

FEASIBILITY STUDY ON TREATMENT TECHNOLOGIES FOR REMOVAL OF ARSENIC FROM WATER

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Abstract - Water contamination has been a significant issue due to various organic, inorganic, and pathogenic ingredients. Arsenic is the most hazardous element in the chemical world, and its presence in drinking water can cause disaster in the world. The lack of quality drinking water in rural communities is still a problem, where expensive water treatment technologies or techniques are not affordable. Arsenic can occur in organic and inorganic forms with varying valence states. Arsenic plays a vital role in its behaviour and toxicity in aqueous systems. Chronic arsenic exposure has devastating health effects like cardiovascular diseases, cancer, and eventual death. Many methods of arsenic removal have been studied, but most of these are too expensive and impractical to be implemented in economically weaker countries. Every available process has limitations and can only be served to a limited extent. This paper overviews arsenic removal in drinking water through different treatment technologies such as oxidation, coagulation-flocculation, adsorption, ion exchange method, and membrane separation. It was observed that the hybrid techniques could successfully remove arsenic contamination from the water.

Index terms – Toxicity, coagulation, flocculation, adsorption, valency, ion-exchange.

I. INTRODUCTION

I.I ARSENIC AS AN ELEMENT

Arsenic (As), the 20th most prevalent trace element in the earth's crust, is a component of about 245 different mineral types, the majority of which are ores containing metals like cobalt, copper, nickel, lead, or sulphide. Numerous industries use arsenic extensively, including electronics, agriculture, wood preservation, metallurgy, and medicine. These human-made sources help release arsenic into the environment and release it from natural geological sources, such as the weathering of rocks containing arsenic and volcanic activity. Arsenic is recognized to be exceedingly harmful to all biological forms. The World Health Organisation has designated this element as a group 1 human carcinogenic material. Recent studies on arsenic's environmental fate and behaviour have increased due to numerous arsenic pollution incidents worldwide and the dangers they pose.

Arsenic is one of the many heavy metals well-known for being hazardous and a priority contaminant. The harmful consequences of the element arsenic are widely known. Millions of people in numerous areas are at risk from arsenic pollution of natural water resources. Epidemiological research shows a strong correlation between several diseases, including cancer, and prolonged exposure to arsenic in drinking water. Chronic arsenic poisoning can result in various health issues for people through contaminated drinking water or agricultural products irrigated by contaminated water.

I.II ARSENIC CONTAMINATION IN WATER

There are numerous ways for natural water resources to become contaminated by arsenic. Natural depositions or runoff from our mining and agricultural lands introduce arsenic to drinking water. A nearby industrial waste disposal facility is another way arsenic can enter the water system. Naturally occurring arsenic dissolves in some rock formations when the groundwater level falls. The industrial sector releases and deposits thousands of pounds of arsenic into the environment each month. Once released, arsenic stays in the environment for a long time and will fall to the ground or water's surface when it rains or snows. As a result, groundwater is quickly contaminated by incoming arsenic. Private wells with high arsenic levels may have used fertilizers that included arsenic or industrial waste.

I.III HARMFUL EFFECTS OF DRINKING ARSENIC WATER

Arsenic in drinking water has a tenuous link to a higher risk of skin, lung, bladder, and kidney cancers, as well as other skin alterations such as hyperkeratosis and pigmentation changes.

Short-term exposure to extremely high quantities of arsenic may result in headaches, nausea, vomiting, diarrhoea, and stomach pain. However, large amounts can quickly kill a person.

II. REMOVAL METHODS OF ARSENIC FROM WATER

The arsenic in the water cannot be washed away or removed by heating or boiling it because some water evaporates during the boiling procedure. As a result, the arsenic concentration may rise slightly as the water is heated to boil. Disinfection with chlorine (bleach) cannot remove arsenic in water. The amount of arsenic that can be removed depends on the water's standards. Arsenic has three primary valences: -3, +3, and +5. Arsenic exists in two oxidation states in aqueous environments: trivalent (III) and pentavalent (V). Therefore, to remove arsenic from water, we employ a variety of methodologies, including oxidation, coagulation, flocculation, adsorption, ion exchange, and membrane technologies.

II.I RESTRICTIVE OXIDATION OF ARSENIC

Since the trivalent form (As(III)Arsenite) is primarily non-charged below pH 9.2 (Nina Ricci Nicomel et al. [1]), the pentavalent form of arsenic (As(V)Arsenate) is the form that is removed by the majority of arsenic removal technologies. Arsenate prefers to co-precipitate with metallic cations or absorb into solid surfaces, making it significantly less mobile than arsenite.

