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A Review of Remediation Strategies against Arsenic (As) Removal from Groundwater by Using Different Filtration Techniques

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ABSTRACT

Water is considered a basic essential for the existence of all living things on earth. Due to the increasing in concentration of heavy metal in water, it is highly harmful for human life. Arsenic is a major contaminant that is present in water due to natural and anthropogenic activities, that threatening the human health and encouraging the dissemination a number of diseases such as inflammatory and neoplastic changes of skin, respiratory system and reproductive system. In the meantime, hundreds of individuals are currently defenceless from this ground water with absorption of the contamination which is greater than its permissible limits. Many of techniques are used to remediate the toxic level of arsenic in water. Arsenic removal done by mainly using two major filtration techniques, which are the, membrane processes- nano filtration (NF) and reverse osmosis (RO). The appropriate techniques must be used in order to fulfill the World Health Organization's (WHO) guiding principle when removing arsenic from drinking water. Based on the results of many investigations, membrane filtration can effectively remove substantial quantities of toxic metals, such as arsenic, at a pressure while still generating high quality water that reduced operational costs. The removing of both kind of the arsenic over a high pressures and pH range is considered to be possible using RO membranes, which are yet another effective membrane technology. In these filtration methods, membrane clogging must be considered as a limitation; however, given the potential for the changing through the proper use of pretreatment and also considered advantages like as the lack of chemical use, insufficient production of sludge, efficiency in removing up to the permissible limit of WHO, and removing a high range of pollutants, they recommend to remove certain contaminants in contrast to another methods.

Keywords: *Heavy metals, arsenic, humans, health, environmental pollution, plants growth.*

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INTRODUCTION

The remediation of arsenic toxicity is done with different filtration techniques. Water is a distinctive element of nature and the basis of survival; it has always been essential for the survival of humans, and it is impossible to survive without it. However, the same water that sustains humans may also cause their death, largely due to their reckless actions (Nasiri et al., 2022). Water pollution has emerged as one of the biggest global issues due to an increasing in worldwide population, advancements in science, and accompanying growth in manufacturing and agricultural activities. However, freshwater resources have also diminished, posing a serious risk for the public's health (Siddique et al., 2020; & Ahmadi et al., 2022). Drinking water contamination puts more than 150 million people at risk and kills more than 20 million people annually (Siddique et al., 2020; & Kundu & Naskar, 2021**)**. The act of adding unwanted substances to the water and changing its quality in manner that is harmful for human beings and the environment is known as "water pollution" (Haseena et al., 2017).

Air pollution, Climate change, untreated sewage discharge, reservoir leaks and population growth followed by excessive use of surface and underground water resources, industrialization, excavating, industries, and highways are merely the sources of pollution. Numerous contaminants, such as radioactive elements, detergents, pesticides, phenolic compounds, trihalomethanes, organic dyes, and heavy metals, may influence the quality of ground water and mark it unfit for human consumption (Kardan-yamchi et al., 2022). The most hazardous water contaminants are potentially toxic substances, whose environmental pollution has grown into a major problem since their entrance into the biological cycle alters both natural and human ecosystems fundamentally (Kardan-yamchi et al., 2022; & Hasanzadeh & Ostvar, 2019).

Heavy metals are defined those compounds having atomic weights larger than 20 amu and density above 5 g cm^{-3} (Ahmed et al., 2022). Many of these metals required for body to perform normal function, however due to its accumulating nature, when they reach in the body in large numbers, either direct or indirect through the air, water and soil cause detrimental effects on health. Therefore, it's imperative to maintain the quantity in limit (Behbudi et al., 2020; & Nazari & Abbas-Nejad, 2015). While these elements occur naturally in the atmosphere, it is well-known that anthropogenic activities are the primary reason that increasing their effectiveness in marine habitats. Over the last ten years, more heavy metals have penetrated in the aquatic environment, and more than 40% of canal are contaminated from heavy metals (Zamora-Ledezma et al., 2021). There are 35 harmful metals that can harm human beings, 23 of which are heavy metals; alongside arsenic (As) is one of the most harmful heavy metal.

Heavy metals and their impacts on human health

The term "heavy metals" (HMs) refers to elements with an atomic number greater than 20 amu and an atomic density above 5 g cm^{-3}, as well as having the characteristics of metal. Some heavy metals, such as ruthenium, silver, and indium, are either generally harmless or essential nutrients (usually iron, cobalt, and zinc). However, they can be harmful in higher concentrations or particular forms. Arsenic, cadmium, mercury, and lead are some more heavy metals that are extremely dangerous. According to the Environmental Protection Agency (EPA), the eight most prevalent heavy metal pollutants are As, Cd, Cr, Cu, Hg, Ni, Pb, and Zn (Ahmadi, 2022).

In the ecosystem, heavy metals are present naturally, and their small amount are beneficial to humans. They support biological functions such as Fe helps in the creation of haemoglobin, Cu aids in oxygen and electron transport, Co aids in cell metabolism, Mn regulates enzyme regulation, Se aids in the production of hormones and antioxidants, and Ni aids in cell growth in humans; this is they are referred to as essential metals. However, when heavy metals are present at more concentrations, they have hazardous effects on humans. Heavy metals are entered into the human body mainly through ingestion (eating or drinking) and inhalation (breathing) by various means, such as living near a site where these metals are disposed of improperly, drinking water, and eating foods contaminated by heavy metals, which cause adverse effects on human being (Odum, 2015).

