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Research Article

# The Impact of Soil Desalination on Reduction of Iron Concentration in Groundwater

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**Abstract:** Brackish water is one source of clean water and drinking water in coastal areas, river estuaries, and small islands. Various studies have carried out that the use of clay can reduce minerals in the water. This research aims to find out and analyze the Cascade Aerator System and Rapid Sand Filter based on Clay in Reducing Iron Concentration in Well Water. The type of research used is experimental with a quantitative approach. In this study, the researchers used the Pretest-Posttest Control Group Design. The study's location was conducted on Sapuli Island in Pangkep Regency, South Sulawesi Province, and Sindulang Satu Village in Manado City, Central Sulawesi Province. The study's design used a Completely Randomized Design (CRD) with a combination of treatments that obtained 6 x 3 = 18 treatment combinations. This study's population is all well water that is in two research areas, and then the sample collection technique is used simple random sampling with 15 samples of well water. The research obtained a decrease in the maximum average iron (Fe) level obtained reached 57.27% by adding a 20-gram of clay as desalination in 10 liters of well water. The decline that occurred in the two study sites did not differ significantly. Reduction of Iron (Fe) levels through Cascade aerators and Rapid Sand Filters by adding clay as a binder due to the material of kaolin in clay.

**Keywords:** Absorption, Clean Water, Brackish Water, Mineral Kaolin, Water Quality.

## 1. Introduction

Water is an essential requirement in human life. About 60% of the bodyweight of a human body contains water [1], [2]. According to WHO [3], for rural areas, 60 liters/person/day, and in urban areas, between 100-150 liters/person/day. Water containing excessive levels of salt can adversely affect health, aesthetics, and the economy. The impact on health is that it can cause osteoporosis, blood vessel dilation, stroke, heart attack, and hypertension. While the impact on aesthetics is that it can cause dry skin, the economic losses that can arise are decreasing soil fertility of agricultural land [4]. In fulfilling clean water needs, humans usually utilize water sources around the settlements, both natural and after processing first [5].

One source of water that can utilize is groundwater or well water. This groundwater can be used as drinking water through shallow wells, in terms of relatively good quality while the quantity is insufficient and depends on the season.

In terms of health, the use of dug wells is not fair if making is not considered, but to minimize the possibility of pollution can be prevented, this prevention can fulfill by observing the physical requirements of the well based on the conclusions of some opinions. Experts in this field, including the location of wells not less than 10 meters from pollutant sources, well floors at least 1 meter in diameter from the excellent wall and watertight, a minimum of 10 meters of sewage drainage and permanent, well lip height 0.8 meters, has a right ring (wall) of at least 3 meters and has a good cap that is strong and tight.

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The data from the results of examining the salinity level of the dug wells in Barrang Caddi Island in 2011 found that 80% of the people using clean water whose salinity ranged from 0.5 – 3.0% during the rainy season and often increased during the dry season. It is necessary to attempt to reduce the salinity of water to obtain sufficient amounts of clean water with quality that meets the health requirements [6].

Many methods for treating saltwater into freshwater; this process is known as desalination. Examples of desalination processes currently being developed are distillation, freezing, ion exchange, solar evaporation, and membrane filtration technology (Reverse Osmosis), but this technique is still quite expensive. A common problem in all types of distillation systems is a crust on equipment [7]. The presence of crust on the evaporator heat exchanger tube reduces thermal efficiency and freshwater production. Because the desalination process must be dried to wash the tubes with acid, competent maintenance, and maintenance are needed [8]. Research related to the use of chlorine in sea salt using Amberlite IRA-400 Resin at various column diameters. Although this method is beneficial because it is straightforward to operate, there is also a disadvantage because it is challenging to obtain synthetic resin, and the cost is high [9], [10].

The other desalination efforts are using appropriate technology in obtaining clean water that meets quality, using clay using consideration that clay has the ability as an ion exchanger, does not require special skills, and is easy to obtain [11]. Hopefully, coastal communities or islands can later utilize this method.

Clay has individual particles that produce plastic properties on the soil when mixed with water. Generally, there are about 15 kinds of minerals which are classified as clay minerals [12]. Among other things, montmorillonite, illite, kaolinite, polygorskite, chlorite, vermiculite, and halloysite. The relationship of clay minerals to absorption water provides a basic form of soil composition. Each particle bonded to each other through the absorption water layer [13].

