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Various techniques for elimination iron and manganese from ground water

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ABSTRACT

There is an effective treatment process, inexpensive materials, and very advanced technology that can be applied for the treatment of water. Drinking water must undergo several treatment steps before use to comply with local drinking water standards. To eliminate iron and manganese from groundwater, a variety of techniques should be employed, such as chemical oxidation, aeration, sedimentation, and filtering with a pressured sand filter. The purpose of this research was to create suitable protocols for the removal and concentration of trace metals of iron and manganese from water. This included the removal of DMI65 and Aldex CR 26 with filtering through multimedia filters. Biological oxidation processes and ceramic membrane processes were also applied after chlorination of the water. When the water treatment included DMI65 and Aldex CR 26 followed by chlorination at a rate of 1.0 mg/l and then biological methods complemented by filtration and ceramic membrane processes, the results showed that the methods used in this research were efficient compared to the conventional methods used. The conventional methods recorded Fe and Mn removal rates of 73.2% and 64.5% respectively. The study showed that iron and manganese removals of 98.8%, 99.2%, 94.6% and 97.8% were achieved when the experiments were conducted at a pH of 7.99 and within a contact time of five minutes. The aim of the study was to test some patents or techniques that can help extract with a specific contact time and contact force the added iron and manganese from the water. It involved the technique of use of oxidative agents and their complexes with filters from plant piping of contemporary bath pot hemispheres. In addition, biological oxidation processes with porous ceramic membranes technology were also used, aimed at the total calcium reduction as a pre-treatment step.

Keywords: removal of iron and manganese, ground water, and other techniques.

INTRODUCTION

Removing manganese and iron from groundwater requires techniques, such as chemical oxidation, aeration, sedimentation, and forced sand removal. The aim of the investigation was to find specific strategies for removing traces of the metals iron and manganese from water. This involves the use of an oxidation distributor, such as DMI65 and Aldex CR 26, followed by filtering the result through a multimedia filter, also after adding chlorine to the water. It uses organic oxidation technique and ceramic membrane method. Water content measurement was carried out using DMI65 and Aldex CR 26 followed by filtration strategy and ceramic membrane. Chlorine was applied in water at 1.0 mg/liter and organic methods were employed. The results prove the high effectiveness of the technique used in this observation, compared to conventional methods. The iron and manganese removal rates were 73.2% and 64.5%, respectively, using conventional techniques. The results indicate a decrease in values for Fe and Mn under pH conditions of 7.99 and 5-minute contact time, reaching 98.8%, 90.2%, 94.6%, and 97.8%; (Knocke *et al.,* 1987 and Kohl *et al.,* 2006). While manganese (Mn) and iron (Fe) often have no negative health effects, they might create unpleasant taste, appearance, and straining. One way to purify private water sources and public water channels is to carry out water treatment. The Earth's crust is known to contain Fe and Mn. The existence of iron in pipes can sometimes lead to the occurrence of iron in the water system. The water from deep wells containing iron and manganese is colorless and pure due to the low oxygen level. This implies that there will not be any changes in flavor, appearance, or straining if iron and manganese are not exposed to air (Linde *et al.,* 2005).

Both Mn and Fe will discolor when exposed to oxygen; manganese will turn brownish-black while iron will oxidize to red brown. This is evident when dishes, glassware, utensils, laundry, and porcelain all have a reddish brown hue. Researchers examine both public and privately owned water supplies using two different methods. The U.S. Environmental protection agency (EPA) has categories for testing public water sources: secondary standards and primary standards. Aesthetic concerns such as taste, color, shape, and strain are the basis for secondary standards. The basic principles are intended to protect human fitness and are based on health considerations. Should they handle private laboratory testing or use EPA methods to test nonpublic water sources? (Taseidifar *et al.,* 2017)

Fe and Mn may be removed from a domestic water system using several strategies. These strategies include chemical reactions. Tiered spillway organic aeration filter and waterfall aeration are often employed in wastewater treatment strategies. In addition to removing iron and manganese from groundwater. Chemical removal using biofiltration was tested by Taseidifar *et al.* (2017). They looked at a short reverse column injected with local biofilms from a Mn filtration plant. The filtration column was injected with a liquid solution of Leptothrix discophora SP-6. Studies have shown that manganese removal is likely over a much wider pH range than previously thought, involves the release of dissolved oxygen (DO), aeration, a unique method employed to remove iron and manganese from water systems.

Water containing appropriate amounts of iron and manganese will discolor textile fibers and items such as paper. By deposition, these ions will severely obstruct the pores of household softening equipment, which lowers the removal and filtration effectiveness. Deposition issues occur when these ions are deposited inside pipelines, which reduces the mass flow of water. Deposition inside heating equipment affects the efficiency of heat transfer and the amount of fuel used, but deposition inside pressure vessels reduces the pressure magnitude. The deposition of these ions in the distribution network results in fewer pipelines, which affects the water supply. In certain cases, this will block the pipelines, which will stop the water from flowing (Suwunwong *et al.,* 2021).

The presence of ions and manganese in water will cause a lot of issues, including germs. Although the bacteria provide no direct health risks, they can generate color stains on some products, such as textile fibers. The iron ions from bacteria can cause red stains, while manganese ions can cause black brown stains. As a result, these ions should be removed. However, these microorganisms can grow in both light and dark environments, so their effects still apply (Tekerlekopoulou *et al.,* 2013).

Since the many strata filtered the ground water up to 30 meters, it was always regarded as pure. Water is regarded as safe to drink, because microbes bind the chemicals that are dissolved in it. Restoring clean water after it has been contaminated by certain substances poses a significant challenge due to the slow filtration and layer-by-layer adsorption processes. The presence of saturated levels of carbon dioxide accelerates its dissolution rate, as it passes through different layers, further impacting the water quality. During this process, the dissolution of both positive and negative ions also takes place (Yang *et al.,* 2015).

