REVIEW OF LITERATURE

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2.1 Iron and manganese sources

Both iron and manganese are well-known metals that frequently coexist in nature, especially in oxygen deficient groundwater. Amphibole, iron sulphide, and iron-rich clay minerals are all iron- and manganese-containing minerals prone to oxidation, can produce iron and manganese as byproducts. Groundwater, which travels through organically rich soil, is capable of dissolving metals like iron and manganese. Industrial effluents, drainage, and landfill leaks are all examples of sources of iron and manganese that are caused by human activity. It is also possible for iron and manganese to be added to groundwater by using the pump components, suitable casing, pipe, and storage tank [65]. In natural conditions, water moves via the organic soil and is eventually ingested by bacteria and the breakdown of organic matter occurs. This process is called percolation. This process uses up dissolved oxygen. The pH drops as a result of the activity of microbes during the breakdown process. Iron and manganese atoms lose an electron without oxygen, lowering their oxidation states to Fe^{2+} and Mn^{2+} respectively. Soluble Fe^{2+}, a ferrous ion, is the most common form of dissolved iron between pH 5 and 8. When groundwater reaches surface, it is exposed to oxygen (O_2), and sets the oxidation process in motion. This results in the transformation of soluble Fe^{2+} and Mn^{2+} into insoluble Fe^{3+} and Mn^{4+}. Additionally, the pH levels rise.

2.2 Origins of iron and manganese in groundwater

2.2.1 Groundwater iron sources

Iron can be made by allowing minerals like pyrite to break down over time. When pyrite breaks down in piles of debris in open-pit coal mines, with groundwater, Fe^{2+} is made.

$7O_2 + 2H_2O + 2FeS_2 = 4SO_4^{2-} + 4H^+ + 2Fe^{2+}$ (Eq. 2.1)

$4CO_2 + 2H_2O + 5FeS_2 + 14NO_3^- = 10SO_4^{2-} + 7N_2 + 4HCO_3 + 5Fe^{2+}$ (Eq. 2.2)

As a consequence of these reactions, $SO4^{2-}$ might be found in the water pumped from a freshwater source. Iron carbonate reacts with carbon dioxide to produce Fe in the solution.

$CO_2 + H_2O + 4\ FeCO_3 = Fe^{2+} + 2HCO_3^-$ (Eq. 2.3)
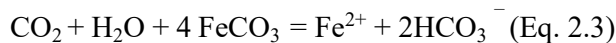
Remobilizing the widely dispersed iron (III) oxy hydrates will be possible if sufficient amounts of hydrogen and carbon dioxide donors are present.

$FeO\ (OH) + H^+ + 2CO_2 = Fe^{2+} + 2HCO^{3-} + e^-$ (Eq. 2.4)
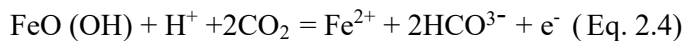
Depending on the sandstones, transit mechanism, and geochemical history, the iron content in soils can vary from 0.5% to 5% [66].

### 2.2.2 The production of manganese

The geographical conditions of the soil and subsurface play a significant role in determining the amount of manganese concentration in the groundwater. The various phases of Manganese that can be present in the soil are listed below [67]. Manganese carbonates 5, Manganese silicates and manganese oxides; in the state of being

exchanged (Mn^{2+}) and saluted; adsorbed on iron oxide; present in organic compounds.

2.3 The chemical association between manganese and iron

2.3.1 Iron's chemistry

Iron may potentially be found in the water resources in any of these states: a) Ferrous iron in its divalent form Fe^{2+} (the soluble form), and b) ferric Iron of the trivalent form, Fe^{3+} (insoluble form). Equation 2.5 illustrates oxidation, in this context, refers to the process of producing trivalent ferric ions from divalent ferrous ions.

$$Fe^{2+} = Fe^{3+} + e^- \text{ (Eq. 2.5)}$$
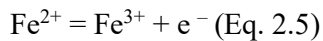
In conditions characterized by a significant high amount of dissolved oxygen, the presence of trivalent ferric ion has the potential to engage in further reactions with hydroxyl groups, ultimately leading to the formation of precipitates (Eq. 2.6).

