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Utilization of Iron Sand Magnetic Minerals Based on Are River Sand of Sesaot to Improve Water Quality

Firda Yuslihan Amri[1], Lalu Ahmad Didik Meiliyadi[1,2*], Muh. Wahyudi[1,2], Muhammad Arif Firmansyah[3], Isniwana Damayanti[4]

[1,3]Departement of Physics Education, Faculty of Education and Teacher Training, Universitas Islam Negeri Mataram, Jln. Gajah Mada 100, Jempong Baru, Mataram, Indonesia
[2]Advance Science and Integration Research Group, Universitas Islam Negeri Mataram, Jln. Gajah Mada 100, Jempong Baru, Mataram, Indonesia
[4]Departement of Natural Science Education, Faculty of Education and Teacher Training, Universitas Mataram, Jln. Gajah Mada 100, Jempong Baru, Mataram, Indonesia

*e-mail: laludidik@uinmataram.ac.id

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Abstract. This research aims to determine the magnetic mineral content, morphology, and effectiveness of Are River (Sesaot) sand-based iron sand in improving water quality in Kebon Kongok. The magnetic mineral synthesis process was carried out using the Solid State Reaction (SSR) method, which includes the stages of washing, drying, heating at 100°C, and magnetic separation. Material characterization was performed using Scanning Electron Microscopy-Energy Dispersive X-ray (SEM-EDX) to analyze mineral content and elemental morphology. The analysis showed a significant increase in iron (Fe) content from 7.57% at 3 hours of grinding to 18.48% at 5 hours, while silica (Si) content decreased from 18.46% to 15.51%. Decreased levels of heavy metals such as iron (Fe), manganese (Mn), and lead (Pb) were measured before and after filtration, indicating the effectiveness of magnetic minerals in adsorbing heavy metals. Fe levels decreased from 0.0037 mg/L to 0.0007 mg/L, Mn levels from 0.0015 mg/L to 0.0008 mg/L, and Pb levels from 0.1415 mg/L to 0.0660 mg/L after filtration for 5 hours. In addition, the physical analysis showed a decrease in Total Dissolved Solids (TDS) from 154 ppm to 146 ppm and conductivity from 308 ms/cm to 293 ms/cm, indicating a reduction in solute concentration. This study concludes that Are River sand-based magnetic minerals synthesized using the SSR method can be an effective solution to improve water quality, contributing to public health and the sustainability of living things. Further research is needed to explore the mechanism of action of magnetic minerals and their potential applications on a wider scale.

Keywords: Morphological Analysis, magnetic minerals, iron sand, water treatment

INTRODUCTION

Water is one of the natural resources that is the source of life for all living things on this earth, no one can deny that water is an important element in human life, not only for consumption, water also helps many human activities (Ezzeddine et al., 2021; Meiliyadi, Rahman, et al., 2024b). And the main problems faced by water resources include the quantity of water that is no longer able to meet the increasing needs and the decreasing quality of water for domestic use (Tarigan et al., 2025). Industrial, domestic and other activities have a negative impact on water resources, which can cause a decrease in water quality (Feng et al., 2021). This condition can cause disturbance, damage and danger to all living things that depend on these water resources. Water is widely used by humans to fulfill their daily needs, both household needs to fulfill water needs for public, social and economic facilities such as for agricultural land. Indonesia faces serious challenges related to water quality amidst rapid population growth and rapid urbanization (Zhang et al., 2025). As the population continues to grow, the demand for clean water increases, while its availability is increasingly limited (Cui et al., 2022).

The condition of river water often does not meet the standards for healthy clean water, as stipulated in environmental health regulations (Nishad et al., 2025). Water that comes directly out of the ground is called a spring. Usually springs are found on mountain slopes, but some are found in the lowlands (umbul springs), besides that springs can also be in the form of seepage.

The standard of drinking water needed by households is determined based on the regulation of the Minister of Health of the Republic of Indonesia No. 492/MENKES/PER/IV/210 concerning drinking water quality requirements (Nurhidayati et al., 2021). Clean water is very important for dynamic life activities, so its quality and quantity must be considered. Clean water that meets health requirements must be free of pollution and meet water quality standards (Syuzita et al., 2022). Many people are found utilizing water that is of poor quality. This can have a negative impact on health.