Effect of Arsenic on human being

Among heavy metals, arsenic is hazardous, inorganic arsenic causes cancer, diabetes, hepatic and renal failure, neurological issues are brought on by low to moderate amounts of As exposure. Women are more prone than males to As-induced skin diseases because their skin is thought to be more vulnerable to the substance, which causes dermatitis. Keratosis, melanosis, and pigmentation are skin lesions that are indicative of As exposure. Another target organ for arsenic poisoning is the brain. Neurological problems are caused by arsenic. Long axon neurons and sensory nerves are more effected than short axon neurons and motor nerves. Pain, numbness in the soles of the feet, and paresthesia are brought on by a decrease in the ability of neurons to detoxify reactive oxygen species and glutathione synthesis. One of the main causes of neurotoxicity is oxidative stress. Arsenic increases preterm birth, fetal loss in pregnant women, and loss of uterine conception. In people, Arsenic leads to steatosis and cardiovascular disease. It contributes to serious illnesses such ischemic heart disease, cerebrovascular disease, and peripheral vascular disease. AS also harms human kidneys (Baastrup et al., 2008; & Odum, 2015).

Effect of heavy metal on plant growth

Heavy metals are naturally found in the crust of the earth; they are neither destroyed nor degraded. Without metal ions, existence wouldn't be possible because it contains inorganic as well as organic elements. Numerous metals, including Fe, Co, Cu, Se, and Zn, are necessary metals. Plants need them to maintain growth and metabolism because they are found in low concentrations. However, hazardous consequences occur when metals are present in amounts that are higher than plants need. Soils are contaminated with heavy metals from both natural and man-made sources. Heavy metals are absorbed by plant roots from the soil and then transferred to other plant parts, where they have a variety of negative effects on the plants (Rascio & Izzo, 2011).

Effect of Arsenic effect on plant growth

Due to its widespread use, arsenic poses a serious threat to the environment and is extremely hazardous to all living things, including plants (non-essential). Arsenic affects plants' growth, yields, and germination by entering them with other essential nutrients. The entry of metalloids and metals as well as the absorption of mineral nutrients depend on the flow of water. However, it has been claimed that several heavy metals have an impact on water flows in a number of plants. The roots of tolerant plants contain higher quantities of arsenic than non-tolerant plants do. The concentration of arsenic is higher in shoots. Arsenic caused the production of ROS such hydroxyl radicals and hydrogen peroxide, which was linked to the oxidation of As (V) to As (III) (Kazemabadi et al., 2021). When ROS generates oxidative stress, it is damaging to macromolecules like proteins, lipids, DNA, and carbohydrates. Arsenic reduces the amount of fresh and dry plant tissue, curled leaves, photosynthesis, and necrosis of leaf blades. Phosphate is necessary for the metabolism of proteins and the transfer of energy, however since P (V) is absorbed through the phosphate transport system, arsenic had an impact on phosphate uptake. Because As (V) and P (V) have several chemical properties, this interferes with phosphate metabolism. It also affects the concentration of other metals like K, Ca, Mn, and Zn. Arsenic also stunts growth, prevents root expansion, lowers fruit production and leaf withering, and can occasionally lead to plant mortality (Behbudi et al., 2020).

Arsenic in water

More than 200 million people have been exposed to groundwater that exceeds guidelines for the amount of Arsenic in water has been observed in more than 105 countries (Hasanzadehe & Ostvar, 2019; & Ahmed et al., 2022**)**. As a consequence, water distillation to remove arsenic has becoming an important concern. The (Table. 1) demonstrated the amount of arsenic in many countries, Latin America containing the highest values and Spain contains the lowest. This can be seen in the table above; arsenic contamination is a problem in numerous waterways around the world.

Studies showed that the extraction of arsenic from the groundwater in these regions by NF and RO membranes is quite efficient. For example, five dissimilar reverse osmosis membranes were used for purify water in Iran, with an 80-ppb arsenic level, and in each case, removal efficiencies of more than 80% were reached (Mozafarian et al., 2007). In research conducted in Bolivia, RO systems were shown to be 99% or more effective to eliminating arsenic (Selvi et al., 2019). The Nanofiltration method was used to eliminate the contaminant in China, a country where the quantity of arsenic in the groundwater is concerning, and it was suggested as a successful method to treat arsenic-rich water (Xia et al., 2007).

Table1. Concentrations of arsenic in resources of water across the world

Country	Water source	Level of Arsenic (As)	References
Pakistan	Ground water	<50 μg L^{-1}	Meliker et al. 2010
India	Ground water	<50 ppb	Rahman et al. 2023
Bangladesh	Urban and rural water	<70 ppb	Shaji et al. 2021
Iran	Drinking water	10-2000 μg L^{-1}	Mozafarian et al. 2017
Turkey	Ground water	120 μg L^{-1}	He and Charlet 2013
Spain	Drinking water	13.1- 292 μg L^{-1}	Shaji et al. 2021
Latin America	Drinking water	10-50 μg L^{-1}	Atlas et al. 2011
United States of America	Drinking water	10-100 μg L^{-1}	Xia et al. 2007

Approaches to remove arsenic from water

Water can be purified via physical, chemical, or biological methods (Alka et al., 2021). Water can be treated to remove arsenic through a number of methods (Table 2), including coagulation and flocculation, ion exchange, membrane processes, oxidation, electrolysis and lime lightning (Nasab et al., 2022; & Kord-Mostafapour et al., 2010**)**. These techniques require an initial treatment step, which frequently involves neutral compounds up to pH 9 and include arsenic. One of the usual constraints of this technique is the ability of the flocculation and coagulation process to filter organic flowing with metal absorptions between the 100 or 1000 mg L^{-1}. Coagulation and sedimentation may render sludge more stable and can get rid of slurry bacteria, but one of the main difficulties of this process is that it makes more slush in general.

The usage of chemicals and the resulting significant increase in functioning costs is another drawback (Alka et al., 2021). Additional efficient method of getting rid of heavy metals is chemical precipitation, however even though it's used frequently, it requires a lot of chemicals. The development of sludge and the ensuing costs, as well as the existence of wasted chemicals, are some of its additional drawbacks (Yang et al., 2019). Flotation is one of the many physical separation methods, and it works quite well when paired with other purification methods. This method has the advantages of removing light and small particles, having a short retaining time, and having minute expenses (Alka et al., 2021). Another method of water filtration that is considered to be efficient is surface adsorption. It offers a number of benefits including ease of use, lower costs, limited by-product creation, and flexibility.