Cloudy color removal occurs through a combination of mechanical straining, sedimentation, and adsorption. In the process of mechanical straining, in a layer of a sand filter, there are small cavities that allow water to pass as flow in the soil [14], [15]. The fine particles that cannot escape from these cavities will be restrained and thus can free water from its dirty content 18. Besides that, there is also a mechanism of sedimentation and adsorption [16]. The reduction of Fe in water aims to minimize the salt content in the water so that it is suitable for use by the community.

Iron (Fe) is one of the elements found almost anywhere in the earth, in all geological layers and all water bodies. In general, Iron in the water can be dissolved. Small amounts of iron compounds in the human body function as forming red blood cells, where the body needs 7-35 mg/day, partly derived from water. However, Fe, which exceeds the dosage needed by the body, can cause health problems. In large doses of Iron, substances can damage the intestinal wall, irritability the eyes and skin. The problem that often occurs when utilizing groundwater is the mineral content. The types of soil water mineral content are quite diverse, including mercury, Iron, manganese, sodium, copper, zinc.

Based on the above, the researchers will try to use clay to decrease the concentration of Iron (Fe) contained in well water dug (brackish water) with the Cascade Aerator and Rapid Sand Filter method.

## 2. Research Methods

### 2.1. Research Design

This research is an experimental study with a quantitative approach. Experimental research is a study used to look for the effect of specific treatments on others in controlled conditions, a controlled condition in purpose is the existence of results from research converted into numbers, for the analysis used is to use statistical analysis. Experimental research is a way to find a causal relationship (causal relationship) between two factors deliberately caused by researchers by eliminating or reducing or eliminating other disturbing factors.

In this study, the researchers used the Pretest-Posttest Control Group Design; this is in line with Singh and Hinkelmann [17], [18], which states that experimental research designs include the Pretest-Posttest Control Group Design. Using this design, the experimental group and the control group have the same characteristics because they are taken randomly from a homogeneous population and [19].

A complete randomized design (CRD) is the simplest type of experimental design. This design is commonly used for experiments that have a uniform or homogeneous media or experimental environment [20], [21]. A complete randomized design (CRD) is an environmental design by placing treatments on all experimental units with complete randomization, and randomization is carried out without restrictions on the experimental unit. For CRD, every difference between experimental units that received the same treatment was expressed as a trial error [22].

According to Montgomery [22], the determination of the number of replications uses a formula like the following:

$$t\,(n-1) \geq 15$$
$$3\,(n-1) \geq 15$$
$$3n-3 \geq 15$$

$3\ n \geq 18$

$n = 6$

From these results, the research experiment was conducted in 6 repetitions.

**Table 1.** Combination Treatment between concentration and repetition

| Repetition | Clay Soil Concentration | | |
|---|---|---|---|
| | 0 mg/10L | 10 mg/10 L | 20 mg/10 L |
| $P_1$ | $P_10$ | $P_110$ | $P_120$ |
| $P_2$ | $P_20$ | $P_210$ | $P_220$ |
| $P_3$ | $P_30$ | $P_310$ | $P_320$ |
| $P_4$ | $P_40$ | $P_410$ | $P_420$ |
| $P_5$ | $P_50$ | $P_510$ | $P_520$ |
| $P_6$ | $P_60$ | $P_610$ | $P_620$ |

The concentration and repetition of meals obtained a combination of treatments as much as 6 x 3 = 18 combinations of treatments in the study to be conducted.

### 2.2. Location

This research was conducted for the first location on Sapuli Island, Mattiro Baji Village, Liukkang Tupabiring North District, Pangkep District, South Sulawesi, then the location of the two Sindulang Satu Villages, Tuminting District, Manado City, North Sulawesi.

### 2.3. Population and Samples

According to Hinton [23], the population is a generalization area consisting of objects or subjects with specific qualities and characteristics set by researchers to be studied and then drawn the conclusion. This study's population dug well water that is located and used by the community for daily activities in the Sapuli Islands, Pangkep Regency, and Sindulang Satu, Manado City.

Roscoe and Diehl [24], [25] recommending the number of samples for experimental research is 10-20 samples. This study used 15 samples with a simple random sampling technique with dug well water sources used by the community at the first location on Sapuli Island, Mattiro Baji Village, Liukkang Tupabiring North District, Pangkep District, South Sulawesi, then the location of the two Sindulang Satu Villages, Tuminting District, Manado City, Sulawesi North.

