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COMPARISON OF REMOVAL TECHNIQUES OF MANGANESE FROM WATER AND WASTE WATER

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Abstract: The pollution of manganese (Mn) ion in both surface and groundwater occurs naturally or by anthropogenic sources. The high level of Mn(II) causes neurological disorder similar Parkinson's disease. This study reviews the reported manganese removal technique from aqueous solutions, including bioremediation, adsorption, filtration, chemical precipitation, and other techniques such as electrocoagulation, ion exchange, coagulation and flocculation, oxidation and filtration, membrane processes, and using oxidation chemicals presenting available choices to solve the problem of manganese pollution. The bioremediation and adsorption technique were found to be the most practical and mostly accepted in the literature. Based on findings this study, in ground waters the highest level of manganese 4.39 to 62.62 mg/L was found in Chhattisgarh, and the lowest level was 0.00 to 0.11 mg/L found in Nigeria. This review summarizes existing awareness on several perspectives of the principals and utilization of removal technique of manganese and critically reviews the difficulties to its commercial achievement and future aspects
Keywords: Manganese removal, Adsorption, Bioremediation, Membrane, Water and waste water

1. INTRODUCTION

Elimination of heavy metal ions from surface and ground waters has been a vital matter. Heavy metals are commonly current as contaminants in a diversity of industrial effluents. Industries like metal plating, metal finishing, rubber processing, fertilizers, mining as well as agriculture discharge these heavy metals into the resources water(Hoyland *et al.* 2014).Manganese (Mn) is often present in ground and surface water, and waste water in the reduced Mn(II) or oxidized Mn(IV) form(Hoyland *et al.* 2014). Some of the challenges related to high Mn concentrations are the blockage of pipes, addition of nasty taste to water, blemish of laundry or toxicity for human health(Funes *et al.* 2014; Fadaei 2021).Manganese level in fresh waters largely spans from 0.001 to 0.2 mg/ L, being more usual levels below 0.0 10 mg/ L(Funes *et al.* 2014).The levels of above 0.2 mg/L in the water sources could have harmful impacts on human health and the aquatic ecosystem(Rudi *et al.* 2020; Taie *et al.* 2021). The contact to high concentration of Mn can cause neurological disorder similar to Parkinson's disease, Kashin-Beck disease, learning disabilities in children, degeneration of brain functioning, hypotension, manganism, aspiration contact may cause; sperm damage, loss of sex drive, pneumonia and injure arterial breastwork and the myocardium (Jeż-Walkowiak *et al.* 2017; Cheng *et al.* 2020b).

In a study by Mthombeni and colleagues demonstrated that children who exposed to 0.240–0.350 mg/L of manganese in water showed defected manual dexterity, speed, short-term memory, and visual recognition compared to children exposed to controlled manganese (Mthombeni *et al.* 2016). Manganese has classified into group four carcinogenicity level (i.e; evidence suggests no carcinogenic properties in humans or animal)(Briffa *et al.* 2020).Various methods have been used for the elimination and/or recovery of metals from contaminated media. There are many methods used to remove manganese from water and wastewater, like precipitation, flocculation, electrochemical, biological, evaporation, ion exchange, oxidizing agents, filtration, chemical perception, reverse osmosis, membrane filters and adsorption(Bakr *et al.* 2018).Nevertheless, these methods are costly, some when impossible, and are not particular for metal-binding specification (Ayangbenro & Babalola 2017). Therefore, Mn removal by different methods could be considered as a promising technique for water quality treatment. In this context, the main aim of this study was to assess the suitability of using various methods for Mn removal from aqueous solution by applying bioremediation, adsorption, chemical precipitation, and filtration techniques.

2. METHODS

The review has principally arranged these methods with the processes. Databases like Google Scholar, Science Direct, and Web of Science are employed to retrieve several papers on the topic. Keywords like "Manganese removal", "bioremediation", "waste water" , "Chemical precipitation, "membrane", "adsorption", "filtration" "Water treatment", and "ground water" are added to the methods above mentioned retrieving appropriate papers. After a whole search and remove articles with no direct association with water manganese removal, a total of 114 original papers are primarily contained in the context of the review. This excludes various review articles providing an understanding of different methods of each treatment. Type of aqueous solutions were investigated this study such as: ground water, artificial water, artificial waste water, and wastewater.