As a result, the conversion of arsenite to arsenate frequently involves the phase of oxidation. Arsenite can be oxidized by oxygen, hypochlorite, permanganate, and hydrogen peroxide. Since atmospheric oxygen is the most accessible oxidizing agent, several treatment methods favour oxidation by air (Pierce M L et al. [2]). However, arsenic oxidation in the air is a prolonged process that can take several weeks.

II.II SEDIMENTATION AND PASSIVE OXIDATION

Passive sedimentation, another name for oxidation with oxygen naturally present in the air during collection and subsequent storage in homes, may decrease arsenic concentration in stored water. According to Nina Ricci Nicomel et al. [1], water must be held for a while long enough to allow oxygen to transfer from the air to the water for passive sedimentation. Water quality, particularly precipitating iron, appears necessary for arsenic reduction through plain sedimentation. Iron and high alkalinity in the water from tube wells contribute to increased arsenic storage.

II.III COAGULATION AND FILTRATION FOR ARSENIC REMOVAL

The most extensively studied technique for removing arsenic from water is coagulation and filtration with metal salts and lime, followed by filtration (Edwards M [3]). Arsenic is taken out of the solution during the coagulation process by coagulation processes.

II.III LIME AS A COAGULANT

Arsenic can be removed from water by adding quick lime, CaO, or hydrated lime, Ca(OH)₂. According to Nina Ricci Nicomel et al. [1], lime treatment is analogous to coagulation with a metal salt. The calcium hydroxide that has precipitated serves as an arsenic-sorbing flocculent. Excess lime must be removed along with precipitates using the sedimentation and filtration processes since it will not dissolve but instead acts as a coagulant aid (Ahmed M F [4]). It has been noted that the removal of arsenic by lines is typically between 40 and 70%. At pH 10.6–11.4, the most effective removal is attained. Lime liquefaction is Possibly used as a pre-treatment before iron or alum coagulation.

II.IV ADSORPTION-BASED ARSENIC REMOVAL

Adsorption, commonly called sorptive filtration, is a technique for removing arsenic from water. Adsorption is a method for removing chemicals from gaseous or liquid solutions by using solids as a carrier. There have been reports of the removal of arsenic from water using various absorptive media, including activated alumina, activated carbon, iron and manganese-coated sand, kaolinite clay, hydrated ferric oxide, activated bauxite, titanium oxide, silicon oxide, and many more natural and manufactured media.

According to Nina Ricci Nicomel et al. [1], The fundamental driving forces of this process are van der Waals forces and electrostatic interactions between the adsorbent surface atoms and the adsorbate molecules. The employment of oxidizing agents as tools to trigger the sorption of arsenic on the media determines how effective sorptive media are.

II.V ARSENIC REMOVAL BY ION EXCHANGE

Ion exchange techniques use a synthetic resin medium with a more precisely defined ion exchange capability. The cross-linked polymer skeleton, or matrix, serves as the foundation for the synthetic resin. According to Clifford D [5], the charged functional groups can be classified as acidic, weakly acidic, strongly basic, or weakly basic. These groups are bonded to the matrix through covalent bonds.

The pH of the water has less of an impact on the ion exchange process. Ion exchange does not remove arsenite because it is uncharged. As a result, in order to remove arsenite via the ion exchange method, As (III) to As (V) must first undergo pre-oxidation; nonetheless, in many cases, this must be done in order to avoid damaging sensitive resins. The resin needs to be renewed as it runs out. Washing with a NaCl solution will quickly regenerate ion exchange resins.

II.VI REMOVAL OF ARSENIC USING MEMBRANE TECHNIQUES

Membrane filtration is a method that can be used to remove arsenic pollutants from water concerning the manufacture of drinking water. Usually, membranes with many pores serve as selective barriers, preventing some water elements from passing through. Pathogens, salts, and different metal ions are just a few contaminants removed from water using synthetic membranes. Water must be pushed through the membrane using a driving force, such as the pressure difference between the feed and permeate sides (Nina Ricci Nicomel et al. [1]). There are typically two types of membrane filtering utilized. Microfiltration, Ultrafiltration, and Reverse Osmosis are examples of low-pressure membranes. Nanofiltration and reverse osmosis are examples of high-pressure membranes. Arsenic removal by membrane filtration is not affected by pH or the presence of other solutes. However, colloidal matter is detrimental (Ali M A et al., [6]). Scaling and membrane fouling can also be caused by iron and manganese. In addition, the membrane cannot be back-washed after becoming contaminated by water contaminants. To prevent clogging, the water must undergo pre-treatment before using membrane techniques to remove the arsenic.

