

## Improvement of Water Quality by Hematite Based on River Sand Magnetic Minerals of Lombok Island

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### Abstract

Hematite synthesis has been carried out using magnetic mineral river sand from several areas on the island of Lombok, namely Tanak Beak, Sesaot, and Lokoq Rangan. Hematite was then used for metal absorbance in polluted water from the river around the Kebon Kongok landfill. The synthesis method used is coprecipitation. The acid used is HCl with a concentration of 7 M and NH<sub>4</sub>OH base with a concentration of 25%. Mineral content analysis was carried out using AAS and EDX. Morphological analysis was made using SEM, crystal structure using XRD, and functional group analysis using FTIR, while TDS and water conductivity were measured using a TDS meter. Based on the results of AAS analysis, it appears that the iron content of hematite synthesized from magnetic minerals of tanak beak, sesaot, and lokoq rangan river sand is 8.79%, 10.84% and 9.01% respectively, while based on EDX analysis, it was found to be 70.42%, 77.99% and 72.55%. The particle size of Sesaot iron sand also has the smallest size, at (0.88 ± 0.17) micrometers, while the largest grain size is obtained in the Tanak Beak area, at (1,288 ± 0.23) micrometers. Based on the results of XRD and FTIR analysis, it can be concluded that hematite nanoparticles were successfully synthesized using iron sand based on the Lombok Island River sand. Mn ions absorbed by hematite-based mineralized magnetic river sand from several areas on the island of Lombok, namely Tanak Beak, Sesaot, and Lokoq Rangan, are 9.39%, 27.07% and 13.82% respectively, which is followed by a decrease in TDS and conductivity of the absorbed water. Hematite derived from river sand magnetic minerals can adsorb Mn metal and improve water quality better when compared to hematite based on Tanak Beak and Lokoq Rangan river sand.

**Keywords:** Hematite; Iron Sand; Magnetic Mineral; River Sand; Water Quality

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## INTRODUCTION

Indonesia is an archipelagic country endowed with abundant natural resources, including natural sand deposits found along its coasts and rivers. According to data from the Central Bureau of Statistics (BPS, 2023), Indonesia has over 5,590 river streams and a coastline stretching more than 99,000 kilometers, making it one of the countries with the largest natural sand potential in Southeast Asia. This potential is largely utilized in conventional ways, particularly as construction material, without further exploration of its mineral content (Meiliyadi et al., 2022).

Sand is not solely composed of silica (SiO<sub>2</sub>); it also contains valuable metal elements such as iron (Fe), titanium (Ti), manganese (Mn), and other rare earth elements. A study by Rianna et al. (2023) found that natural sand from coastal and

riverine areas in Indonesia contains iron minerals ranging from 8–35%, depending on the geological location and type of deposit. This presents significant potential for the development of functional materials such as adsorbents, catalysts, pigments, and even components in nanotechnology and magnetic materials engineering (Nandee et al., 2024; Setiadi et al., 2016).

Studies by Ashraf et al. (2020), Khan et al. (2021), Setiadi et al. (2016), and Tadic et al. (2022) report that iron oxide minerals commonly found in iron sand include magnetite ( $\text{Fe}_3\text{O}_4$ ), maghemite ( $\gamma\text{-Fe}_2\text{O}_3$ ), and hematite ( $\alpha\text{-Fe}_2\text{O}_3$ ). These oxides possess unique magnetic properties and crystalline structures that enable their use in various industrial applications. Among them, hematite ( $\alpha\text{-Fe}_2\text{O}_3$ ) has gained special attention due to its thermal and chemical stability, non-toxicity, and modifiable surface structure to enhance the adsorption of heavy metal ions (Setiadi et al., 2016; Tadic et al., 2022).

Although hematite can be extracted from river sand, its utilization in Indonesia remains very limited. Local research mostly focuses on characterizing sand for construction use rather than water purification or the application of magnetic materials as heavy metal adsorbents. For instance, in the areas of Pringgajurang and Pringgabaya Villages (East Lombok), natural sand is abundant, but its mineral content and technological potential have not been optimally explored (Didik et al., 2021).

Heavy metal water pollution is an urgent national and global issue. Data from the Ministry of Environment and Forestry (KLHK, 2022) shows that 68% of major rivers in Indonesia suffer from light to severe pollution, mainly caused by domestic, agricultural, and industrial activities. Heavy metals such as Fe, Cu, Pb, and Mn are common contaminants found in both domestic and industrial wastewater. Even at low concentrations, these metals can cause acute and chronic toxic effects on living organisms and accumulate in the food chain (Canli & Furness, 1993; Hussain et al., 2019; Li et al., 2021; Liang et al., 2018; Meiliyadi et al., 2024).

According to Indonesian Ministry of Health Regulation No. 32 of 2017, the maximum allowable concentrations for heavy metals in water are as follows: Fe (max. 0.3 ppm), Cu (0.05 ppm), Pb (0.05 ppm), and Mn (0.01 ppm). Water that exceeds these limits is categorized as polluted and unfit for domestic use. A study by Meiliyadi, Zainur Rahman, and Zain (2024) found that river water near the Kebon Kongok landfill in West Lombok had an average Mn concentration of 0.036 ppm, which is 3.6 times higher than the safe threshold.

