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Arsenic in Groundwater: Understanding the Pathways from Pollution to Human Health and Remediation via PLE Method

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Abstract: Arsenic *contamination in groundwater poses a significant threat to human health, necessitating a comprehensive understanding of the pathways through which this toxic element infiltrates drinking water sources. This scientific investigation focuses on elucidating the mechanisms of arsenic pollution in groundwater and explores a novel remediation approach utilizing Polymeric Ligand Exchange (PLE) method. The study begins by evaluating the sources and geochemical processes that contribute to elevated arsenic concentrations in groundwater. Anthropogenic activities, such as mining, agricultural practices, and industrial discharges, often lead to the release of arsenic into aquifers. The hydrogeochemical interactions influencing the mobilization and transport of arsenic within the subsurface are examined, providing insights into the complex dynamics governing its presence in groundwater. The prevalence of arsenic contamination in groundwater, utilized for irrigation, human consumption, and industrial purposes, has evolved into an epidemiological challenge. Inorganic arsenic is established as highly toxic in both acute and chronic scenarios, entering the human body through ingestion, inhalation, or skin absorption and subsequently spreading across various organs like the lungs, liver, kidneys, and skin. Arsenic poisoning exhibits diverse clinical manifestations, making accurate diagnosis contingent upon heightened awareness. Early detection of arsenicosis is challenging due to its nonspecific symptoms, which overlap with various other diseases. Existing remedies for arsenicosis have proven unsatisfactory through repeated application and experience, with melanosis potentially disappearing but keratosis remaining unaffected, although complications may be averted.*

Key Words: *Arsenic poisoning, Arsenicosis, Human health, Polymeric ligand exchange, Anthropogenic activities*

1. INTRODUCTION:

Arsenic exists primarily in two distinct oxidation states: arsenate (As5+) and arsenate (As3+). These oxidation states, As5+ and As3+, are mutually convertible through oxidation, transforming As3+ into As5+, and reduction, converting As5+ into As3+. Another manifestation of arsenic is in its organic form, resulting from the biomethylation of inorganic arsenic. Within the realm of biology, various organisms including plants, aquatic creatures like fish and crabs, as well as the human body, harbor organoarsenic compounds. Uttar Pradesh comes under upper and Middle Ganga plain. Himalayan Mountain and Tibet plateau, consider as the biggest source of arsenic contamination in the Gangetic region and this contamination are evidently becoming life threatening in almost every year4. Geographically Uttar Pradesh situated in the northern region of India and border of Nepal. The river Ganga and Ghaghara are two major river flows from northeast to southeast. First time in UP arsenic introduced as a contaminant in Ballia district .Status of Arsenic Contamination in Eastern U.P.: In U.P. Jal Nigam and UNICEF combinedly reported and identified in 18 districts. Arsenic above the 50 ppb limit for drinking and Arsenic according to WHO limit was found in 31 districts [1,2]. Times of India also reported "Ground water arsenic contamination of Uttar Pradesh exceeds to the value of BIS(Bureau of Indian Standards) permissible limit of 0.01 mg/liter across 31 districts of the state. Arsenic contamination in Ballia district: District Ballia is located in the eastern part of UP with shared in 17 blocks. This concern has gained significant attention due to its far-reaching implications, not only for the safety of drinking water but also for its impact on irrigation efforts. Azam A.'s pioneering work in [3,4] illuminated the prevalent oxidation states of arsenic, primarily existing as arsenate (As5+) and arsenite (As3+), as further elucidated in subsequent research by Azam A. and Kunwar in [5] (Azam A. and Kunwar [6] JOWPPR Pg. no. 1-4, 2018).