Multiple levels of filtration are employed to decrease the oxygen content, turbidity, and various biological contaminants, such as bacteria and viruses in water. Subsurface water contamination usually occurs due to the existence of a wide range of materials, including inorganic, organic, and bioactive substances. Inorganic substances, as they do not easily decompose and persist in water, demand increased attention due to the significant threat they pose to drinking water. Currently, there is a diverse array of technologies and techniques accessible for purifying groundwater (Zou *et al.,* 2016).

Scientists have presented research findings on water treatment involving iron and manganese ions, as well as coli orphic bacteria, using silica carbonate-loaded filters. The recommended approach has a primary disadvantage, which is the requirement to adjust the pH value of the filtrate.

In addition to making it more difficult to maintain technological equipment, the use of reagents to acidify the filtrate to drinking water standards raises the cost of 1 m^3 of treated water. It is believed that the simpler aeration approach with subsequent filtration using foam polystyrene filters is more ideal and dependable. However, it should be noted that the stated procedure is not very effective when used to treat weak acidic waters with limited alkali reserves (Tjandraatmadja *et al.,* 2008).

In this case, it is crucial to utilize a thorough approach to bio-physical-chemical water treatment. A modern trend in biotechnology for water purification includes the use of iron bacteria to treat groundwater for drinking water supply. The elimination of positive ions like iron and manganese is accomplished through an oxidation and deposition process, which is affected by different operational physical and chemical variables. The pH level significantly influences the oxidation process of these positive ions; typically, an increase in pH enhances the oxidation rate (Tekerlekopoulou *et al.,* 2008).

Increasing temperature enhances the reaction rate through oxidation, approximately doubling for every 10 °C rise. Conversely, at elevated concentrations of organic carbon, the reaction rate tends to decline, as the increased organic carbon reduces the availability of dissolved oxygen necessary for oxidation. The time variable drastically affects oxidation processes; as an instance, the deposition of manganese calls for a appreciably longer duration in comparison to the oxidation of iron, which occurs within mins, whilst manganese oxidation might also take several hours (Shamohammadi *et al.,* 2011).

A novel method is to catalytically oxidize advantageous ions, specifically manganese ions, into manganese oxide for the reason of disposing of them from water through ion alternate. The filtration medium, referred to as manganese green sand, is made out of a mineral clay called glauconitic. This clay is prominent by way of its specific nodular grain structure that is covered with manganese oxide, giving it ion trade properties. Following the oxidation of effective ions to their respective oxides in water, the next step involves filtration using anthracite. Moreover, manganese green sand is enormously powerful in facilitating the oxidation and removal of manganese from water (Patel *et al.,* 2019).

Aeration is a preliminary operation that precedes filtration techniques. This allows the iron ions to be oxidized to oxide size. Its oxidation charge occurs with the help of several operating factors, including phase, pH, organic carbon content, and temperature, in addition to using manganese oxide aeration to oxidize the manganese. However, the oxidation rate of manganese is noticeably slower compared to iron ions. Therefore, a long storage time is required to achieve a good oxidation process. One of the greatest drawbacks to this process is the need for a large tank. The maximum efficiency of manganese removal by aeration is approximately 40% at pH 9.0, which increases to 70% when pH is increased to 11.1 (Kozlov *et al.,* 2004).

Chlorination

Oxidation methods in water treatment include the use, cost-effectiveness, and availability of chlorine used for its effectiveness as an oxidant. Chlorinated water can be transmitted in two main ways: a number of operational parameters, including pH levels, temperature, retention time, and the amount of chlorine required for full oxidation, affect how much chlorine is required for oxidizing iron and manganese. Theoretically, 0.64 mg/l of Fe(II) and 1.3 mg/l of Mn(II) are needed to oxidize 1 mg/l of each element. However, because of the presence of organic molecules and other elements in the water, greater volumes are frequently required in actual applications. Temperature, pH, retention time, and chlorine dosage all have a great influence on the chlorine oxidation process. Iron ions undergo oxidation more quickly at a pH of 5.0, reaching full oxidation at pH values between 10 and 15. Given that iron ions oxidize efficiently at 2 °C, pH 5.0, and reaction time of 90 seconds, reaction duration is critical. When using chlorine, pH is also a key factor in the oxidation of manganese ions. At a pH of 7.0, it is evident that using a chlorine dose roughly four times the theoretical requirement yields a minimum oxidation duration that can oxidize 30% of the manganese in the water (Kiyani *et al*., 2013).

Oxidation media (DMI65 and Aldex CR 26)

This material, sand coated with manganese, has the capability to oxidize iron and finds practical applications in the treatment of municipal and drinking water. Depending on the manufacturer, this material has an effective particle diameter of 0.48 mm and contains 85–90% MnO_2. It is recognized as a catalytic agent for the oxidation of iron in the presence of oxygen. For optimal effectiveness, the pH of the water being treated should range from 6.8 to 9.0. Additionally, this medium can be utilized to remove manganese, although in this case, the pH must exceed 8.0. It is important to note that aeration is necessary to address the lower dissolved oxygen levels typically found in groundwater. The chlorination process significantly enhances the removal efficiency of laboratory media such as DMI65 and Aldex CR 26; however, it does not improve their capacity for manganese removal. The regeneration process is crucial for periodically restoring the activity of the material, ensuring its effectiveness in manganese removal, while also ensuring that the water is free from oils, organic matter, and chlorine (Kiyani *et al.,* 2014).