To address this issue, technology-based solutions that are local, affordable, eco-friendly, and effective are urgently needed. One widely studied approach in scientific literature is the use of hematite as a heavy metal adsorbent. Hematite has a modifiable surface, is resistant to acids and bases, and does not react with water. Additionally, hematite can form complexes with heavy metal ions through surface interactions, making it a promising material for wastewater treatment (Ashraf et al., 2020; Sherin et al., 2024).

Various hematite synthesis techniques have been developed, including solid-state reaction, sol-gel, coprecipitation, and sonochemistry (Rianto et al., 2018; Sebayang et al., 2018). Among these, coprecipitation is one of the simplest and most cost-effective methods to produce hematite from local iron sand. This method does not require complex equipment, can be conducted at the laboratory scale, and yields

relatively uniform particle sizes. The synthesized hematite can then be tested for its adsorption capacity against heavy metals such as Mn.

Previous studies have evaluated the effectiveness of natural sand-based materials as adsorbents. Awodi et al. (2023) demonstrated that synthetic zeolite sand could reduce Pb levels in slaughterhouse wastewater by up to 50%. Kinoti et al. (2024) used nanocellulose derived from clay to reduce Pb by 99.28%. Meanwhile, Meiliyadi et al. (2024) developed nanosilica from river sand that reduced Mn concentrations by 11.20%.

However, no specific studies have compared the adsorption capabilities of hematite synthesized from river sand in Lombok Island, despite the island having numerous rivers with distinct geological characteristics. For example, the Tanak Beak River lies in an active volcanic zone in Central Lombok, while the Sesaot and Lokoq Rangan Rivers are located in lowland and ancient hilly regions. These differences are expected to influence the mineral composition, morphology, and crystalline structure of the resulting hematite.

Global research generally focuses more on the use of magnetite ( $\text{Fe}_3\text{O}_4$ ) or mixed iron oxides as adsorbents, whereas pure hematite from geographically specific local sources such as rivers in Lombok remains underexplored. Moreover, no systematic comparative approach has been undertaken to analyze the relationship between geological location, mineral content, and the adsorption capacity of hematite for heavy metals.

The state of the art in heavy metal adsorbents highlights iron oxides as among the most effective materials due to their magnetic properties, high surface area, and strong chemical interactions with heavy metals. Hematite stands out because of its stability in acidic and basic environments and its effectiveness as an adsorbent. Nevertheless, exploration of synthesized hematite from Indonesian river sand in a geographically specific manner is still very limited.

This research proposes the synthesis of hematite from natural river sand in three distinct locations on Lombok Island (Tanak Beak, Sesaot, and Lokoq Rangan), which has not been previously conducted. A systematic comparative approach will evaluate the effectiveness of the synthesized hematite in adsorbing heavy metals (particularly Mn) from polluted water. The correlation between mineral characterization (SEM, XRD, EDX, FTIR) and the adsorption capacity of hematite from each source aims to reveal the relationship between crystal structure and ion adsorption performance.

With increasing water pollution caused by heavy metals, especially in areas near landfills and densely populated regions, and the lack of water treatment solutions based on local resources, the development of synthetic hematite from Lombok-river sand becomes a strategic and sustainable step. The findings from this study are expected not only to strengthen the national scientific database but also to be directly applicable in small- and medium-scale water treatment systems in affected villages.

## METHOD

### Research Design and Variables

This study employs a quantitative experimental approach as it involves the manipulation of an independent variable (synthetic hematite adsorbents derived from various river sand sources) and observes its effect on a dependent variable (reduction

in heavy metal concentrations in water). It is also categorized as comparative research, as it compares the effectiveness of hematite synthesized from three different river sand sources: Tanak Beak, Sesaot, and Lokoq Rangan. Furthermore, it falls under the category of applied research because it aims to provide practical solutions to water pollution by utilizing local resources (river sand-based hematite) as heavy metal adsorbents. Independent Variable: Types of synthesized hematite from different sand sources in Lombok. Hematite synthesized from Tanak Beak River sand (Central Lombok). Hematite synthesized from Sesaot River sand (West Lombok). Hematite synthesized from Lokoq Rangan River sand (North Lombok).

These variables are manipulated to test how effective each source is in reducing heavy metal content. Dependent Variable: The effectiveness of the synthesized hematite in improving water quality after treatment. Indicators measured include, physical parameters, chemical parameters, reduction efficiency of heavy metals

The effectiveness of hematite is evaluated against a laboratory-prepared control. To ensure validity, all other conditions during the experiment are kept constant. The independent variable (sand source location) is expected to influence the dependent variable (adsorption capacity for heavy metals) due to potential differences in mineral composition, crystal structure, and surface area of the synthesized hematite from each source. Characterization techniques such as SEM, XRD, FTIR, and AAS will be used to analyze the physicochemical properties of hematite from each location, which will then be correlated with the variation in Mn adsorption capacity.

