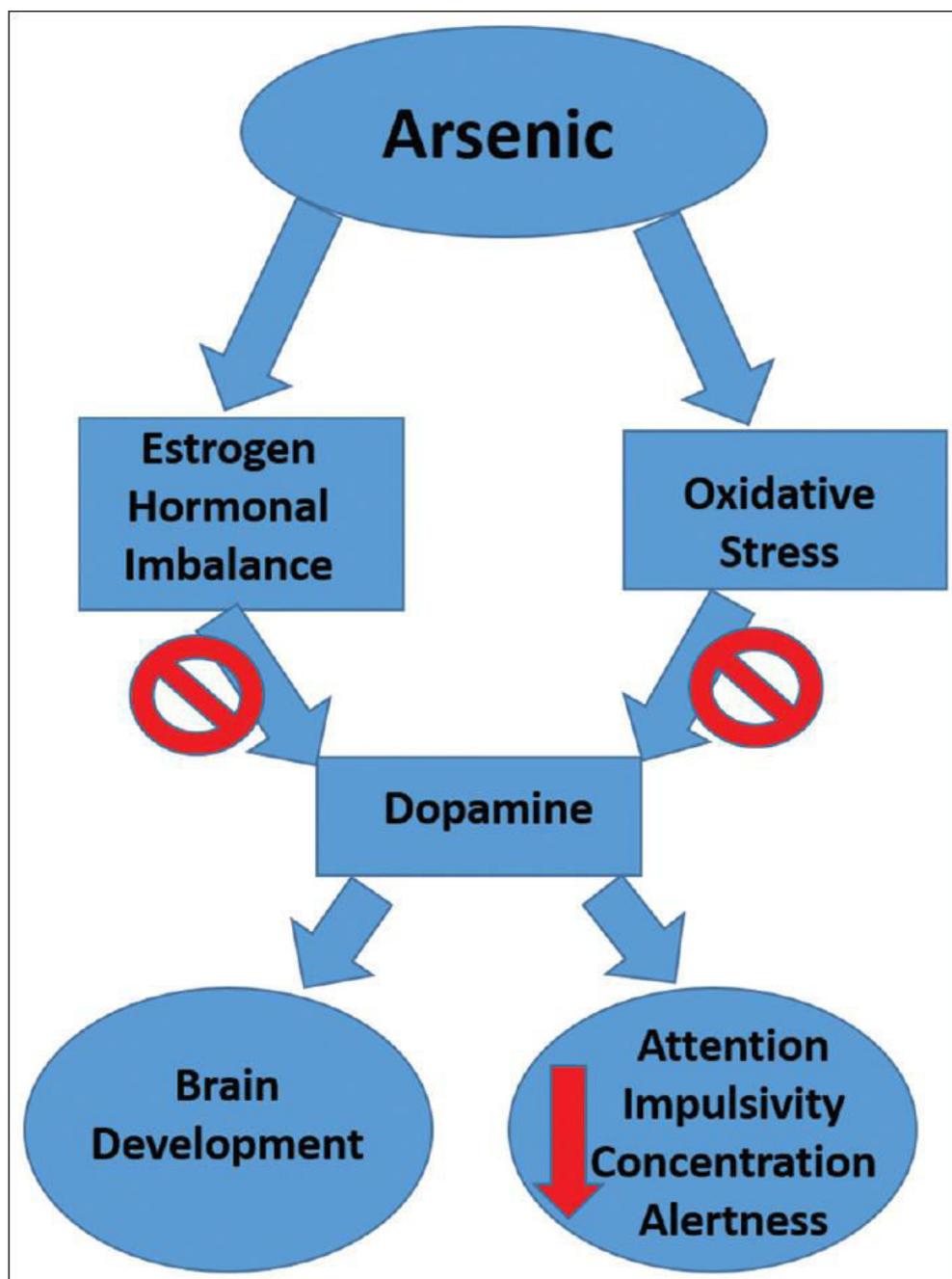
- Pratapgarh
- Kushinagar
- Mau
- Balrampur
- Deoria
- Siddharthnagar

