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A comparison of studies examining the effects of arsenic on global human health and specific regions in Nigeria.

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Abstract

Arsenic occurs naturally in high concentrations in groundwater in various countries and is extremely toxic in its inorganic state. The primary threat to public health arises from the contamination of drinking water, food preparation, and irrigation of crops. Prolonged exposure to arsenic through water and food consumption is linked to cancer, skin lesions, cardiovascular disease, and diabetes. Additionally, early-life exposure may negatively impact cognitive development and increase mortality in young adults. The crucial measure in affected communities is preventing further arsenic exposure by ensuring a safe water supply. Arsenic is a naturally occurring element widely distributed in the environment air, water, and land. Elevated exposure occurs through contaminated water, food, industrial processes, and tobacco consumption, leading to chronic arsenic poisoning with characteristic effects such as skin lesions and cancer.

Keywords: Health; Contaminated water; Arsenic exposure; Environment; Cancer

1. Introduction

Soils, sediments, and groundwater contain organic molecules that contain arsenic. When arsenic is used for industrial purposes, mining, ore melting, or other processes result in the formation of these compounds. Mostly found in fish and shellfish, organic arsenic compounds. When arsenic is inorganic, it is extremely poisonous. The main source of arsenic contamination that affects human health is contaminated water used for drinking, cooking, and irrigating crops (Orosun 2021). Cancerous sores on the skin can result from prolonged exposure to arsenic in food and drink. Since arsenic is a semi-metal. Bright, silver-grey, and brittle in its metallic state.

A well-known toxin is arsenic (As). Insecticides and rat poison occasionally contain compounds with arsenic, although their application is closely regulated. Metal ores and other geological formations like igneous and sedimentary rocks are frequently linked to concentrations in groundwater. With the weathering of geological minerals and rocks, they are naturally introduced into groundwater. Anthropogenic activities include mining, abrasion of groundwater, sources of

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industrial effluent, and the use of pesticides in agricultural areas can induce contaminations. A significant and prevailing factor in the mobility of arsenic in groundwater is typically natural processes. Groundwater typically contains trivalent arsenic, one of arsenic's inorganic forms.

Volcanic ashes from the Andes deposited on the plains of Chaco and Pampas are the source of naturally occurring arsenic (As) in Argentine groundwater from the Quaternary period. There is a range of less than 0.005 mg/L to 1.22 mg/L of arsenic in groundwater in the Chaco plains sections of Salta province. Consuming crops irrigated by polluted water or drinking water contaminated with arsenic for an extended period of time can lead to toxic poisoning, which increases the risk of skin pathologies, internal and skin malignancies, peripheral nervous system and cardiovascular diseases, and even psychological disorders. According to Analia et al. (2012), arsenic levels can be measured in blood, urine, fingernails, and hair.

Groundwater believes to be rich (AS) is a problem that is being researched and investigated more and more. There have been reports of high As concentrations in groundwater in a number of locations worldwide (Fig 1). Extensive contaminations in Argentina, Bangladesh, Chile, China, India, Mexico, Taiwan, Thailand, and Vietnam have sparked interest in investigating the sources and releases of these contaminants from the aquifer matrix respectively (Izah, and Srivastav 2015)).

The fact that it is a known carcinogen and can cause a variety of human issues makes the health dangers quite concerning. A variety of cancers can affect the kidney, bladder, skin, lung, liver, and numerous heart conditions such hypertension, coronary heart disease, and heart disease. and endocrine systems; and lung disorders (Akagbue and Baba Aminu 2023a; Akagbue et al., 2023b; Akagbue et al., 2023c).