### **Magnetic Mineral Sample Preparation from River Sand**

This study aims to determine the characteristics and heavy metal adsorption capacity of magnetic minerals based on hematite extracted from river sand. Sampling is conducted from three rivers on Lombok Island: Tanak Beak River (Central Lombok), Sesaot River (West Lombok), and Lokoq Rangan River (North Lombok), as illustrated in Figure 1 (Sampling Map). The research flow is presented in Figure 2 (Research Flowchart). Sampling was conducted at three different times of day (morning, noon, and afternoon) at each location, approximately 10 meters from the riverbank. Each location was sampled three times (triplicates) as biological replicates, with 1 kg of wet river sand collected per replicate. The samples were sieved using a <math>250\ \mu\text{m}</math> mesh to homogenize grain size.

Magnetic mineral separation was carried out using a neodymium magnet (NdFeB) with a magnetic field strength of approximately 1.2 Tesla to obtain the magnetic iron oxide fraction. The magnetic sand was sun-dried for 4 hours under controlled temperature and humidity, followed by oven-drying at 100 °C for 2 hours to remove residual moisture. The final mass was measured to calculate the percentage of natural magnetic mineral content (Meiliyadi et al., 2022).

### **Hematite Synthesis via Coprecipitation Method**

A total of 50 grams of magnetic sand extracted from each site was dissolved in 200 mL of 7 M hydrochloric acid (HCl, Sigma Aldrich, PA). The dissolution process was conducted with continuous stirring using a magnetic stirrer at 70 °C for 1 hour at a speed of 1000 rpm. The resulting solution was then slowly titrated with 25% ammonium hydroxide (NH<sub>4</sub>OH) solution under constant stirring until the pH reached 8.5, measured using a digital pH meter. Once the pH stabilized, the mixture was left undisturbed for 12 hours (aging stage) to optimize hematite formation.

The precipitate was collected using vacuum filtration and washed four times with 100 mL of distilled water until the filtrate reached neutral pH (confirmed with litmus paper). The final precipitate was then oven-dried at 200 °C for 2 hours to obtain hematite powder ready for characterization (Setiadi et al., 2016).



**Figure 1.** Research Sampling Locations



**Figure 2.** Research Flowchart

### Characterization of Hematite

Sample characterization was conducted to determine the morphology, crystal structure, elemental composition, and functional groups of the synthesized hematite.

1. Morphology and particle size were analyzed using a Scanning Electron Microscope (SEM) Jeol JSM-IT300 at an acceleration voltage of 20 kV, operating in secondary electron mode.
2. The elemental composition was determined using Energy Dispersive X-ray (EDX) spectroscopy as a complement to the SEM analysis.

3. Crystal structure was analyzed using an X-Ray Diffractometer (XRD), PanAnalytical X'Pert PRO, with Cu K $\alpha$  radiation ( $\lambda = 1.5406 \text{ \AA}$ ), in a  $2\theta$  range of  $10^\circ$ – $80^\circ$ , and a scan rate of  $2^\circ$  per minute.
4. Functional groups in the compounds were identified using Fourier Transform Infrared Spectroscopy (FTIR), Shimadzu IRTracer-100, in the spectral range of  $400$ – $4000 \text{ cm}^{-1}$  with ATR mode.
5. The iron (Fe) content was determined using Atomic Absorption Spectroscopy (AAS) at a wavelength of  $248.3 \text{ nm}$ , calibrated with standard solutions.

### Effectiveness Test of Hematite in Improving Water Quality

Wastewater samples were collected from the Babak River near the Kebon Kongok landfill, a site previously reported to be contaminated with manganese (Mn) heavy metal. For comparison, distilled water was used as a control (blank). The analysis was conducted before and after treatment using  $0.5 \text{ grams}$  of synthesized hematite in  $100 \text{ mL}$  of wastewater. The adsorption process was performed by stirring the mixture with a magnetic stirrer for  $1 \text{ hour}$  at room temperature, followed by  $30 \text{ minutes}$  of settling. The analyzed water quality parameters included total Dissolved Solids (TDS) in ppm. Electrical Conductivity in  $\mu\text{S/cm}$ . Temperature, measured using digital TDS and conductivity meters. Manganese (Mn) concentration, measured using AAS. Additionally, the adsorption effectiveness was evaluated by calculating the percentage reduction in Mn concentration.

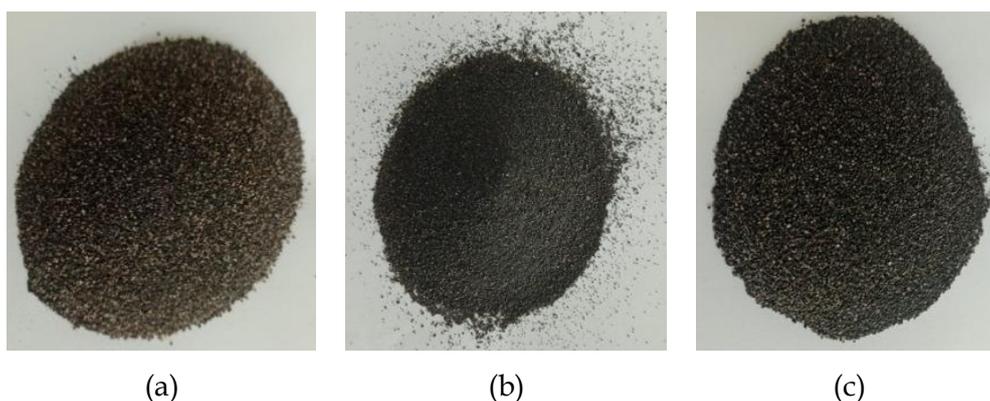
## RESULTS AND DISCUSSION

River sand obtained in the areas of Tanak Beak, Sesaot, Lokoq Rangan has a large magnetic mineral content of iron sand. These magnetic minerals are separated using permanent magnets. This aims to separate between magnetic minerals and impurities. We can calculate the amount of iron sand magnetic mineral content of some river sand by comparing the mass of sand after separation with sand that has not been separated with impurities. The results of the calculation of the amount of iron sand content in each river sand are shown in Table 2.