About 78 per cent of the population in the state lives in rural areas and depends on ground water for irrigation, drinking, cooking and other domestic use. The risk of exposure to arsenic is much higher in rural areas than cities as piped water supply is not available in most villages.[9,10]



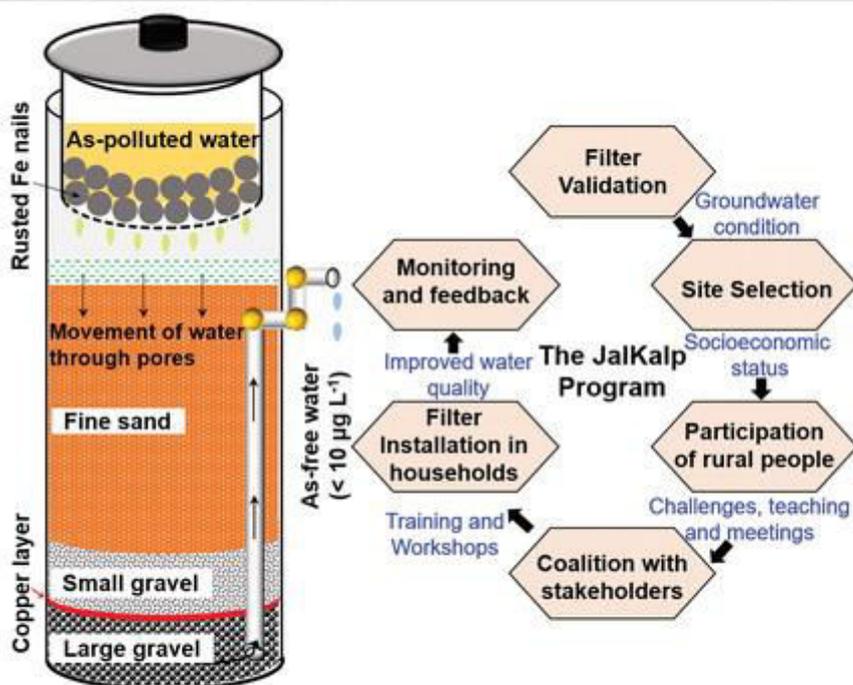
II. DISCUSSION

Arsenic occurs naturally as a trace component in many rocks and sediments. Whether the arsenic is released from these geologic sources into groundwater depends on the chemical form of the arsenic, the geochemical conditions in the aquifer, and the biogeochemical processes that occur. Arsenic also can be released into groundwater as a result of human activities, such as mining, and from its various uses in industry, in animal feed, as a wood preservative, and as a pesticide. In drinking-water supplies, arsenic poses a problem because it is toxic at low levels and is a known carcinogen. In 2001, the USEPA lowered the MCL for arsenic in public-water supplies to 10 micrograms per liter ($\mu\text{g/L}$) from 50 $\mu\text{g/L}$. In recent decades, arsenic contamination in ground water and its impact to human life have been one of the serious problems of every country. The contamination of drinking water supplies with natural occurring arsenic is major health problem. The authors have studied the arsenic contamination in district Ghazipur (U.P.), India [11,12]



One of the major causes for neurological problems, skin cancer, skin eczema, sensory disorder, pulmonary insufficiency, hypertension, acute renal failure, leukemia and peripheral vascular disease is consumption of arsenic contaminated water. The process of the development of human body is also affected by consuming contaminated arsenic water. It was discussed the source and mobilization process of arsenic contamination in ground water which affecting major parts of the Southern West Bengal and Western Chattisgarh. It has been studied the bladder cancer due to arsenic in drinking water. Also it was determined the metal contents in the groundwater of Sahebgunj district, Jharkhand, India, with special reference to arsenic. Arsenic exposure through groundwater to the rural and urban population in the Allahabad-Kanpur track in the upper Ganga plain was discussed by researchers.[13,14]

Modified Biosand Filter for Provisioning of Potable Water to Rural Households Affected by Chronic Arsenic Pollution in Groundwater Environmental Engineering Science



Conclusion: Low-cost modified biosand filter "JalKalp" made of locally available materials can be a suitable alternative for arsenic and pathogen removal for economically-weaker households.

