

Study on the Removal of Arsenic from Water by Various Methodologies

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Abstract

There is a great impact on fresh water in the world; this is because of the drastic increase in the human population which leads to the continuous shortage of fresh water. Scientists found various methods to solve this crisis. These include treating industrial wastewater, purifying the seawater, drinking water taken from the ground etc. This review sheds light on the traditional and modern methods applied for this purpose with a focus on the use of natural materials as sustainable and environmentally friendly sources for creating new materials used in this regard. Mainly this review helps to remove the harmful metal arsenic present in industrial waste and groundwater. There are various methods used to remove these particles which are present in the wastewater. Some of the important methods include reverse osmosis, adsorption, extraction, and absorption of the targeted particles using various nanoparticles. Wastewater treatment can be done in three different categories. They are chemical, mechanical, and biological. In this article, we will learn how the metal arsenic can be removed from wastewater by various methods.

Keywords: Arsenic • Wastewater • Flocculation • Coagulation • Reverse osmosis • Waste water treatment

Introduction

Wastewater treatment is a process used to remove contaminants from wastewater and convert it into effluent that can be returned for the same treatment to increase its purity. Once returned to the same water cycle, the effluent creates an acceptable impact on the environment or is reused for various purposes (called water reclamation) and also it doesn't create any harmful things to the environment as well as living organisms [1]. Generally, wastewater contains variously dissolved and suspended solids in it. These are very harmful and cause severe damage when we consume them without any pre-treatment. In this article, we can be able to know the removal of arsenic which is a metal present in wastewater by various methods. This metal creates numerous effects on human health when we consume water which contains arsenic as a dissolved solid. So it is mandatory to remove the metal in any water (groundwater, industrial wastewater) arsenic is a chemical element, which is represented by the symbol as and has the atomic number 33. It is mostly present in minerals. Generally, arsenic combines with sulphur. In the Copper (Cu) and Lead (Pb) refining process Arsenic (As) is produced as a by-product [2]. Arsenopyrite is a substance that contains arsenic in huge amounts. While heating the arsenopyrite it causes arsenic to sublime and produces iron (II) sulphide. Some research found that arsenic is an essential one in diet. It must be low in number. In large doses of arsenic, it is a suspected carcinogen.

Once arsenic gets into our body, it creates a bond with the atoms present in hair. By analysing that hair sample, we can be able to know that they are exposed to arsenic. It also presents in some organisms like prawns which is in surprising amounts and less harmful when it is consumed.

Arsenic contamination of groundwater is widespread and there are many regions where arsenic contamination of drinking water is significant. As per WHO, at least 140 million people from 70 countries have been drinking water which contains arsenic level at value of 10 micrograms per litre. Urinary arsenic levels are majorly classified into three levels namely, normal, high normal, high [3]. The normal urinary arsenic value is less than 50 micrograms or exactly that number per litre. High normal level ranges from 50-200 micrograms per litre. High level ranges value is greater than 200 micrograms per litre. A recent study observed that arsenic level in groundwater is quite high in some countries. Inorganic arsenic is highly toxic to living organisms. Contaminated water used for food preparation, drinking and irrigation of food crops poses a major threat to human health from arsenic. The main anthropogenic sources for the contamination of groundwater with arsenic are the burning of fossil fuels, mining, use of arsenical fungicides, insecticides and fungicides in agriculture, and wood preservatives. The burning of coal has a severe effect on the contamination of arsenic in the environment [4].

Arsenic may cause different types of severe cancer which includes lung and skin cancer. The association between chronic

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arsenic exposure and cancer is strongest for bladder, skin and lung cancer. Liver (because it widely targets dispersed enzymatic reactions, arsenic affects all of the human organ systems. Dermal effects are the most sensitive endpoint from arsenic exposure. While several studies may identify effects on other endpoints at the same exposure level which produces the database for dermal effects which is said to be stronger than for effects on other endpoints [5].