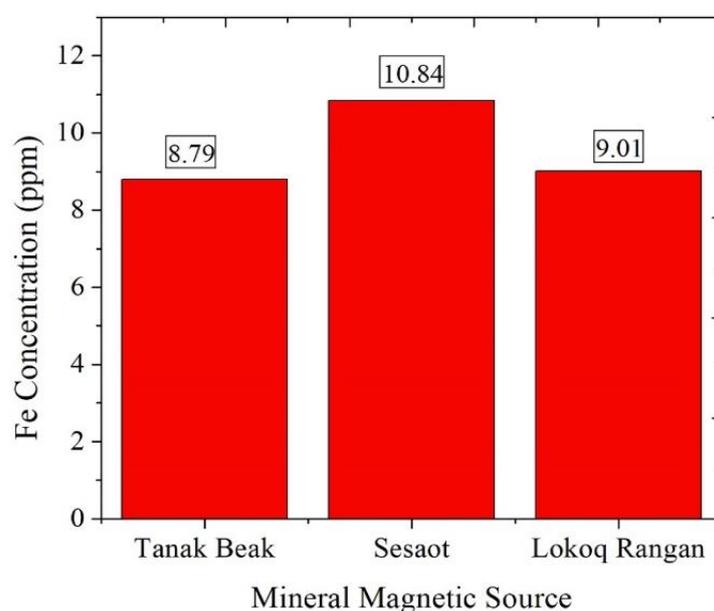
**Table 2.** Percentage of Magnetic Mineral Content in Coastal and River Sand

Magnetic Mineral Source	Mass (gram)		Percentage (%)
	Natural Sand	Magnetic Sand	
Tanak Beak	100.01	80.31	80.30
Sesaot	100.22	88.84	88.65
Lokoq Rangan	100.26	83.78	83.56

Based on Table 2, it can be seen that the magnetic mineral of river sand in the Sesaot area has the largest iron sand magnetic mineral content with a content of  $88.65\%$  while the smallest content is obtained in the Tanak Beak area with a content of  $80.30\%$ . This is reinforced by the colour of sand samples in each region as shown in Figure 3.



**Figure 3.** Magnetic Minerals of Iron Sand Sourced From the Areas of (a) Tanak Beak, (b) Sesaot, and (c) Lokoq Rangan



**Figure 4.** Magnetic Mineral Concentration of Iron Sand Analysed Using AAS

Figure 3 shows the colour of the sand in each collection area. Based on Figure 3, it can be seen that the sand taken in the Sesaot area has a deeper black colour than the others while the sand taken in the Tanak Beak area has a brighter black colour. This is in line with the magnetic mineral content of iron sand shown in Table 1. The blacker the colour of a sand, the greater the iron content (Didik et al., 2021). Iron content can also be characterised using AAS. The iron content in Lombok river sand-based hematite is shown in Figure 4.

Figure 4 shows the Magnetic mineral concentration of iron sand analysed using AAS based on Lombok island river sand synthesised using the coprecipitation method. Based on Figure 4, it can be seen that the iron content in the Sesaot river area has the largest concentration of 10.84 ppm while the smallest iron content is in the Tanak Beak area. This explains that the Fe concentration is the cause of the blacker colour in the river sand-based hematite of the Sesaot area.

The mineral content characteristics of hematite synthesised using the coprecipitation method were analysed using EDX. Characterisation of mineral content in EDX uses X-rays emitted by secondary electrons. The process is the same as SEM

but has a different output (Xie et al., 2024). Analysis of the characteristic X-ray radiation emitted by the sample by secondary electrons will produce information regarding the mineral content in the sample (Yan et al., 2022). The mineral content of the resulting hematite sample is shown in Table 3.