3. RESULTS AND DISCUSSION

These articles were from various methods, adsorption (16) bioremediation (13), Chemical precipitation (5), and filtration (4) (Tables 1, 2,3,4).

— Bioremediation

Bioremediation is a novel method for the elimination and recovery of heavy metal ions from polluted environments, and involves using living organisms to decrease and/or recover heavy metal pollutants into less hazardous forms, using the activities of algae, bacteria, yeast, fungi, or plants. It has been applied to the elimination of heavy metals from polluted wastewaters and soils. This technique is an absorbing alternative to physical and chemical methods, and the use of microorganisms play a significant function in heavy metal remediation. Correspondingly, the use of microorganisms to remediate contaminated environments is supportable and helps to restore the natural state of the contaminated media with long term environmental profits and cost effectiveness(Gupta *et al.* 2016).These organisms help to detoxify hazardous constituents in the environment. The process can operation naturally or can be enhanced through the addition of electron acceptors, nutrients, or other parameters. Detoxification can occur through the valence transformation mechanism. This is chiefly appropriate in the case of metals whose various valence steps differ in toxicity(Ayangbenro & Babalola 2017).

Biosorption, bioaccumulation, biotransformation, and biomineralization are the methods applied to microorganisms for their concatenated existence in metal contaminated environment. These methods have been used for remediation procedures(Dixit *et al.* 2015). Based on findings this study, the removal of Mn by bioremediation (i.e; bacteria, algae, yeast, plant and fungi) is very effective, with removal performances spanned between 39 to 98% (Table 1).Bioremediation is of very less effort, less labor severe, cheap, ecofriendly, sustainable, and moderately easy to execution.Most of the limitations of bioremediation relate to the slowness and time-consumption(Mukhopadhyay *et al.* 2021).Presently, Mn is removed from groundwater via two traditional techniques: biological oxidation and contact catalytic oxidation. Biological Mn elimination has been studied widely for groundwater treatment and has been successfully practical in water purification facilities (primarily in Europe) since the 1980s (Hoyland et al., 2014). Biological oxidation treatment is the process of passing raw Mn-contaminated water through a filter including Mn-oxidizing bacteria (MnOB) that naturally oxidize Mn (II) to Mn (IV) (Hoyland et al., 2014). As MnOB needs a entirely aerobic media for Mn oxidation and precipitation, the filter should always be fed with compressed air to ensure that MnOB has adequate oxygen to function properly (Pacini et al., 2005; Burger et al., 2008).Manganese oxidizing bacteria Leptothrix, Gallionella, Pseudomonas, Siderocapsa, Crenothrix, Hyphomicrobium and Metalloaenium (Cheng *et al.* 2017).Current researches propose that Fe–Mn co-oxide can remove Mn from groundwater under low or even no dissolved oxygen conditions. There is, however, inadequate literature concerning the elimination of Mn from groundwater under anaerobic status(Cheng *et al.* 2020b).

In a study by Mane and Bhosle, illustrated that the optimum removal efficiency Mn from aqueous solution was 99.73% using algae Spirogyra sp, and Spirullina sp(Mane & Bhosle 2012).In a study by Anahid and co-workers reported that used from Aspergillus niger, Aspergillus foetidus and Penicillium simplicissimum for removal Mn from aqueous solution(Anahid *et al.* 2011). In a study by Vázquez-Ortega and Fein reported that used from Pseudomonas putida and Bacillus subtilis for removal Mn from aqueous solution(Vázquez-Ortega & Fein 2017).Another study reported that used from Pseudomonas sagittaria for removal Mn from ground water, the optimal Mn removal performance 95% at 28°C during 6 days(Optimization of bacterial bioaugmentation for groundwater Mn removal using a waste based culture medium and lyophilization).