Many efforts have been made to improve water quality, some of which are biosorption, precipitation and absorption methods (Meiliyadi, Ruhana, et al., 2023). Of the several methods of improving water quality, the absorption method is one of the recommended methods. In the process, the absorption method involves the bonding of chemical compounds, ion exchange and the ability of attraction between molecules (Liosis et al., 2021). In this method, absorbent material is needed, some researchers have found that magnetic minerals found in iron sand can be used as absorbents because they have the absorbance power of fellow magnetic mineral content (Meiliyadi, Rahman, et al., 2024a).

Iron sands are sand deposits that contain iron ore particles. These deposits are formed due to the destruction process by weather, surface water, and waves of the original rock containing iron minerals (Meiliyadi, Wahyudi, et al., 2023; Yahdi et al., 2025). In some coastal areas, there is potential for iron sand that can be utilized as industrial raw material. Iron sand can be found in river sand, quarry sand and beach sand (Rahmi et al., 2019; Sukirman et al., 2018; Vopel et al., 2017). Iron sand is naturally ferromagnetic (magnetic properties with strong magnetic attraction) with magnetic minerals such as magnetite (Fe_3O_4), hematite (ɑ–Fe_2O_3) and maghemite (ɣ- Fe_2O_3) in sand having strong magnetic properties (Marik et al., 2019; Tiwow et al., 2018; Vopel et al., 2017). River sand is sand sourced from quarrying or mining in rivers. Steep rivers have a swift flow, so that the deposit of rock particles will vary quite large at a certain distance, usually there are not many fine grains and the rocks are quite clean.

Non-magnetic minerals in iron sand such as silicon oxide $Si\,O_2$ have a fairly high percentage and affect the magnetic properties (Meiliyadi et al., 2022). The presence of these minerals contributes to the magnetic properties of iron sand. Iron sand that has a high content of magnetite (Fe_3O_4) will provide strong magnetic properties while those with many gangue minerals such as several other elements such as K, C, Na, Mg, Al, Si, and Ca will reduce the magnetic properties of iron sand (Ningsih; et al., 2019). The size of iron sand affects the content of magnetic minerals and also affects the attraction to external magnetic fields. The magnetic mineral content of iron sand has a potential role in improving water quality problems. Minerals such as magnetite (Fe_3O_4), hematite (ɑ ɑ–Fe_2O_3), and maghemite (ɣ- Fe_2O_3) contained in iron sand have magnetic properties that can be utilized. The use of these magnetic minerals can help in the control and filtration of water to remove polluting substances that affect water quality.

Several studies have used iron sand to improve water quality. Meiliyadi et al., (2025) used hematite to reduce heavy metal levels in aquatic environments. (Meiliyadi, Wahyudi, et al., 2023) also synthesized silica-based beach sand to purify polluted water around landfills. Liosis et al. (2021) also successfully synthesized an adsorbent from natural materials to purify water.

However, from previous research, there has been no research on the utilization of magnetic minerals from iron sand synthesized using the solid state reaction method to improve the quality of polluted water. Therefore, it is necessary to conduct studies and research on the synthesis and utilization of iron sand magnetic minerals based on are river sand of Sesaot to improve water quality in kebon kongok.

RESEARCH METHODS

This research was conducted at the physics laboratory of UIN Mataram, using the solid state reaction synthesis method with varied scouring applied to iron sand (Didik et al., 2021;

Yahdi et al., 2025). Samples of river sand are taken at the edge of the river, then the sand samples are dried by drying them under the sun for a day (Didik & Wahyudi, 2020), then the iron sand samples are separated from impurities using a permanent magnet 4 times, the iron sand samples that have been separated are washed using distilled water 4 times and heated in an oven at 100 degrees Celsius for 2 hours, iron sand that has been in the oven is then filtered using a 200 mesh sieve to separate the iron sand from other component components, the iron sand sample is divided into 3 with each sample weighing 20 grams and synthesized in each sample using the solid state reaction method which has a variation in the length of grinding, namely 3 hours, 4 hours and 5 hours. After completion of the synthesis, the iron sand samples were then characterized using a Scanning Electron Microscope (SEM) tool to see the morphology and magnetic mineral content contained in the sample and the grain size distribution of each sample (Masruroh et al., 2014). The research flowchart is shown in Figure 1.