Biological technique

Soils classified as oxidizing iron types harbor numerous types of bacteria. These bacteria thrive under specific conditions, including the availability of water, carbon dioxide, suitable temperatures, and essential nutrients such as food and iron. They exist in communities and produce polymeric substances that encase them, adhering to surfaces and forming flocs of iron particles in water treatment facilities. Microbiologists have conducted studies on the physiology and ultrastructure of several of these distinctive microorganisms (Nassar *et al.,* 2003).

Water pollution, especially wastewater contamination with heavy metals. Eventually, it became more global and caused great concern in various sectors. The method combines with oxidation, adsorption and membrane treatment. It is often used to deal with heavy metal pollution in wastewater (Maliki *et al.* 2019).

Researchers are now turning their attention to using microalgae to collect iron pollution from water. For example, Cynthia et al. reported effective removal of heavy metals from the water at the end of the mine with an increase in molybdenum (Mo) 99.9% and copper (Cu) 64.7%. These effects were similarly supported using the research of Rosario *et al.* on copper in acid mine water. It was found that the cell density adding value and the lipid content decreased with the increase in Cu sensing. Wang *et al.* conducted short-term and long-term research on Microcystis aeruginosa, investigating the kinetics of the adsorption and purification of inorganic arsenic in a microcystic environment. According to the previous research, living algae can grow and remove arsenic (Jain *et al.,* 2016) (Figure 1).

MATERIAL AND METHODS

The Fe and Mn stock solutions were obtained from ChemTech in the local market. Bacterial strains of iron and manganese were acquired from a biofilter water treatment facility. The reference testing methods and equipment used for inductively coupled plasma (ICP) analysis are detailed in Table 1. Quality control data related to the testing methods are presented in Table 2. Two identical 60 mL water samples were prepared in prewashed polyethylene bottles for metal analysis. A 0.45 μm filtering medium was utilized to separate suspensions from one of the samples. Both samples were acidified with a 1:1 ratio of HNO_3 to H_2O and stored at room temperature prior to the identification process. Dissolved iron and manganese concentrations were measured using JY Ultima Inductively Coupled Plasma - Emission Spectroscopy according to coupling specifications (Akoto *et al.,* 2007 and APHA, 2024). For all 20 samples, cleaning was recommended. Reagents and field cleanup for first-class handling were utilized. Before measuring dissolved metals, the ICP-ES was calibrated. The test sample was tested for every 10 samples produced. Field blanks were prepared with 60 mL deionized water. All metal ion and water samples were divided into mL bottles. One hundred twenty-five two bottles produced four 60 mL vials. The samples were collected in 250 mL vials. This step was done to reduce the possibility of contamination of the samples used in the metal dissolution analysis and to guarantee a unique appearance while protecting the integrity of the findings.

RESULTS AND DISCUSSION

Water treatment techniques

The goal of the current study was to investigate suitable and efficient ways to remove iron and manganese ions from water that was going to be treated. In addition to biological treatment, the study used oxidation methods, such as chlorination, oxidative processes, and filtration medium like

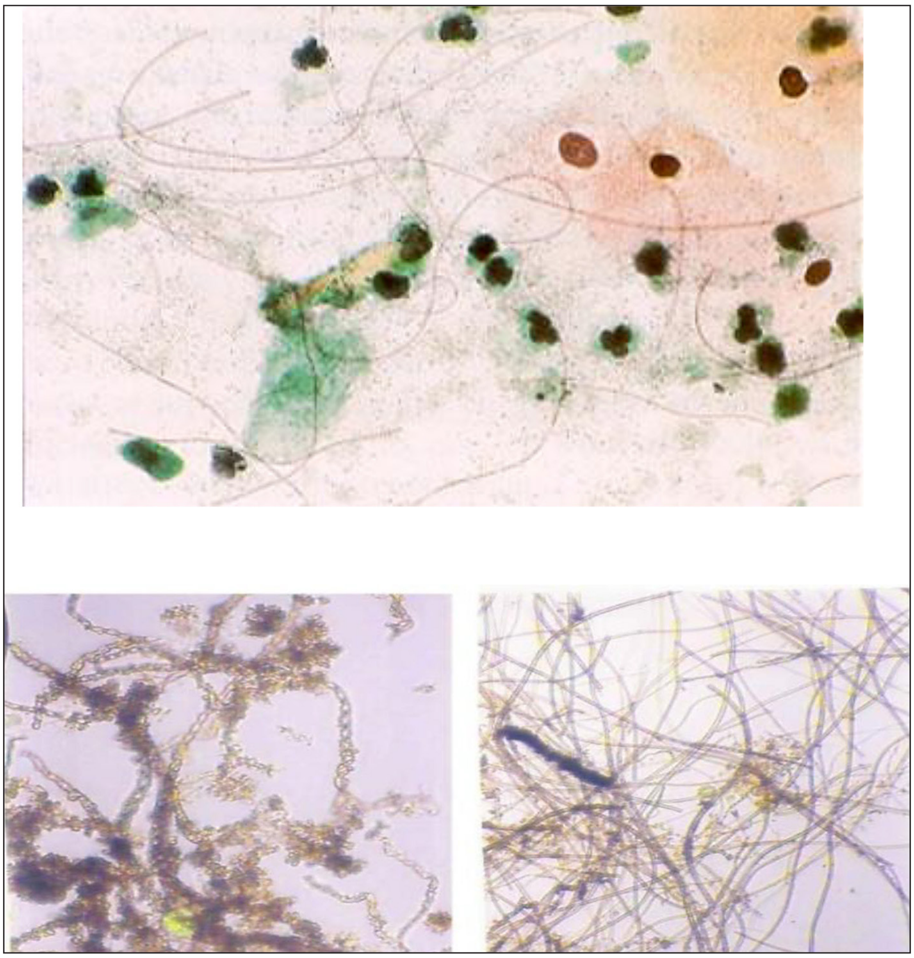

Figure 1. An image taken with a light microscope shows the stalks of *Gallionella* sp. another light microscope image captures the sheaths of *Leptothrix* sp.