$$3OH^- + Fe^{3+} = Fe\,(OH)_3 \text{ (Eq. 2.6)}$$
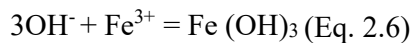
We summarize the comprehensive series of events occurring in an oxidation-reduction reaction, as represented by equation 2.7.

$$Fe^{2+} + 3H_2O = Fe\,(OH)_3 + 3H^+ + e^- \text{ (Eq.2. 7)}$$
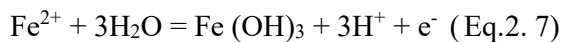
Not only does the pH of the solution affect the stability of iron ions, but so does the movement of electrons, The measurement of redox potential, commonly called pE, serves as a means of quantification. A high positive pE value indicates the insolubility of iron under oxidizing conditions. On the other hand, when the conditions are reducing, a low value of pE indicates that iron is soluble.

2.3.2 The chemical processes involving manganese in water

There are two different forms of manganese that can be discovered in water: (a) manganese oxide (Mn^{4+})(stable) (b) manganous oxide (Mn^{2+}) (soluble). Manganese does notbehave the same way Iron does when it occurs in nature. Equation (2.8) demonstrateshow one form of Manganese can be transformed into another.

$2H_2O + Mn^{2+} = MnO_2 + 4H^+ + 2e^-$ (Eq.2.8)
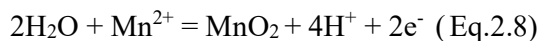
2.4 Iron and manganese's effects on drinking water

As pH and redox potential (pE) rise, the correlation between iron and manganese shows that Fe^{2+}(ferrous ion) often resides in a region with a lower redox potential and a pH range that falls somewhere between 5.5 & 8.2; this range also covers the entire range. This also suggests that ferrous ion (Fe^{2+}) is oxidized more readily and speedily than manganese (Mn^{2+}), as indicated by the previous sentence. At pH values of the solution is greater than 8, and the redox potential is between 420 and 790 mV, this usually takes place with the element Fe^{3+}. When MnO_2 is elevated over this redox potential, the compound is in its stable state. When water-soluble manganese and iron are present in drinking water supplies, there will be a great deal of undesirable effects. The World Health Organization (WHO) recommends treating water to remove iron and manganese when concentrations reach 0.3 mg/l and 0.1 mg/l, respectively. [46]. Iron and manganese concentrations of 0.2 mg/l and 0.05 mg/l, respectively, have been proposed as optimal by the European Union. The Environmental Protection Agency (EPA) has established secondary standards for iron and manganese, which are 0.3mg/l and 0.05 mg/l, respectively. [68].

If the concentrations are found to be higher than these recommendations, the water will need to be treated before it can be consumed. It is possible that users of the water and the municipality that supplies drinking water to customers will run into a number of problems if the water is not treated. Both manganese and iron are capable of causing their own unique set of vexing problems. Iron and manganese have the potential to produce a dark-coloured substance when they undergo a chemical reaction with the tannins present in tea, coffee, and alcoholic beverages. Consequently, these elements can influence the appearance and taste of both food and water. Iron can leave a rusty-brown stain on clothing, cutlery, dishes, and glasses [69]. Excessive amounts of Fe & Mn will impart a metallic flavour to water and stain various materials, such as clothing, paper, and plastics [70]. The precipitation of Iron and Manganese can cause residential water softeners to become clogged and diminish the softening process's effectiveness [71]. Fe and Mn can also cause buildup in pressure tanks, pipes, and water heaters. This buildup is related to a pressure decrease as well as a reduction in the volume of water that is accessible, in addition to an increase in the cost of appliances that use water. When buildup leads to the need for repairs to the water softener or pipes, the costs can quickly add up. The potential exists for the build-up of iron and manganese within the distribution channels to result in a reduction in the inner diameter of the pipe, ultimately leading to pipe obstruction. Presence of iron and manganese bacteria is yet another issue that arises as a result of these elements being present in water. These bacteria do not pose any health risk; instead, they cause the blackish-brown(manganese) and brownish-red (iron) slime that can accumulate in water storage containers like tanks of toilets and cause water distribution systems to become clogged. Whether the conditions are light or dark, the development of bacteria will be promoted

by the presence of Manganese and Iron in the water.

