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Techniques for Reducing Iron (Fe) Content in Groundwater: an Article Review

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ABSTRACT

Iron is a chemical element that is found in almost every place on earth, including in well water or groundwater. Iron can be suspended in water with organic substances or inorganic solids in the form of ferrous cations (Fe^{2+}) and ferries (Fe^{3+}). The presence of iron that exceeds the threshold can cause detrimental effects such as corrosion of the piping, the color of the water turns brown, smells bad, and can cause health problems. The iron content in groundwater can be reduced so that it can be used as water that is fit for consumption or use in everyday life. This study aims to determine several types of techniques used to reduce iron in groundwater or well water through literature studies. Techniques covered include filtration, aeration, adsorption, coagulation, electrocoagulation, and cascade aerators. The results showed that the greatest reduction in efficiency was found in the combination type of adsorption technique and filtration technique by more than 99.1%, then followed by the electrocoagulation technique of 99.74%. From all the techniques studied in this study, it can be concluded that all techniques can reduce iron levels in which the combination of adsorption and filtration techniques is the most effective.

Keywords: Technique, reduction, iron content, groundwater

1. Introduction

Water is a chemical compound that is very important for human life and other living things. The function of water for life cannot be replaced by other compounds [1]. For humans, water is used for household, industrial, agricultural, fishery, and other purposes [2]. Clean water is water that meets health requirements and must be boiled before consumption [3]. Clean water quality parameters must meet the requirements of physics, chemistry, and biology. Clean water quality requirements must meet the provisions stipulated in the Regulation of the Minister of Health RI No.492 / MENKES / PER / IV / 2010 [4].

The need for clean water for human life continues to increase in line with the rapidly increasing population. The development of civilization and the increasing population will increase the activities of human life. The waste generated from human activities can pollute Groundwater so that it can pollute the water source. Groundwater is used as raw water for drinking water purposes. Some of the parameters of water pollution include changes in color, taste, smell, and the presence of hazardous pollutants such as heavy metals Zn (Zinc), Cd (Cadmium), Pb (Plumbum), Fe (Iron), and Mn (Manganese). The levels of these substances must meet the health standards that have been set [5].

Iron (Fe) is a chemical element that is easily found in almost every place on earth, in all geological layers, one of which is in well water or groundwater. Iron (Fe) in water can be dissolved, suspended, or combined with organic substances or inorganic solids [6]. Iron is found in the form of ferrous cations (Fe^{2+}) and ferries (Fe^{3+}). In natural waters with a pH of around 7 and sufficient dissolved oxygen levels [7].

Iron cannot be produced by the body, so to meet iron sufficiency must be obtained from food. Iron has an important role in the body to form hemoglobin (Hb) [8]. According to WHO, the amount of iron needed to be consumed should be following the amount of iron released in the body [9]. The adequacy rate of iron minerals is between 0.3 mg to 18 mg/day with a range of ages from 0 months to 80 years of age which are also differentiated by gender [10].

The presence of iron (Fe) content that exceeds the threshold can cause corrosive pipes, the color of the water turns yellow to brown after a while in contact with air. Other effects can also cause unpleasant odors, yellow spots on clothes and can cause health problems or disorders such as damage to the intestinal wall and decreased lung function [11]. The maximum limit of chemical iron (Fe) allowed for clean water is less than 0.3 ppm [12].

The iron content found in sources such as groundwater, in excess amounts must be reduced to avoid the negative effects of its use [13]. Iron content reduction technology can be done in several ways, including oxidation, Ion exchange, sequencing process, lime softening, adsorption, and filtration [6].

In previous research, there was a decrease in iron (Fe) levels in groundwater using the filtration method using a ceramic filter with variations in the depth of groundwater sources [6], using conventional cascade aeration methods and vertical aeration buffle channel cascades with variations in discharge [14], using moringa seeds as a coagulant using the coagulation method with various concentrations [2], using the adsorption method with manganese greensand adsorbent and filtration with carbon filters [15], using the electrocoagulation method [16], using the method cascade aerator [17]. This study aims to determine several techniques for reducing iron (Fe) levels in groundwater based on a literature study.