Table 1. The testing methods

Parameter	Reference test method	Laboratory instrument
Fe	EPA 200.7	ICP Varian
Mn	EPA 200.7	ICP Varian

DMI65 and Aldex CR 26, to remove these metals. Table 3 describes the characteristics of the iron and manganese levels in the untreated groundwater.

Aeration and chlorination technique

The raw water was treated as follows: the water was aerated for 10 minutes with a small air pump (15 L/min) at pH 8.1 and water temperature 24.2 °C, then 2.0 ppm was added, and after a contact time of 10 minutes and water settling for 10 minutes, the treated water was treated with a small model (7.5 cm diameter, 60 cm length, containing sand media of 0.7 to 1.2 mm) and filtered. The treated water was analyzed and the results showed the removal rate of iron treatment (contact time 30 minutes).

The removal rates of iron removal (water pH 8.1, contact time 30 minutes, water temperature 24.2 °C) are as follows: minimum, maximum and average removal rates are 63%, 68.4% and 67.3% respectively. The process flow of aeration and chlorination treatment is shown in Table 4 and Figure 2. The removal rates of manganese (water pH 8.1, contact time 30 minutes, water

Table 2. Quality control data

Parameter	LOQ (mg/l)	Accuracy (%)	Precision	Bias (±mg/l)
Fe	0.001	97.2	96.8	+ 0.006
Mn	0.001	98.4	97.6	+ 0.005

Table 3. Raw water quality

No	Parameter	Unit	Min.	Max.	Average
1	Temerature	°C	14.2	27.6	23.1
2	pH	-	7.91	8.12	7.98
3	Conductivity	µS/cm	912	1030	994
4	TDS	mg/l	548	621	598
5	Sulphate	mg/l	77.2	86.4	82.1
6	Chloride	mg/l	92	98	95
7	Iron	mg/l	0.46	0.57	0.52
8	Mangnese	mg/l	0.59	0.64	0.62

temperature 24.2 °C) were as follows: minimum, maximum and average removal rates were 59.3%, 67.2% and 64%, respectively, if aeration and chlorination treatment was used, as shown in Table 4 and Figure 2.

The process of removing iron and manganese from domestic and drinking water through aerobic oxidation is challenging and time-consuming. The results of this process may often be unsatisfactory due to difficulties in completing the oxidation process under varying water conditions and pH values. The growth of iron bacteria on sand filters or valves can lead to water discoloration and increased turbidity, further complicating the removal process. Ion exchange is considered a promising method for removing iron and manganese ions from groundwater, especially when their concentration does not exceed 5 mg/l.

A study conducted in northern Croatia on the extraction of iron, manganese, and ammonia from groundwater revealed difficulties with nitrification and total iron and manganese removal. The full-scale trickling filter comparison of the Lekkerkerk Oasis water treatment plant revealed variations in manganese removal and problems with nitrification integration, which resulted in rivalry amongst biological processes for vital substrates. The role of biological processes and autocatalysis in liquid phase manganese removal was shown in laboratory testing, with a focus on the reliance on variables including temperature, sludge age, and redox potential.

In 1984, Wong *et al.* conducted a study on the removal of iron and manganese ions from groundwater through aeration, chlorination, and microfiltration (MF). The study involved jar tests

Table 4. Average of removal precentages after aeration and chlorination

No	Parameter	Unit	Min.	Max.	Average
1	Iron	mg/l	0.17	0.18	0.17
		%	63	68.4	67.3
2	Mangnese	mg/l	0.24	0.21	0.22
		%	59.3	67.2	64.5

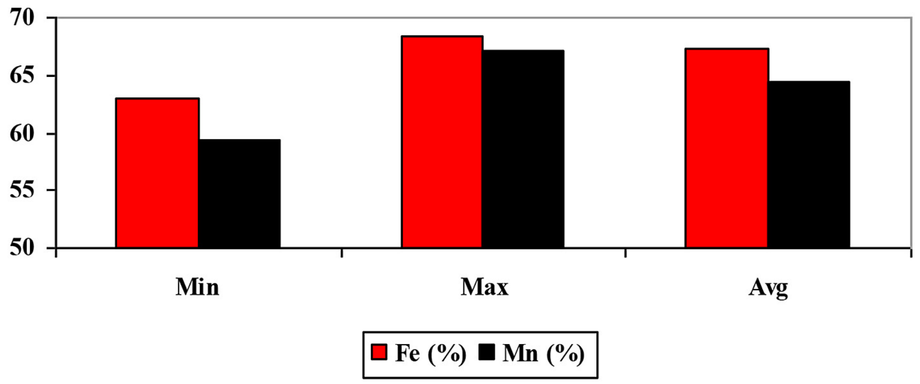

Figure 2. Removal precentages of iron and manganese after aeration and chlorination

to investigate the removal of iron and manganese under specific conditions of oxidant dosage, pH value, and reaction time. Additionally, a pilot test was carried out at the Changhua Water Treatment Plant, where raw water containing iron and manganese ions was oxidized with NaOCl and filtered by MF, with the use of a particle counter to examine the oxidized metal ion particles in the membrane permeate. The observation of the jar trials found out that a pH above 7 and a NaOCl dosage exceeding three mg/L were essential to reap a manganese removal efficiency of over 90%. According to the study, the manganese awareness inside the permeate decreased regularly from 0.1 to 0.01 mg/L after weeks of operation, with the buildup of Fe-Mn oxide at the membrane contributing to the manganese removal.