2.5 Elements that regulate the elimination of iron and manganese

Generally, oxidation and precipitation are employed to eliminate dissolved Iron and Manganese from groundwater. The efficiency of the removal process is influenced by various chemical and physical factors associated with water. The following factors are being measured: total organic carbon (TOC), temperature, pH, and dissolved oxygen levels. Oxidation rates speed up in alkaline environments and slowdown in acidic ones. Manganese oxidation requires a pH more than 9.3, and iron oxidation requires a pH greater than 6.3. The oxidation rate in water is slowed down by carbonic acid because of the reduction in pH. Increasing the temperature speeds up the oxidation process, whereas decreasing the temperature slows it down. Typically, the rate of chemical reactions doubles for every 10°C increase in temperature. Increases in total organic carbon reduce the availability of oxygen, preventing the oxidation of Fe and Mn. Additionally, to sum up, time is a major factor. Manganese precipitation will require more time than iron precipitation. Typically, iron precipitation can occur within minutes, whereas manganese precipitation might take many hours [10,67,72].

2.6 Iron and manganese removal

Two distinct methods exist for the treatment of Fe and Mn.

• Ex-situ - elimination of ferrous & manganous elements

• In-situ - elimination of ferrous & manganous elements

2.6.1 Iron and manganese removal from ex-situ

The Ex-situ method involves groundwater treatment through various processes; Various methods are employed in treatment systems, such as ion exchange, aeration,

chemical oxidation, filtration, and pH adjustment with a neutralizing filter. These processes are applied to the surface after the abstraction of groundwater. Typically, different chemical and physical reactions of aeration, manganese greensand, and chemical oxidation with potassium permanganate, ozone or chlorine oxide are used in conventional iron and manganese treatment plants. Various operational issues may arise during these procedures [73-75].

2.6.1.1 Filtration followed by oxidation

Filtration and oxidation are commonly used to remove iron and manganese from water. Initially, the water undergoes oxidation, transforming soluble iron (Fe^{2+}) and manganese (Mn^{2+}) into their insoluble forms, ferric iron (Fe^{3+}) and manganese dioxide (MnO_2). Oxidizing agents such as chlorine (Cl_2), potassium permanganate ($KMnO_4$), and ozone (O_3) are often used [76].

For instance, chlorine oxidizes iron and manganese as follows:

- Iron: $4Fe^{2+} + O_2 + 2H_2O \rightarrow 4Fe^{3+} + 4OH^-$

- Manganese: $2Mn^{2+} + O_3 + 4H^+ \rightarrow 2MnO_2 + 2H_2O$

The oxidized particles are then removed through filtration using various media like sand, anthracite, or manganese greensand. Manganese greensand is a common filter medium that is treated with potassium permanganate to enhance its oxidative capacity.

The iron and manganese must first be oxidized to the extent where they are transformed into insoluble compounds before the filtration process can begin. In simple terms, oxidation transfers electrons from iron and manganese elements to the oxidizing agent. The ferrous ion, which has a charge of $Fe^{2+,}$ will undergo oxidation to

become the ferric ion, which has a charge of Fe^{3+}. The outcome of this process will lead to the creation of the hydroxide compound, Fe $(OH)_3$, which is insoluble. A similar phenomenon will occur with manganese, as the Mn^{2+} ions will undergo oxidation to Mn^{4+}, resulting in the formation of insoluble MnO_2 throughout the entirety of this process. In the process of oxidation, various oxidants such as chlorine dioxide, potassium permanganate and chlorine are employed. In the context of oxidation, smaller groundwater systems usually make use of potassium permanganate or chlorine due to the ease with which dosing may be accomplished, the requirement of essential equipment, and the low cost of the chemicals. Chlorination results in substantial oxidation of iron and manganese on a massive scale. The oxidation of divalent Fe and Mn by chlorine can lead to the production of trihalomethanes in fluids that have a very vivid colour (THMs). Potassium permanganate, often known as $KMnO_4$, is more expensive than other chemicals when it comes to its use as an oxidant.