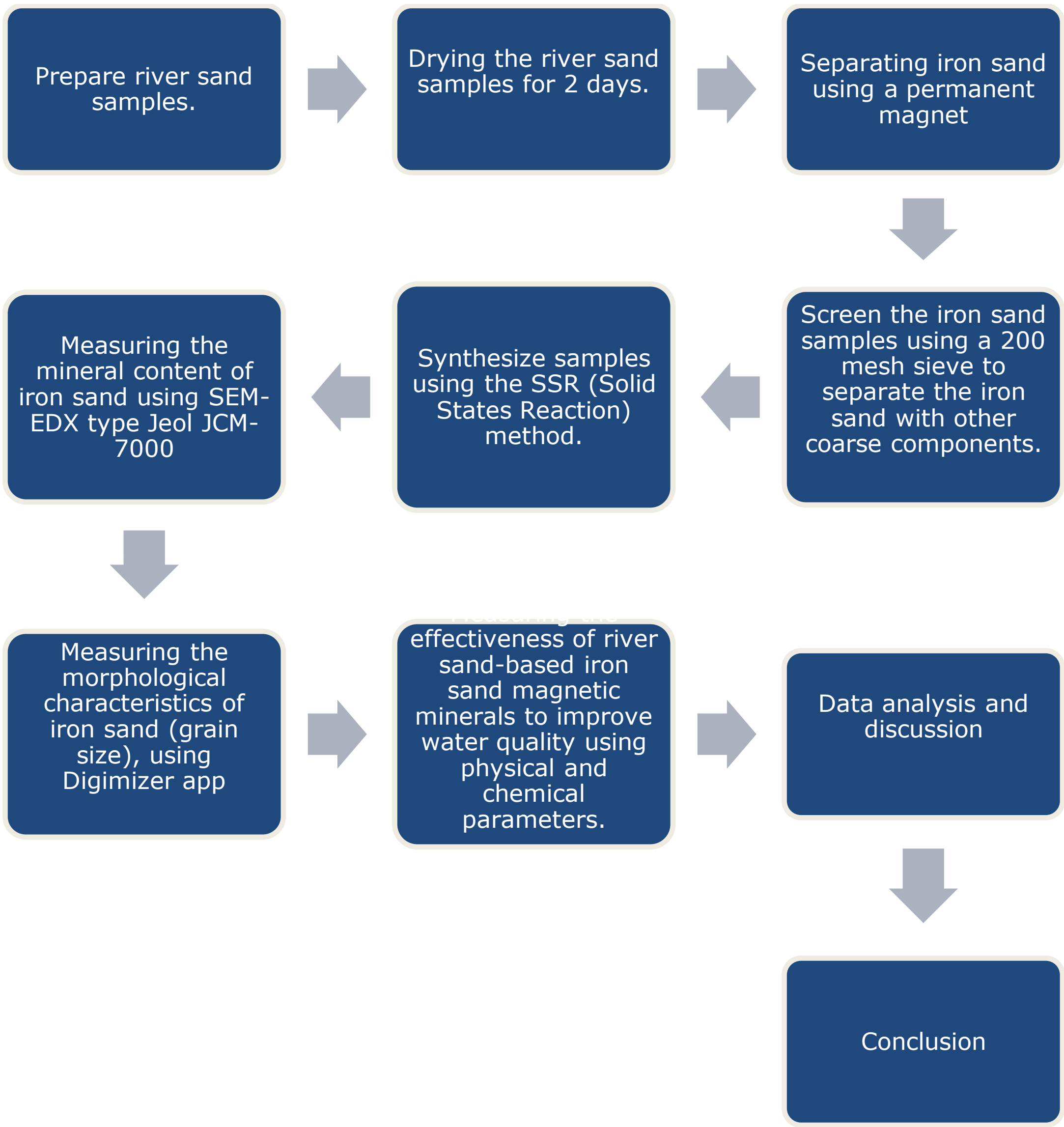


Figure 1. Research Flow Chart

After characterization using a scanning electron microscope, the samples were then used to filter water taken from the Kebon Kongok River, which was contaminated with heavy metals. After filtration, the heavy metal content of the samples before and after filtration was examined, including Mn, Fe, and Pb, using chemical parameters, namely atomic absorption spectrophotometry, and physical parameters, namely a TDS meter, to determine the pH, conductivity, and TDS.

RESULTS AND DISCUSSION

The magnetic mineral content of iron sand analyzed using the EDX method can identify chemical elements on the surface of the sample. Iron sand samples were crushed for 3, 4, and 5 hours to determine the effect of grinding time on the chemical content of iron sand. The following is a description of the chemical element content data based on the results of Table 1.