2. Materials and Methods

This study is a literature review study by analyzing several techniques for reducing iron content in groundwater. This research was conducted using a qualitative descriptive research design with an experimental approach. The parameters observed were iron content in groundwater using reduction techniques such as filtration, aeration, adsorption, coagulation, electrocoagulation, and cascade aerators.

2.1. Filtration

Filtration is the process of purifying or filtering water through the media, whereas long as the water flows through the media there will be a quality improvement. This is due to the separation of suspended and colloid particles, reduction of other bacterial organisms, and the exchange of chemical constituents present in water [18]. The filtering process aims to remove suspended solids and reduce iron levels through porous media [19]. This process is intended to remove dissolved and undissolved materials using absorption [6].

2.2. Aeration

Aeration is a process of adding air or oxygen in water by bringing water and air into close contact, by spraying water into the air, or by giving air fine bubbles and letting it rise through the water [19]. This process is an effort to increase the oxygen concentration contained in water so that the oxidation (aeration) process of biology by microbes will run well [18]. The aeration process usually consists of an aerator, settling tank, and filter or filter. An aerator is a tool for touching oxygen from the air with water so that the iron in the raw water reacts with oxygen to form ferric compounds that are relatively insoluble in water.

2.3. Adsorption

Adsorption is the process of collecting substances dissolved in solution by the surface of the absorbent substance. Both of them often appear simultaneously with a process, so that there is something called sorption. In adsorption, there are what are called adsorbents and adsorbates. Adsorbents are absorbent substances, while adsorbates are substances that are absorbed [20]. Adsorption is the process of binding a molecule from the gas or liquid phase into an adsorbent from an adsorbate [21]. The most potential adsorbent is activated carbon. Activated carbon is a porous solid containing 85-95% carbon [22].

2.4. Coagulation

Coagulation is defined as the process of destabilizing colloid loads of suspended solids including bacteria and viruses with a coagulant, thus forming flocks, with the influence of gravity being sedimented [13]. Commonly used coagulant materials are alum ($Al_2(SO_4)_3$), ferrous sulfate ($FeSO_4$), ferric sulfate ($Fe_2(SO_4)_3$), poly aluminum chloride (PAC), ferrous chloride ($FeCl_2$), ferric chloride ($FeCl_3$), and natural coagulants of moringa seeds [23].

2.5. Electrocoagulation

Electrocoagulation is a process of coagulation or clotting with electric power through an electrolysis process to reduce or decrease metal ions and particles in the water. The basic principle of electrocoagulation is the reaction of reduction and oxidation (redox) [24]. In an electrocoagulation cell, the oxidation event occurs at the positive (+) electrode, namely the anode, while reduction occurs at the negative (-) electrode, namely the cathode [16]. The electrocoagulation (electrochemical) method is used to reduce the concentration of pollutants such as iron in groundwater using a certain voltage to precipitate pollutants in the form of iron oxide.

2.6. Cascade Aeretator

Cascade aeretator is a tool for aeration with a gravity system. The working principle of the cascade aeretator (aeretator cascade) passes water on plates or plates arranged in steps like steps. The water that descends through the cascade will come into contact with oxygen in the air [14].

The cascade aeretator method is able to increase oxygen by 60-80% from the highest amount of oxygen in water [25]. The cascade aerator consists of 4 to 6 stages, with a height of approximately 30 cm for each stage with a speed of 0.01 m^3 / second per m^2 [26].

3. Results and discussion

Based on the results of a literature study on the reduction of iron content in groundwater or well water with several techniques, data was obtained as listed in **Table 1**. From **Table 1**, it can be seen that reducing iron content in groundwater can be done by several techniques. All the techniques used were found to reduce iron levels with an average reduction effectiveness of more than 80%. From the results of the literature study, it was found that the adsorption technique combined with the filtration technique was followed by the electrocoagulation technique which was the most effective technique. The effectiveness of reducing iron content with the adsorption-filtration technique resulted in a percentage greater than 99.1% while the electrocoagulation technique was 99.74%. This technique can be used as an alternative to water treatment with high iron content. This technique is not only easy to apply, but the media used is also easy to find and the price is relatively affordable. The greatest reduction effectiveness of each technique is shown in **Figure 1**.