### 2.4. Procedures

Based on the explanation described, then the procedures or framework in this study are as follows:

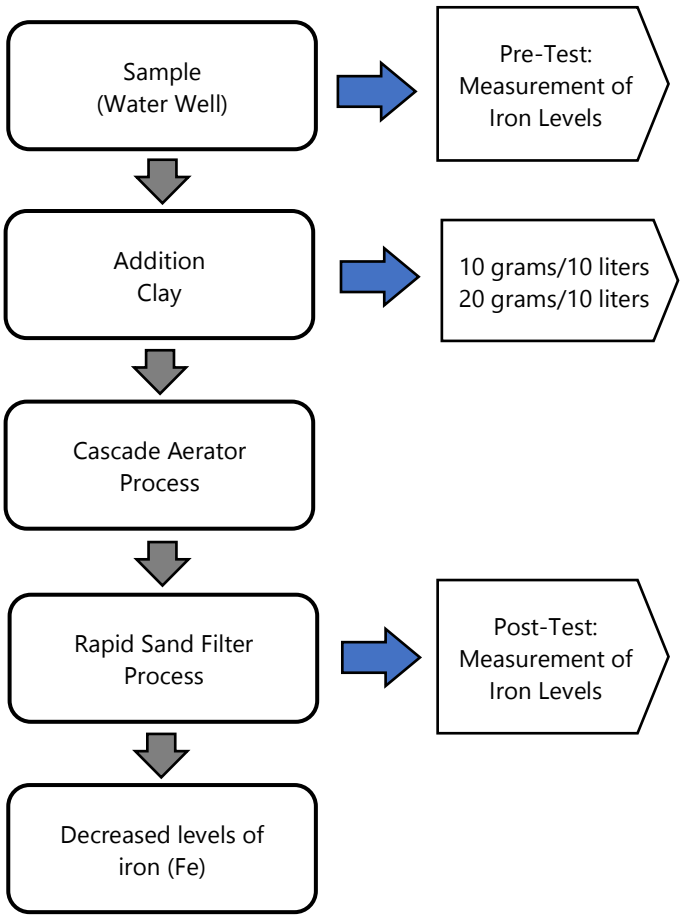


**Figure 1.** The framework of Implementation Procedure

## 3. Result and Discussions

Measurement data on iron (Fe) levels in the study was obtained by measuring through an iron test kit in mg/l units. The water samples used came from Sapuli Island, Mattiro Baji Village, North Liukkang District, Tupabiring, Pangkep Regency, South Sulawesi, and Sindulang Satu Village, Tuminting District, Manado City, North Sulawesi. The results of measurements of iron (Fe) levels of research in Pangkep Regency and Manado City.

One of the simple and environmentally friendly ways of treating water is through a filtering process with a simple water filtration installation using natural materials. A natural material used as a filter in a simple water purification plant is activated natural clay.

Table 2 above shows the results of Iron (Fe) measurements in Pangkep Regency with the highest iron content before treatment in sample number 1 with the acquisition of 22.21 mg/L, then the lowest in-sample number 7 with the acquisition of 13.75 mg/L. The results of measuring Iron (Fe) on average before treatment were obtained 18.24 mg/L, after treatment (clay 0 gr) obtained 14.83 mg/L after treatment (clay 10 gr) obtained 9.72 mg/L.