In a study by Piazza and co-workers reported that used from Pseudomonas spp for removal Mn from groundwater (Piazza *et al.* 2019). In a study by Li and co-workers illustrated that the optimum removal efficiency Mn from ground water was 96.69% using Acinetobacter sp., Bacillus megaterium and Sphingobacterium sp at pH 7.09, and temperature 20.15°C(Li *et al.* 2016). In a study by Marcus and co-workers illustrated that removal Mn from drinking water using Alphaproteobacteria (Afipia, Bosea, and Reyranella)(Marcus *et al.* 2017). In a study by Calderón-Tovar and co-workers illustrated that the optimum removal efficiency Mn from ground water was above 40% using Aeromonas sp and Stenotrophomonas sp (Calderón-Tovar *et al.* 2020). In a study by Marcus and co-workers illustrated that removal Mn from drinking water using Hydrogenophaga spp (Marcus *et al.* 2017). In a study by Li and co-workers illustrated that removal Mn from groundwater using gallionella, exiguobacterium and citrobacter (Dong *et al.* 2021). In a study by Pani and co-workers illustrated that removal Mn from wastewater was about 78.4% using bacterial biofilm(Pseudomonas beteli, Stenotrophomonas sp)(Pani *et al.* 2017). In a study by Diaz-Alarcón and co-workers illustrated that removal Mn from natural groundwater was about 15.26% at 2 to 3 min, pH 7.24 using magnetotactic bacteria(Diaz-Alarcón *et al.* 2019).Therefore, more researches need to concentration on the development of new clean environmentally acceptable techniques with commercial practicability.

Table 1. Bioremediation of manganese in water and waste water

Type of microorganism	Water and waste water types	Removal efficiency	Mn (II) (level	Time exposure	Ref
Bacillus pumilus	Surface water	>98%	0.1–0.2(mg/L)	1-2 days	(Hoyland *et al.* 2014)
Comamonas, Pseudomonas, Mycobacterium, Nocardia and Hyphomicrobi	Artificial substrates	0.41 kg/ Mn.m^3.d	100 g/L	131 days	(Shoiful *et al.* 2020)
Pseudomonas Putida	Artificial wastewater	56.2% to 65.0%	10-40 mg/L	2 h	(He *et al.* 2019)
Biogenic manganese oxides	Freshwater	11.4 mg/ L. d	-	370 days	(Kato *et al.* 2017)
Stenotrophomonas sp and *Lysinibacillus* sp	Mine water	58.5% and 70.9%	50 mg/L	14 days	(Barboza *et al.* 2015)
Serratia marcescens sp	Artificial wastewater	56–64.25%	40 mg/L	16 days	(Queiroz *et al.* 2018)
Bacillus	Elevated underwater	1.76 µg/ g.d	5.49 mg/L	7-10 days	(Sujith *et al.* 2014)
Crenothrix	Real groundwater	95.90%	0.9-1.3 mg/L	112 days	(Cheng *et al.* 2017)
Pseudomonas putida	Waste water	up to 75%	10 mg/ L	48 h	(McKee *et al.* 2016)
Bacillus, Arthrobacter, Pseudomonas, Corynebacterium	Groundwater	39%	1 mg/ L	30 days	(Meng *et al.* 2020)
Pseudomonas sagittaria	Groundwater	95%	1 mg/ L	7 days	(Casalini *et al.* 2020)
Bioremediation(aerobic and anaerobic)	Groundwater	>80%	15-20 mg/ L	18 days	(Cheng *et al.* 2020b)