Table 1. Several types of techniques for reducing iron content in groundwater

No.	Technique	Iron analysis method*)	Iron content (mg / L)		Reduction effectiveness (%)	References
			Before	After		
1.	Filtration	SF	2,66-3,1	0,1-0,2	95,20	[6]
		-	2,4	0,26	89,20	[16]
		SF	3,15	0,13	95,87	]27]
2.	Aeration	-	2,4	0,8	66,70	[16]
		SF	*3,1*	*0,167*	94,60	[28]
3.	Adsorption-filtration	SF	6 ,0	< 0,05	>. 99,1	[15]
4.	Coagulation	SF	99,80	31,8.	68,14	[2]
5.	Electrocoagulation	SF	1,29	0,0034	99,74	[16]
		AAS	-	-	99,70	[29]
6.	Cascade aerator	AAS	4,08	0,72	82,35	[17]
7.	ACC	SF	2,63	0,10	96,20	[14]
	ACBCV	SF	2,45	0,14	94,29	
8.	WA	SF	4,18	0,38	90,70	[30]
	MPA	SF	4,18	0,30	92,62	

Note : SF : Spectrophotometry, AAS : Atomic absorption spectrophotometry, ACC : Aetator cascade conventional, ACBCV: Aeretator cascade buffle channel vertical, WA : Waterfall aerator, MPA : Multiple platform aerator

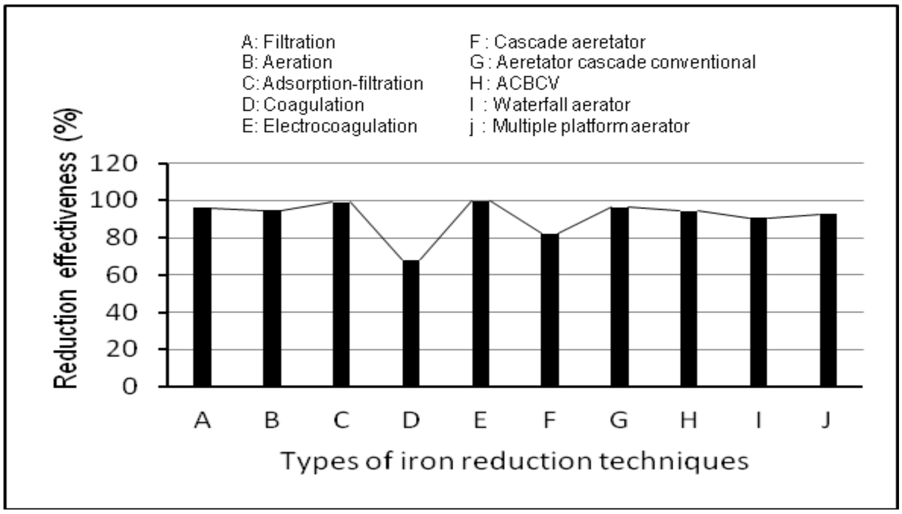

Figure 1. Effectiveness of reducing iron levels in groundwater

The purpose of using the technique of reducing iron levels is to get the maximum result of decreasing iron levels so that the groundwater produced after experiencing a treatment process is suitable for consumption. Each of the techniques used has several advantages and disadvantages. Knowing some of these techniques can then be taken into consideration to choose the best and most appropriate technique to use as needed.

3.1. Reduction of Iron Content with Filtration Techniques

The decrease in iron content in the filtration technique is due to filtering by the ceramic or sand filtering media used as the filtration medium. According to Febrina Febrina and Ayuna [6], that filtration is used to separate impurities (particulates) that can be in the water. This is also following the opinion of Yazid [31] that filtering or filtration is a method of separation to separate solids from liquids using a porous device (filter). The basis for this separation method is based on the difference in particle size between the solvent and the dissolved. The filter will hold solids that have a particle size larger than the filter pores and pass the solvent.

Naturally, water filtering occurs on surfaces that have permeated the soil layer. In the filtering process, large enough particles will be filtered out on media such as sand, while bacteria and colloidal materials that are smaller are not completely filtered out. The space between the grains serves as sedimentation where the dissolved grains settle. The dissolved colloid material is likely to be captured due to the electrokinetic force. Many of the dissolved materials cannot form a floc and the deposition of the lumps enters the filter and is filtered.