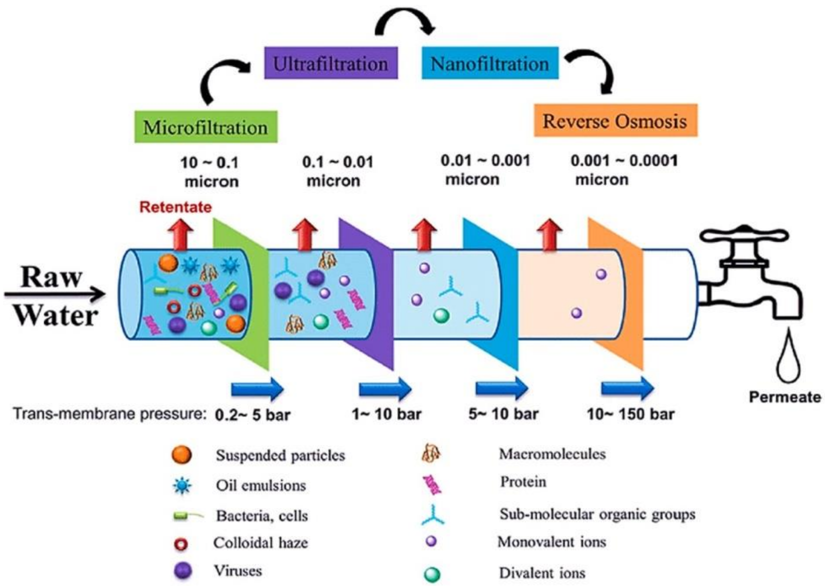

Fig.1. Characteristics of membrane processes

The lack of efficient, affordable adsorbents is this method's primary flaw. Furthermore, this procedure takes a while to attain equilibrium. A physicochemical procedure called ion exchange has a high start-up cost but produces less sludge than chemical precipitation. Even in little quantities, it can quickly and effectively remove ions. Additional limitations of this method include its selectivity and the release of hazardous chemicals during mastic renewal (Alka et al., 2021; & Worou et al., 2021) electrolytic remediation is a technique that includes providing direct electrical current to a chemical cell's electrodes; however, the need to utilize fewer minor chemicals and produce less slush outweighs the advantages. The prohibitive price of electricity and basic supplies makes this strategy ineffective (Alka et al., 2021).

Filtration processes to remove Arsenic from groundwater

The usage of membrane methods for water distillation has gained consideration recently due to their simplicity of use, capability to reduce costs and the number of operational units, ability to improve valued products, and ability to increase profitable access to all membrane types worldwide (Selvi et al., 2019). These techniques are also acknowledged as the most effective methods to remove arsenic (Kundu & Naskar, 2021; & Alka et al., 2021). Membrane treatments are non-thermal methods of refining a solution that is saturated with solutes. They are divided into two groups; low-pressure membranes, such as ultrafiltration (UF), microfiltration (MF) and pressurized membranes, such as reverse osmosis (RO) and nanofiltration (NF) (Yang et al., 2019). Since these processes do not involve the usage of additives, they are considered as "clean" methods in the separation field and also superior to other methods of separation because they are simple to use, highly efficient, and do not generate any sludge Additionally, it may eliminate a variety of pollutants (Siddique et al., 2020).

The most effective methods for eliminating arsenic are nanofiltration and reverse osmosis, each of having tiny pores. While ultrafiltration and microfiltration had a poor removing ability and are mainly useful for removing the particle of arsenic (Moafi et al., 2021). This is because due to membranes' larger pores are proportionate to the magnitude of the arsenic particle. The two most efficient filtration methods are reverse osmosis and nanofiltration. Nanofiltration, a membrane technique for water purification, is used to get rid of multivalent ions, chemical compounds, bacteria, viruses and pesticides (Rajendran et al., 2021). This process is particularly effective in removing heavy metals from inorganic solutions. One of its downsides is decreased process efficiency in the event of an increase in contaminant concentrations and sieve obstruction brought on by sediment produced by colloids and ions (Orooji et al., 2016; & Mohammad et al., 2015).

Reverse osmosis is a highly effective form of water filtration with an advanced level of ion exclusion capability. This method has several benefits, including high purification efficacy, the lack of chemicals, and a diminished requisite for skilled labour. The disadvantages are membrane blockage, the requirement to substitute them, and a rise in operational costs; all of these issues can be resolved by utilizing an effective prior management method (Mohammad-Razdari & Fanaee, 2021; Kundu & Naskar, 2021; & Maddah & Chogle, 2017).

Nanofiltration

Nanofiltration are most advanced and efficient pressure-based membrane technique for separating multivalent ions from monovalent ions utilizes nanofiltration having holes with a size range of 0.001-0.01 m. Reverse osmosis and ultrafiltration are among its separation capabilities (Orooji et al., 2016; & Rehmani & Amini, 2016). Typically, nanofiltration membranes contain two layers. Protective layers offer isolation, whereas thin and dense layers give protection from system pressure (Orooji et al., 2016). Cellulose acetate, cellulose diacetate, cellulose triacetate, Polyamides, piperazine, and other significant polymers are used to make nanofiltration membranes (Suhalim et al., 2022). These membranes come in many different forms, such as spiral, sheet, tube, and fiber (Worou et al., 2021). Nanofiltration membranes have the ability to remove a sizable fraction of heavy metals, especially arsenic, and may produce high-quality effluent (Yan et al., 2022). Other significant advantages of this strategy include decreased operating costs, energy costs, and consumption costs (Siddique et al., 2020). These membranes are also a practical and acceptable way of removing calcium and magnesium ions from water (Mokhtari et al., 2010). A few examples of nanofiltration membranes that have been utilized to remove arsenic from water are the NF70, NF90, NF45, TFC-50, UTC-70, ES-10 and TFN membranes (Rahman et al., 2023).