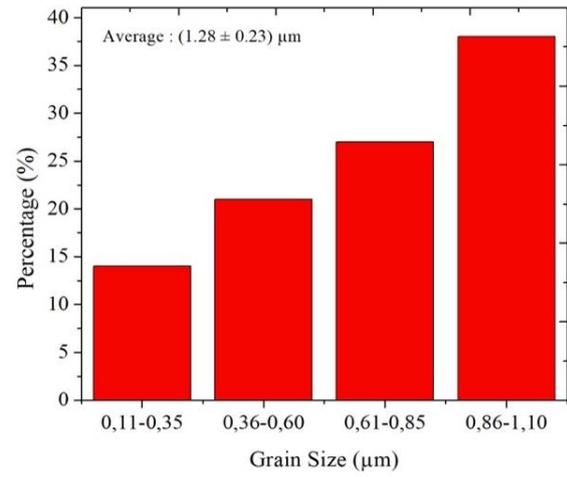
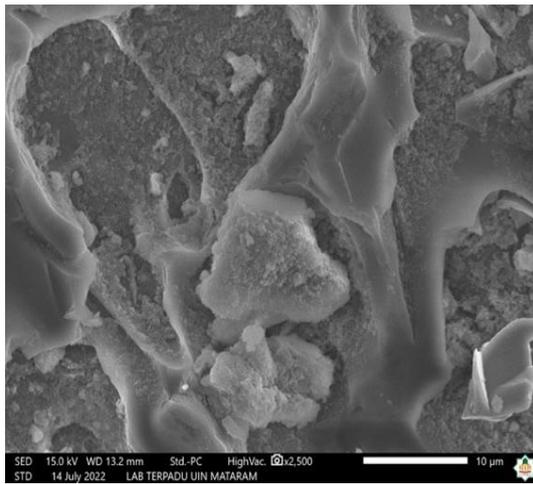
**Table 3.** Mineral Content of Hematite Analysed by Using EDX

Minerals	% atomic		
	Tanak Beak	Sesaot	Lokoq Rangan
Na	1.86 ± 0.12	3.57 ± 0.09	4.15 ± 0.18
Mg	7.68 ± 0.19	1.35 ± 0.05	2.55 ± 0.12
Al	4.65 ± 0.14	10.34 ± 0.12	9.03 ± 0.20
Fe	70.42 ± 0.27	77.99 ± 0.17	72.55 ± 0.31
K	0.23 ± 0.03	0.39 ± 0.02	1.72 ± 0.08
Ca	2.09 ± 0.09	3.76 ± 0.08	2.25 ± 0.10
Ti	1.30 ± 0.08	0.70 ± 0.04	1.64 ± 0.09
Si	11.33 ± 0.29	1.90 ± 0.08	5.91 ± 0.23

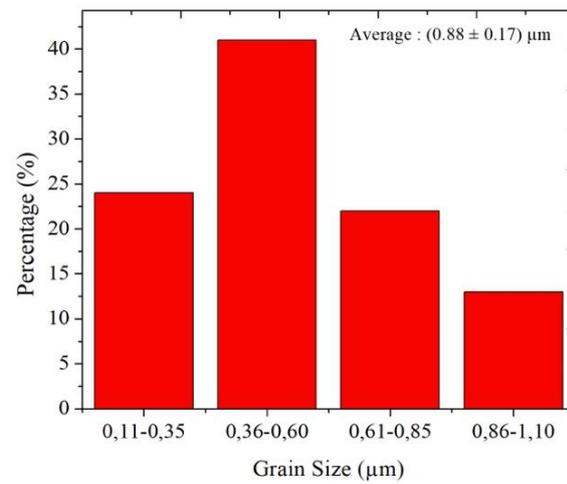
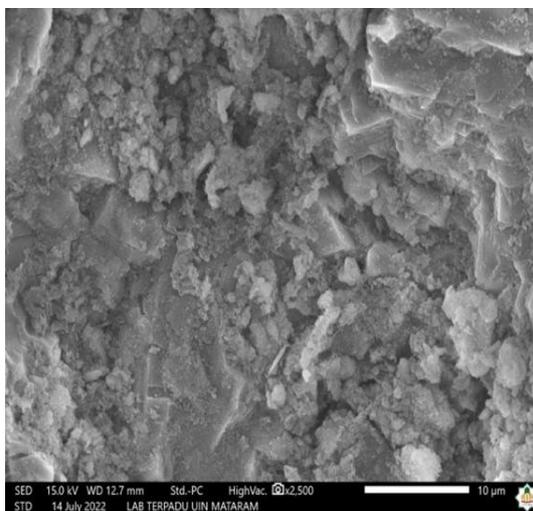
Table 3 shows the mineral concentrations in each sample. It can be seen that the highest Fe content is possessed by hematite sourced from the Sesaot area river. While the smallest Fe content is obtained in hematite sourced from river sand in the Tanak Beak area. The principle of EDX analysis is that when an electron interacts with a material, the electron is scattered by other electrons surrounding the atomic nucleus of the material. Scattered electrons are called primary electrons and electrons in orbit will be reflected out of the system, resulting in a void that will be filled by electrons from the outer shell. Since the outermost electrons have higher energy, when they move into lower energy orbits. They release energy in the form of photons, known as characteristic X-rays (Zhang, Liu, et al., 2024). The energy spectrum of the emitted characteristic X-rays has a specific energy that depends on the atomic number of the material. By knowing the energy of the characteristic X-rays emitted, it is possible to know the atomic number of the material emitting the characteristic X-rays and also the relative content of each material (Raharinaivo et al., 2024).

The morphological characteristics of hematite synthesised by the coprecipitation method were analysed using SEM (Scholz & Gärtner, 2024). SEM uses a secondary electron beam. The source filament is heated highly so that the electrons on the outer shell will have the energy to move to a trajectory that has higher energy. As a result, the electrons on the trajectory will be radiated. These electrons are referred to as secondary electrons. The results of the analysis using SEM are shown in Figure 5.