Table 1. Magnetic mineral content in iron sand samples analyzed using SEM EDX

Element	Atom %		
	3 Hours	4 Hours	5 Hours
O	54.59±0.96	49.81±0.94	48.83±0.90
Mg	2.93±0.15	4.66±0.20	5.30±0.21
Al	7.40±0.21	6.49±0.33	6.22±0.20
Si	18.46±0.33	18.46±0.32	15.51±0.30
K	0.79±0.07	0.50±0.05	0.44±0.05
Ca	2.62±0.12	2.64±0.12	4.21±0.16
Fe	7.57±0.29	13.35±0.40	18.48±0.46
Cu	2.04±0.21	1.96±0.22	1.28±0.17

The results in the table show that the oxygen (O) element content dominates the iron sand content, in the grinding process for 3 hours the result is 54.59%, in the grinding process for 4 hours the result is 49.81%, then in the grinding process for 5 hours the result is 48.83%. Although the concentration of this element decreased as the grinding time increased. This decrease can be indicated by the oxidation process that occurs during grinding, which has the potential to affect the physical and chemical properties of iron sand. However, this is not the case for iron (Fe) content, where the iron (Fe) content increases significantly in the process, in the 3-hour grinding process the result is 7.57%, in the 4-hour grinding process the result is 13.35%, then in the 5-hour grinding process the result is 18.48%. Conversely, the silica (Si) content decreased from 3 hours of grinding, the result was 18.47%, in the process of grinding for 4 hours the result was 18.46%, then in the process of grinding for 5 hours the result was 15.51% as the grinding time increased.

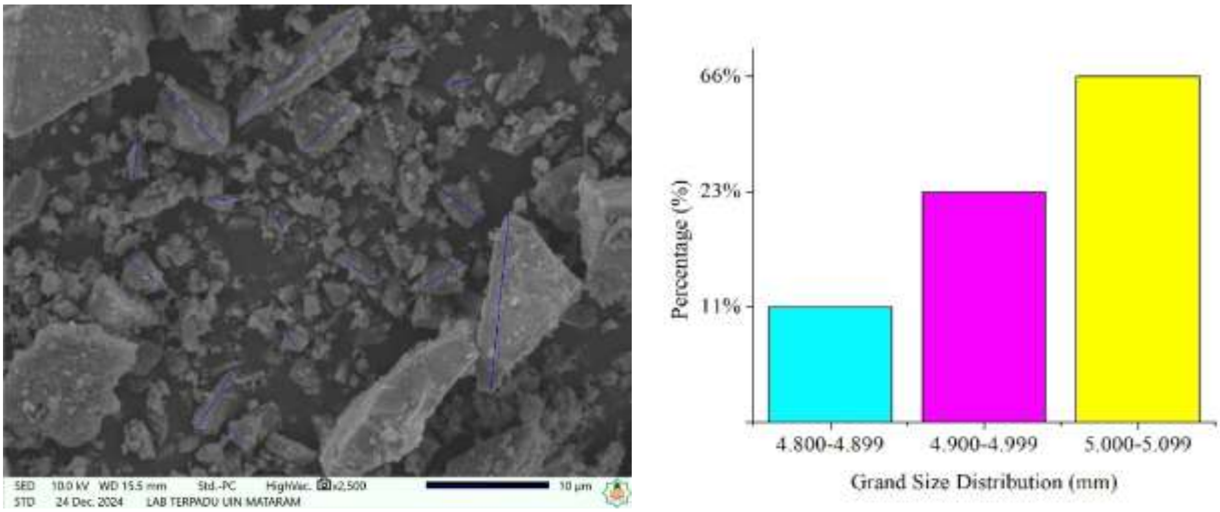
This indicates that the grinding process can separate silicate minerals from the magnetic grouping, thereby increasing the Si content of the analyzed material. This increase is likely due to the release of non-magnetic minerals such as silicates during the grinding process. The magnesium (Mg) and calcium (Ca) contents show fluctuations or increases, which may explain the utilization of these elements.

These results show that oxygen (O) dominates the iron sand content, although its concentration decreases as the scouring time increases. This decrease could be indicated by the oxidation process that occurs during grinding, potentially affecting the physical and chemical properties of the iron sand. In addition, changes in the concentration of other elements such as iron (Fe) and silica (Si) also need to be considered, as they can contribute to the quality and usefulness of iron sand in improving water quality.