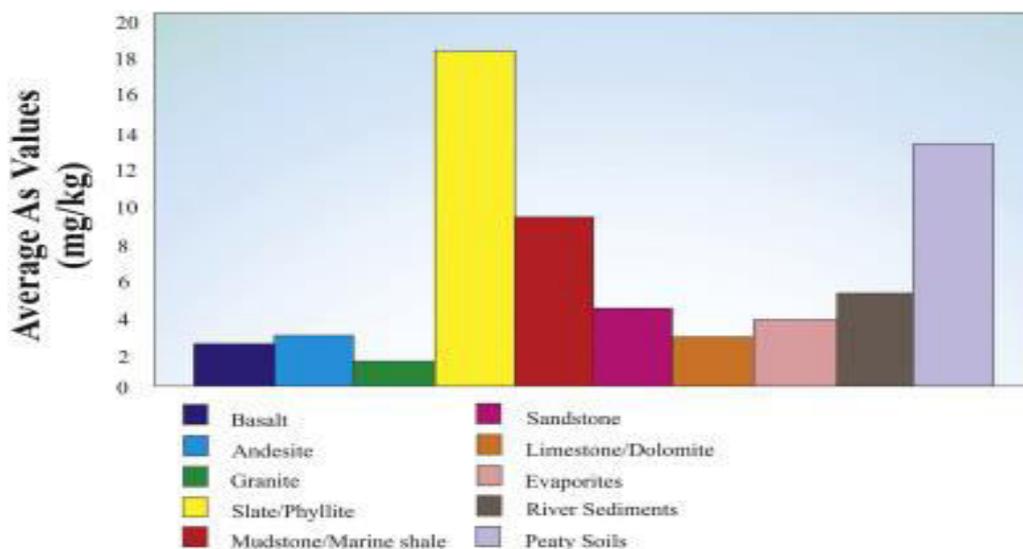
Reference: Akshat Verma, Lalit Mohan Sharma, Gaurav Pahuja, Jacklin Jeke Nilling, Ankit Kumar and Abhas Singh