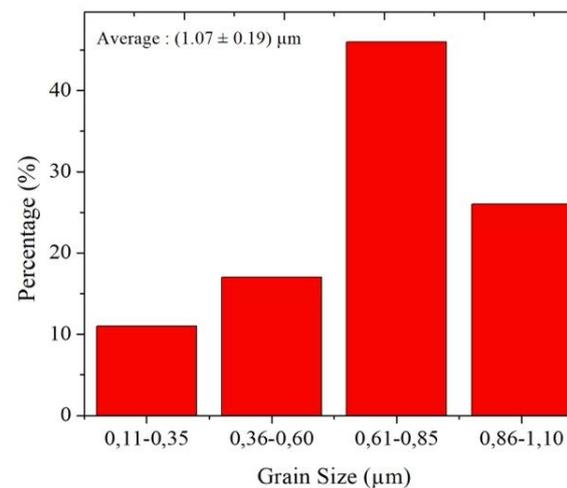
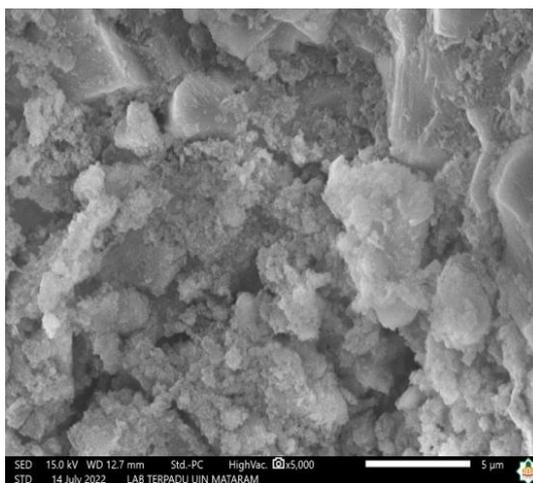
Figure 5 shows the morphology of hematite analysed using SEM. It appears that the hematite based on Sesaot river sand magnetic minerals has a smaller grain size. This is because Sesaot river sand-based hematite has a greater Fe content than other river sands. In addition, Sesaot river sand-based hematite is sourced from fragments derived from the volcanic ash of Mount Rinjani so that it has finer grains (Nandee et al., 2024). The crystal structure of the hematite synthesized from the three regions was analyzed using an X-Ray Diffractometer. Nanoparticle phase analysis was carried out using match 3.2 software. The results of the nanoparticle phase analysis are shown in Figure 6.



(a)

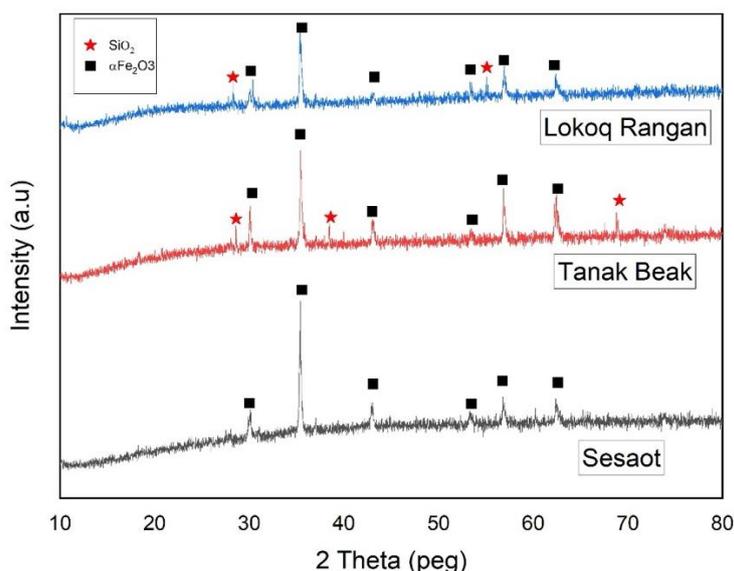


(b)



(c)

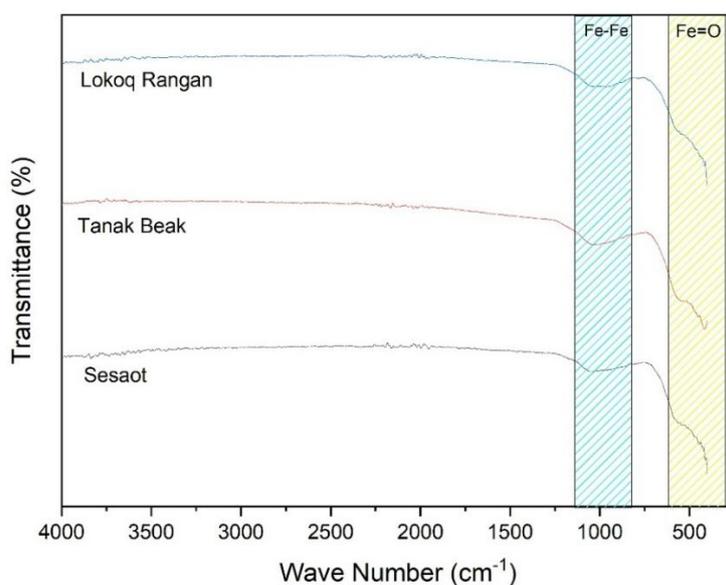
**Figure 5.** Morphology of Hematite Based on Lombok Island River Sand Analysed Using SEM and its Grain Size Distribution (a) Tanak Beak, (b) Sesaot, (c) Lokoq Rangan