Iron sand, which contains a lot of iron, can serve as an effective filtration medium in the process of improving water quality, helping to remove contamination and improve water clarity (Sebayang et al., 2018). By utilizing treated iron sand, we can create a more efficient filtration system, which not only reduces heavy metal levels but also increases the content of health-beneficial minerals (Nayak et al., 2024). Therefore, a deeper understanding of the composition and characteristics of iron sand is essential to optimize its use in environmental applications, particularly in efforts to improve the quality of water suitable for consumption.

The morphological characteristics of river iron sand taken from the Are River pass in Sesaot Village, Narmada District, West Lombok Regency, which were measured and analyzed using

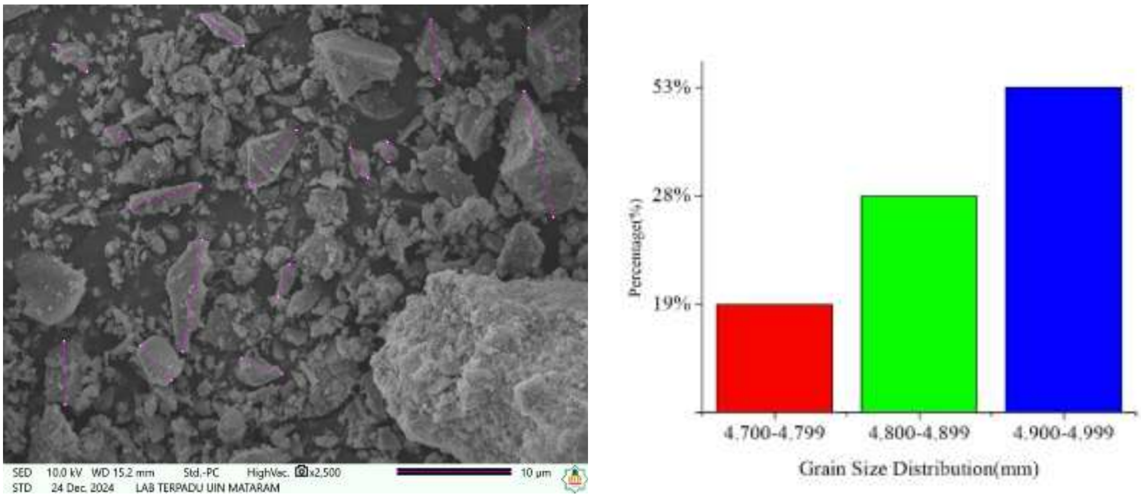
SEM-EDX (Scanning Electron Microscope-Energy Dispersive X-ray) are river iron sand samples with 3,4,5 hours of scouring time shown in the following Figure 2.



(a) (b)

Figure 2. (a) morphology of iron sand with SEM magnification 5000x for 3 hours grinding, (b) the percentage size distribution of iron sand with 3 hours grinding.

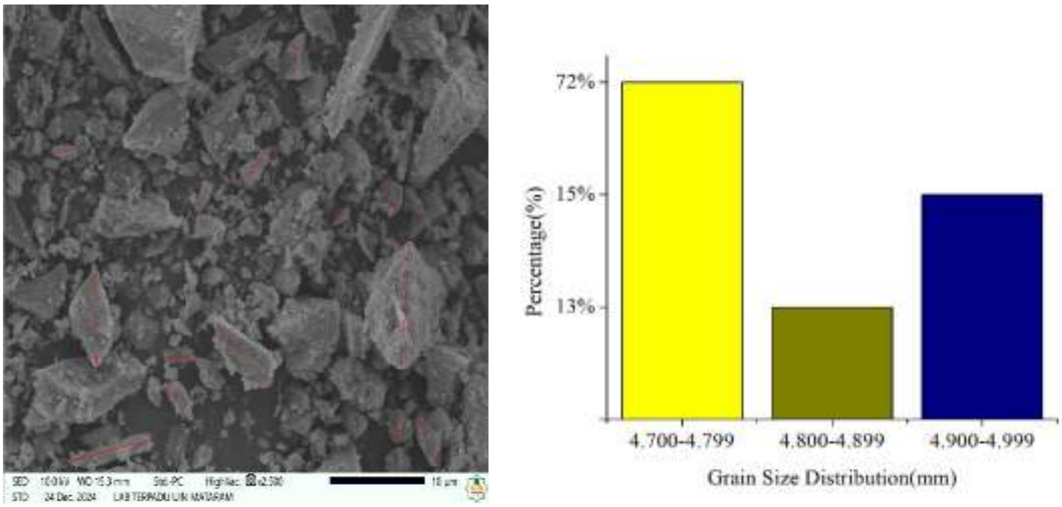
In the sample with 3 hours of grinding, the morphological characteristics show that the sand grains have a relatively rounder shape and a smoother surface as can be seen from Figure 2, which shows that these sand grains have an average size of about 5.0 μm, with a fairly even size distribution. Shorter grinding tends to produce grains with a finer and rounder morphology, which can improve the filtration ability and reactivity of the material in environmental applications.