Physiological effects of arsenic exposure

- Several types of skin lesions, patchy skin hyperpigmentation are the most common effects of heavy chronic exposure.
- It is difficult to explain strong associations between disease and arsenic exposure, as the prevalence and spectrum of diseases linked to chronic arsenic exposure differ not only between countries, but even within countries.
- Arsenic can cause lung and skin cancers and may cause other types of severe cancers.
- The association between chronic arsenic exposure and cancer is strongest for lung, skin and bladder cancer. Liver (angiosarcoma), kidney, and other cancers have limited strength of association.

Removal of arsenic

Various technologies have been used for the removal of arsenic from groundwater. The most commonly used technologies are co-precipitation with alum or iron, adsorptive filtration (by using activated alumina), ion exchange, and membrane processes such as reverse osmosis [6].

EPA (Environmental Protection Agency) identifies the following treatment methods as the best available technologies for the removal of arsenic from drinking water:

- Anionic exchange.
- Reverse osmosis.
- Iron oxide filters.
- Activated alumina.
- Modified coagulation/filtration.
- Modified lime softening.
- Electro dialysis reversal.

The most cost-effective method for the removal of arsenic from water appears to be reverse osmosis; commonly called RO. RO is often referred to as molecular filtration. It works by the principle of forcing water through a selective membrane [7]. Filtration through activated carbon will remove 40%-70% of the arsenic present in the water. Anion exchange can reduce it by 90%-100% whereas reverse osmosis has a 90% removal rate, and distillation is also a good method for the removal of arsenic and it will remove about 98% of arsenic present in the water. The filter is a short-term solution to remove arsenic from the well water. It is the cost-effective way the removal of arsenic from well water. Iron oxidation and manganese dioxide filtration remove iron from the system similarly to water softeners. In this process, the system also may remove both arsenic (V) and arsenic (III) with varying levels of effectiveness through oxidation. Now, we see the methods of removal of arsenic in groundwater in a detailed manner [8].

Materials and Methods

Materials

There are several materials used for the removal of arsenic in wastewater. Some of the important materials used for the removal of arsenic are Y-aluminium oxide nanoparticles, natural clinoptilolite zeolite, cupric oxide particles (the main nanoparticle which is used to remove the arsenic present in the wastewater), aluminium electrodes, activated carbon and activated alumina.

Methods for the removal of arsenic

A novel removal of Arsenic using Cupric Oxide (CuO) nanoparticles: The arsenic adsorption process by CuO nanoparticles was kinetically rapid and it follows the pseudo second order rate. The CuO particles were continuously flowing through the reactor which is effective in filtering arsenic from natural and spiked wastewater. The regenerated CuO nanoparticles were also so much effective in filtering the arsenic particles from the groundwater. Mass balance data for arsenic from regeneration studies suggested that a maximum of 99% of input arsenic concentration was recovered. The CuO nanoparticle treatment did not have any major effects on the chemical quality of groundwater samples [9]. The results of this study suggest that CuO nanoparticles have a high potential for developing a simple process for the removal of arsenic from water.

Analysis of arsenic: The water samples were analysed for the presence of arsenic and trace element concentrations by Inductively Coupled Plasma-Mass Spectroscopy (ICP-MS) were also analysed. The detection limit for arsenic by ICP-MS was 0.001 milligram per litre. Ion Chromatography (IC) was used to measure the anionic concentrations. In the supplemental material, more information is provided regarding the model number and detection limits of these two instruments. Using a Hitachi H-7000 with a Gatan Ultra scan 4000 digital camera, CuO nanoparticles were imaged using Transmission Electron Microscopy (TEM). After being mixed in ethanol and subjected to ultrasonic vibration for 30 min, the samples were laid out on a copper grid that had been coated with carbon for TEM investigation [10]. The BET technique was used to analyse the surface area of CuO. Nanoparticles were dried using this approach at 110 C in an inert environment before being measured. Utilizing a TriStar 3000 analyser, nitrogen adsorbed on the surface of the particles was examined. Utilizing an orion five star pH probe, the pH was determined. Arsenic removal from a groundwater sample that had been treated with arsenic was shown to be more successful with regenerated CuO nanoparticles than with original CuO nanoparticles. This is most likely caused by the CuO nanoparticles renewed reactive surface area. While the arsenic contents in the outflow groundwater sample reduced significantly from 110 to 6.0 lg/L, the pH increased slightly from 7.56 to 7.83. Up to 14 L of groundwater samples were run through the reactor at first, with arsenic contents remaining below 10 lg/L. The concentrations of main and trace elements in the groundwater sample were not significantly impacted by the regenerated CuO nanoparticle treatment. In fact, the treated groundwater sample's Cu concentration dropped from 0.058 to 0.011 mg/L. These findings imply that arsenic can be removed from water using regenerated CuO nanoparticles. Data on the mass balance of arsenic derived from CuO nanoparticle regeneration.