— Adsorption

Currently, adsorption displayed rapid development and high potential for usage in industrial water and wastewater processing due to the strengths of high treatment performance, low energy use, and environmentally friendliness(Ahmadi *et al.* 2020; Li & Zhang 2020). According to findings this study, the highest adsorption capability was achieved120.6 mg/g by Zostera marina plant adsorbent and the lowest level was 1.08 mg/g by Calcite limestone adsorbent (Figure 1 and Table 2). For the purpose of manganese elimination from wastewater, a number of adsorbents like resins, minerals, industrial wastes, bio-sorbents, nanomaterials, and iron-based adsorbents have been confirmed to be prospective and their adsorption behavior and performance towards Mn was extensively studied. A wide table of several adsorbents from literature is collected and their adsorption capacities under several status (pH, co-existing ions, retention time, dose, temperature) for manganese removal (Liu *et al.* 2021). Based on findings this study,the removal of Mn by adsorption method is very effective, with removal performances spanned between 1.08 to 120 mg/g (Table 2). Limitations of this process included low efficiency/cost ratio, ineffectiveness at high metal level. In a study by Bakr and colleagues demonstrated that maximum manganese adsorption capacity was about 20.20 mg/g at pH 5, and temperature 24.85°C from aqueous solutions by using Co/Mo layered double hydroxide(Bakr *et al.* 2016).In a study by Jovanovic and co-workers stated that maximum manganese adsorption capacity was about 30 to 50 mg/g at pH 6.2, and temperature 25-55°C from aqueous solutions by using beads of Zeolite A(Jovanovic *et al.* 2016).One study reported that maximum manganese adsorption capacity was about 1.9 mg/g at pH 4.5, and temperature 23°C from aqueous solution(Esfandiar *et al.* 2014). In a study by Ahmed and co-workers stated that maximum manganese adsorption capacity was about 0.417 mg/g at pH 6, and time 150 min from aqueous solutions by using sugar cane bagasse (Ahmed *et al.* 2015).In a study by Akpomie and Dawodu illustrated that maximum manganese adsorption capacity was about 94.32meq/100g at pH 6, and temperature 23°C from aqueous solutions by using Montmorillonite(Akpomie & Dawodu 2014).In a study by Badrealam and co-workers illustrated that maximum manganese adsorption capacity was about e 0.1579 mg/g (95.5%) at time 60 min , and 3.0g tea waste from synthetic wastewater by using tea waste(Badrealam *et al.* 2019). In a study by Pavan Kumar and co-workers illustrated that maximum manganese adsorption capacity was about 6.24 mg/g (99.8%) at pH 5, time 60 min and temperature 40°C from aqueous solutions by using corn cob and Strychnouspotatorum seed powder(Kumar *et al.* 2018). In a study by Mosoarc and co-workers illustrated that maximum manganese adsorption capacity was about 54.94 mg/g (above 98%) at pH 6, time 15 min, and adsorbent dose of 10g/L from aqueous solutions by using wood ash(Mosoarca *et al.* 2020). In a study by Idrees and co-workers illustrated that maximum manganese removal above 80% at pH 6, time 180 min, and adsorbent dose of 0.25g/L from aqueous solutions by using Biochar (Idrees *et al.* 2018).In a study by Al-Wakeel and co-workers illustrated that maximum manganese adsorption capacity was about 1.3 mmol/g at pH 6, time 150 min, and temperature 25°C from aqueous solutions by using glycine modified chitosan resin(Al-Wakeel *et al.* 2015). In a study by Funes and co-workers demonstrated that maximum manganese removal was above 98% at pH higher than 9, from aqueous solutions by using magnetic microparticles (Funes *et al.* 2014).((Esfandiar *et al.* 2014). In a study by Ma and co-workers demonstrated that maximum manganese adsorption capacity was about 130.625 mg/g at 298.15 K ,and time 30 min from aqueous solutions by using Pleurotus ostreatus nanoparticles (Ma *et al.* 2013).