**Figure 6.** Phase Analysis of Hematite Based on Lombok Island Iron Sand

Based on Figure 6, it appears that the nanoparticles formed from the synthesis of iron sand-based nanoparticles on the island of Lombok are hematite crystallite phase. In hematite-based iron sand sesaot area it appears that the hematite formed is a single hematite crystal. However, in iron sand based on river sand in the tanak beak and lokok rangan areas, there is an additional phase, namely  $\text{SiO}_2$ . The hematite formed was also analyzed for functional groups using FTIR. The results of functional group analysis using FTIR are shown in Figure 7.

Based on Figure 7, it can be seen that there is an absorption at a wavelength between  $900$  and  $1000\text{ cm}^{-1}$  which shows the shear vibration of the Fe-Fe bond. In addition, Fe=O double fibrations also occur at absorption lengths of  $450$  to  $500\text{ cm}^{-1}$ . Based on the results of XRD and FTIR analysis, it can be concluded that hematite nanoparticles were successfully synthesized using iron sand based on Lombok island river sand.



**Figure 7.** Functional Group Analysis Using FTIR

### Analysis of Heavy Metal Absorbance

The Lombok island magnetic mineral-based hematite samples were then used to improve water quality. Water samples were taken from the babak river area located around the Kebon Kongok landfill. The percentage of heavy metal reduction after filtration using hematite based on Lombok island river sand is shown in Table 4.

**Table 4.** Conductivity, TDS and Mn Metal Content of Water Samples Before and After Filtration

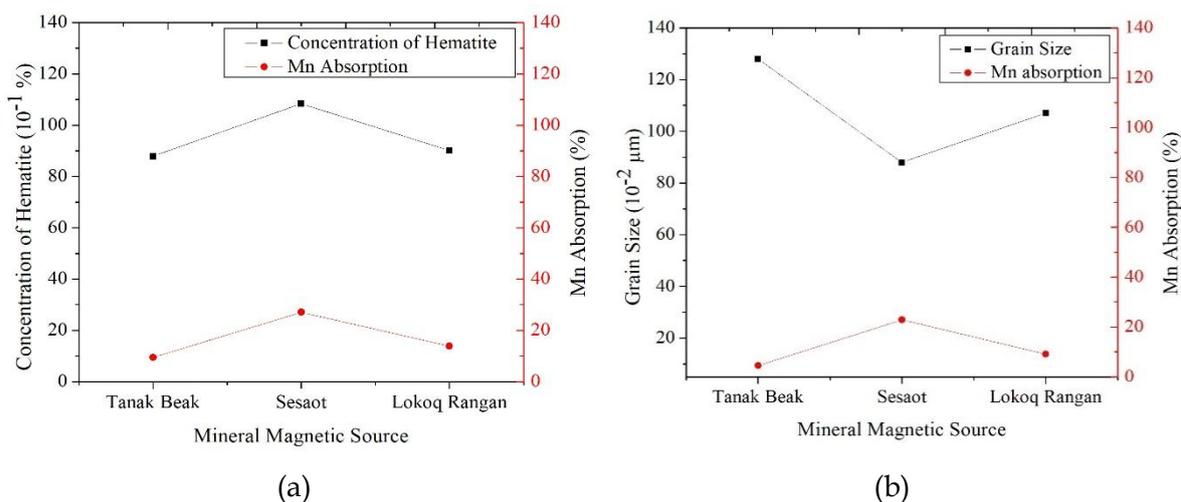
River Sand Source	Conductivity ( $\mu\text{S}/\text{cm}$ )			TDS (ppm)			Mn Content (ppm)		
	Before	After	Differences (%)	Before	After	Differences (%)	Before	After	Differences (%)
Tanak Beak	687.12	645.53	6.05	527.1	470.59	10.72	0,0181	0,0164	9.39
Sesaot	687.12	540.57	21.32	527.1	432.65	17,91	0,0181	0,0132	27.07
Lokoq Rangan	687.12	611.42	11.02	527.1	463.80	12.01	0,0181	0,0156	13.82

Table 4 shows the values of conductivity, TDS and Mn content of the water samples of the round river around kebon kongok landfill. It appears that the values of all parameters were reduced after filtration. The largest decrease in parameter values was shown by filtering using hematite based on the Sesaot River. The magnitude of the reduction in physical and chemical parameter values is influenced by the iron content and grain size of the synthesised hematite. The graph of the reduction in physical and chemical parameter values caused by iron content and grain size is shown in Figure 8.