The amount of potassium permanganate administered must be strictly regulated. If we use insufficient permanganate, not all of the iron and manganese will be oxidized. Water will become pink if we use enough to contaminate the pipelines. Precipitates formed by permanganate can clog filters, which is another problem with this chemical. Aeration of water can be achieved either through or without a pH buffer. Iron and Manganese can undergo oxidation when the pH is sufficiently elevated. The process of oxidizing soluble Manganese necessitates a significantly elevated pH level if a potent oxidant is absent. The pH must be at least 9.5 for Manganese to be fully oxidized, whereas the pH range of 7.0 to 8.0 is sufficient for the oxidation of Iron during aeration.

The oxidation reaction of ferrous bicarbonate by oxygen is shown below.

$O_2 + 2H_2O + 4Fe(HCO_3)_2 = 4Fe(OH)_3 + 8CO_2$ (Eq. 2.9)
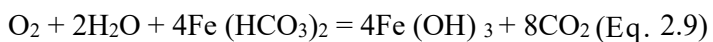
Following the aeration process, the residual iron (Fe) and manganese (Mn) can undergo oxidation employing a potent oxidizing agent such as ozone, chlorine dioxide, potassium permanganate, or chlorine. In the presence of humic or fulvic substances, ozone may not be efficient for the oxidation of iron and manganese. The strict regulation of dosage is imperative due to the potential conversion of reduced manganese to permanganate by ozone, resulting in the formation of pink water [52]. Ozone has the ability to undergo oxidation of ferrous iron, as demonstrated by the following chemical reaction:

$2Fe^{2+} + O_3 (aq) + 5H_2O = 2Fe(OH)_3 (s) + O_2 (aq) + 4H^+$ (Eq. 2.10)
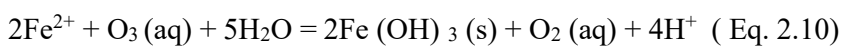
It takes more oxidizing power to oxidize Mn^{2+} than it does to oxidize iron. Here, you can see the ozone oxidation of manganese in action.

$Mn^{2+} + O_3 (aq) + H_2O = MnO_2 (s) + O_2 (aq) + 2H^+$ (Eq. 2.11)
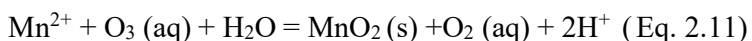
In the last few years, an increasing interest has emerged in using ozone to treat a wide range of water quality problems [77]. Manganese greensand is the most typical media for pressure filtering to remove iron and manganese. This substance has been processed and is formed of distorted grains of the clay mineral glauconite. It is used as a filtering medium. A coating of manganese oxide can be found on the material. As a result of its ion exchange capabilities, glauconite will improve the adhesion of the coating. This treatment will catalyze the chemical oxidation reactions required to eliminate iron and manganese. Continuous potassium permanganate application

maintains this layer. Another substance that can be used to remove iron and manganese is "Anthra/sand," which is sometimes referred to as "iron man sand." After the oxidation of iron and manganese, sand or anthracite is utilized in the filtration procedure. The utilization of this filtration medium makes it possible to remove these insoluble iron and manganese oxides from the solution. In addition, manganese greensand can also be utilized as a medium for the filtration process. When manganese needs to be eliminated via pressure filtration, manganese greensand is the predominant medium employed to remove manganese.

2.6.1.2 Removal of iron and manganese by ion exchange

Ion exchange involves using resin materials to exchange iron and manganese ions with sodium ions (Na^+). This method is particularly effective for lower concentrations of iron and manganese and is typically used in household water softeners.

In the event that we wish to get rid of a few trace concentrations of Fe and Mn, we can utilize the ion exchange approach, which carries a chance of temporary blockage. Sodium removes Iron and Manganese through ion exchange. In the iron exchange reaction, sodium cycles with iron and manganese, much like magnesium and calcium in the softening process [78].

$$NaR_2 + Fe^{2+} = Fe\ R2 + 2Na^+ \text{ (Eq. 2.12)}$$

2.6.1.3 Removal of iron and manganese by chemical oxidation

Chemical oxidation employs strong oxidants like potassium permanganate, chlorine, and ozone to precipitate iron and manganese. These oxidants are added to the water, converting Fe^{2+} and Mn^{2+} to insoluble forms that can be filtered out [79].

2.6.1.4 Removal by membrane filtration

Membrane filtration methods, including reverse osmosis, nanofiltration, and ultrafiltration, are highly effective at removing iron and manganese. These methods use semipermeable membranes to separate dissolved metals from the water, achieving up to 99% removal efficiency [80].