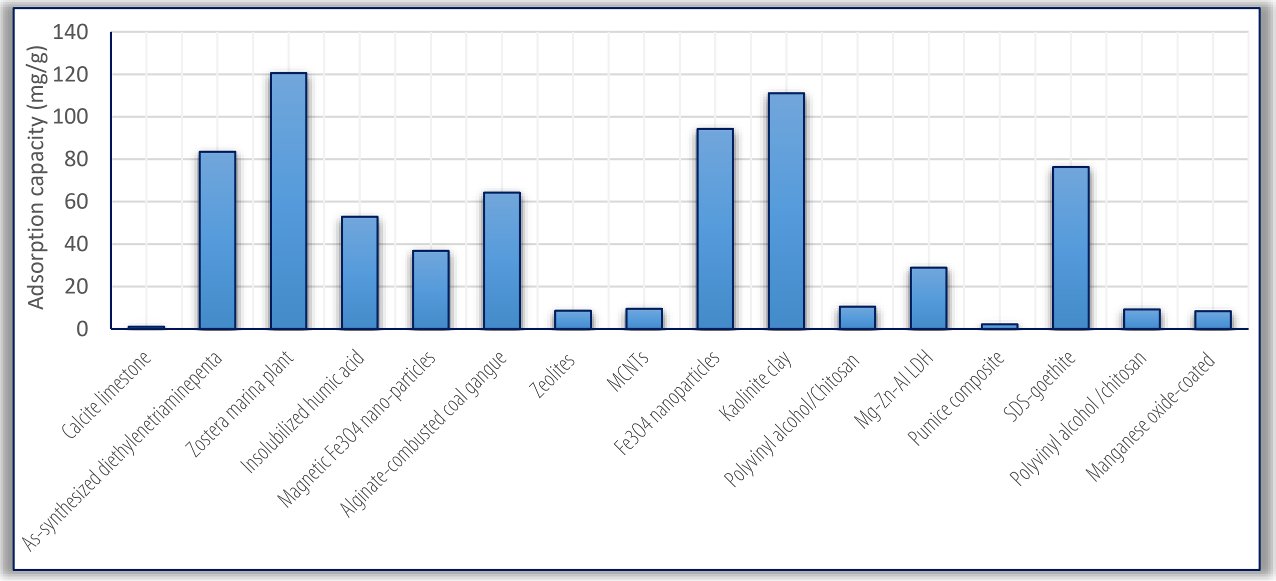

Figure 1. Comparison of the adsorption capacities of various adsorbents

Table 2. Adsorption of manganese from aqueous solutions

Adsorbents	Type of environment	pH	Temperature	Time	Removal efficiency	Ref
Calcite limestone	Mine water	6.5-8	-	60-180 min	1.08 mg/g	(Silva *et al.* 2012a)
As-synthesized diethylenetriaminepentaacetate acid intercalated Mg/Al layered double hydroxides (LDHsDTPA)	Artificial water	2.5 - 6.5	20–40°C	210 min	83.5 mg/g	(Huang *et al.* 2019)
Zostera marina plant	Artificial water	6.5	-	120 min	120.6 mg/g	(Deniz & Tezel Ersanli 2020)
Insolubilized humic acid	Artificial water	5.6	298.15 K	240 min	52.87 mg/g	(Zhao *et al.* 2020)
Magnetic Fe_3O_4 nano-particles	Aqueous solution	8	25°C	24 h	36.81 mg/g	(Liu *et al.* 2017)
Alginate-combusted coal gangue	Artificial solution	5	343 K	30 min	64.29 mg/g	(Mohammadi *et al.* 2019)
Zeolites (NaA, NaX, and HZSM-5)	Wastewater	4	308-323 K	24 h	8.6 mg/g	(Lin *et al.* 2020)
Multi-walled carbon nanotubes (MCNTs)	Artificial solution	4	-	30 min	9.5 mg/g	(Zhu *et al.* 2016)
Fe_3O_4 nanoparticles	Artificial solution	8	25°C	10 h	94.23 mg/g	(Liu *et al.* 2017)
Kaolinite clay	Artificial solution	6	300 K	3 h	111.11mg/g	(Dawodu & Akpomie 2014)
Polyvinyl alcohol/chitosan (PVA/CS)	Aqueous solution	6	25°C	2 h	10.515 mg/g	(Abdeen *et al.* 2015)
Mg-Zn-Al LDH/montmorillonite nanocomposite	Artificial solution	6	298, 308 and 318 K	75 min	4.5, 26.4 and 28.9 mg/g	(Bakr *et al.* 2018)
Pumice composite	Artificial solution	7	25°C	24 h	2.19 mg/g	(Çifçi & Meriç 2017)
SDS-goethite	Artificial solution	3–10	25°C	60 min	76.3 mg/g	(Mohammed *et al.* 2017)
Polyvinyl alcohol /chitosan	Artificial solution	5	30 °C	90 min	9.225 mg/g	(Abdeen *et al.* 2015)
Manganese oxide-coated hollow polymethyl methacrylate microspheres	Artificial solution	Above 8	25°C	70 min	8.373 mg/g	(Dutta *et al.* 2021)