III. ADVANTAGES AND DISADVANTAGES

When choosing the right oxidant for oxidation, it is essential to consider the interfering elements present in water because they can significantly alter the oxidation's kinetics. Total organic Carbon (TOC) present in water decreases as the rate at which ozone oxidizes arsenite significantly (Nina Ricci Nicomel et al., [1]). It has been demonstrated that competing anions and organic materials in groundwater significantly impact the utilization of UV/Titanium dioxide in arsenic oxidation. This involves a difficult-to-dispose-of As-bearing residue produced by a complicated procedure. Therefore, it is crucial to choose oxidants carefully to effectively remove arsenic from a solution by oxidation (Edwards M [3]). The cited drawbacks of oxidation alone render it a less effective technique for removing arsenic from water.

The main disadvantage of the coagulation-flocculation process sometimes called the filtration method, is the significant volume of sludge concentrated in arsenic. To avoid the adverse effects of secondary pollution of the environment, this sludge must be managed (Johnston et al., [7]). In addition, treating the sludge is expensive. Therefore, this procedure is less practical because of these constraints, especially in practical settings.

The filters used in filtration have pores with a diameter of 0.1 μm . Additionally, this type of filter is safe for drinking water filtration because it has no taste or odour and is chemically inert. Arsenic and heavy metals can be removed from water using a process devised by Misra and Lenz that involves precipitated mixed hydroxides followed by DE filtration (Misra M et al. [8]). In one of the laboratory-scale studies, a reagent dose of 1000 mg/L lowered a starting arsenic concentration of 100 mg/L by 90%—numerous drawbacks, including the requirement for reagents, a lengthy conditioning period, and pH adjustment.

Due to its numerous benefits, including relatively high arsenic removal efficiency, easy operation, handling, cost-effectiveness, and lack of sludge protection, adsorption has been reported as the most extensively used approach for arsenic removal (Pierce M L et al. [2]). Arsenic adsorption is highly influenced by the pH and system concentration. Arsenate adsorption is encouraged at low pH levels, but arsenite adsorption can be maximized between pH 4 and 9 (Nina Ricci Nicomel et al. [1]). Arsenic is not the only ion present in contaminated water; phosphate and silicate ions are also present and compete with it for adsorption sites. The type of adsorbent used can also affect how well adsorption removes arsenic and system parameters (Clifford D [5]). Low specific surface areas and irregular pore structures in most traditional adsorbents result in low adsorption capabilities. A lack of selectivity, weak interactions with metallic ions, and problems with regeneration may also constrain the ability of these sorbents to reduce arsenic concentrations to lower levels.

IV CONCLUSION

Arsenic is a persistent groundwater pollutant that can severely negatively influence a person's health when consumed through drinking water, among other sources. Arsenic emissions from anthropogenic sources and natural sources, including not the least several. Asian countries call for on-site clean-up to lower the toxicity hazards. The adsorption process uses a material, such as activated alumina, to bind to arsenic molecules and remove them from the water. An efficient adsorbent can remove up to 95% of arsenic from water. Other materials, such as iron oxide, sand, and carbon, can also be used for arsenic adsorption. However, these materials are less effective than activated alumina. Other recent research have shown that natural materials with effective arsenic removal capabilities include egg shells and java plum seeds (Shakoor et al., 2019) [9]. After the initial oxidation of arsenite by either bacterial activity, ambient oxygen, or chemical reagents, conventional procedures typically remove arsenate. A coagulation/flocculation procedure makes reducing the particle size of soluble species feasible, allowing removal by precipitation or membrane filtering in a subsequent phase, it is also noted that utilising a higher dose of the precipitation agent increases precipitation efficiency (Pohl, 2020) [10].

In contrast, ion exchange resins can immediately immobilize. As ions, pH effects and competition from other ions, like phosphate or silicate, can interfere with this action. However, due to their low adsorption capacities and limited ability to regenerate and reuse the adsorbents, the practical application of these conventional and non-conventional techniques still needs to be expanded.

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