DOI: 10.1089/ees.2020.0290

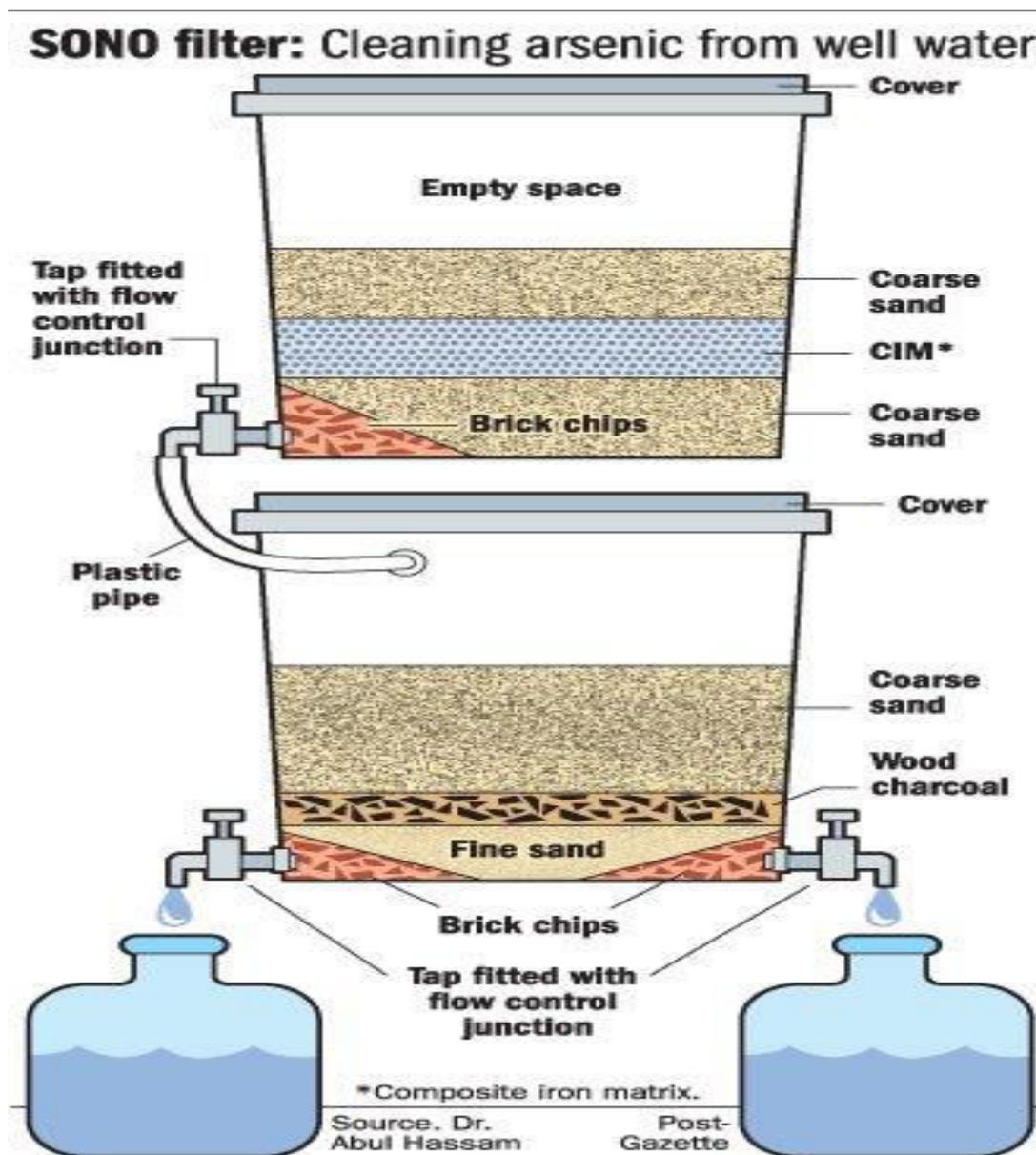
Graphical Abstract Created by: Akshat Verma et al.