Oxdative and filtration media: DMI 65 technique

The untreated water underwent processing through DMI 65 media at a flow rate of 10 liters per minute, with a water pH of 8.1 and a temperature of 24.2 °C. Following filtration using a small model containing DMI65 media sourced from Chemtech Co., the treated water was analyzed, indicating the percentage of iron removal. DMI-65, a highly effective catalytic water filtration material, is designed to remove iron and manganese without requiring chemical regeneration or potassium permanganate. Its microporous design effectively reduces dissolved iron levels to as low as 0.001 ppm and manganese to 0.001 ppm, functioning as an oxidation catalyst for quick oxidation and filtration of solid particles. For iron removal treatment at a water pH of 8.1 and a temperature of 24.2 °C, the minimum, maximum, and average removal percentages using DMI65 media were 98%, 99.2%, and 99.1% respectively, as detailed in Table 5 and illustrated in Figure 3. Similarly, for manganese removal treatment under the same water conditions, the minimum, maximum, and average removal percentages were 97.8%, 99.0%, and 98.8%, respectively, when utilizing DMI65 media, as presented in Table 5 and depicted in Figure 3.

Ion exchange, biological trickling filters, reverse osmosis, nanofiltration, and aeration are some of the technologies used to extract iron and manganese from water. Because $Fe(OH)_3$ flocs have a catalytic effect on the oxidation of Fe^{2+}, studies have demonstrated that adding $Fe(OH)_3$ speeds up the reaction when iron and manganese are treated by aeration. Aeration, retention tanks/settling, and filtering are standard methods used in the majority of iron and manganese removal facilities in the United States. The presence of $Fe(OH)_3$ flocs in contact filters and the coating of filter media with $Fe(OH)_3$ demonstrate their exceptional ability to absorb Fe^{2+}. According to the research, the filter must age in order for the flocs

Table 5. Average of removal precentages with DMI65

No	Parameter	Unit	Min.	Max.	Average
1	Iron	mg/l	0.009	0.0046	0.0046
		%	98	99.2	99.1
2	Mangnese	mg/l	0.0134	0.001	0.0139
		%	97.8	99.0	98.8

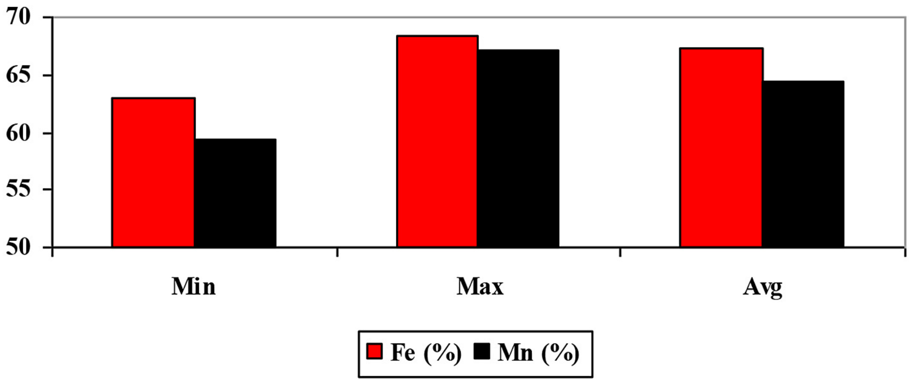

Figure 3. Removal precentages of iron and manganese with the DMI 65 technique

to replace the precipitate. According to Andersen et al., γ-FeOOH is an efficient catalyst among different iron oxides and is essential in the oxidation processes of iron and manganese. The 1987 study by Knocke *et al.* concentrated on greater initial Mn^{2+} concentrations and showed how manganese oxides produced by aeration catalyzed Mn^{2+} oxidation. Sung's analysis shows that iron oxide functions as a catalyst just as well as manganese oxide in the aeration-based removal of Mn^{2+}.

Davies and Morgan found that goethite (α-FeOOH) accelerates the oxidation of Mn^{2+} more quickly than silicon oxide or lepidocrocite (γ-FeOOH). Tüfekci and Sarikaya found that the catalytic action of Fe^{3+} grows up to 600 mg/L and that after this concentration, Fe^{3+} has no discernible effect on the oxidation of Fe^{2+}. According to the research, the catalytic impact increases over the course of three days as the $Fe(OH)_3$ sludge ages, possibly speeding up the reaction of Fe^{2+} radicals in the interaction of Fe^{2+} with oxygen. For the oxidation rate of Mn^{2+}, comparable catalytic effects were noted up to 700 mg/L concentration for MnO_2.

MnO_2 increases the oxidation of Mn^{2+} up to 800 mg/L, after which it has no discernible effect, according to the research by Chen et al. (2017). The 2004 study by Kozlov et al. showed that as the MnO_2 sludge ages, the catalytic action of MnO_2 increases over a four-day period. Celik's study highlighted that while aeration is a somewhat sluggish method of removing Mn^{2+} at a pH of 8.5, the addition of $Fe(OH)_3$ and/or MnO_2 greatly increases the removal efficiency of Mn^{2+}. Chen et al. (2017) reported similar results. According to Cheng's research, iron and manganese can both be totally removed from a solution if there is sufficient dissolved oxygen present. However, only iron is eliminated when the dissolved oxygen drops below 3 mg/L, leaving manganese in the solution. In a study by Štembal et al., dissolved oxygen levels varied from 8 to 17 mg/L and different aeration systems were used throughout four different layouts. The study investigated groundwater iron concentrations ranging from 0.98 to 2.45 mg/L. After treatment, the iron concentration was reduced in a filter placed at a depth of 0.8 m to a standard level of 0.3 mg/L.