(a) (b)

Figure 3. (a) morphology of iron sand with SEM magnification 5000x for 4 hours grinding, (b) the percentage size distribution of iron sand with 3 hours grinding.

After grinding for 4 hours, the morphological characteristics of the iron sand began to show changes. Figure 3 shows that the sand grains undergo slight erosion, which results in a decrease in the average size to 4.9 μm. This process can be interpreted as the beginning of the effect of longer scouring, where the surface of the grains starts to show unevenness and an increase in the number of sharp edges. Research by Sari, et al showed that the surface potentially increases interaction with contaminants in water.



(a) (b)

Figure 4. (a) morphology of iron sand with SEM magnification 5000x for 5 hours grinding, (b) the percentage size distribution of iron sand with 5 hours grinding.

In the sample with a grinding time of 5 hours, the morphological characteristics are more clearly visible. Figure 4 shows that the iron sand grains undergo more significant erosion, with the average size decreasing to 4.7 μm. The grain surface becomes coarser and more irregular, which can affect the physical and chemical properties of the iron sand. Research by Rahmawati et al. indicates that longer grinding can increase the reactivity of the material, but can also reduce the physical stability of the grains, which needs to be considered in industrial applications.

Table 2. The average grain size of iron sand samples was analyzed using the Digimizer app.

Duration of Scouring	Average grain size of river sand (μm)
3 Hours	5,0
4 Hours	4,9
5 Hours	4,7

Table 2 shows the average size of the river sand grain distribution based on the scouring time. This data can show that a decrease in grain size occurs as the scouring time increases, which can be attributed to the erosion process and morphological changes that occur. This decrease in grain size can affect the properties of iron sands, such as adsorption ability and chemical reactivity, which are very important in the utilization of iron sands to improve water quality in Kebon Kongok.

Overall, the morphological characteristics of river iron sands from Are River Sand show that the length of scouring has a significant influence on the size and shape of the sand grains (Meiliyadi, Wahyudi, et al., 2024). This is important to consider in the processing and utilization of iron sand, especially in the utilization of iron sand to improve water quality in Kebon Kongok (Meiliyadi, Rahman, et al., 2024b). This study indicates that as the scouring time increases, the size of the iron sand grains tends to decrease, and their shape becomes increasingly irregular. These morphological changes are very important to consider in the processing and utilization of iron sand, especially in the context of water quality improvement and other applications.

For example, iron sands with smaller grain sizes and more irregular shapes can increase the surface area, thereby increasing their effectiveness as filtration media (Tan et al., 2022). In addition, these morphological characteristics can also affect the physical and chemical properties of iron sands, which in part can contribute to their successful industrial applications, such as in the manufacture of construction materials or in mineral separation processes.Therefore, an indepth understanding of how scouring time affects the morphology of iron sands is essential to optimize their use in various fields, including in efforts to maintain and improve water quality.

Table 3. Atomic Absorption Spectrophoto (AAS) test results for each water sample

No.	Heavy Metals	Unit	Test Results			
			Before Filtering	3 hours	4 hours	5 Hours
1	Fe	mg/L	0,0037	0,0019	0,0017	0,0007
2	Mn	mg/L	0,0015	0,0013	0,0012	0,0008
3	Pb*	mg/L	0,1415	0,1132	0,0849	0,0660

The test results of heavy metal levels shown in Table 3 show that before the water was filtered, iron (Fe) levels were recorded at 0.0037 mg/L. After the filtration process using sand through a 3-hour grinding process, the Fe level decreased to 0.0019 mg/L, in the filtration process using sand through a 4-hour grinding process, the Fe level decreased to 0.0017 mg/L and continued to decrease until it reached 0.0007 mg/L after the filtration process using sand through a 5-hour grinding process. This decrease in iron levels shows that magnetic minerals are very effective in adsorbing heavy metals from water.