Arsenicosis has been known to be a health problem in some parts of our country. It occurs mainly by drinking Arsenic contaminated ground water and also through contaminated food chain or Industrial pollution for prolonged period. It results in skin manifestations such as Keratosis, Melanosis and may also affect lungs, liver or lead to various types of cancers. The condition is preventable if measures are taken to provide safe drinking water to the community, promotion of nutrition and also if diagnosed early. With a view to formulate Guidelines for prevention, control and management of Arsenicosis, an Expert Group was constituted .After detailed round of discussions and subsequent exchange of communications, these Guidelines have now been finalized.[15,16]

Arsenic occurs naturally in the environment and can be released into water through natural activities such as hydrothermal action & dissolution of rocks. It occurs in both inorganic and organic forms. Inorganic Arsenic compounds (such as those found in water) are highly toxic while organic Arsenic compounds (such as those found in seafood) are less harmful to health. Shift from surface water and shallow open well sources to deep tube well in Arsenic affected areas has also led to Arsenic contamination in some States. Arsenic leaching may also occur from industrial sources or from Arsenic containing insecticides, herbicides or rodenticides.



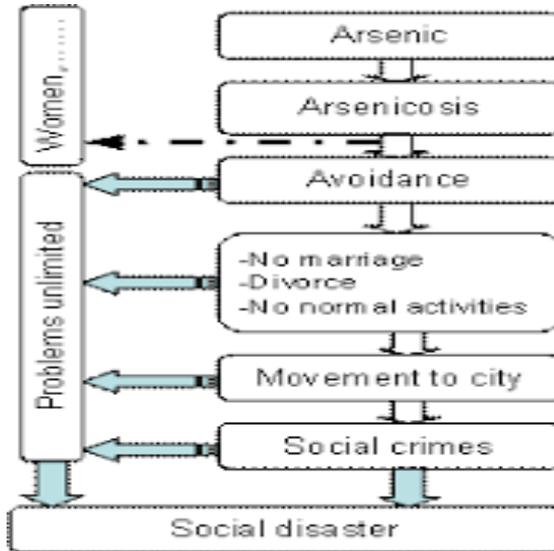
People are exposed to elevated levels of inorganic Arsenic by drinking and using contaminated water (mostly groundwater) for cooking, irrigation of food crops, industrial processes and smoking tobacco. Arsenic is also found in groundwater at an average of between 10m and 60m depth and deeper groundwater is generally free from Arsenic. Arsenic contamination of groundwater may also occur from anthropogenic activities such as mining, over exploitation of ground water etc. In rural areas, more than 85% of drinking water sources are ground water based. Long-term exposure to inorganic Arsenic can lead to chronic Arsenic poisoning. Skin lesions and skin cancers are the more characteristic features. Presently there is no effective remedy for Arsenic poisoning. The only effective management is through prevention by finding safe alternative sources of drinking water. Once patients switch to a safe source of drinking water, the skin lesions improve and this improvement may be accelerated by taking High Protein Diet, Vitamin B Complex, Anti-oxidant supplements (e.g. Vitamins A, C, E and Selenium). The health impact of exposure to Arsenic depends on the dose, the modality and duration of exposure as well as the source and type of Arsenic. The first visible symptoms caused by exposure to high Arsenic concentrations in drinking water are abnormal black-brown skin pigmentation known as melanosis and symmetrically distributed, multiple, small elevated lesions of palms and soles known as keratosis. If the Arsenic intake continues, skin de-pigmentation develops resulting in white spots that looks like raindrops (medically described as leukomelanosis). Palms and soles further thicken and painful cracks emerge. These symptoms are described as hyperkeratosis and can lead on to skin cancer. The disease syndrome caused by chronic Arsenic exposure is called Arsenicosis and it develops when Arsenic contaminated water is consumed for prolonged period of time. It is recognized that Arsenicosis may manifest with or without skin manifestations. [17] However, as skin manifestations are the leading reason for a patient to seek medical care, hence these are used for diagnosis of Arsenicosis based on dermal manifestations, generally Hyperpigmentation and keratosis. Though pigmentation and keratosis are the specific skin lesions characteristics of chronic arsenic toxicity, it also produces various systemic manifestations over and above skin lesions, important ones being chronic lung disease like chronic bronchitis, chronic obstructive pulmonary disease, liver disease like non-cirrhotic portal fibrosis and other diseases like polyneuropathy, peripheral vascular disease, nonpitting oedema of feet/hands. Trivalent Arsenic is believed to be a carcinogen that induces chromosomal abnormalities including changes in the structure and number of chromosomes and sister chromatid exchanges. The pentavalent Arsenic causes Arsenolysis. The exact molecular mechanism of Arsenic induced carcinogenesis is less understood. [18]



Health Education is absolutely necessary to change community behavior related to use of water, which in turn will help in prevention of Arsenicosis. Vulnerable populations should also be made aware about common signs and symptoms of Arsenicosis through use of simple, pictorial, context specific IEC material at the community and facility levels. A combination of learning experiences will have to be designed to help individuals and communities prevent Arsenicosis and facilitate early diagnosis and treatment by increasing their knowledge or influencing their attitudes Every opportunity – interfaces between health care provider and individuals, groups and communities – e.g. Inter personal communication in clinics, group meetings and mass meetings organized by health and other sectors, should be utilized to disseminate relevant messages. Traditional folk media, street plays etc. involving the community could also help in awareness generation, motivation and adoption of safe water use practices such as not using water from Hand pumps and Tubewells coloured Red for drinking and cooking purposes[19]