**Table 2.** The results of measurements of iron (Fe) levels of research in Pangkep Regency and Manado City

| No. Sample | Iron (Fe) mg/l (Pangkep Regency) | | | | Iron (Fe) mg/l (Manado City) | | | |
|---|---|---|---|---|---|---|---|---|
| | Before Treatment | Clay 0 gr/10 L | Clay 10 gr/10 L | Clay 20 gr/10 L | Before Treatment | Clay 0 gr/10 L | Clay 10 gr/10 L | Clay 20 gr/10 L |
| 1 | 22.21 | 15.82 | 9.95 | 7.26 | 22.22 | 18.21 | 12.36 | 10.19 |
| 2 | 19.11 | 15.32 | 9.95 | 7.26 | 23.11 | 18.91 | 13.42 | 11.32 |
| 3 | 12.32 | 10.11 | 8.15 | 6.09 | 22.32 | 18.31 | 12.94 | 10.21 |
| 4 | 17.25 | 13.78 | 9.95 | 7.55 | 23.13 | 19.12 | 13.26 | 11.46 |
| 5 | 20.61 | 16.82 | 12.12 | 9.89 | 22.56 | 18.56 | 12.24 | 10.52 |
| 6 | 18.43 | 15.33 | 12.16 | 8.15 | 22.43 | 18.43 | 13.21 | 10.63 |
| 7 | 13.75 | 11.35 | 8.22 | 6.34 | 23.65 | 19.32 | 14.12 | 9.78 |
| 8 | 18.73 | 15.23 | 8.52 | 5.98 | 23.29 | 18.52 | 13.15 | 10.94 |
| 9 | 20.47 | 16.55 | 11.31 | 8.74 | 22.67 | 18.44 | 12.72 | 11.12 |
| 10 | 20.12 | 16.53 | 8.96 | 6.74 | 23.18 | 18.85 | 12.87 | 10.86 |
| 11 | 15.31 | 12.65 | 9.47 | 7.42 | 23.28 | 19.12 | 13.66 | 10.55 |
| 12 | 17.37 | 13.72 | 8.27 | 5.67 | 23.65 | 19.33 | 13.34 | 11.45 |
| 13 | 17.58 | 14.62 | 8.26 | 5.12 | 22.91 | 18.96 | 13.38 | 11.21 |
| 14 | 19.53 | 15.12 | 10.44 | 7.92 | 23.34 | 18.68 | 12.92 | 9.66 |
| 15 | 18.39 | 15.72 | 9.84 | 6.85 | 23.85 | 19.78 | 13.87 | 9.38 |
| 16 | 19.56 | 16.44 | 9.66 | 6.55 | 23.61 | 18.82 | 13.44 | 11.55 |
| 17 | 21.38 | 18.92 | 11.22 | 7.98 | 22.89 | 18.18 | 12.98 | 10.72 |
| 18 | 16.13 | 12.83 | 8.52 | 6.23 | 22.79 | 18.34 | 13.31 | 9.81 |

For the results of measuring Iron (Fe) in Manado City with the highest iron content before treatment in sample number 15 with the acquisition of 23.85 mg/L, then the lowest in-sample number 1 was 22.11 mg/L. The results of measuring Iron (Fe) on average before treatment were obtained 23.05 mg/L, after treatment (clay 0 gr) obtained 18.77 mg/L after treatment (clay 10 gr) obtained 13.18 mg/L.

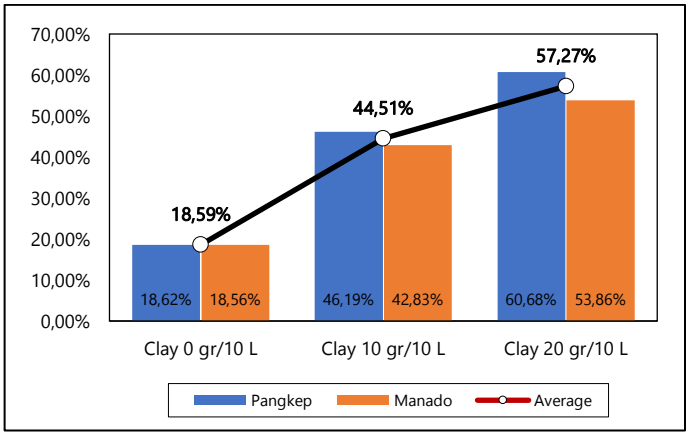


**Figure 2.** Percentage of Decreased Iron (Fe) Level for Pangkep Regency and Manado City.

From figure 2, it can see that there is a significant decrease in iron (Fe) levels with the addition of clay as desalination. The maximum decrease in iron (Fe) levels obtained reached 57.27% with the addition of 20 grams of clay in 10 liters of well water. The decline that occurred in the two study sites did not differ significantly. External factors that influence measurement results, such as temperature, weather, and depth of well, are not considered.

The decrease in Iron (Fe) levels through the medium of Cascade Aerator and Rapid Sand Filter by adding clay as a binder is due to the material of kaolin in clay. Kaolin itself is clay with a large surface area, physical and mechanical stability, stable layer structure, and large cation exchange capacity, so kaolin is an excellent material as an adsorbent. Based on kaolin's physical and mechanical properties, kaolin activation was carried out to reduce chloride and Fe levels in water [26].