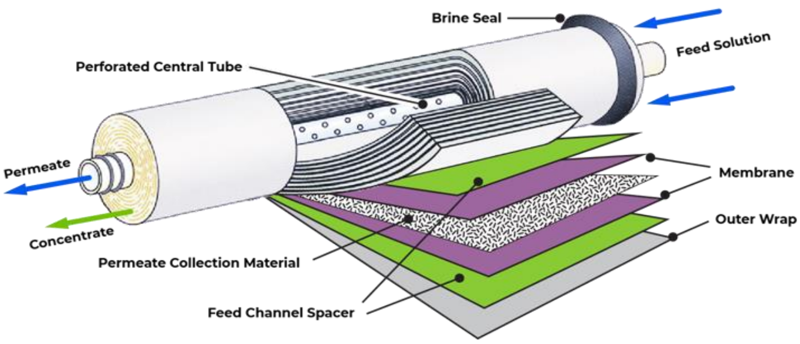

Fig.2. Characteristics of Reverse osmosis

Reverse osmosis

The reverse osmosis process (with a pores dimension of 0.0001 meters) is one of the most recent methods to eliminate membrane-bound arsenic, where the circulation of water via a membrane that is semi-permeable reverses so that clean water moves from the concentrating portion toward the diluted side and ions are excluded from through the membrane (kumar et al., 2019; & Richter et al., 2022). This membrane has the capacity to remove a wide range of huge particles, monovalent ions, and small pollutants (Kazemabadi et al., 2021).

The Reverse osmosis and nanofiltration membranes are both made of significant polymers, such as cellulose acetate, cellulose diacetate, cellulose triacetate, polyamides, and piperazine (Suhalim et al., 2022). This method works effectively under various pressure and pH situations. The high removal efficiency, no chemical reliance, mechanical resilience, stability of the chemical, ability to tolerate intense heat, decreased requirement for an experienced worker and relatively low electrical consumption of this method are further benefits. Reverse osmosis membranes such as BW30, FT30, TFC-ULP, PVD, TFC-SR, XLE, BE and AD (Fig. 2) are some of those utilized to remove arsenic (Rahman & Hasegawa., 2011; & Kundu & Naskar, 2021). The biggest challenge in putting membrane processes into practice is the clogging of the membranes caused by various contaminants, including colloidal debris, inorganic compounds, organics that have been dissolved, and bacteria which if addressed, may be expected to increase performance.

Membrane's treatment provides a number of advantages over technologies for water purification and arsenic removal (He & Charlet, 2013; & Akbari et al., 2010). Nanofiltration and Reverse osmosis membranes are pricey to purchase initially, and they occasionally need to be replaced when they clog, which drives up the cost (Figoli et al., 2010). Membrane's cleaning, improving system operation conditions, and employing low-fouling membrane materials can all help reduce membrane clogging (Akbari et al., 2010). Suspended particles render clogging worse and slow down the process; these effects can be avoided by reducing the toughness of the incoming water flowing before filtration and using the appropriate pretreatment (Hasanzadeh & Ostvar, 2020; & Rehmani & Amini, 2016). Due to the fact that arsenate ions are frequently negatively charged in natural water ($HAsO_4^2$ and H_2AsO_4), similar to the majority of the utilized NF and RO membranes (H_3AsO_3), arsenate is much more rejected than arsenite, which is neutrally charged. This method has a flaw that can be remedied by rising the pH level that attracts the arsenite (Meliker et al., 2010). It should be pointed out that RO membranes may eliminate a greater quantity of arsenite than Nanofiltration ones at low pH levels due to their larger pore sizes (Rahaman et al., 2023). A further weakness in this strategy is that arsenite has low removal power than arsenate (Richter et al., 2022). Furthermore, this method has the disadvantage that NF membranes cannot remove monovalent ions due to their low molecular mass, which results in a significant decline in efficacy when the number of pollutants rises (Saitúa et al., 2010). Given the above, selecting a membrane according to the characteristics and the purity of water would reduce the constraints of this method and improve the efficiency of the whole process (Meliker et al., 2010).

Studies of arsenic removal by NF & RO

Several studies investigated for the exclusion of arsenic by using nanofiltration and reverse osmosis. Several factors that affect the nanofiltration method's efficiency to remove arsenic were assessed by (Akbari et al., 2010). The results of this study show that the clearance rate decreases as the absorption of arsenate and arsenite and rises because arsenic permeates the membrane and forms an accumulation of layer on its surface. The flow of dissolved materials remains constant as pressure rises, creating dilution and a reduction in the absorption of arsenic which improves the exclusion of arsenite and arsenate. Similar to this, raising pH speeds up evacuation by making arsenic's charge more negatively. On the other side decrease in kinematic stickiness and a rise of penetrability due to evacuation is reduced when temperature rises. Additional salts reduce the Donan potential, which consequently reduces the amount of eliminated arsenate. The highest efficiencies were 95.11% and 99.02% for arsenite and arsenate, respectively (Mortazavi et al., 2010).

Research conducted by Figoli (2010) that compared the efficacy of two NF membranes (NF30 and NF90) to remove the toxicity of arsenic under all test conditions, NF90 membrane performed better than the NF30 membrane. According to this research, rising pH are more important and meaningful impact on the NF30 membrane capability to eliminate arsenic then did lowering the temperature at which it operated or the amount of arsenic (Mukhtari et al., 2010). As stated by Nguyen et al. (2009) found that the removal of arsenate and arsenite greater than before with rising in pH levels between 4 and 10 with arsenite being completely removed at pH 8 to 10.