— Chemical precipitation

Chemical precipitation is a process that employs reagents containing carbonate of manganese, sodium carbonate and limestone to remove metals like Mn(Alka *et al.* 2021). Based on findings this study, the elimination of Mn by chemical precipitation (i.e. carbonate of manganese, limestone, sodium carbonate, polyaluminium chloride, aluminium sulphate and potassium permanganate) is very efficient, with elimination efficiencies spanned between 8 to 99.99%. Limitations of these processes included high pH requirement, waste generation, high operating cost.In a study by Zhang and co-workers used hydroxide precipitation to recycle Mn(II) from synthetic wastewater, manganese precipitation about 30% of the Mn was eliminated at pH 8.0 over 60 min(Zhang *et al.* 2010). Another study used limestone to remove Mn from synthetic solutions about 99.35% of the Mn was removed at pH 9, and time 90 min(Silva *et al.* 2010).In a study by Mckee and co-workers stated that used limestone and soda ash to remove Mn from aqueous solutions between 98 and 100% can be attained at pH between 9.4 and 9.8(McKee *et al.* 2016). In a study by Fu-wang and co-workers stated that used potassium manganese and aluminum chloride to remove Mn from aqueous solutions between 82% and 100% can be attained at pH 9.20 (Zhao *et al.* 2009). In a study by Zhang and co-workers stated that used hydroxide precipitation to remove Mn from aqueous solutions 71.4% can be attained at pH 8.2 and concentration of Mn 1791 mg/L(Zhang *et al.* 2010).

Table 3. Specification of manganese removal from aqueous solution using chemical precipitation techniques

Type of coagulant	Mn (II) (mg/L)	Reaction time	pH	Removal efficiency	Ref
Air oxidation and $CaCO_3$	200 g/L	420 min	pH >5.8	About 98%	(Pakarinen & Paatero 2011)
Carbonate of manganese	1 mg/L	3 h	6.6	over 99.99%	(Yu *et al.* 2019)
Limestone	3.71 mg/L	6 h	10.0	93%	(Torres *et al.* 2018)
Sodium carbonate and limestone	140 mg/L	90 min	above 8.5	99.9%	(Silva *et al.* 2012b)
Aluminium sulphate and potassium permanganate	1.5 to 4.5 mg/L	-	6.5	8 to 24% and 72%	(Zogo *et al.* 2011)
Aluminium sulphate (VI) and polyaluminium chloride	0.6 mg/L	5-25 min	6.84 to 7.37	-	(Krupińska 2017)

— Filtration

Based on findings this study, the elimination of Mn by filtration (i.e; slow sand filter, rapid sand filter, and biofiltration) is very effective, with removal performances spanned between 20 to 95% (Table4). Limitations of these processes included membrane fouling, and high operational cost.In a study by Jia and co-workers used manganese oxide coated sand for Mn(II) removal from groundwater at time 2 h(Jia *et al.* 2015).In a study by Tang and co-workers demonstrated that used ultrafiltration for Mn removal from groundwater, the average removal was above 95% at 30 to 50 days (Tang *et al.* 2021b). In a study by Tang and co-workers reported that used gravity driven membrane for Mn removal from surface water, the average removal was about 58% at 10 days(Tang *et al.* 2020). In a study by Zeng and co-workers demonstrated that used biofilter for Mn removal from ground water(Zeng *et al.* 2019).Another study reported that used bioaugmented quartz-sand filters for Mn removal from ground water(Bai *et al.* 2016).In a study by Zeng and co-workers stated that used filtration for Mn removal from ground water, the removal was above 96.6%(HuiPing *et al.* 2019).