2.6.2 In-situ iron and manganese removal

In-situ methods treat iron and manganese within the aquifer before the water is pumped to the surface. This approach involves introducing oxidants directly into the groundwater through injection wells, creating an oxidized zone where iron and manganese precipitate out of solution.

Before pumping, an in-situ removal is a beneficial approach involving eliminating dissolved iron and manganese in groundwater. A long while ago, people would purify water that contained too much iron and manganese in water treatment plants by adding an oxidant to the water after abstraction. This process precipitated and filtered away contaminants, leaving behind clean water. Oxygen was utilized as an oxidizing agent, either in its pure form or employing aeration using a cascade aerator. In order to maximize the removal effectiveness of iron and manganese, it was necessary to periodically replace the sand layers that functioned as filters in this type of treatment plant, resulting in substantial operating and capital expenditures [81].

2.6.2.1 Ferrous and manganous oxidation

In-situ oxidation is based on injecting oxygenated water into the aquifer, promoting the oxidation of Fe^{2+} to Fe^{3+} and Mn^{2+} to MnO_2. The reactions are similar to those in ex-situ processes:
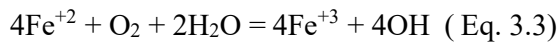
- $Fe^{2+} + O_2 + 4H^+ \rightarrow Fe^{3+} + 2H_2O$

- $Mn^{2+} + O_2 + 4H^+ \rightarrow MnO_2 + 2H_2O$

The precipitated iron and manganese remain in the aquifer, thus preventing them from entering the pumped water.

The oxidation reaction is the basis for underground iron and manganese removal. In subterranean environment iron and manganese undergo oxidation when oxygen rich water is introduced to the well. As the following equations describe, divalent ferrous ions (Fe^{2+}) can be oxidized to trivalent ferric ions (Fe^{3+}).

$Fe^{2+} = Fe^{3+} + e^-$ (Eq. 3.1)

$O_2 + 4H^+ + 4e^- = 2H_2O$ (Eq. 3.2)
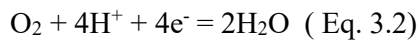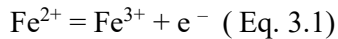
The total equation for the process is

$4Fe^{+2} + O_2 + 2H_2O = 4Fe^{+3} + 4OH$ (Eq. 3.3)

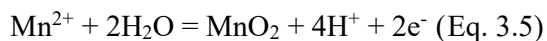In high dissolved oxygen content conditions upon combining with hydroxyl groups, the trivalent ferric ion can precipitate into a solid state.

$Fe^{+3} + 3OH^- = Fe\,(OH)_3$ (Eq. 3.4).
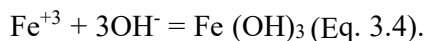
The formula for the manganese oxidation reaction is as follows:

$Mn^{2+} + 2H_2O = MnO_2 + 4H^+ + 2e^-$ (Eq. 3.5)

Iron and manganese in solution are oxidized to insoluble Fe^{3+} and Mn^{4+}, respectively,

which precipitate as oxyhydroxides. As compared to typical treatment, the Mn and Fe precipitates are not thrown away like trash, but instead are buried [54,82].

2.6.2.2 NITREDOX method

In addition, identicalin-situ procedures (such as the NITREDOX- method) have been established to eliminate nitrate using this technology. The NITREDOX method combines nitrogen and oxygen injection to simultaneously remove nitrate, iron, and manganese from groundwater. An oxidized zone can be created by periodically injecting aerated water through injection wells positioned in a circular formation surrounding the source well which enhances the natural filtration capacity of aquifer. Geochemical and hydrogeological circumstances may influence the number of injection wells. Injection wells necessitatedegassing and oxygenating the water before use. An oxygenator, a type of specialized aerator, can be used for this purpose [83].