When the concentration of arsenic was increased from 20 to 100 g L^{-1}, the effectiveness of the removal of arsenates increased from 89 to 96%, but the effectiveness of the removal of arsenite decreased from 44 to 41%. Arsenate removal was more effectively accomplished with the help of Cl ions than with SO_4^{-2} ions (Akin et al., 2011). In addition to effectively removing 95% arsenate, As stated by Mortazavi et al. (2010) research found that the NF300 membranes also remove 97% sulphate,75% TDS and 88% hardness (Momtazan et al., 2015). The Malakootian et al. (2015) calculate the efficacy of the nanofiltration technique to eliminate toxic metal from sulfate containing drinking water. Malakootian et al. (2015) results showed that polyamide type membrane used for Nano filtration are suitable for eliminating sulphate and heavy metals from drinking water at the same time because they can produce high-quality effluent and removing a high proportion of toxic metals at lower pressure (Yan et al., 2022).

The results of the investigation showed that 98% hexavalent chromium (Mortazavi et al., 2010) and 85% fluoride were removed (Chang et al., 2014). The research conducted by Worou (2021) for removing the toxicity of arsenic in water by means of nanofiltration membranes, these membranes will ultimately surpass existing arsenic elimination technology. According to Siddique et al. (2020) nanofiltration is effective for treatment of soft water, industrial effluent, removing colour and removing arsenic from water (Rashidi Mehrabadi et al., 2006). A study was carried out by Saboori et al. (2018) to determine the various factors that affected the RO system. According to the studies, there were significant differences in the amount of arsenic in the input solution, and among the tests on solutions with concentrations level 0.018 and 2 mg L^{-1}, the 1.5 mg L^{-1} solutions was the highest removing rate of 98% at and optimal pressure of 190 bar. In addition, 5-valent arsenic particles undergo a phase transition from neutral to mono anionic then di-anionic as pH rises, resulting in a greater elimination of arsenic.

The rise in temperature also enhanced the efficiency of extracting arsenic from the solution by altering solvent viscosity, increasing solvent and solute permeability and increasing osmotic pressure. It has been demonstrated that the most effective arsenic removal occurred between 20 and 30 C. Due to changes in the low viscosity of the solution, this factor has a little affect in the temperature ranging from 4–10 C. The most arsenic was found to be removed at the optimal concentration of 1.5 mg/L at pH 9 and a temperature of 23 C, or roughly 95.98% (Kazemabadi et al., 2021). Golami's (2017) study indicates that the RO system performs best at the pressure of 190 psi pH = 6.9, 25 °C temperature and has a removal efficiency above 99% (Hassan et al., 2023). Raising the pressure enhanced the removal of both types of arsenic. The efficiency of the removing the both forms of arsenic improved as the driving force, or pressure, in the reverse osmosis system whereas fluctuations in concentration had no effect (de Souza et al., 2019).

After comparing five different reverse osmosis membrane types, (Mozafarian et al., 2017) chose the TFC-SR membrane, in spite of the PVD membrane had the greatest arsenic recovery (98.1%), because of its larger output flow than the PVD membranes (almost twice as much) and its effectiveness in removing arsenic (96.1%) (Mozafarian et al., 2017). Chang et al. (2014) found that the removing of trivalent arsenic by low-pressure of nanofiltration membranes technique and reverse osmosis is essentially in the pH range of 4–9 but significantly rises at pH over 9. The removal effectiveness of the nanofiltration membrane reduced by 10% and by 30% when Na_2SO_4 (0.1 Mm) salt was present, however the removal efficiency of the reverse osmosis membrane didn't alter appreciably as the content of arsenic enlarged (between 50 or 400 g L^{-1}). Reverse osmosis was able to extract arsenic with an efficiency of over 90% while nanofiltration was only able to remove arsenic with an efficiency of over 50% due to the huge size of the membrane pores.

A study was carried out by Teimouri and Mahdiarfar (2017) to evaluate safe arsenic removal methods. According to their research, the best membrane technique for remove arsenic from drinking water are reverse osmosis and nanofiltration. Furthermore, it was found that reverse osmosis technique can removed more pollutants simultaneously but the nanofiltration technique requires high quality of effluent (Mozafarian et al., 2007). Furthermore, (Kundu & Naskar, 2021) found that all the membranes procedures had a larger capability to remove 5-valent arsenic than 3-valent arsenic in their investigation on excluding arsenic by membrane methods. The amount of arsenic that can be removed via membrane processes depends significantly on the solution's pH and the membrane's electric charge.

Table2. Evaluating the effectiveness of nanofiltration and reverse osmosis in the elimination of arsenic from groundwater

Removal Process	Experiment conditions					Removal Efficiency (%)	Reference
	Membrane type	Concentration	Temp.	Pressure	pH		
NF	NF-30 NF90-2540	100–382 μg/L 100–1000 μg/L	10–25°C 27–37°C	310–724kPa 4–7 bar	1.2–8.8 3–11	As^{5+}: 95 As^{3+}: 86.75-95.11	Nguyen et al. 2009
	NF-90	20–100 μg/L	25°C	138–552 kPa	4–10	As^{3+}: 44	Akin et al. 2011
	NF-30	100–1000 μg/L	15–40°C	2–12 bar	3.1–5	As^{5+}: 77-88	Pezeshki et al. 2023
	NF90 NF	50–400 μg/L	20°C	0.41–0.82 MPa	2–10	As^{5+}: 94.4–98 As^{3+}: 10-40	Nicomel et al. 2016
RO NF	LPRO NF90	100 μg/L	20°C	3.1–5 bar	3.1–5	As^{3+}: 65-90 As^{3+}: 67.72	Rahaman et al. 2023
RO NF	NF270 XLE				As^{3+}: 57.96 As^{3+}: 98.23		
RO	BW30 PVD	69.3 μg/L	8–21°C	5–14 bar	5–9	As^{3+}: 97.47 As^{3+}: 98.1	Mozafarian et al. 2017
	TFC-SR FT30				As^{3+}: 96.1 As^{3+}: 89.2		
	TFC-ULP BW30				As^{3+}: 83.2 As^{3+}: 90		
	TE2521	0.0–2.5 mg/L	25–30°C	190-210 psi	6–8	Total As: 95-99	Chun et al. 2017
	SWHR	50–750 μg/L	20°C	10–35 bar	4.1-9.1	As^{3+}: 92.5	de Souza et al. 2019
	TW40	0.2–18 mg/L	4–30°C	190 bars	5–9	Total As: 95-99	Kazemabadi et al. 2021