IV. RESULTS

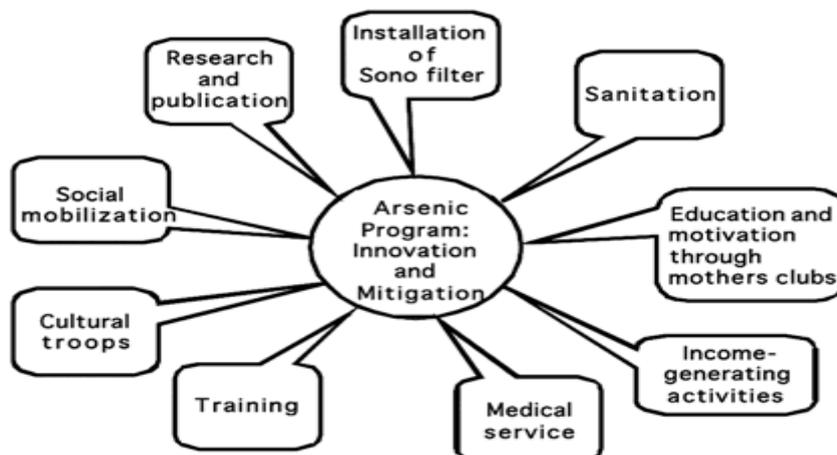
Trainings to be undertaken at the Central, State and District level. Training of Trainers to be organized for State Nodal Officer, District Nodal Officers, at the National Institutions / Head Quarter of any affected State / Medical College by the experts.



Besides, Laboratory Technicians of the identified laboratories for estimation of Arsenic in hair, nails and urine will undergo training at any recognized National Reference Laboratory. Further, trainings, advocacy and sensitization of various categories of health professionals /personnel at different levels of health care facilities will be undertaken at district level. These includes Policy Makers, Health workers, ASHAs, ANMs, Anganwadi Workers, PRIs, VHSC & Teachers. Strengthening of existing laboratory diagnostic facilities for Arsenic content in water, Hair & nails, urine in district hospitals/ medical colleges/ Public Health Laboratories for early detection and confirmation of Arsenicosis cases to be done in the affected areas. Sentinel sites must be established in the Medical Colleges.[20]

Symptomatic treatment of Arsenicosis at the PHC with referrals. A referral mechanism is to be developed to refer the affected person to the trained dermatologist / specialist in the district hospital/state hospital or state medical college for further diagnosis and management . Patients need to be screened for associated malignancies (esp. skin malignancies) and systemic complication (esp. respiratory, hepatic, neurological, and peripheral vascular affection) which are the major cause of mortality and morbidity; and treated accordingly. Keratolytic agents (e.g., 5-10% salicylic acid or 20% urea) may be given for symptomatic management of keratosis. Supplementation with high protein diet, B-vitamins and Antioxidants (e.g., Vitamins A, C and E etc.) to be undertaken as these. may reduce the risk of Arsenic-related skin lesions

Integrated Arsenic-Mitigation Program



Arsenicosis is defined as a chronic health condition arising from prolonged ingestion of Arsenic above the safe dose for at least six months, usually manifested by characteristic skin lesions of melanosis and keratosis, occurring alone or in combination, with or without the involvement of internal organs. Clinical Criteria _ the first diagnostic criterion requires the presence on physical examination of any of the pigmentary or keratotic skin signs listed earlier. These signs encompass a spectrum of non-cancerous and cancerous cutaneous findings that are well-recognized features of chronic Arsenic ingestion. Laboratory Criteria _ a reliable history of consuming water with an elevated concentration of Arsenic for at least six months is sufficient to establish exposure. In the absence of adequate information regarding a subject's exposure history, the finding of elevated levels of Arsenic in a subject's hair or nails could offer presumptive evidence of elevated Arsenic exposure. Arsenic testing should be conducted using standardized sample collection methods and acceptable laboratory techniques as elaborated subsequently Suspected Case _ A —suspected case is a subject who shows characteristic skin lesions or pigmentary changes or keratosis on first presentation and who has not undergone in-depth medical examination or laboratory testing. The classification of —suspected case is temporary. It should be reclassified as —probable, —confirmed or —non-Arsenic after further clinical examination and or laboratory testing. Probable Case _ A —probable case is a suspected case that has undergone further clinical examination and belongs to one of the two categories as below: Either (a) a suspected case showing melanosis AND bilateral keratosis involving palms and soles OR (b) a suspected case showing unilateral melanosis or keratosis after excluding other skin lesions mimicking Arsenicosis.[19,20] Probable cases whose Arsenic tests are subsequently found to be negative maintain the status of probable case. Clinically Confirmed case _ A —clinically confirmed case is a —probable case in whom the presence of other Arsenicosis-simulating skin lesions has been ruled out by differential in-depth skin examination by either a trained dermatologist or an Arsenic expert. The differential features to be used are given in Annex 2. Laboratory Confirmed Case _ A probable case classified on the basis of differential skin diagnosis becomes a —laboratory confirmed case when subsequent laboratory tests for Arsenic prove to be positive. Clinically and Laboratory Confirmed Case _ A —clinically and laboratory confirmed case is a —clinically confirmed case in whom the Arsenic test is also positive by the criteria recommended. Non-Arsenic Case _ A —non-Arsenic case is a —suspected or —probable case in which the medical specialist finds that the patient's skin condition is due to a cause other than Arsenic exposure.