In certain locations, the process of pumping groundwater has attracted oxygen-rich near-surface water into an aquifer that is typically anoxic. This has led to the oxidation of As-rich pyrite, which has released As into solution (Siame et al., 2023). Environmental Protection Department FDEP reported that nineteen of those wells had As levels beyond the current drinking water regulations, and even more wells 34 out of 93 had molybdenum levels over 40 mg/L. This research seeks to clarify how arsenic is mobilized in the aquifer and whether arsenic originates from anthropogenic (i.e., mining) or geogenic (i.e., naturally occurring) sources. The study area will be given first. Following that, a review of the literature regarding a recent investigation into the issue in Lithia will be carried out. With an emphasis on the source and mobilization of As, the outcomes will be presented. Before summarizing the most significant findings with respect to the literature, there is a discussion of the findings.

Sulfur-containing minerals are highly attracted to arsenic, a metalloid. Arsenopyrite FeAsS is formed because pyrite is one of these minerals. Arsenic As3± and Arsenic As4± are formed in the tropics by oxidative weathering. With three electrons in the outer shell, its electrical structure is 3d10 4s2 4p3, and it is located in the VA column of the periodic table. A range of oxidation states are possible with this structure. 3, 0, ±3, and ±5. It comes in both inorganic and organic forms. According to Rashid and Mridha (1998), the inorganic As (3) from as H2AsO3 is 40–60 times more poisonous than As (v) form as H2As04. The main minerals that contain arsenic are arsenopyrites (FeAsS), arsenic trisulfide (As_2S_3), realgar (As_4S_4), and orpriment. (Islam and Islam, 2006–2008), 2005–2007).

2. World distribution of arsenic (as)

Groundwater contamination whether due to natural or human-caused sources and with multiple socioeconomic ramifications, is becoming a significant environmental issue in many regions of the world. Consuming groundwater that is rich in As exposes millions of individuals to high doses of As in a number of different nations. There is ample evidence of elevated levels of As in groundwater in the Indian State of West Bengal, Bangladesh, Vietnam, USA, China, Argentina, Chile, and Mexico. Globally, the estimated number of impacted individuals is 150 million, and this number is expected to rise as more affected regions are consistently identified.

Among the world's most dangerous substances is arsenic, a well-known carcinogen. prolonged exposure to hazardous inorganic substances by humans (for five to ten years) As related health problems such as skin disorders, skin cancers, internal cancers (bladder, kidney, and lung), diseases of the vessels of blood of the legs and feet, possibly diabetes, elevated blood pressure, and reproductive disorders can be brought on by consuming food and water. This condition is commonly referred to as arsenicosis. The inorganic forms of arsenic (AsIII and AsV), which are trivalent and pentavalent respectively, are more common and hazardous in the terrestrial environment than the biological forms as a whole. As interacts with cysteine residues' sulfhydryl groups to produce adverse effects on general protein metabolism with high toxicity. When someone becomes a victim of arsenicosis, it has a devastating effect on their ability to support themselves, their families, and their economy. Social exclusion of women results from physical deterioration. Increased

As at greater views. Contamination of an area can lead to poor market value of potentially polluted agricultural products, poverty, individual impairment, and stress on society, which in turn affects the affected farmers' income. The average individual cannot identify or avoid As due to its lack of taste, odour, colour, or exposure (Shiv Shankar et al.,, 2014).