Oxdative and filteration media: Aldex CR 26 technique

At a rate of 10 L/min, the raw water was processed by passing it through the Aldex CR 26 medium, maintaining a pH of 8.1 and a temperature of 24.2 °C. During the treatment process, a small filtration model measuring 60 cm in length and 7.5 cm in diameter was employed. The Aldex CR 26 medum, which was bought locally from Chemtech Co., was placed onto it. Following treatment, the water was examined to determine the extent of iron and manganese removal, with a focus on removal efficiency. Under the specified circumstances of pH 8.1 and 24.2 °C, iron removal percentages using Aldex CR 26 medium were measured at a minimum of 98.2%, a maximum of 99.3%, and an average of 99.1%. These results are detailed in Table 6 and visually represented in Figure 4. Similarly, for manganese removal under the same conditions, the removal percentages using Aldex CR 26 media were a minimum of 97.8%, a maximum of 99.8%, and an average of 98.0%. These data are also presented in Table 6 and illustrated in Figure 4. Aldex CR 26 is a unique material designed to possess exceptional catalytic abilities necessary for the removal of various impurities from both potable and non-potable water sources. It acts as an insoluble material that oxidizes elements in the liquid, such as hydrogen sulfide, iron, and manganese, forming nano-particles of metal oxides within the resin bed to create strong chemical connections with arsenite (As III) and arsenate (As V).

This enables Aldex CR 26 to effectively eliminate arsenic, as well as iron, manganese, and hydrogen sulfide. In addition to Aldex CR 26, there are various forms of manganese oxide (MnOx) which have demonstrated effectiveness as adsorbents for heavy metal ions, dyes,

Table 6. Average of removal precentages with Aldex CR 26 technique

No	Parameter	Unit	Min.	Max.	Average
1	Iron	mg/l	0.008	0.0041	0.0042
		%	98.2	99.3	99.1
2	Mangnese	mg/l	0.0131	0.001	0.012
		%	97.8	99.8	98.0

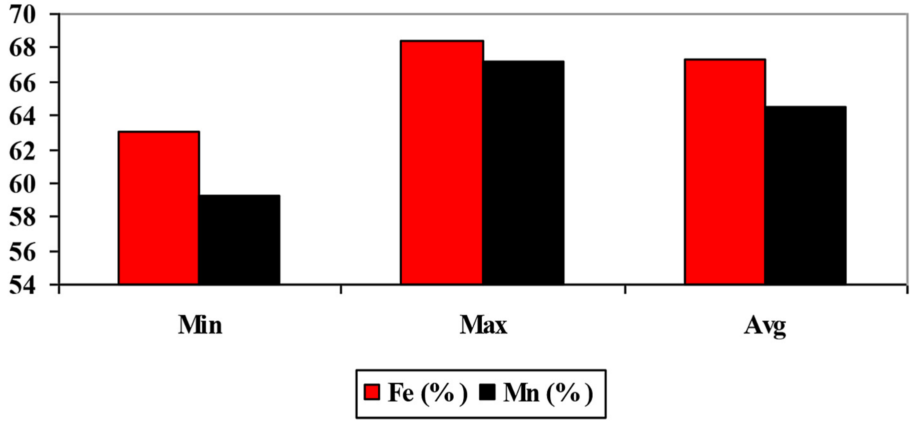

Figure 4. Removal precentages of iron and manganese with Aldex CR 26 technique

and other contaminants due to their excellent physicochemical properties. By using a patented multi-media formulation based on naturally occurring zeolites, electromedia offers an alternative to manganese oxide-coated media and does away with the necessity for potassium permanganate regeneration (Taseidifar et al., 2017). It is critical to remember that every filtration medium has unique benefits and drawbacks. Pilot testing should be used to choose the best medium and oxidant in order to thoroughly assess all significant design variables.

In 26 water treatment plants (WTPs) around Korea, the average manganese removal efficiency using MnO_2-coated medium was 93.5% (with a range of 0.05 to 0.97 mg/L). Full-scale experiments at a water treatment facility in Belgium showed that the filters with MnO_2-coated anthracite (MOCA) had a much superior manganese removal rate (> 90%) than those without a MOCA layer (around 10%). A common method for removing iron and manganese from drinking water is rapid sand filtration (RSF) following aeration; however, because little is known about the factors influencing removal rates, its effectiveness varies. Data from over 100 water treatment plants in countries such as the Netherlands, Belgium, Germany, Jordan, and Serbia emphasize the complexity of manganese removal through the aeration–RSF system, influenced by multiple water quality factors and operational parameters (Wong, 1984). A broad range of manganese removal rates (9% to 100%) dependent on operating times was found in recent studies conducted in the Netherlands utilizing dual-media RSFs with anthracite and sand. On the other hand, iron and ammonia elimination demonstrated steady rates of 80–100% and 97–100%, respectively. With wells that reach depths of about 150 meters and an average production of 25 L/s, groundwater is an essential and sustainable supply of water in the Terai region of southern Nepal. However, one major obstacle to using groundwater as drinking water is its quality. A study conducted in three regions of the eastern Terai found that 107 out of 175 groundwater samples had iron levels over the national drinking water quality standards (NDWQS) of 0.30 mg/L and 88 out of 175 had manganese levels beyond the limits of 0.20 mg/L.

In Nepal, RSF aeration structures are the most widely used method of groundwater treatment, because of its low cost and ease of use. The higher disposal fees for iron and manganese resulting from other technologies are not feasible in Nepal and different developing areas. Due to the high cost chemical requirements and complex conservation strategies. The oxidation and removal of manganese through aeration of RSF structures is, however, slower and more difficult than iron oxidation, for which unpredictable water quality properties in the aeration structure and the design criteria of the remediation system are responsible (Zaw, 1999).

The purpose of viewing has changed to evaluate the efficiency of iron and manganese removal within current RSF aeration plants in the Terai region and explore the potential use of MnO_2 blanket media as a more efficient technique for those problems. Manganese was assessed using two filters topped with anthracite and three common leaching media: quartz sand, manganese sand, and MnO_2 coated ceramic (ferrolyte)—as well as addition of pre-chlorination under different operating conditions of coagulation (Adekola *et al.,* 2016).