Manganese (Mn) levels also showed a significant decrease. Before filtering, the Mn level was recorded at 0.0015 mg/L, in the filtering process using sand through a 3-hour grinding time the result was 0.0013 mg/L, in the filtering process using sand through a 4-hour grinding time the result was 0.0012 mg/L and after filtering using sand through a 5-hour grinding time, this level decreased to 0.0008 mg/L. This decrease in manganese levels indicates that magnetic minerals are not only effective in reducing iron levels, but also manganese, which can contribute to an overall improvement in water quality. Manganese (Mn) is one of the compounds found in the surrounding environment.

One of the most dangerous heavy metals is lead (Pb). Before filtering, the Pb level was recorded at 0.1415 mg/L, in the filtering process using sand through a 3-hour grinding time, the Pb level decreased to 0.1132 mg/L, then in the distillation process using sand through a 4-hour grinding time to 0.0849 mg/L and after filtering using sand through a 5-hour grinding time, the Pb level decreased to 0.0660 mg/L. Lead (Pb) is one of the metals used in the food and non-food industries that can cause poisoning. So Pb, needs to be considered because it includes heavy metal conditions that are harmful to living things. The decrease in lead levels is very significant, considering that lead can cause poisoning, especially in children.

Table 4. Table of the effectiveness of heavy metal absorption by iron sand samples

No.	Duration of Scouring	Effectiveness of Heavy Metal Sorption (%)		
		Fe	Mn	Pb
1	3 Hours	48,65%	13,33%	20,00%
2	4 Hours	54,05%	20,00%	40,00%
3	5 Hours	81,08%	46,67%	53,36%

The results of the analysis of the effectiveness of heavy metal absorption in Table 4 show the effect of grinding time on the ability of heavy metal absorption by materials with Fe, Mn, and Pb content. This analysis used three durations of grinding time, namely 3 hours, 4 hours, and 5 hours. The effectiveness of heavy metal absorption for each of the analyzed heavy metal elements Fe, Mn, and Pb varied according to the duration of grinding.

For Fe content, increasing the grinding time had a significant impact on increasing the effectiveness of heavy metal absorption. At 3 hours, the effectiveness of heavy metal absorption by Fe content was recorded at 48.65%. This figure increased to 54.05% when the grinding time was 4 hours. The effectiveness of Fe sorption reached its peak at 5 hours, which was 81.08%. This clearly illustrates that the longer the grinding time, the greater the effectiveness of Fe in absorbing heavy metals. This can be indicated that the grinding process enlarges the surface area of the Fe material, thus increasing its adsorption capacity towards heavy metals.

For Mn content, the effectiveness of heavy metal absorption also increased as the grinding time increased, although the increase was not as great as that observed for Fe content. In the 3-hour grinding process, Mn was only able to absorb heavy metals with an effectiveness of 13.33%. This figure increased to 20% at 4 hours and reached 46.67% at 5 hours. This shows that although the increase in effectiveness of Mn is not as fast as Fe, there is a similar pattern where longer grinding time improves the efficiency of heavy metal absorption. This is likely related to the slower nature of Mn in developing adsorption capacity compared to Fe.

Then for Pb content, the effectiveness of heavy metal sorption also showed a consistent increase. At 3 hours of grinding, the effectiveness of heavy metal absorption by Pb was recorded at 20%. When the scouring time was 4 hours, the effectiveness increased to 40%. At 5 hours, the effectiveness of Pb sorption reached 53.36%. The results showed that although the increase in the effectiveness of heavy metal sorption by Pb was not as great as Fe, the effect of grinding time on Pb efficiency was still significant. This indicates that the grinding time affects the ability of the Pb material to absorb heavy metals, most likely by increasing the surface interaction between the material and heavy metal ions.

Overall, the results of this analysis confirm that grinding time is an important factor in enhancing the effectiveness of heavy metal sorption by materials containing Fe, Mn and Pb. Of the three elements tested, Fe showed the best performance in sorbing heavy metals, followed by Pb, and then Mn. The higher effectiveness of Fe can be explained by the material characteristics of Fe which is more reactive and has a higher adsorption capacity compared to Mn and Pb. This study provides important insights in the heavy metal effluent treatment process, where scouring time settings can be optimized to improve the efficiency of the adsorption process.