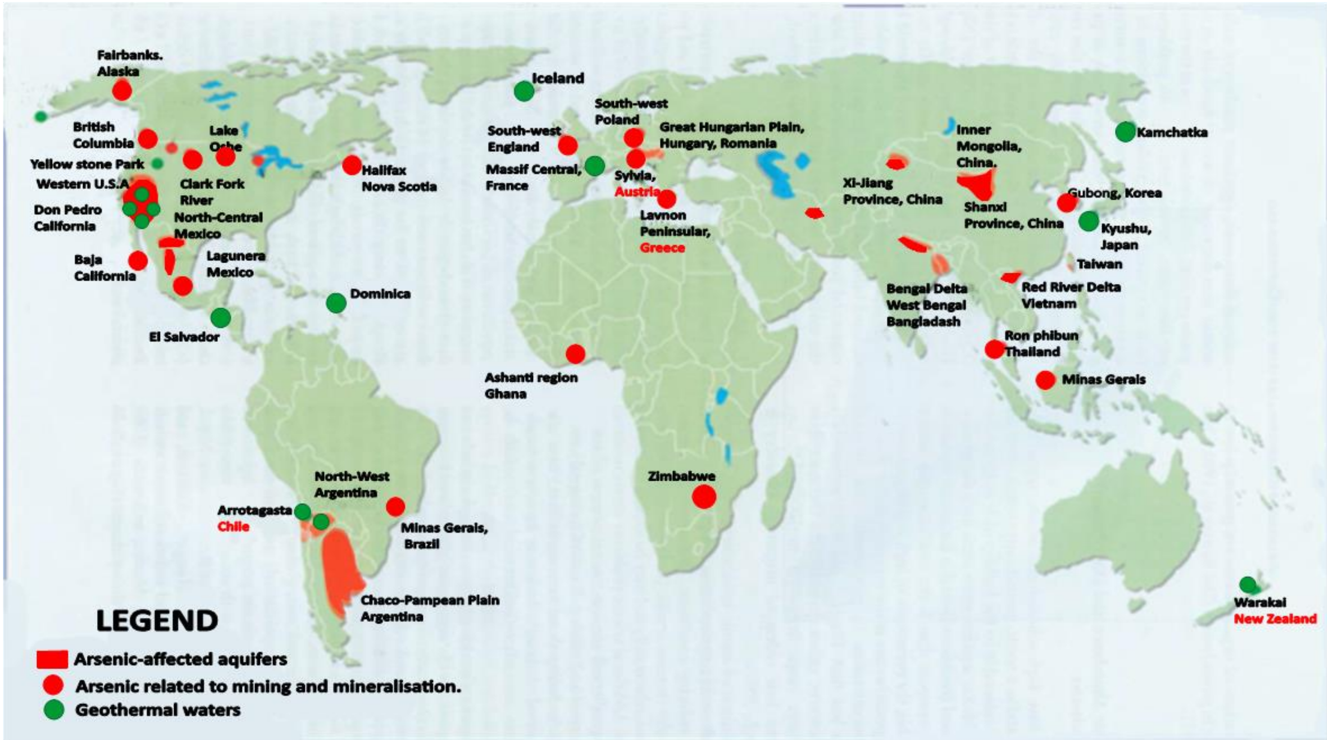

Figure 1 A global map showing the locations of established groundwater arsenic contamination (Jos A. Centeno, Gijsbert B. Vandor Voet, and Robert B.Finkelman,2007)

Table 1 Status of As pollution in natural groundwater throughout several nations. (Shiv Shankara, Uma, and Shikha Shanker, 2014)

Country	Ground water Arsenic level ppb	Permissible limit ppb
Afghanistan	10 – 500	10 (WHO)
Australia	1 – 12 (Groundwater) 1 – 73 (Drinking water) 1 – 220 (Surface water)	
Bangladesh	< 1–47	50 (WHO)
Brazil	0.4–350 (Surface water)	10 (WHO)
Cambodia	1 – 1610	10 (WHO)
Canada	1.5–738	10 (WHO)
China	50 – 4440	50 (WHO)
Finland	17 – 980	10 (WHO)
Greece	Upto 10,000	10 (WHO)
India	10 – 3200	50 (WHO)
Japan	1 – 293	10 (WHO)

Mexico	8 – 620	25
Nepal	Up to 2620	50
Pakistan	Up to 906	50
Taiwan	10 – 182	10 (WHO)
Thailand	–>5000	10 (WHO)
USA	Up to 2600	10 (USEPA)
Vietman	<1–305	10 (WHO)

3. Arsenic (as) in Nigeria

It has been established that arsenic exists in the Northern Benue Trough in Gombe State's Kaltungo district. Basalt, biotite granite, coarse porphyritic granite, and Bima Sandstone are the sources of arsenic in this region. Utilizing an Inductively Coupled Plasma Optical Emission Spectrophotometer (ICPOES), Optima 2000 DV, the Department of Geology and Mining at the University of Jos' Petroleum Technology Development Fund (PTDF) Geochemistry Laboratory detected arsenic. Arsenic concentrations frequently follow the Benue Trough's northeast-southwest pattern. The high amount of arsenic noticed this region is a product of mid-Santonian magmatism in the Benue Trough. Due to the host rocks weathering, and erosion, arsenic is released into the groundwater and surface water in this region. It adheres to mineral surfaces as an anion, particularly the iron in biotite. This explains why iron and arsenic are mobile during local weathering and deposition.