2.7 Content of iron and manganese in the aquifer

The stratification of soil and bedrock exhibits variation across different locations, causing the composition of groundwater to vary as well. The dissolved oxygen concentration is highest in rain water, melted ice, and snow melt. Iron and manganese concentrations will be low when this water seeps into the earth quickly. In some instances, surface water does not seep straight into groundwater due to a less impermeable stratum. Therefore, groundwater often contains low percentages of dissolved oxygen and high levels of Fe and Mn. Such circumstances exist beneath the clayey soils. The factors influencing groundwater flow are also crucial. In addition to the geology and hydrology of the region, physical, biological, and chemical elements are crucial in determining the composition of groundwater. Bacterial growth and

multiplication require a carbon supply; therefore, as the bacteria's affinity for manganese increases, their demand for organic carbon, as compared to carbonates, and carbon dioxide increases [72]. Researchers referred to these microorganisms as iron bacteria and concluded that they are found anywhere Fe and Mn are detectable inthe water [84]. As the water pours into the well, it carries with it a variety of organic debris, some of which feeds the growing population of bacteria.

2.8 Sorption

The term "sorption" is often used interchangeably with "adsorption" and "absorption," as well as "ion exchange," due to its ability to describe all three processes. In the absorption process, the substance penetrates the solid whereas in the adsorption process, the chemical binds to the surface of a solid. The term "ion exchange" means exchanging one type of ion for another at the solid's surface, between one chemical and another. Clay minerals, oxy-hydroxides, and organic matter can absorb chemicals and are prevalent in soils and aquifers, along with other absorbent substances. Hydrologists deem these sorption mechanisms crucial because they govern the movement of contaminants in soils and aquifers. The sorption process results in the separation of pollutants between the solid and solution phase. Consequently, of the sorption procedure, pollutants travel more slowly in the groundwater [85-86] and are thus subject to retardation. If the rate of sorption is greater than the rate at which water is flowing, we shall classify this process as an equilibrium reaction. However, a sorption process is labelled as a non-equilibrium reaction if it proceeds more slowly. [87]. Heavy metal ions and other contaminants are bound to the surfaces of organic materials and oxides with varying charges through a process called sorption. These

solids with varying charges can absorb ions without releasing an equal number of other ions into the solution. The surface charge of the solid can exhibit either a negative or positive polarity, contingent upon the solutes present in the solution and the pH level. Nevertheless, these solid entities regulate the movement of heavy metals with both positive and negative charges. By absorbing in protons as well as other ions from the solution, oxides and hydroxides are able to develop a surface charge that varies with pH. The presence of surface charge induces a potential difference between the surface and the solution, thereby facilitating the migration of ions towards the surface [88].

2.9 Background theory of adsorption

Adsorption is the process of removing a substance's constituent and adhering it to the surface of another. Adsorption takes place between a substance (the adsorbate) and a surface (the adsorbent) in other words the adsorbate is the material that is adsorbed, while adsorbent is the surface on which it occurs. To modify the chemical form of the adsorbate, a reaction must take place involving the adsorbate and the adsorbent, as in chemical adsorption. The adsorptive site of an adsorbent is a shared electron pair between the adsorbent and the adsorbate [89]. As proposed by the in-situ Fe removal theory, iron can be extracted by injecting oxygenated water into an anaerobic aquifer via a tube well. Iron that has been oxidized precipitates out to form an adsorbent in an oxidation/precipitation zone that develops around the well. The sorption capacity of soil is improved by the addition of this newly manufactured adsorbent [90].

Following the reaction that occurs, the precipitate takes in the Fe^{2+} [91].

$XFe^{2+} + FeOOH = FeOOH_1\text{-}Y \ Fex \ (2x\text{-}y) + +yH^+$

In the event that it halts the injection process and proceeds to reverse the flow, specific

outcomes may occur. It is essential to weigh all potential consequences before taking any action; the iron concentration in the water either becomes undetectable or decreases significantly. This continues until there is evidence of an iron breakthrough at the well.

2.10 Filtration for iron and manganese removal

Groundwater serves as the only available or most common drinking water source in numerous developed countries. The groundwater treatment is relatively straightforward, requiring simple aeration and subsequent filtering. The filtration procedure may involve two phases.

Step 1: A pre-filter is used to remove iron from the water.

Step 2: Removal using post-filtration to get rid for e.g., ammonium and Manganese.