Table 5. Results of water quality analysis using physical parameters

No.	Duration of Scouring	TDS	Conductivity
1	3 Hours	154 ppm	308 ms/cm
2	4 Hours	151 ppm	301 ms/cm
3	5 Hours	146 ppm	293 ms/cm

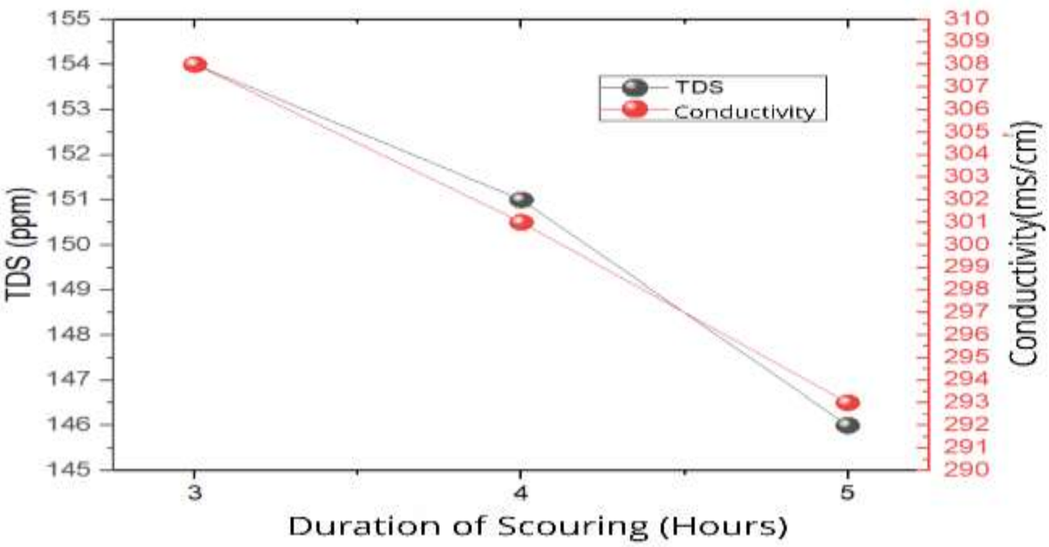


Figure 5. Graph of the relationship between scouring time with TDS and conductivity

Table 5 show the changes in water quality based on the physical parameters, namely TDS (Total Dissolved Solids) and electrical conductivity, during the scouring process with different durations. TDS, which indicates the amount of dissolved substances in water. This decrease was followed by a decrease in conductivity, which continued to decrease with the duration of scouring

(Yahdi et al., 2025). The decrease in TDS and conductivity indicates that the scouring process helps to reduce the solute content, thereby improving water quality. This is in line with the theory that the number of dissolved ions is directly proportional to the electrical conductivity, so a decrease in TDS directly decreases conductivity.

Figure 5 illustrates the decrease in TDS (Total Dissolved Solids) and conductivity of water during the scouring process with different scouring durations. TDS showed a decrease from 154 ppm to 146 ppm, while conductivity decreased from 308 μS/cm to 293 μS/cm between 3 to 5 hours. This graph shows a direct relationship between the decrease in TDS and conductivity, reflecting that scouring is effective in reducing the solute content of the water, thus improving the quality of the polluted water.

CONCLUSION

Based on the results of research that has been conducted on the Synthesis and Utilization of Iron Sand Magnetic Minerals Based on Are River Sand (Sesaot) to Improve Water Quality in Kebon Kongok, it can be concluded that; The grinding process for 3, 4, and 5 hours affects the content of magnetic minerals in the concentration of the main elements in iron sand, such as iron (Fe), silica (Si), magnesium (Mg), and calcium (Ca). Analysis of the morphological characteristics of river iron sand from the Are River sand in Sesaot Village shows that the length of grinding is an important factor in this process, the longer the grinding, and the smaller the sand grain size, the more content that can be filtered. Then regarding the effectiveness of magnetic minerals in improving water quality in Kebon Kongok. Fe material showed the highest adsorption results compared to Mn and Pb, due to its more reactive characteristics. Furthermore, the SSR (Solid State Reaction) method in synthesizing iron sand has advantages such as a simple process and relatively low cost. However, the drawbacks lie in the difficult control of particle size and the possibility of formation of unwanted phases. Overall, this study shows that magnetic minerals can be an effective, efficient, and environmentally friendly solution to improve water quality.

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