Both nanofiltration and other effective ways of removing arsenic carry a threat of blockage due to material unseating, although this risk is reduced by the preliminary treatment method (Kundu & Naskar, 2021). Furthermore, (Hassan et al., 2023) found that NF and RO are the most operative methods for remove arsenic from contaminated ground water (Hassan et al., 2023). In Table 3 displays several reverse osmoses and nanofiltration techniques' application scenarios and efficacy.

Mechanism for removing arsenic

One of the most important methods for eliminating contaminants like arsenic is through the application of membranes with a large number of pores, owing to their particular nature, keep specific water components from departing. The repulsion force for this action (between the feed and permeate sides) is the difference in pressure between the two sides (Kundu & Naskar, 2021; & Nicomel et al., 2016). Nanofiltration is a complicated high pressure membranes technology that separates ions (Dona exclusion) through size exclusion and electrostatic charge repulsion (Babaakbari et al., 2020; & Kundu et al., 2021). Another high pressure (5-120 bar) method for removing arsenic from water is reverse osmosis, which separates two solutions with different chemical densities using a semi-permeable membrane. When the applied pressure is greater than the osmotic pressure, the water flux's direction is reversed during the Ro process (Mozafarian et al., 2017).

CONCLUSION

One of the major water contaminants is arsenic which has detrimental effect on all living things like plants and humans. In terms of arsenic removal methods, membrane treatments are currently quite relevant due to their unique advantages. In this review, two membrane techniques for the exclusion of arsenic were reviewed; nano filtration (NF) and reverse osmosis (RO). These two membrane mechanisms are the best to eliminating arsenic, and their concentrations can even go under the permitted level. In every study that was looked at, the removal of arsenic (V) has been done to a greater than the elimination of its arsenic (III). Reverse osmosis membrane was also effective for removing the arsenic (III) than nanofiltration. It was studied that raising the pH substantially enhanced the efficiency of the membranes in all conditions. The presence of different ions also affected its efficiency. So, this review concluded that these two processes, in spite of some usage limitations have potential to turn into the most efficient ways to remove arsenic.

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All authors are contributed equally and equal response is observed from all authors.

REFERENCES

Ahmadi, A. (2022). Evaluation of heavy metal pollution in water resources of tabriz plain using qualitative indicators. *Iranian Journal of Irrigation and Drainage, 15*(6), 1421-1431.

Ahmed, S. F., Kumar, P. S., Rozbu, M. R., Chowdhury, A. T., Nuzhat, S., Rafa, N., & Mofijur, M. (2022). Heavy metal toxicity, sources, and remediation techniques for contaminated water and soil. *Environmental Technology & Innovation*, *25*, 102114.

Akbari, H., Mehrabadi, A. R., & Torabian, A. (2010). Determination of nanofiltration efficency in arsenic removal from drinking water. *J. Environ. Heal. Sci. Eng. 7*(3), 273–278.

Akin, I., Arslan, G., Tor, A., Cengeloglu, Y., & Ersoz, M. (2011). Removal of arsenate [As (V)] and arsenite [As (III)] from water by SWHR and BW-30 reverse osmosis. *Desalination, 281*, 88-92.

Akin, I., Arslan, G., Tor, A., Cengeloglu, Y., & Ersoz, M. (2011). Removal of arsenate [As (V)] and arsenite [As (III)] from water by SWHR and BW-

30 reverse osmosis. *Desalination, 281*, 88-92.

Alka, S., Shahir, S., Ibrahim, N., Ndejiko, M. J., Vo, D. V. N., & Abd Manan, F. (2021). Arsenic removal technologies and future trends: A mini review. *Journal of cleaner production, 278*, 123805.

Altaş, L., Işık, M., & Kavurmacı, M. (2011). Determination of arsenic levels in the water resources of Aksaray Province, Turkey. *Journal of Environmental Management, 92*(9), 2182-2192.

Baastrup, R., Sorensen, M., Balstrom, T., Frederiksen, K., & Raaschou-Nielsen, O. (2008). Arsenic in drinking-water and risk for cancerin Denmark. Environ. *Health Perspect, 116*, 231–237.

Babaakbari, M., Hasani, S., Delavar, M. A., & Neyestani, M. (2020). Comparison of arsenic removal from water by magnetite and titanium oxide Nanoparticles, Ferrosilicon and ferrosilicon magnesium. *Iranian Journal of Soil and Water Research, 50*(10), 2633-2644.

Behbudi, G., & Shayesteh, K. (2020). Methods for removing heavy metals from water and wastewater: a review study. *J. Res. Environ. Heal. 6*(2), 145–160.

Chang, F.-f., Liu, W.-j., & Wang, X.-m. (2014). Comparison of polyamide nanofiltration and low-pressure reverse osmosis membranes on as (III) rejection under various operational conditions. *Desalination, 334*(1), 10–16.

de-Souza, T. D., Borges, A. C., Braga, A. F., Veloso, R. W., & de Matos, A. T. (2019). Phytoremediation of arsenic-contaminated water by Lemna Valdiviana: An optimization study. *Chemosphere, 234*, 402-408.