In a study by Du and co-workers reported that used powdered activated carbon-amended membrane bioreactor (i.e., Leptothrix, Pseudomonas, Hyphomicrobium and Planctomyces) for Mn removal from surface water, the average removal was about 98.3% at 20–49 d(Du *et al.* 2017). In a study by Lin and co-workers demonstrated that used microfiltration and preoxidation for Mn removal from ground water(Lin *et al.* 2013). In a study by Kenari and co-workers demonstrated that used fluidized bed (PFB)-ceramic MF/UF hybrid process for Mn removal from drinking water to below the aim value of 0.020 mg/L(Kenari & Barbeau 2017). In a study by Cheng and co-workers stated that used aeration-manganese sand filter-ultrafiltration for Mn removal from ground water, the removal was above 90%(Cheng *et al.* 2020a). In a study by Tang and co-workers revealed that used hybrid bio-cake layer and UF membrane process, gravity-driven membrane for Mn removal from ground water, the average removal was above 97%(Tang *et al.* 2021a).One study reported that efficiency of biofilteration depended to temperature, pH, redox potential, dissolved oxygen , microbial adaption- sludge age, backwash intensity and period, and nutritional conditions(Tekerlekopoulou *et al.* 2013).

Table 4. Specification of manganese removal from aqueous solution using filtration

Removal method	Type of environment	Main findings	Comment	Ref
Filtration(silica sand and chalcedonite sand)	Real water	Manganese elimination in the chalcedonite bed was around 25% and in silica sand was around 20%	Filtration rate of 6 m/h, start-up time = 42–48 days	(Jeż-Walkowiak *et al.* 2015)
Sand filter	Real water	Removal efficiency above 50%, the efficiency of filters in warm seasons was higher than in cold seasons	Backwash rate 9.2 m/h, Mn level =0.744 mg/L	(Kalvani *et al.* 2021)
Coupling technique (filter+ chlorine dioxide)	Artificial solution	Removal efficiency above 95%,	ClO_2 dose 0.99 mg/L, flow rate 282.6 mL/min, Mn level =1.0 mg/L	(Chen *et al.* 2016)
Filter (coated glass beads)	Artificial solution	Mn elimination capacity of the beads increased with higher reactant levels during coating	O_2 level of 5.8 mg/l, pH=8.5, Mn level 1000 mg/L	(Rose *et al.* 2017)
Filtration (natural materials)	Raw water	Klinopur-Mn is suitable for elimination of manganese	Filtration rate 5.33 m/h, average level 8.3	(Barloková & Ilavský 2010)

— Other techniques to removal manganese

Other conventional manganese removal plants such as ion exchange, coagulation and flocculation, oxidation and filtration using oxidation chemicals, like O_2, O_3, $KMnO_4$ and NaOCl , electrocoagulation, and membrane processes, i.e. nanofiltration and microfiltration. In a study by Kouzour and co-workers stated that used aeration process to remove Mn from drinking water about 90% can be attained at pH 9.5, concentration of Mn 5-20 mg/L, and less than 40 min(Kouzbour *et al.* 2017).One study reported that using oxidation agents, such as O_2, NaOCl, and KMnO4 to remove Mn from ground water at initial concentration 0.5 mg/L(Van Genuchten & Ahmad 2020).In a study by Elaraby and co-workers stated that used ozonation process to remove Mn from ground water about 89% can be attained at pH 9-12, concentration of Mn 1 mg/L, and ozone dose of 3 mg/L(El

Araby *et al.* 2009). In a study by Kononova and co-workers stated that used ion exchange to remove Mn from aqueous solutions above 90% can be attained at time 1440 min, concentration of Mn 5000 mg/L(Kononova *et al.* 2019).In a study by Shafei and co-workers stated that used Electrocoagulation to remove Mn from synthetic wastewater about 87.9% can be attained pH 7, concentration of Mn 100 mg/L(Shafaei *et al.* 2010). One study reported that used oxidation/filtration to remove Mn from drinking water about 95% can be attained pH 8.5, concentration of Mn 1.81 mg/L(Roccaro *et al.* 2007).