The average crustal abundance of 2 ppm is far below the high concentration of arsenic in all rock types at Kaltungo and its surroundings in Nigeria. The concentration typically varies between 152,900 and 235,200 ppm in coarse porphyritic granite and between 232,200 and 243,100 ppm in biotite granite. Between 228,700 and 87,540 parts per million are found in the Bima Sandstone, and between 174,600 and 151,600 parts per million are found in the local basalts.

High quantities are found in the northern regions of Biu Volcanic, North-Eastern Province of Nigeria, Kano state, Zaria and surrounds, Kaduna, Borno states, Sokoto, and in the south-western states of Osun and Ogun. When compared to Northern Nigeria, the Southern region of Nigeria does not have as much information about arsenic contamination of water. Aside from the latest tests conducted in 2013, which found that the quantity of arsenic in Yenagoa, Bayelsa state, was 0.03 mg/l, the concentration in the Niger Delta is precisely below the allowable range. In a same vein, the concentration in Abia state is lower than that which is allowed for a source of potable water. (Sylvester Chibuezeh and Srivastas Arun, 2015).

Table 2 Nigerian drinking water sources' level of arsenic content (Sylvester and Arun, 2015)

Various source of drinking water	As contents (mg/l)	Locations
Surface water, mg/l	0.03 -0.477	Biu Volcanic, North-Eastern Province of Nigeria
Groundwater, mg/	l 0.006 - 0.424	
Hand dug wells, mg/l	0.40 - 0.60	Karaye Local Government area, Kano state.
Tap pumped water, mg/l	0.09 – 0.16	
Hand pump operated borehole,	0.08 – 0.16	
Well Water mg/l	0.765 highest level	Getso in Gwarzo Local Government area, Kano State.
	0.809 highest level	Kutama in Gwarzo Local Government area, Kano State.
Borehole, mg/l	0.002 – 0.008	Zaria and environs
well water, mg/l	0.02 – 0.51	
well water, mg/l	0.34	Jeba, Jemaa, Kachia, Kagarko, Kauru, Kaura,

Borehole water, mg/l	0.14	Sanga and Zangon Kataf local government area in Kaduna state
Well water, mg/l	0.20 – 0.40	Ikara, Kubau, Kudan, L ere, Makarfi, Sabongari,
Borehole water, mg/l	0.03 – 0.14	Soba and Zaria local governments area of Kaduna
Borehole, mg/l	0.02 – 0.04	Maiduguri, Borno State
Sachet water	0.17-0.25	Sokoto, Metropolis
Well water	0.21-0.38	
Tap water	0.22-0.28	
Ground water	0.00 – 0.38 (dry season) 1 – 3.06 (Rainy season)	Ibadan Oyo State
Borehole, mg/l	0.00 – 0.05	Odeda region, Ogun state
Well water , mg/l	0.00 – 0.07	
Borehole, mg/l	0.03 – 0.47	Ijebu land, Ogun state

3.1. Sources of arsenic

Man-made and natural processes such ground water, mineral ore, and geothermal processes can release arsenic into the environment (no citation yet). Geological sources of exposure: As previously mentioned, As can be found in both naturally occurring and man-made sources, such as industry, mining, medicine, food, and drink.