These findings imply that the regeneration mechanism recovered 99.4% of the input arsenic content.

Arsenic removal from groundwater by electrocoagulation:

There are many ways to remove arsenic from water, but the majority of them are not practical since they use adsorbents with low adsorption capabilities and call for the addition of oxidants. Arsenic removal by electrocoagulation utilising iron electrodes (ECFe) is a promising approach. While factors like pH, current intensity, initial arsenic concentration, and co-occurring ions like phosphate, silicate, Natural Organic Matter (NOM), bicarbonate, sulphate, nitrate, and chloride may affect the effectiveness of ECFe's ability to remove arsenic, albeit it is unknown exactly how. In order to see these effects and better comprehend ECFe, experiments were created and run. The findings show that high arsenic elimination effectiveness (with respect to iron dose) depends on the oxidation of Fe (II) produced during ECFe. Arsenic removal per unit weight of iron dissolved was found to be most effective at lower current intensities and pH 7. According to observations, arsenic interacts with ferric hydroxides and forms phosphate complexes with iron (II). With time, these complexes and precipitates are rearranged to produce iron hydroxides that have a significantly higher affinity for phosphate.

Results and Discussion

Silicate had little impact up to 20 mg/L, but at 30 mg/L it was found to limit the amount of arsenic removed by ECFe. However, bicarbonate, sulphate, nitrate, and chloride had little impact on the removal of arsenic by ECFe. Increasing NOM concentrations likewise inhibited the removal of arsenic. Old ferric hydroxides in the reactor reduced the amount of Fe (II) needed to produce a concentration of less than 10 ppb by promoting interfacial reactions (Figure 1).

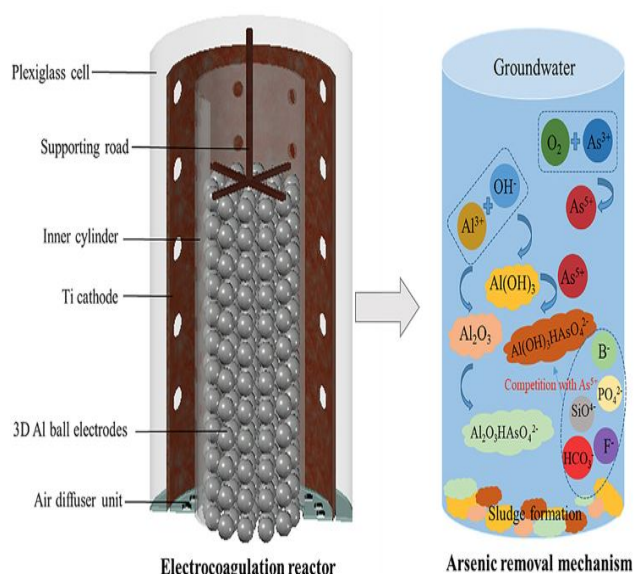


Figure 1. Electrocoagulation reactor and arsenic removal mechanism.