2. TEMPORAL AND SEASONAL VARIABILITY OF ARSENIC IN GROUNDWATER:

It was reported a clear temporal and seasonal variability of As concentrations in different samples. During post monsoon season As concentration decreases in samples. The variability in As concentrations is likely to be associated with the seasonal fluctuations in groundwater recharge and the impact of irrigation drawdown. Difference in Arsenic concentration during pre and post monsoon seasons is correlated in terms of its concentration. A definite relationship exists between the behavior of arsenic and rainfall intensity. With increasing rainfall intensity rate of dilution increases which minimizes the arsenic concentration in the groundwater. During monsoon period there is considerable decrease in the arsenic concentration. Thus it can be said that there is a strong correlation exists between rainfall condition, dilution effect and arsenic concentration. Contrary to this, during winter season and pre monsoon seasons there is an increase in the concentration which is associated with the decrease in dilution effect. The intricate interplay of multiple factors intricately regulates the concentration and movement of arsenic within groundwater systems. These factors encompass the redox potential (Eh), the dynamic equilibrium of adsorption and desorption processes, precipitation and dissolution phenomena, as well as the crucial arsenic speciation [7]. The pH level, alongside the presence and concentration of competitive ions, along with biologically mediated transformations, also exert substantial control over arsenic behavior, as articulated in publication [8]. The potential for arsenic contamination in surface waters is due to the increased release of arsenic into water from sediments. During the dry season, arsenic in sediments has a poor ability to resuspension. Therefore, little arsenic is transported downstream. During the wet season, flooding upsets the sediment and water balance, allowing arsenic to resuspension and downstream transport of pollution [8,9]. A captivating temporal pattern emerges in the realm of arsenic dynamics across various seasons, as revealed in Azam A. [10] study. During the monsoon season, there is a notable increase in arsenic content, attributed to the breakdown of Fe(III)-oxy hydroxides. In contrast, the pre-monsoon period witnesses the reversible adsorption of arsenic onto Fe(III) oxy hydroxides [11,12]. Significantly, Azam A. investigation in the same year established a clear connection between arsenic behavior and the intensity of rainfall, emphasizing the crucial link between environmental conditions and arsenic mobilization [13].

3. INNOVATIVE GEOCHEMICAL APPROACH FOR TARGETED ARSENIC REMOVAL:

Water and wastewater treatment facilities worldwide grapple with a significant challenge in effectively removing trace elements like Arsenic (As), particularly when faced with highconcentrations of competing major ions in the background (Mandal et al., 2013; Ramana and Sengupta, 1992). The conventional methods to eliminate As(Arsenic) often struggle to counteract the impact of these background ions, leading to reduced cost-efficiency (Korngold et al., 2001; Pincus et al., 2019). This situation hinders their practicality due to economic, environmental, and societal factors, resulting in gaps in achieving the desired selective removal of As(Arsenic). This challenge becomes more pronounced in scenarios where water sources have only minimal As(Arsenic) contamination, which is exacerbated when compared to the abundance of other dissolved chemical species crucial for safe drinking water. Consequently, there is an urgent need for mechanisms that exclusively target As(Arsenic) removal while focusing on maximizing efficiency and selectivity [14,15]. Enter the innovative frontier of anion exchange polymeric ligand exchange (PLE), a recent development offering an augmented arsenal for arsenic removal from drinking water. PLE exhibits greater selectivity and capacity in the presence of formidable competing anions— chloride, sulfate, bicarbonate, and phosphate. This breakthrough holds the potential to overcome the limitations of traditional approaches and provide a more effective solution for arsenic removal, addressing a critical concern in water treatment and environmental preservation [15].

4. ARSENIC TOXICITY:

Arsenic acts as a protoplastic poison by affecting the sulphydryl group of cells, disrupting enzymes, cell respiration, and mitosis. The chronic poisoning and medicinal usage of arsenic have been recognized for a long time. Historically, arsenic was administered orally in formulations like Fowler's solution for various purposes, including the treatment of asthma, leukemia, and other malignancies. Arsenic was also used parenterally for conditions like syphilis, topical eosinophilia, trepanosomiasis, lichen planus, verruca planum, and psoriasis. The domestic, agricultural, and industrial uses of arsenic in insecticides, weedicides, rodenticides, and arsine are diminishing due to the introduction of less toxic pesticides. Consuming arsenic-contaminated beer has been linked to chronic hepatitis and hepatic cirrhosis. The non-dermatological effects of chronic arsenical poisoning from arsenic-contaminated drinking water were first reported in 1961 in Taiwan and later in Chile and India. Saha's report is the initial documentation in world literature of chronic arsenical dermatosis resulting from the consumption of arsenic-contaminated tube well water [16-26]. Presently, it is widely accepted that different species of an element can have varied toxicological and biological impacts on both animal and human systems. This principle naturally extends to compounds as well.

5. FUTURE SCOPE:

1. The challenge of selectively extracting arsenic (As) from aqueous solutions is a complex endeavor shaped by various geochemical factors. Within natural waters or wastewater, a multitude of common anions coexist, often at significantly elevated concentrations, creating a competitive environment for As adsorption processes. Consequently, unraveling efficient techniques for arsenic separation stands as a prominent realm of research.
2. Research efforts will focus on developing targeted therapies to mitigate the toxic effects of arsenic, addressing both acute and chronic exposure. Nanotechnology may play a crucial role in designing drug delivery systems that specifically target arsenic-affected tissues, minimizing collateral damage to healthy cells.
3. Furthermore, advancements in personalized medicine may lead to tailored treatment approaches based on individual susceptibility and genetic factors. Integrating artificial intelligence into diagnostic processes can enhance accuracy and efficiency in identifying arsenic poisoning cases.

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COMPETING INTERESTS:

Authors have declared that no competing interests exist.

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