However, the greatest number of reportable poisoning cases worldwide were caused by exposure to naturally occurring geological sources of As, such as groundwater, geothermal springs, volcanic deposits, and As-rich coal. For instance, As mobilised from coal burning resulted in serious health issues in Slovakia and China. (Robert B. Finkelman, Gijsbert B. Vandor Voet, Chin-Hsiao Tseng, and Jose A. Centeno, 2007)Volcanoes, weathering of arsenic-contaminated rocks and ores, and commercial or industrial activity are some of the natural and industrial sources of arsenic emissions into the atmosphere. The earth's crust naturally contains arsenic, and mining and industrial use are primarily responsible for its environmental dispersion.

3.1.1. Groundwater

underneath the surface contaminated groundwater is the source of the biggest arsenic threat to public health. Many nations, including Argentina, Bangladesh, Chile, China, India, Mexico, and the United States of America, have naturally occurring high concentrations of inorganic arsenic in their groundwater. The sources of exposure include drinking water, contaminated crops that are irrigated with it, and food that has been prepared with it.

Table 3 The sources of exposure include drinking water, contaminated crops

Arsenic Sources	**Environmental contamination**
Tube wells and arsenic supplied by an aquifer that is polluted geologically.	Drinking water.
Mineral Ore.	Drinking water and soil.
Natural land source erosion, discarded mining and mill tailings, and items containing arsenic that are carried by precipitation	Drinking water and Soil.

3.1.2. Industrial processes

Arsenic is a byproduct of the industry's process of smelting, which involves separating metal from rock, for a variety of metal ore, including cobalt, gold, lead, nickel, and zinc. In the manufacturing of glass, pigments, textiles, paper, metal adhesives, wood preservatives, and ammunition, arsenic is employed as an alloying agent. In addition, arsenic is utilised in the tanning of hides and, to a lesser degree, in medicines, feed additives, and insecticides.

3.1.3. Mining activities

The majority of the African Precambrian Complex, including the Greenstone Belts, has seen metallic sulphide mineral occurrence.As a result, aquifers over most of Africa now contain arsenic. Gold mining in Ghana and South Africa, metal sulphide mining in Zimbabwe and South Africa, and coal mining in South Africa have all resulted in the environmental introduction of arsenic, which loves sulfurides.

There was acid mine drainage (AMD) at Iron Duke Mine, close to Mazowe, Zimbabwe, with a pH of 0.52.A study on the geochemistry of mine waters in the Midlands, Shamva Greenstone Belt, and Harare was conducted when this was noticed. With the highest dissolved arsenic concentration on earth, the mine fluids from Iron Duke Mine in Mazowe contain roughly 72 mg/l of arsenic.

3.2. Effect of arsenic to human health

Human health can be adversely affected by arsenic, and the level of toxicity varies depending on intake; it can be categorised as acute, sub-acute, or chronic toxicity, accordingly. It is a lethal silencer. Its lethal dose (LD) for humans is 125 milligrammes, making it four times more dangerous than mercury. The final type of poisoning is brought on by contaminated drinking water.Arsenic poisoning is undetectable in its early stages and takes 8 to 14 years to affect a person's health, depending on their nutritional status, immune system, and amount of arsenic they have consumed. (Islam and Islam, 2005-2007; 2006-2008).

Humans are primarily exposed to arsenic by ingesting, inhalation, and skin contact. Drinking water contaminated with arsenic over an extended period of time is known to cause skin cancer, and there is strong evidence that it also raises the risk of bladder, lung, kidney, liver, colon, and prostate cancers. Additionally, recent research has demonstrated that arsenic is linked to other non-neoplastic illnesses, such as diabetes mellitus, heart disease, cerebrovascular disease, lung disease, and disorders of the arteries, arterioles, and capillaries (Engel and Smith, 2004). People who suffer from chronic Hepatitis B infection, protein insufficiency, or malnourishment may be particularly vulnerable to the harmful effects of arsenic (WHO, 2011). Elderly people and children can also be particularly vulnerable groups. Table I lists the issues and bodily organs that are typically impacted by arsenicosis. Thickening and darkening of the skin, nausea, vomiting, diarrhoea, numbness in the hands and feet, partial paralysis, and blindness are all signs of arsenic poisoning. Arsenic toxicity is dose dependant, especially on the pace at which arsenic compounds are ingested and eliminated from the body; nonetheless, arsenic accumulates within the body and slowly exits through the hair and nails. The majority of the arsenic that is consumed is eliminated from the body by the skin, hair, nails, urine, and breath. When arsenic is consumed in excess, part of it builds up in tissues and prevents the activity of biological enzymes.