Arsenic removal by reverse osmosis technique: A partly permeable membrane is used in the Reverse Osmosis (RO) method of water purification to extract bigger particles, undesirable compounds, and ions from drinking water. In reverse osmosis, the chemical potential

differences of the solvent, a thermodynamic characteristic, are exploited to overcome the osmotic pressure collinear feature. Reverse osmosis is employed in both industrial operations and water production because it can remove a wide variety of biological species, primarily bacteria, as well as dissolved and suspended chemical species from water. As a result, the solute is held on the pressurised side of the membrane while the pure solvent is allowed to cross to the other side of the membrane. Smaller components of the solution, such as solvent molecules, such as water, and H_2O , should be able to move readily through the pores (holes) of this membrane while larger molecules or ions should not be able to do so.

In a typical osmosis process, the solvent naturally passes through a membrane from a region with a low solute concentration to an area with a high solute concentration (low water potential).

When the difference in solvent concentration on each side of an Osmotic pressure is created as a result of the solvent moving into the more concentrated solution when the membrane is decreased, which reduces the gibbs free energy of the system. Reverse osmosis is the process of using external pressure to change a pure solvent's direction of flow. The procedure is comparable to previous uses of membrane technology.

In contrast to filtration, reverse osmosis uses an osmosis mechanism to move fluid over a membrane. The method can theoretically attain complete efficiency regardless of variables like the solution's pressure and concentration because the main removal mechanism in membrane filtration is straining, or size exclusion, where the pores are 0.01 micrometres or larger. Instead, reverse osmosis employs a membrane that is either nonporous or uses nano filtration with pores that are 0.001 micrometres in size. Differences in solubility are the main mechanism for removal, and the process depends on pressure, solute concentration, and other factors.

Reverse osmosis is most famously used to purify saltwater into drinkable water by eliminating the salt and other waste products from the water molecules. According to studies, RO is up to 95% effective at removing the most typical type of arsenic that is regularly detected in well water in maine. Most contaminants in water are eliminated using reverse osmosis. A membrane is pushed through with water. While treated water goes through, the water's components, including arsenic, are left on the membrane. Millions of people worldwide are exposed to arsenic-contaminated water, and inorganic arsenic causes cancer. Regulated limits for the presence of arsenic in drinking water generally do not apply to private domestic wells. Well owners frequently utilise Reverse Osmosis (RO) systems to lower arsenic levels; however, these systems may not always be successful. 19 RO devices were found in a survey of 102 residences in Nevada. The average arsenic concentrations before and after RO filtration were 443 g/l and 87 g/l, respectively. Following filtration, the average reductions in arsenic contents were 356 g/l and 79%, respectively. In 10 residences, post-filtration concentrations exceeded 10 g/l, whereas in four homes, they exceeded 100 g/l. These data demonstrate that RO filters do not ensure the safety of drinking water and that some people are nevertheless exposed to very high arsenic concentrations despite legal requirements (Figure 2).

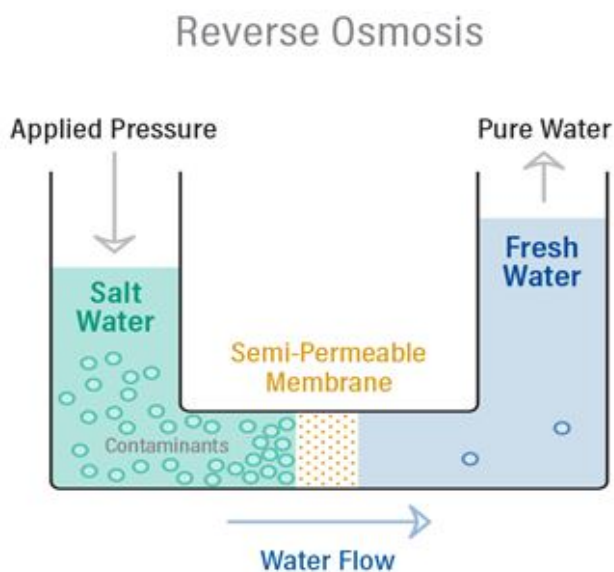


Figure 2. Reverse osmosis.