The source is from the Himalayas. There are lots of minerals there, among them is arsenopyrite, which is made up of iron and arsenic that is not water soluble. It is carried down by the waters from the mountains. [18,19]



When the river meanders or changes its course, and people start living in those areas, the arsenopyrite is left behind and people are exposed to it. The arsenopyrite ostensibly lies dormant without visibly harming anyone, but it has an impact. But this was before the 1970s when people depended more on surface water from open wells etc., for their consumption. Soon handpumps became very popular. It was convenient, water was clean (arsenic is colourless,

odourless and is not visible in the water) and easily accessed. Wells were abandoned and groundwater began to be overexploited, which has contributed to groundwater contamination with arsenic.

It is a thumb rule for us now. Wherever we detect high iron content, we know that chances of that area containing arsenic is high. But after the 70s, UNICEF, WHO, etc., conducted studies where they found bacterial infections from surface water sources caused high infant mortality due to diarrhoea in third world countries (India was considered third world then). They were encouraged to go for handpumps. [17,18]

If water is treated before consumption, if the nutrition of the people is taken care of with enough greens and antioxidants, it can be arrested. We have seen an improvement in skin conditions, etc., in villages where the surface water has been treated. Of course, it is important to realise that this is possible as long as the arsenic poisoning has not led to cancer, in which case reversing it is difficult.

V. CONCLUSIONS

There is no complete solution. It is difficult to completely root out the problem of high arsenic. What can be done is to ensure safe drinking water to the population along with a nutritious diet. This could mitigate the severity of the impact. But it is an acute problem. We are doing reverse tracing at the cancer hospital. We get about 25,000 cancer patients a year at our hospital. When it is established that a patient has cancer and traces of arsenic is found in his blood, hair and nails, we test water in their village to see if it has high arsenic content.

There are many reasons for cancer, and we are still in the process of collecting data on how many of them are directly linked to arsenic. [19]

There is a lot of technology to provide safe water. The problem lies with transferring that technology to a rural area. Scientists may conduct tests and surveys, but the need of the hour is social scientists who can actually bring about change at the ground level. In 2012, we set up a HAIX treatment facility to remove iron and arsenic from the water. The technology is mostly mechanical and simple. It is still providing arsenic-free water. We entrusted the looking after the unit to an elderly farmer, who ensures that it is in working order. Any mitigation structure needs community participation. But yes, a comprehensive plan should be there for both quantity and quality of water. The hurry to supply water to everyone should not increase the disease burden.

Both reverse osmosis and electrodialysis (also called electrodialysis reversal) can remove arsenic with a net ionic charge. (Note that arsenic oxide, As_2O_3 , 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. In subterranean arsenic removal, aerated groundwater is recharged back into the aquifer to create an oxidation zone which can trap iron and arsenic on the soil particles through adsorption process. The oxidation zone created by aerated water boosts the activity of the arsenic-oxidizing microorganisms which can oxidize arsenic from +3 to +5 state SAR Technology. No chemicals are used and almost no sludge is produced during operational stage since iron and arsenic compounds are rendered inactive in the aquifer itself. Thus toxic waste disposal and the risk of its future mobilization is prevented. Also, it has very long operational life, similar to the long lasting tube wells drawing water from the shallow aquifers. Nanomaterials with intrinsically high surface energy prepared using naturally abundant ingredients can be helpful in creating green products. Using nanomaterials, it is possible to effectively destroy microorganisms, adsorb arsenic. [20]

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