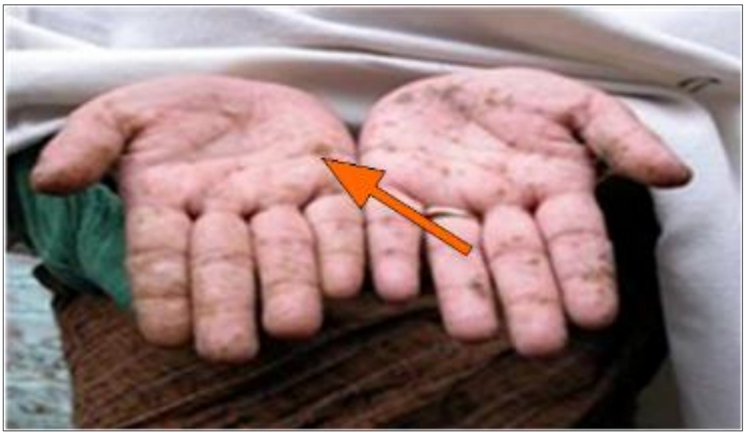

Figure 2 Signs of arsenicosis: spots on the hand(Islam and F Islam , (2005-2007); (2006-2008)

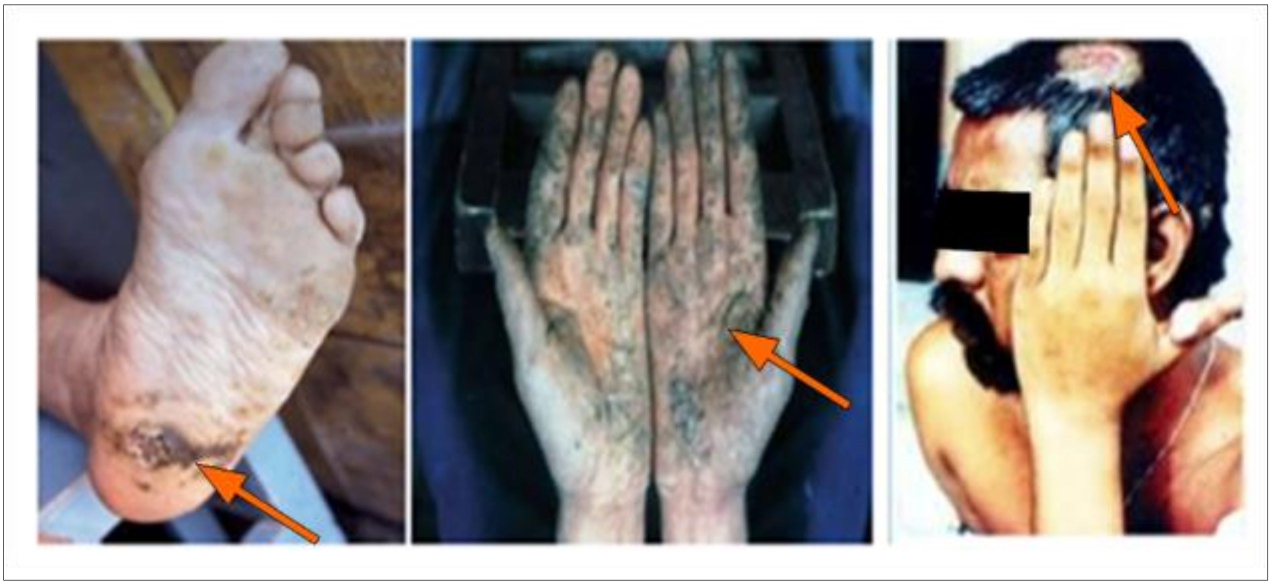

Figure 3 Hyperkeratosis/ulceration of the foot & hands and hair (Islam and Islam , (2005-2007), (2006-2008))