Technologies based on chemicals (such as flocculation) and physical processes (such as membrane filtration) (e.g., flocculation, membrane filtration) may give way to this environmentally friendly, low-impact more sustainable and greener method of providing drinkable water. Dissolved manganese and iron must be eliminated. Water discoloration and a metallic flavor can result from manganese and iron in the water supply, and corrosion and precipitation can damage the distribution system. Mn and Fe can be eliminated physicochemical, biologically, or else by combining both methods. Theoretically, aeration can achieve manganese physicochemical oxidation and precipitation. Manganese removal via simple aeration and precipitation is rendered unimportant under typical conditions for treating drinking water since the process is delayed unless the pH is elevated much above neutral. Manganese could also adsorb to the material that is currently used for filtering, producing manganese oxidation via

autocatalysis. Typically, iron is less difficult to get rid of. To begin, iron undergoes an oxidation reaction when exposed to oxygen at a pH of 7, then precipitated and filtered. The investigation of the biological elimination of manganese and iron has been a topic of scholarly inquiry for a considerable duration due to the potential significant cost savings in energy and chemicals that could be achieved through its application. [92-96]. In addition, the process of biological oxidation of manganese (Mn) and iron (Fe) leads to the formation of coarser precipitates compared to chemical oxidation. As a result, there is a reduced occurrence of filter clogging, necessitating a lesser number of backwashes. New filters are often initiated using "rule-of-thumb" techniques. In many cases, the sand from previously used filters or the sludge from the backwash process is used to inoculate newly constructed filters., but this results in unpredictability in the initial performance of the filters. For a filter to effectively remove manganese or iron through biological means, the necessary microorganisms must be present, and their physiological and nutritional needs must be met. Parameters that affect the biological processes and their interactions are an area where our understanding of quick sand filters' microbiology and processes is lacking. When oxygen levels are low, investigations have revealed that iron and ammonium removal are in direct conflict with one another, and both processes may negatively impact manganese removal [97-98]. However, the causes of these effects are still unknown. Various types of biofilters are necessary to achieve sustainable elimination of salts from drinking water through the utilization of biofiltration techniques. [99].

There is growing concern around the world about the consequences of the disposal of large quantities of hazardous waste mainly solid and liquid materials into the nature, it has become a worldwide concern especially in the last few decades [72,73,77,84,85].

Because the earth does not have a sufficient supply of freshwater, releasing wastewater that has not been treated or has only been partially treated is considered the most significant danger to humankind and civilization [100-104] and aquatic life [105-109]. Humans are currently confronted with a deep concern regarding the increasing industrial, agricultural, and urban activities that use large amounts of water and produce highly contaminated effluents are causing a major problem for the world's freshwaters, and this problem is only becoming worse [86-88] and the escalation in water use due to climate change [110-114]. Another major factor in the poisoning of freshwater sources is the insufficient management of these effluents, especially in developing countries [115-119]. As a result, these practices continue to introduce numerous dangerous contaminants into the world's very little freshwater supplies [120-125].

As a consequence of this, numerous undesirable contaminants have magnified to unsafe levels in water natural resources, putting the health of those who consume dirty water or eat contaminated food at serious risk [126-129]. Heavy metals are widely recognized as a highly hazardous class of pollutants in both freshwater and wastewater environments. This is owing to their detrimental effects on the ecosystem and their deadly effects on consumers' health, such as humans, even at shallow doses. Many aquatic organisms accumulate these poisons because they are not biodegradable. Some heavy metals, such as Hg and Ar, are said to be extremely dangerous to consumers at levels above the permissible level, which is often measured in micrograms. They can induce hereditary and uncommon diseases and fatal illnesses such as cancer. In addition, they can rapidly reach toxic levels in the bodies of aquatic organisms and, by extension, in humans via the food chain. Getting rid of harmful pollutants in freshwater

systems and wastewater is therefore of critical relevance. The appropriate treatment of wastewater and freshwater, as well as the regulation of the quality of drinking water, are essential components for reducing the freshwater deficit.

Therefore, establishing a consistent and environmentally friendly approach to wastewater treatments is of global importance. Adsorption strategies are currently considered sustainable wastewater treatment solutions for various reasons. First, they are effective at separating different types of wastewater contaminants. A second benefit is that the absorption process is simplified and more cost-effective when natural materials are used. The process is considered more eco-friendly than alternatives because the adsorption materials can be reused. Heavy metal removal from synthetic wastewater requires specialized treatment methods and also cost-effectively, it is possible to create and design a novel hybrid filter (Model pollutant: iron).