Arsenic removal from wastewater by using activated carbon: It has been discovered that iron impregnated activated carbons are particularly efficient at removing arsenic. Arsenate and arsenite, two oxy-anionic arsenic species, form complexes with the surface sites to adsorb at the iron oxyhydroxide surface. We wanted to pack as much iron as we could into the carbon pores while still leaving as much of the iron available for sorbing arsenic. In rapid small-scale tests (RSSCTs) utilising groundwater from Rutland, Massachusetts, surface oxidation of carbon by $\text{HNO}_3/\text{H}_2\text{SO}_4$ or $\text{HNO}_3/\text{KMnO}_4$ increased the amount of iron that could be loaded to 7.6%-8.0%; arsenic remained below 10 ppb until 12,000-bed volumes (40-60 ppb arsenic, and pH of 7.6-8.0). Surface oxidation significantly enhanced the concentration of carboxylic and phenolic surface groups, according to Boehm titrations. Additionally, assessed was iron impregnation through precipitation or iron salt evaporation. Internal iron loading increased the iron content to 9%-17%, and external and internal iron loading elevated the iron content to 33.6%. During RSSCTs, these iron tailored carbons penetrated 25,000-34,000 bed volumes to 10 ppb arsenic. There was some iron loss due to the 33.6% iron loading. Chemically oxidising the carbons, they were then iron loaded. The elimination of arsenic from these iron loaded carbons was then evaluated using RSSCTs that used Rutland groundwater. The iron loading data for these oxidised carbons and their bed volumes to breakthrough in RSSCT. For iron loading, carbon oxidation was often highly effective. Iron loading was increased by nitric acid/sulfuric acid oxidation compared to nitric acid oxidation alone.

Granular activated carbon, sometimes known as "GAC," may remove a variety of contaminants from groundwater and vapours, including radon, solvents, Polychlorinated Biphenyls (PCBs), dioxins, and other industrial chemicals. It can also remove radon and other radioactive elements.

Due to its ability to combine with particular coenzymes to create complexes, arsenite, As (III) is more harmful to plants and animals than As (V) and methylated species (10 and 70 times, respectively) among the different oxidation states. The widespread use of arsenic in herbicides, pesticides, fungicides, glass manufacture, and the glass

manufacture, and the electronic industry are other major sources of arsenic in natural streams. Many researchers have developed various technologies, including reverse osmosis, ion exchange, adsorption, and adsorbents, to remove arsenic from aqueous solutions. Pre-oxidation of As(III) to As(V) is necessary for high arsenic removal from drinking water supplies with high concentrations of As because As(V) is more effectively removed from water than As(III) (III). In order to remove a wide variety of contaminants or dangerous substances from aqueous solutions, such as aromatic compounds, heavy metal ions, and others, activated carbon has been acknowledged as a powerful and effective adsorbent. Adsorption is a physical phenomenon that heavily depends on pore volume and surface area. An extremely porous material, AC has a surface area ranging from 300 to 2500 m^2/g . Its exceptional adsorption characteristics are the result of the vast number of very small pores (micropores) that give it a large inner surface. Due to its highly hydrophobic nature, its primary use is the removal of organic contaminants from aqueous solutions that have a relatively high MW, such as pigments and colours. Simple inorganic metallic ions or tiny anions are more difficult to remove with AC. This essay, however, focuses on its potential use in the removal of inorganic arsenic from water, which often resides in the form of an anion.

Conclusion

Conventional adsorbents of aluminium, iron, and titanium have various limitations which involve oxidation of the wastewater and removal of competing ions so the adsorption of arsenic by CuO (Cupric Oxide particles) is kinetically fast but efficiently low when compared to other arsenic removal methods.

The electrocoagulation method has poor efficiency for the removal of arsenic from the industrial and groundwater since current density varies due to certain reasons. Major reasons include the absence of hypochlorite and the other metals which are mixed with arsenic. The activated carbon method is also similar to the removal of arsenic by the cupric oxide method. By the study on the various journals for the removal of arsenic from waste and groundwater, we conclude that Reverse Osmosis (RO) is the best method for the removal of arsenic. Because the design of the equipment is very low in cost and efficiency is quite good when compared to the other removal techniques.

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