3.2. Reduction of Iron Content with Aeration Techniques

The reduction in iron levels with aeration techniques occurs due to the process of adding oxygen to the water, causing an oxidation reaction which eventually forms a precipitate of $Fe(OH)_3$. According to Effendi [7], if groundwater is in contact with air and undergoes oxygenation, the ferric ion in ferric hydroxide $Fe(OH)_3$, which is abundantly present in groundwater, will be oxidized to ferrous and immediately experience precipitation (precipitation) and form a reddish color in water. The addition of oxygen is carried out as an effort to take pollutants contained in water so that the concentration of pollutants will be lost or even eliminated.

In practice there are two ways to add oxygen to water, namely by introducing air into the water or forcing water upward to come into contact with oxygen. Aeration techniques have been widely used to treat water that has too high a content of iron (Fe).

3.3. Reduction of Iron Content with Adsorption Technique

The decrease in iron content by the adsorption technique occurs because there is an ion exchange process and the binding of Fe^{2+} metal in the pores of the manganese greensand media and is followed by a filtration technique using activated carbon. According to Hartini [25], the absorption capacity of activated carbon occurs due to a large number of micro-sized pores. This is following the opinion of Yazid [31], that adsorption is a separation method to clean material from its impurities by withdrawing the adsorbent. The use of this method is used to purify water from microscopic impurities or microorganisms, whiten brown sugar due to impurities.

3.4. Reduction of Iron Content with Coagulation Technique

The reduction in iron levels with the coagulation technique is due to the collision process between coagulant media such as negatively charged moringa seeds and positively charged colloids (iron) so that it will form a precipitate. The use of natural coagulants such as those from grains is greatly influenced by the surface area of the powder produced. The wider the surface of the coagulant material, the greater the collision between iron and the coagulant. Coagulation techniques are generally effective when using synthetic coagulants such as alum ($Al_2(SO_4)_3$). This is following the opinion of Akbar [2], that several factors influence the occurrence of coagulation and flocculation, including the type of coagulant, concentration or dose of coagulant, stirring speed, degree of acidity (pH), settling time, turbidity, and temperature.

3.5. Reduction of Iron Content with Electrocoagulation Techniques

The reduction in iron levels with electrocoagulation techniques is due to the ion release reaction at the anode which causes oxidation of the release of the Al^{3+} cation. The Al^{3+} cation will bind with OH^- forming $Al(OH)_3$ produces gas bubbles that carry contaminants in the water to the surface of the water which will turn brownish-yellow in color. According to Hanum, et al. [32], each electrolysis cell has two electrodes, a cathode, and an anode. The aluminum electrode which acts as a source of Al^{3+} ions at the anode and functions as a coagulant in the coagulation-flocculation process that occurs in the cell. Whereas at the cathode a cathodic reaction occurs by forming bubbles of hydrogen gas which function to increase the suspended floc which cannot settle in the cell.

The increase in voltage in the electrocoagulation process will be directly proportional to the decrease in the levels of iron (Fe) produced. In electrocoagulation, coagulation occurs in the water sample and a floc is formed which will settle so that the levels of pollutants such as iron in water decrease. When the voltage is increased, the amount of current flowing is large so that the number of ionic particles increases. The number of ions formed results in an increase in the formation of $Al(OH)_3$ which acts as a coagulant so that more pollutants can be precipitated.

3.6 Reducing Iron Levels with the Cascade Aeretator Technique

The decrease in iron levels with the cascade aerator technique is due to the oxidation process by contacting water with air which will later form ferric hydroxide ($Fe(OH)_3$) deposits. The use of the cascade aerator technique is influenced by the time, angle, and number of steps used. As Hartini's opinion [25] states that the more steps are used, the oxidation reaction will run more perfectly. The rate of oxidation in this technique is also influenced by the pH of the water. Generally, the higher the pH of the water, the faster the oxidation reaction speed. Sometimes it may take up to several hours after the aeration process starts depending on the characteristics of the raw water.

4. Conclusion

Based on the results of a literature study on reducing iron levels in groundwater, it can be concluded that iron levels can be reduced by several reduction techniques. Most of the techniques are capable of lowering iron levels by over 80% effectiveness. Each technique has advantages and disadvantages depending on usage needs. The most effective technique is obtained using a combination of adsorption-filtration and electrocoagulation techniques.

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