Figoli, A., Cassano, A., Criscuoli, A., Mozumder, M. S. I., Uddin, M. T., Islam, M. A., & Drioli, E. (2010). Influence of operating parameters on the arsenic removal by nanofiltration. *Water research, 44*(1), 97-104.

Hasanzadeh, M., & Ostvar, F. (2019). A review of arsenic removal methods from water resources, Environ. *Res. Techn. 4*(6), 39–46.

Haseena, M., Malik, M. F., Javed, A., Arshad, S., Asif, N., Zulfiqar, S., & Hanif, J. (2017). Water pollution and human health. *Environmental Risk Assessment and Remediation, 1*(3), 16-19.

Hassan, H. R. (2023). A review on different arsenic removal techniques used for decontamination of drinking water. *Environ. Poll. Bioavail, 35*(1), 2165964.

He, J., & Charlet, L. (2013). A review of arsenic presence in China drinking water. *J. Hydrol. 492*, 79–88.

Kardan-yamchi, H., Ehrampoush, M. H., & Ebrahimi, A. A. (2022). Investigating the relationship between heavy metals in drinking water and cancer: a systematic review. *Iran. J. Canc. Care, 2*(3), 22–36.

Kazemabadi, M., Miralinaghi, M., Ahmad Panahi, H., & Haji Shirazi, R. M. S. (2021). Removal of arsenic from aqueous solution using single-walled carbon nanotubes modified with poly allylamine hydrochloride. *Journal of Water and Wastewater; Ab va Fazilab (in persian), 32*(1), 136-146.

Kord-Mostafapour, F., Bazrafshan, E., & Kamani, H. (2010). Survey of arsenic removal from water by coagulation and dissolved air floatation method. *Iran. J. Health Environ. 3*(3), 309–318.

Kumar, R., Patel, M., Singh, P., Bundschuh, J., Pittman Jr, C. U., Trakal, L., & Mohan, D. (2019). Emerging technologies for arsenic removal from drinking water in rural and peri-urban areas: Methods, experience from, and options for Latin America. *Science of the Total Environment, 694*, 133427.

Kundu, S., & Naskar, M. K. (2021). Perspective of membrane processes for the removal of arsenic from water: an overview, *Trans. Indian Ceram. Soc.*, *80*(1), 28–40.

Maddah, H., & Chogle, A. (2017). Biofouling in reverse osmosis: phenomena, monitoring, controlling and remediation, *Appl. Water Sci. 7*(6), 2637–2651.

Malakootian, M., Golpayegani, A. A., & Rajabizadeh, A. (2015). Survey of nanofiltration process efficiency in Pb, Cd, Cr+6 and Cu ions removal from sulfate-containing waters. *J. Water Wastewater*, *25*(5), 13–20.

Meliker, J. R., Slotnick, M. J., AvRuskin, G. A., Schottenfeld, D., Jacquez, G. M., Wilson, M. L., & Nriagu, J. O. (2010). Lifetime exposure to arsenic in drinking water and bladder cancer: a population-based case–control study in Michigan, USA. *Cancer Causes and Control*, *21*, 745-757.

Moafi, M., Ardestani, M., & Mehrdadi, N. (2021). Use of zinc oxide nano-photocatalyst as a recyclable catalyst for removal of arsenic and lead ions from polluted water. *J. Health, 12*(1), 130–143.

Mohammad, A. W., Teow, Y. H., Ang, W. L., Chung, Y. T., Oatley-Radcliffe, D. L., & Hilal, N. (2015). Nanofiltration membranes review: Recent advances and future prospects. *Desalination*, *356*, 226-254.

Mohammad-Razdari, V., & Fanaee, S. A. (2021). Comprehensive review of different types of water desalination. *Journal of Renewable and New Energy*, *8*(1), 21-32.

Mokhtari, Gholami, Shaker-Khatibi, Mohammad, Hosseini, Mir., & Hamed, Seyed (2010). Influence of the concentration, pH, temperature and pressure parameters on arsenic removal from drinking water via reverse osmosis process. *Scientific Research Journal of Ardabil University of Medical Sciences, 10*(3), 261-269.

Momtazan, M., Moazed, H., & Pourreza, N. (2015). Removal of cadmium from drinking water using reverse osmosis process. *J. Irrig. Sci. Eng.*, *37*(4), 87–96.

Mortazavi, B., Barikbin, B., & Moussavi, G. R. (2010). Survey of nano filtration performance for hexavalent chromium removal from water containing sulfate. *Iran. J. Health Environ. 3*(3), 281–290.

Mozafarian, K., Madaeni, S. S., & Khoshnodie, M. (2017). Evaluating the performance of reverse osmosis in arsenic removal from water. *J. Water Wastewater, 17*(4), 22–28.

Nasab, H., Rajabi, S., Eghbalian, M., Malakootian, M., Hashemi, M., & Mahmoudi-Moghaddam, H. (2022). Association of As, Pb, Cr, and Zn urinary heavy metals levels with predictive indicators of cardiovascular disease and obesity in children and adolescents. *Chemosphere, 294*, 133664.

Nasiri, A., Rajabi, S., Hashemi, M., & Nasab, H. (2022). CuCoFe2O4@ MC/AC as a new hybrid magnetic nanocomposite for metronidazole removal from wastewater: Bioassay and toxicity of effluent. *Separation and Purification Technology, 296*, 121366.

Nazari, Y., & Abbas-Nejad, A. (2015). Determining the origin and distribution of arsenic in groundwater in the rayen plain (southeast of kerman) using statistical techniques. *Sci. Res. Quar. Earth Sci. 24*(94), 117–128.

Nguyen, C. M., Bang, S., Cho, J., & Kim, K. W. (2009). Performance and mechanism of arsenic removal from water by a nanofiltration membrane. *Desalination*, *245*(1-3), 82-94.

Nicomel, N. R., Leus, K., Folens, K., Van Der Voort, P., & Du Laing, G. (2016).