**Table 5.** Comparison of Percentage Reduction in Physical and Chemical Parameter Values With Other Studies

Absorbent materials	Source	Sumber Air yang diabsorbansi	Percentage Difference (%)			Conductivity	TDS	Ref.
			Mn	Cu	Pb			
Hematit	Sesaot River sand	Babak River around Kebon Kongok Landfill	27.07	Not measured	Not measured	21.32	17.91	This research
Hematite	Ferite (II) Sulfate	Slaughterhouse Wastewater	Not measured	Not measured	0.11	Not measured	30.83	(Awodi et al., 2023)
Nanosilica	River sand	Babak River	12.50	Not measured	20.33	8.42	8.43	(Meiliyadi et al., 2024)
Aspergillus niger	Natural source	Lake Griro Water	Not measured	More than Pb	Less than Cu	-	-	(Kinoti et al., 2024)

Based on Table 5, it can be seen that hematite synthesised from sesaot river sand can absorb Mn metal more optimally than other absorbent sources. When compared to silica, hematite also has a greater absorbance ability because hematite has better magnetic properties when compared to silica.



**Figure 8.** Relationship Graph of (a) Fe Concentration in Hematite and Mn Metal Absorption Percentage, (b) Particle Size and Mn Metal Absorption Percentage

Figure 8 (a) shows the decrease in physical and chemical parameter values caused by hematite iron content and 8 (b) shows the decrease in physical and chemical parameter values caused by iron grain size. Iron is magnetic so it will easily attract heavy metals (Rivera et al., 2023; Sherin et al., 2024; Tadic et al., 2022). It is a law of physics that magnetic objects will easily attract metals. Heavy metal Mn is a transition element that has ferroelectric properties. Ferroelectric materials are materials that have intrinsic magnetic properties so that they can be easily attracted by magnets (Tahir et al., 2023). The more iron content in hematite will cause more heavy metal attracting material. As a result, more heavy metals will be deposited on the hematite material used as an absorber.

Apart from the iron content in the hematite material, the absorbance strength is also caused by particle size. The smaller the hematite particle size, the more metal ions will be absorbed (Khan et al., 2021; Liu et al., 2022; Zhang, Ding, et al., 2024). This is because the smaller the particle size, the larger the absorption cross-sectional area so that more metals will be absorbed, especially metal ions that have a size larger than the grain size. There are several previous studies that use iron sand magnetic minerals as heavy metal absorbents as shown in Table 5.

This study successfully demonstrates the synthesis and application of hematite derived from river sand magnetic minerals in Lombok for manganese adsorption in polluted water. However, there are several important limitations that must be acknowledged. First, the study did not include adsorption isotherm modeling (e.g., Langmuir, Freundlich) or kinetic modeling (e.g., pseudo-first-order or pseudo-second-order), which are standard analytical tools in adsorption research. These models are crucial for determining adsorption capacity, understanding surface interaction mechanisms, and evaluating adsorption rate behavior. The exclusion of these models was due to experimental limitations and access to analytical tools. Future research should incorporate these approaches to provide a more rigorous understanding of the adsorption mechanism and to validate the material's performance under varying conditions.

Additionally, while the characterization of elemental composition and particle morphology was carried out, the specific influence of mineral impurities (e.g., Si, Mg,

Al) on adsorption performance was not thoroughly analyzed and should be investigated further.

## CONCLUSION

Hematite has been synthesised from river sand magnetic minerals originating from several areas on the island of Lombok namely tanak beak, sesaot, lokoq rangan and geres. Based on the results of AAS analysis, it appears that the iron content of hematite synthesised from magnetic minerals of river sand tanak beak, sesaot, lokoq rangan and geres is 8.79%, 10.84%, 9.01% and 9.98% respectively, while based on EDX analysis, it is 70.42%, 77.99%, 72.55% and 72.90%. The particle size of Sesaot iron sand also has the smallest size of  $(0.88 \pm 0.17)$  micrometres while the largest grain size is obtained in the Tanak Beak area of  $(1.288 \pm 0.23)$  micrometres.

Based on the results of XRD and FTIR analysis, it can be concluded that hematite nanoparticles were successfully synthesized using iron sand based on Lombok Island river sand. Mn ions absorbed by hematite-based mineralised magnetic river sand from several areas on the island of Lombok namely tanak beak, sesaot, lokoq rangan and geres are 9.39%, 27.07%, 13.82%, 19.88% respectively which is followed by a decrease in TDS and conductivity of the absorbed water. Sesaot river sand-based hematite can absorb the most Mn metal because it has the smallest grain size and the largest Fe content.

## RECOMMENDATIONS

In this study, hematite was successfully synthesized via coprecipitation from magnetic minerals sourced from river sands in Tanak Beak, Sesaot, Lokoq Rangan, and Geres on Lombok Island. Among the synthesized materials, Sesaot-based hematite exhibited the highest Mn adsorption efficiency, attributed to its high iron content and smallest particle size. These findings support the potential of using geographically sourced river sand as a raw material for water purification technologies, especially in local or rural contexts. However, the study is limited by the absence of adsorption isotherm and kinetic modeling, which are essential for a deeper mechanistic understanding of adsorption behavior. Future investigations should apply these models and explore the role of mineral impurities on adsorption performance. Despite these limitations, this research provides a promising foundation for the development of regionally appropriate, cost-effective water treatment materials based on natural mineral resources.

### Author Contributions

All authors have read and agreed to the published version of the manuscript.

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### Conflict of interests

The authors declare that there is no conflict of interest.

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