Clay is a deposit that has a particle size smaller or equal to 0.002 mm. Clay, with a micro-conical size up to the conical sub-microstructure formed from weathering the chemical elements that make up the rock [27]. The clay minerals character generally occurs because of forming a molecular structure framework from the merging of tetrahedron molecules to form regular gaps and channels, causing a porous structure. Gaps and channels in the

structure that occur allow a molecule to pass through it to be trapped in it. These properties make clay minerals used as absorbent materials for hazardous metals, filter molecules, and ion exchangers [28].

According to Buckman [29], one of the most critical characteristics of colloidal colloids, both mineral and organic, is their ability to adsorb cations. Ion Fe is always found in natural water with low oxygen levels, such as groundwater and airless lake areas [30]. The presence of weaving mills, paper, and industrial processes can form the presence of ferric solutions. Fe can be removed from the water by oxidizing to Fe (OH)3, which is insoluble in water, followed by precipitation and filtration. The oxidation process is carried out using air, commonly called aeration, by entering the air in the water [31].

To reduce the Fe content, including aeration. Aeration is water treatment by contacting it with air. The purpose of aeration is to add the amount of oxygen in the water, reduce the amount of CO, and also be used to treat water containing Fe and Mn too high [32]. This aeration method is usually by contacting/spreading water with air over a thin plate, through small water droplets (waterfall aerators), or by mixing water with air bubbles. In this way, the amount of oxygen in the water can increase between 60 - 80% [33], [34].

The filtration process is part of water treatment, which, in principle, is to reduce organic materials and organic materials that are in the water. Removal of suspended solids by filtration has a vital role in purifying groundwater and artificial purification in water treatment plants. The material used as a filter media is sand, which has excellent filtering properties, is hard, and can be durable to be used free from dirt and insoluble in water.

A rapid sand filter is a filter that has a fast filtration speed, ranging from 4 to 21 m/hour. This filter is always preceded by a coagulation-flocculation and precipitation process to separate suspended solids. If turbidity in fast sand filter influents ranges from 5-10 NTU, the efficiency of turbidity reduction can reach 90 - 98% [35].

Rapid Sand Filter is a water filter that can produce more filtered water discharge than the Slow Sand Filter. However, this filter is less useful to deal with the smell and taste in filtered water. Also, because of the rapid flow of water, the bacterial layer that is useful for removing pathogens will not form, and what happens in the Slow Sand Filter so that it will require a more intensive disinfection process [36].

In general, the filter layer material used in the Rapid Sand Filter is the same as the Slow Sand Filter, namely sand, gravel, and stone. The apparent difference is in the direction of water flow when filtering. In the Sand Filter Slow, the water's direction flows from top to bottom, while in the Quick Sand Filter from the bottom up (up-flow). Besides, Rapid Sand Filter can generally backwash or wash the filter without dismantling the entire filter [37].

Groundwater flow is an intermediary of geology which continuously influences chemical elements on the environment around it in the soil. The layer of soil that passes through water contains certain chemical elements, an iron compound. Iron (Fe) is a significant element in rock and is one of the chemical elements found in almost every place on earth, in all geological layers and all water bodies [30].

The content of the chemical elements in water depends on the geological formation where the water is located and the water's geological structure. For example, if during the trip water through an iron-containing rock, the water will automatically contain Iron and other elements [38]. The size of the dissolved material depends on how long the water contacts the rock. The longer the water contacts the rock, the higher the elements dissolved in it.

Iron content in groundwater, especially in well water, occurs a lot. Groundwater, which generally has a high concentration of carbon dioxide, can cause anaerobic conditions. This condition causes the iron concentration in insoluble minerals (Fe3+) to reduce to iron soluble in the form of a two-valent ion (Fe2+). Iron concentrations in groundwater vary from 0.01 mg/l -25 mg/l. In surface water, rarely found Fe content exceeds one mg/l, but in groundwater, Fe content can be much higher. High concentrations of Fe can be felt and can stain fabrics and kitchen utensils [39].

## 4. Conclusion

Cascade aerator and the rapid sand filter is one of a variety of methods intended to reduce Iron (Fe) in water. With the addition of binders, in this case, clay is obtained because of a significant decrease in iron content in water. To provide clean water appropriate for the community, especially in coastal areas, this needs to do through direct research that can immediately be applied in the field.

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