4. PERSPECTIVES OF MANGANESE IN DIFFERENT COUNTRIES

According to findings present study, in waters the highest level of Mn 4.39-62.62. mg/L was found in Chhattisgarh (Raipur City), and the lowest level was0.00 to 0.11 mg/L found in Nigeria(Umunya) (Table 5), and the WHO and European Union guideline both were value of 0.05 mg/L (Table 6).Based on US Environmental Protection Agency, the maximum manganese concentration in domestic water supplies is 0.005 mg/L(Chen *et al.* 2014). The suggested limit in potable water is 0.05 mg/Land between 0.01 and 0.02 mg/Lin water meant for industrial purposes(Abdeen *et al.* 2015).Similarly, its maximum concentration, based on the Brazilian legislation, is 0.01 and 1 mg/L for surface water and wastewater, respectively(Silva *et al.* 2010).Manganese rarely reaches levels of 1 mg/ L in real surface waters and is usually current at levels of 0.2 mg/L or less(Tekerlekopoulou *et al.* 2013). One study stated that manganese concentration about1.5 mg/L or higher in surface water and was found 0.575 to 3.05 mg/L in groundwater(Subari *et al.* 2018).

Table 5. Water quality criteria for Manganese

Country/Organization	Level (mg /L)	Ref
World Health Organization	0.05	(Organization 2009)
United States Environmental Protection Agency	0.05	(Dietrich & Burlingame 2015)
European Union	0.05	(Council 1998)
China	0.1	(Li *et al.* 2016).
Iran	0.4	(Standards & Iran 2010)
Egyptia	0.04	(Elwakeel *et al.* 2015)
Argentina	0.05	(Casalini *et al.* 2020)
India	0.5	(Adhikary *et al.* 2011)
Nigeria	0.2	(Marsidi *et al.* 2018)
Malaysia	0.1	(Marsidi *et al.* 2018)
Japan	0.04	(Marsidi *et al.* 2018)

Table 6. Manganese levels in ground water from several countries

Regions/countries	Manganese concentration (mg/L)	Ref
Argentina	0.25 - 1.00	(Casalini *et al.* 2020)
Iran(Mazandaran)	0.036-0.744	(Kalvani *et al.* 2021)
China	0-1.8	(Yang *et al.* 2020)
China (Changchun)	0.0036-2.57	(Zeng *et al.* 2021)
China(Harbin city)	0.9-1.3	(Cheng *et al.* 2017)
China(south)	3.41	(Hou *et al.* 2020)
Nigeria(Umunya)	.0.00-0.11	(Mgbenu & Egbueri 2019)
Nigeria (Onitsha)	.01-0.34	(Egbueri 2020)
Nigeria (Ajao)	0.00–0.23	(Ukah *et al.* 2020)
South Africa (Limpopo)	0.01-0.48	(Molekoa *et al.* 2019)
India(Tamil Nadu)	0.04-0.24	(Kumar *et al.* 2017)
India (Delhi)	0.3-3	(Adhikary *et al.* 2011)
Chhattisgarh (Raipur City)	4.39-62.62	(Khan & Jhariya 2017)
Italy (alluvial)	0.0001-0.0638	(Tiwari *et al.* 2021)
Saudi Arabia (Wadi Fatimah)	0.001-0.281	(Sharaf 2013)

5. CONCLUSIONS AND PERSPECTIVES

The objectives of this study were to provide a complete evaluation of the main concepts and limitations of Mn(II) elimination from water and waste water.

This article summarizes a wide range of techniques including adsorption, bioremediation treatment, filtration and chemical precipitation, and other techniques such as electrocoagulation, ion exchange, coagulation and flocculation, oxidation and filtration, membrane processes, and using oxidation chemicals, which have been used so far for the removal of manganese from the water and wastewater. Generally, it is not possible to select the best technique because each one has strengths and disadvantages. The adsorption and bioremediation treatment were found to be the most usable and frequently adopted in the literature. These processes can be applied to future work to remove Mn from water and waste water in both pilot and actual.

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