Technologies for arsenic removal from water: current status and future perspectives. *International Journal of Environmental Research and Public Health*, *13*(1), 62.

Nicomel, N. R., Leus, K., Folens, K., Van Der Voort, P., & Du Laing, G. (2016). Technologies for arsenic removal from water: current status and future perspectives. *International Journal of Environmental Research and Public Health*, *13*(1), 62.

Odum, H. T. (2015). Back Ground of Published Studies on Lead and Wetland. In: Howard T. Odum (Ed), *Heavy Metals in the Environment Using Wetlands for Their Removal*, Lewis Publishers, New York USA, pp. 32.

Orooji, N., Takdastan, A., Raeesi, G. R., & Panah-Pour, E. (2016). Nanofiltration system efficiency in urban water treatment and removal of pollutants in Molasani water treatment plant. *Irrigation Sciences and Engineering*, *39*(4), 201-212.

Rahaman, M. S., Mise, N., Ikegami, A., Zong, C., Ichihara, G., & Ichihara, S. (2023). The mechanism of low-level arsenic exposure-induced hypertension: Inhibition of the activity of the angiotensin-converting enzyme 2. *Chemosphere*, *318*, 137911.

Rahman, M. S., Reza, A. S., Ahsan, M. A., & Siddique, M. A. B. (2023). Arsenic in groundwater from Southwest Bangladesh: sources, water quality, and potential health concern. *Hydro Research, 6*, 1-15.

Rahman, M. A., & Hasegawa, H. (2011). Aquatic arsenic: phytoremediation using floating macrophytes. *Chemosphere*, *83*(5), 633–646.

Rahmani, A. R., & Amini, S. (2016). Removal of arsenic from aquatic environments by amended and unamended oak tree sawdust. *J. Water Wastewater, 26*(6), 42–49.

Rajendran, R. M., Garg, S., & Bajpai, S. (2021). Economic feasibility of arsenic removal using nanofiltration membrane: a mini review. *Chem. Pap. 75*(9), 4431–4444.

Rascio, N., & Izzo, F. N. (2011). Heavy metal hyperaccumulating plants: How and why do they do it? And what makes them so interesting? *Plant Science, 180*, 169–181.

Rashidi Mehrabadi, A., Akbari, H., & Torabian, A. (2006). Determination of Nanofiltration Efficency in Arsenic Removal from Drinking Water, The first specialized conference on environmental engineering. *Iran. J. Environ. Health. Sci. Eng. 7(*3), 273-278.

Richter, F., Kloster, S., Wodschow, K., Hansen, B., Schullehner, J., Kristiansen, S. M., & Ersbøll, A. K. (2022). Maternal exposure to arsenic in drinking water and risk of congenital heart disease in the offspring. *Environment International, 160*, 107051.

Saboori, N., Azizi-Mobasser, J., & Asadi, A. (2018). Removal of arsenic in water environment by reverse osmosis method and zero valent iron nanoparticles. *J. Water Wastewater, 28*(6), 39–47.

Saitúa, H., Campderrós, M., Cerutti, S., & Padilla, A. P. (2005). Effect of operating conditions in removal of arsenic from water by nanofiltration membrane. *Desalination*, *172*(2), 173-180.

Selvi, A., Rajasekar, A., Theerthagiri, J., Ananthaselvam, A., Sathishkumar, K., Madhavan, J., & Rahman, P. K. (2019). Integrated remediation processes toward heavy metal removal/recovery from various environments-a review. *Frontiers in Environmental Science, 7*, 66.

Shaji, E., Santosh, M., Sarath, K. V., Prakash, P., Deepchand, V., & Divya, B. V. (2021). Arsenic contamination of groundwater: A global synopsis with focus on the Indian Peninsula. *Geoscience Frontiers, 12*(3), 101079.

Siddique, T. A., Dutta, N. K., & Roy Choudhury, N. (2020). Nanofiltration for arsenic removal: challenges, recent developments, and perspectives. *Nanomaterials, 10*(7), 1323.

Suhalim, N. S., Kasim, N., Mahmoudi, E., Shamsudin, I. J., Mohammad, A. W., Mohamed Zuki, F., & Jamari, N. L. A. (2022). Rejection mechanism of ionic solute removal by nanofiltration membranes: An overview. *Nanomaterials, 12*(3), 437.

Teimouri, R., & Mahdiarfar, M. (2017). Comparison of safety technologies on arsenic removal from water. *Journal of Biosafety, 9*(4), 79–92.

Worou, C. N., Chen, Z. L., & Bacharou, T. (2021). Arsenic removal from water by nanofiltration membrane: potentials and limitations, *Water Pract. Technol. 16*(2), 291–319.

Xia, S., Dong, B., Zhang, Q., Xu, B., Gao, N., & Causseranda, C. (2007). Study of arsenic removal by nanofiltration and its application in China. *Desalination, 204*(1-3), 374-379.

Xia, S., Dong, B., Zhang, Q., Xu, B., Gao, N., & Causseranda, C. (2007). Study of arsenic removal by nanofiltration and its application in China. *Desalination, 204*(1-3), 374-379.

Yan, C., Qu, Z., Wang, J., Cao, L., & Han, Q. (2022). Microalgal bioremediation of heavy metal pollution in water: Recent advances, challenges, and prospects. *Chemosphere, 286*, 131870.

Yang, Z., Zhou, Y., Feng, Z., Rui, X., Zhang, T., & Zhang, Z. (2019). A review on reverse osmosis and nanofiltration membranes for water purification. *Polymers, 11*(8), 1252.

Zamora-Ledezma, C., Negrete-Bolagay, D., Figueroa, F., Zamora-Ledezma, E., Ni, M., Alexis, F., & Guerrero, V. H. (2021). Heavy metal water pollution: A fresh look about hazards, novel and conventional remediation methods. *Environmental Technology & Innovation, 22*, 101504.