4. Mitigation of arsenic

There are two distinct, though not incompatible, strategies to reduce the negative effects of groundwater contamination with arsenic on human health:

- Prevention
- Cure

Prevention: It is crucial to check every tube well and population to identify contaminated ones and the level of contamination in order to prevent further exposure to arsenic contamination. The tube well screening has already been completed by the GoB.The tube well is marked with green paint that is safe to drink and red paint that indicates a concentration of arsenic higher than the national threshold. The following actions to supply all populations with water free of arsenic.

4.1. Water purification to remove arsenic

There are many ways for removing arsenic from water. Since various techniques are used for each type of arsenic—organic or inorganic—it is crucial to distinguish between them in order to do this. The majority of arsenic in groundwater is found in inorganic forms, such as arsenides and arsenates. Effective techniques consist of membrane filtration, iron and aluminium coagulation, and ion exchange. Arsenic has also been successfully removed from mine fluids using buffering techniques. Hydrous ferric oxides can precipitate arsenic at a wide pH range, which is another promising strategy for removing arsenic from mine fluids, according to sequential extraction speciation studies and geochemical modelling techniques. Utilising ferns that bio-accumulate significant amounts of arsenic, one can remove arsenic from soils.

4.2. Locally adopted as removal technology

The water in the Fill and Draw Unit FDU is tainted with arsenic, and the necessary amounts of oxidant and coagulant are added to it. After mixing the water for 30 seconds at a spin speed of 55 per minute, the mixture is left overnight to settle. Anybody who wishes to drink water must add the same volume of tainted water to their drink. Impurities, such as arsenic, in the water are adsorbed on the surfaces of the activated alumina grains when it flows through a dense column of activated alumina. Based on those ideas, the Activated Alumina Unit AAU in relation to the Bangladesh University of Engineering and Technology (BUET) operates. A system was created by the BUET Iron Coated Sand Unit ICSU to make iron coated sand in accordance with a set protocol. 350 bed volumes could be treated to meet Bangladesh's 50 parts per billion drinking water guideline, according to the findings (Ahmed and Rahman 2000).

4.3. Bucket treatment unit (btu)

The iron-based chemical coagulation/co-precipitation method used in the arsenic removal system developed by the Bangladesh Council of Scientific and Industrial Research (BCSIR) Filter Unit is followed by sand filtration.Based on the concepts of coagulation, co-precipitation, and adsorption processes, the DPHE-Danida Project created the Bucket Treatment Unit (BTU). By employing 100 mg/L of ferric chloride and 1.4 mg/L of potassium permanganate—also referred to as modified BTU units—BUET was able to improve upon the BTU and get greater outcomes. A reverse osmosis water dispenser for the home, model number MRT-1000, was advertised by Jago Corporation Limited and produced by B&T Science Co. Limited. Additionally, Stevens Institute Technology Units use two buckets: one for mixing packets of calcium hypochloride and iron sulphate, and another for separating flocs using the filtration and sedimentation procedures. Upon combining with a stick, the chemicals manifestly create huge flocs. According to BAMWSP, DFID, and Water Aid Bangladesh (2001), this approach is successful in lowering arsenic levels to less than 0.05 mg/L in 80 to 95% of studied samples.