Biological treatment technique

The raw water underwent treatment as follows: it was directed through a sand medium that contained both iron and manganese bacteria sourced from the environment (specifically, a location rich in iron and manganese oxides) at a flow rate of 1.5 liters per minute, with water pH at 8.1 and a temperature of 24.5 °C. This treated water was then filtered through a smaller model (7.5 cm in diameter and 60 cm in length, filled with sand media containing the iron and manganese bacteria) for a contact duration of 12 hours. Upon analysis of the treated water, results indicated that the percentage of iron removal was 100% across all trials at the stated pH and temperature, as outlined in Table 7. Similarly, the removal percentage for manganese was also 100% in all trials involving biological media under the same conditions, as detailed in Table 7.

The pilot-scale biological aerated-filter (BAF), constructed from plexiglass and standing at a height of 3 meters with an external diameter of 185 centimeters, is intended for operation over several months. The presence of manganese oxidation is shown by the material inside the filter turning black. A perforated pipe on the top of the filter out directs water from the pinnacle tank thru a flowmeter before spilling onto the biofilter layer. Afterwards, it descends to the bottom of the filter, which is also perforated and connected to a pump.

Deng *et al.* (2021) reported that the filter medium is made up of separate layers: the 0.8-meter-tall higher layer is made from materials with diameters between 3.1 and 5.5 mm, and the 0.8-meter-tall decrease layer is made of materials with diameters among 1.6 and 3.2 mm. The manufacturing of dissolved oxygen at the water's surface is recommended via this unique material arrangement (Tekerlekopoulou *et al.,* 2008).

A biosand filter (BSF) represents a conventional, low-drift filtration device often applied for community ingesting water treatment. Research through Tekerlekopoulou *et al.,* 2013, examined the effectiveness of an iron oxide-amended biosand filter within the elimination of viruses. This investigation included both laboratory and area experiments, in which iron was positioned at the pinnacle of the filter to enhance the interaction time between the viruses and iron oxides. The effects confirmed that the incorporation of iron is critical for retaining a consistent float, even in small quantities that would no longer be detectable in a BSF without iron. Furthermore, the look at indicated that the performance of virus retention via iron-amended biosand filtration is influenced through the particular situations of the water source, in addition to the quantity and composition of the iron introduced.

Water paramters that affect the efficiency of iron and manganese removal

The goal of the current study was to investigate suitable methods and efficient treatments for eliminating iron and manganese ions from purified water.

Water temperature

The study revealed that lower water temperatures lead to a substantial decrease in the rate of biological oxidation, resulting in reduced removal rates of Fe and Mn. Conversely, as the water temperature rises, the percentage of Fe and Mn removal improves, along with enhanced effectiveness of biological treatment. This trend, illustrated in Figure 5, indicates that both iron and manganese removal rates are greater at elevated water temperatures.

Water pH

Figure 6 shows how the pH of four aqueous solutions treated with microalgae changed as the algae grew. The pH trend for each experimental group was similar; it increased steadily over the course of the longer culture period and finally stabilized at pH = 10. Similar patterns and events have been described by other studies. In lipid productivity studies, for instance, Han et al.

Table 7. Average of removal precentages with biological treatment technique

No	Parameter	Unit	Min.	Max.	Average
1	Iron	mg/l	0.001	0.001	0.001
		%	100	100	100
2	Mangnese	mg/l	0.001	0.001	0.001
		%	100	100	100

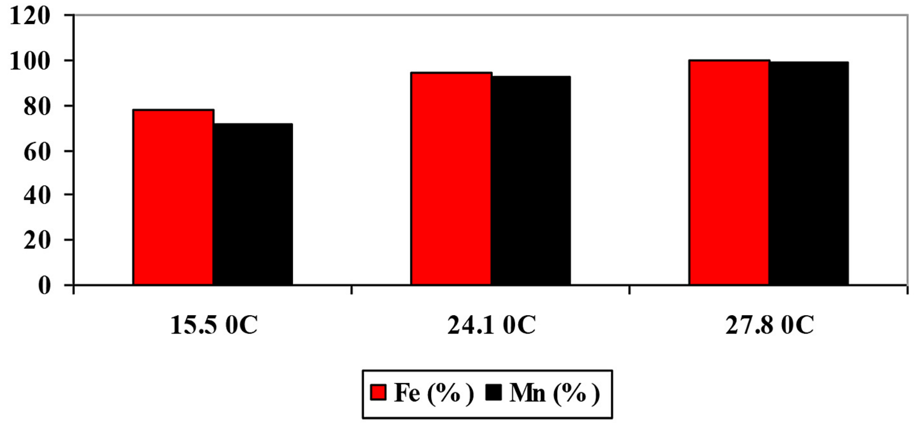

Figure 5. Removal precentages of iron and manganese with water temperature variation

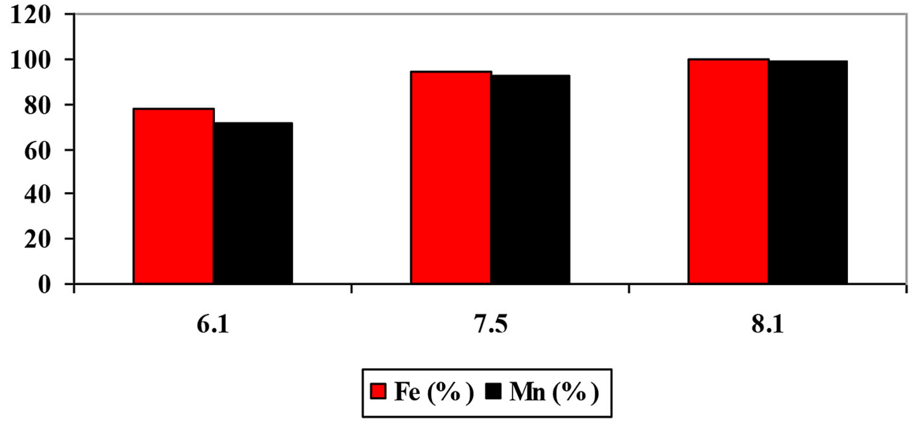

Figure 6. Removal precentages of iron and manganese with water pH variation

employed Chlorella pyrenoidosa and discovered that the pH rose rapidly from 7.8 to 9.5. Additionally, Wang et al. investigated the effects of varying pH treatments on the quantity, growth, and biochemical composition of triacylglycerol (TAG) in the Leguminosae family member Auxenochlorella protoecoides KP7. They discovered that TAG, starch, and chlorophyll levels are influenced by pH.

One important biological factor affecting the habitat of aquatic microalgae is the pH level of the water. By altering CO_2 availability, improving the effectiveness of inorganic carbon use, and changing cell membrane permeability, it mainly affects algal growth and metabolism in three important ways. It also indicates how well the microalgae are growing and how well they are able to use the carbon sources in the solution. The four forms of inorganic carbon found in water are CO_2, H_2CO_3, HCO_3^-, and CO_3^{2-}, and they are all in balance.

$$CO_2 + H_2O = H_2CO_3 = H^+ + HCO_3^- = \\ = 2H^+ + CO_3^{2-} \qquad (1)$$

Contact time

As shown in Figure 7, the results show that a higher percentage of iron and manganese removal results from a longer contact duration. The experimental data underscore that retention time has a substantial impact on the elimination of dissolved metal ions through the biological oxidation process.

Tekerlekopoulou *et al.* (2008) proposed that the behavior of biological iron and manganese can be easily understood through the stability diagram (Eh-pH) used to oxidize these metals before filtration. This is particularly relevant when they exist in their reduced, soluble forms (Fe^{2+} and Mn^{2+}) in groundwater that lacks dissolved oxygen. Traditional physical-chemical treatment processes require conditions conducive to strong oxidation due to kinetic reaction factors, resulting in an Eh value that is significantly higher than the boundary separating the reduced and oxidized stability fields. To remove iron practically, these procedures require strong aeration at a pH higher

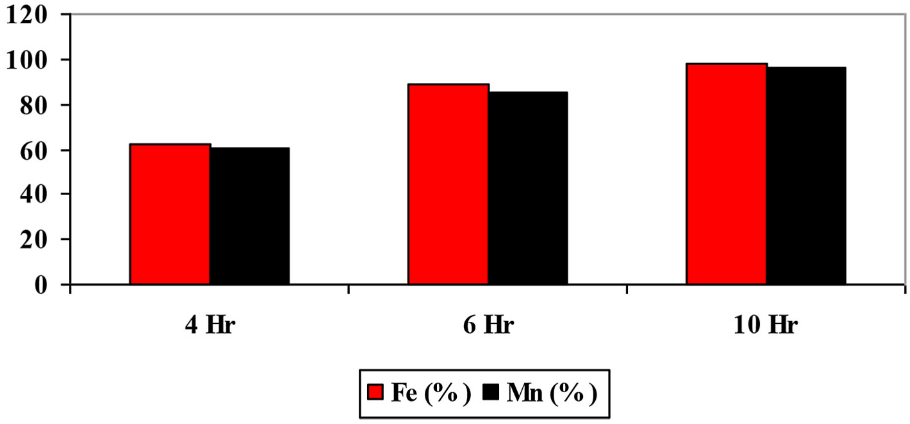

Figure 7. Removal precentages of iron and manganese with contact time

than 7.2 and oxidizing chemicals such ozone (O_3), potassium permanganate ($KMnO_4$), or chlorine dioxide (ClO_2) to remove manganese. On the other hand, biological treatments for manganese and iron offer benefits in terms of ease of use and affordability (Suwunwong *et al.,* 2021).

CONCLUSIONS

It was discovered that the average concentrations of manganese ions and dissolved iron metal were 0.62 and 0.52 mg/l, respectively. These levels were higher than those advised by the WHO. For this reason, water should be treated before drinking.

The removal rates of iron removal with aeration and chlorination treatment (water pH 8.1, contact time 30 minutes, water temperature 24.2 °C) are as follows: minimum, maximum and average removal rates were 63%, 68.4% and 67.3% respectively, and in the case of manganese, the removal rates were as follows: minimum, maximum and average removal rates were 59.3%, 67.2% and 64%, respectively.

In the case of using oxdative and filteration media: DMI 65 Technique and Aldex CR 26 with iron ions, at water pH of 8.1 and temperature of 24.2 °C, the minimum, maximum, and average removal percentages were recorded as follows: 98%, 99.2%, and 99.1%, with DMI 65, respectively, and the removal ratios of 98.2%, a maximum of 99.3%, and an average of 99.1%, using Aldex CR 26 medium, while in the case of manganese ions, at a water pH of 8.1 and a water temperature of 24.2 °C, the minimum, maximum, and average removal percentages were found to be: 97.8%, 99.0%, and 98.8%, respectively, when utilizing DMI65 media, and under the same conditions, the recorded removal percentages were: a minimum of 97.8%, a maximum of 99.8%, and an average of 98.0%, with the Aldex CR 26 medium.

In biological treatment, the removal ratios of both Fe and Mn were 100% at water at a flow rate of 1.5 liters per minute, with water pH at 8.1 and a temperature of 24.5 °C.

The factors affecting the biological performance of removal iron and manganese are the water pH, contact time, and water temperature. The study found that the performance of treatment increased with the contact time, pH and water temperature.

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