4.4. Basic techniques for biological arsenic removal.

Two mechanisms involved in detoxification are arsenic trivalent (AsIII) oxidation and arsenic pentavalent (AsV) reduction (Ahmed 2000). Multiple studies have also documented the connection between bacterial species and the reduction of arsenates through the anaerobic oxidation of organic substrates. Dissimilatory arsenate reducing bacteria, also referred to as arsenate respiring bacteria (ARD), include the following bacteria: Bacillus arsenicoselenatis, Geospirillum barnesi, Desulfutomaculum auripigmentum, Geospirillum arsenophilus, and Chrysiogenes arsennatis (Engel, and Smith, (2004). AsVas is a terminal electron acceptor that these bacteria use in their respiration mechanism. Components like ozone, hydrogen peroxide, chlorine, or potassium permanganate are typically added to carry out the oxidation of As III. It is not recommended to treat drinking water with chemical reagents since they frequently produce unwanted byproducts such trihalomethanes (THMs). One possible substitute for chemical oxidation of As III is biological oxidation. Groundwater concentrations of arsenic are known to be significantly influenced by iron and manganese, two common undesirable elements that cause aesthetic issues in drinking water. As has been reported to be biologically oxidised by a number of bacterial species [35,208,209]. We refer to certain native bacteria as "iron and manganese-oxidizing bacteria" when they are involved in the biological oxidation of arsenic. These bacteria have been effectively used in continuous groundwater treatment for the biological oxidation of arsenic.

It has been discovered that a promising method for the efficient removal of arsenic from groundwater is the biological oxidation of iron by two bacteria, Gallium ferruginea and Leptothrix ochracea. During this process, microorganisms and iron oxides are coated on filter medium, creating the perfect conditions for arsenic to be adsorbed and extracted from the water. These bacteria have been shown to oxidise trivalent arsenic in ideal experimental settings, helping to remove nearly all arsenic (up to 95%) even at initial concentrations of 200 mg/L . Under the previously mentioned experimental circumstances, the pentavalent arsenic content can be significantly reduced, resulting in residual values below the recently implemented limit of 10 mg/L. This method has various benefits over traditional physicochemical treatment procedures and effectively eliminates arsenic from groundwater. Because it does not require the addition of chemical reagents to oxidise trivalent arsenic, it is an economical and environmentally beneficial solution. Additionally, since the sorbents (iron oxides) are continuously created in situ, there is no need for monitoring of a breakthrough point as there is in other sorption processes. Owing to its combination treatment method (biological oxidation, filtration, and sorption), groundwater can effectively remove inorganic contaminants like iron, manganese, and arsenic at the same time.

5. Conclusion

In the environment and in all living things, As is a common place element. Many minerals that contaminate sulphur can be found in natural sources; the most prevalent being arsenopyrite. As levels in native plants and animals reflect species differences, while soil and water levels are mostly determined by geologic inputs from mineral weathering processes. Marine organisms like crustaceans and certain fish, as well as various types of marine plants like algae and seaweed, frequently have high levels of arsenic in their natural states.

The majority of man-made arsenic comes from the by-products of smelting nonferrous metal ores, mainly copper and, to a lesser extent, lead, zinc, and gold. The American Smelting and Refining Company's copper smelter in Tacoma, Washington, is the only manufacturer and refiner of arsenic trioxide in the country. Sweden is the world's top producer of arsenic, and it is a major import. Insecticides, herbicides, desiccants, wood preservation, and feed additives are the agricultural pesticide categories where arsenic is most commonly used. Lead arsenate, calcium arsenate, and sodium arsenate were among the earlier inorganic insecticides that were made from arsenic trioxide as their basic material. Monosodium and disodium methanearsonate, as well as carbodylic acids, are three herbicides that are among the more recent significant organic arsenical pesticides. for feed additives that serve as phenylarsonic acid substitutes. Arsenic has a few small applications, mostly in medicine, glass making, metallurgical applications, and as a catalyst in various manufacturing processes.

Recommendation

- More laboratory and epidemiological studies should be done to investigate the possibility that chemicals containing arsenic are carcinogenic.
- Further investigation is needed to fully understand the consequences of low-level, long-term arsenic exposure on people, domestic animals, wildlife, and aquatic creatures.
- Further research is needed regarding the potential teratogenic and mutagenic effects of arsenicals.
- Detailed investigation is needed to understand the toxicity of arsenic inhalation.

Compliance with ethical standards

Disclosure of conflict of interest

No conflict of interest to be disclosed.

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