INTERNATIONAL JOURNAL of OIL PALM

Volume 7, Number 3, 2024
Page: 1–8
DOI: 10.35876/ijop.v7i3.124

ISSN: 2599-3496 print
ISSN: 2614-2376 online

Renewable Water Filtration Innovation from Palm Oil Mill Effluent Waste

Sufina Azzahra*, Martha Rianna, Nabila Agustin

Department of Physics, Universitas Sumatera Utara, Medan, 20155, Indonesia

ABSTRACT

Indonesia is the largest palm oil producing country in the world. According to data from the North Sumatra BPS in 2021, palm oil production was 5,311,884 tons. Every palm oil factory disposes of its liquid waste, which results in waste pollution becoming a very crucial issue to be addressed immediately because it has many negative impacts. Palm oil mill effluent (POME) is rich in minerals and carbon, but POME waste is currently not fully utilized optimally. The purpose of this research is to produce the latest innovation in water filtration to realize SDGs 2045 on clean water and sanitation, and to study the effectiveness of magnetic which will be applied as clean water filtration by utilizing POME waste and natural sand containing α-Fe_2O_3, alumina (Al_2O_3), and magnetic minerals with well water as samples in this study. The combination of POME waste and natural sand with chemical synthesis and calcination methods at a temperature of 500 ^oC as activation of activated carbon and magnetic metals. The results of the synthesis of POME and natural iron sand obtained solids in the form of black powder. In the VSM test, the magnetization versus magnetic field data of Fe_3O_4/activated carbon POME obtained a magnetic saturation value of 10.13 emu/g. In the XRD test results of activated carbon materials, composites of activated carbon iron oxide and iron oxide and the synthesis results have diffraction patterns similar to the XRD database from JCPDS and in the COD and BOD tests. It proves a decrease in COD and BOD levels in well water before and after filtration with a large range, and indicates the success of the filtration process. In the AAS test as an identification of Fe metal in well water samples, Fe metal becomes <0.00206 (mg/L) starting from 0.01 (mg/L).

Keywords: Calcination, magnetic, natural sand

INTRODUCTION

Indonesia has more than 3.2 million square kilometers or around 3.28 billion square meters of water. Despite having a very large water area large, the country is facing a shortage of clean water due to the presence of dirty water in some areas. Basic needs such as water must be obtained by every human being, therefore making people have to buy it (Nainggolan *et al*. 2019). The Indonesian Ministry of Health has regulated the requirements for clean water as stated in Indonesian Ministry of Health Regulation No. 416 of 1990 concerning dissolved metal content in the quality of clean water used must be a maximum of 1.0 mg/L iron (Fe). In general, Indonesian people increase quality water with filtering water in a way conventional (Latuconsina *et al.* 2022). In this research, filtration which used is a renewable method which own better effectiveness compared to conventional method which is quite

*Corresponding author:
Department of Physics, Universitas Sumatera Utara, Medan
Corresponding authors: sufinaazzahra1@gmail.com

complicated, namely by utilizing palm oil mill effluent (POME).

Indonesia is the biggest producer and exporter of palm oil in the world. According to data from BPS (2021), North Sumatera in 2021 produce palm oil (PO) up to 5,311,884 tons. The total productivity of PO will be directly proportional to the waste produced. Compared with other types of waste, liquid waste from the palm oil industry or often referred to as palm oil mill effluent (POME) has the highest capacity level with a large environmental pollution impact. It is known that 1 ton of crude palm oil requires 5–7.5 tons of water and more of the remaining 50% ends up as POME (Putera *et al.* 2022). Every palm oil mill is also produce liquid waste which result as pollution waste, and it is a very crucial issue that needs to be addressed immediately because it has many implications. POME waste processing usually only uses technology which is implemented by covering conventional waste ponds (covered lagoons) with anaerobic system and not yet regarded as renewable innovation (Winanti 2019). POME waste is currently not fully utilized optimally, even though POME is rich in minerals and carbon which can potentially be convert to be a clean filtration water based on magnet with added sand nature (Lee *et al*. 2019). Natural sand is an abundant natural resource, contain various magnetic minerals, one of which is α-Fe_2O_3 which is an oxide iron. It can used in sensor gas, catalyst, and material electrode. Besides, α-Fe_2O_3 can used as main material for making magnet permanent (Sihombing and Amiruddin 2020). This potencial is in harmony with our research objective: for producing the latest innovations in water filtration to realize SDGs 2030 regarding clean water and sanitation, and review the effectiveness of the magnetic which will be applied as clean water filtration by utilizing POME waste and sand aid natural.

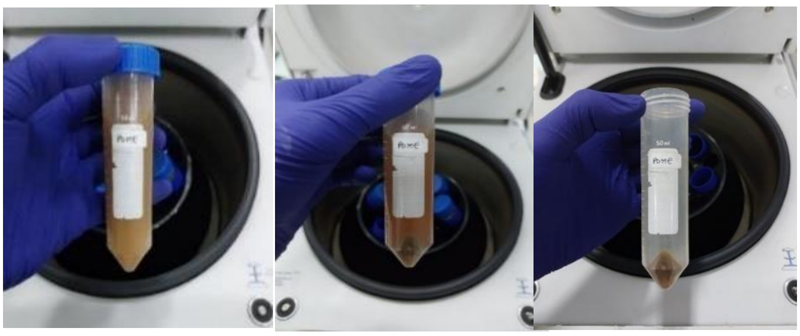
The aim of this research is expected to produce and study on magnetic effectiveness that can be applied as renewable clean water filtration from waste POME and natural sand. The output targets of this research are as follows: (1) produce a progress report and final report on the potential for clean water filtration absorption of iron metal (Fe) after being innovated from POME waste and natural sand; and (2) scientific articles to be published at the national level as a reference source for the wider community.

MATERIALS AND METHODS

The material used in this research is POME waste, sand nature, HCl 37%, NaOH 2 M, ethanol 96%, aquadest. The equipment used in this research are beaker glass, Erlenmeyer flask, Erlenmeyer vacuum, vacuum machine, measuring cup, glass funnel, petri dish, analytical balance, furnace, centrifuge, oven, pipette drops, Whatman filter paper no.42, tea filter paper, universal indicator, hot plate and magnetic bar. The fixed variables in this research were the variations in POME concentration, and the natural sand used in the research in variations A, B, and C. The independent variable on this research was interval time on magnetic deposition process which generated. The dependent variable in this research wass characterized by scanning electron energy dispersive X-Ray microscope (SEM-EDX), vibrating sample magnetometer (VSM), X-Ray diffraction (XRD), and atomic absorption spectrophotometer (AAS).

Research Stages

This research consists of several stages, namely preparation of raw materials, centrifugation of POME and sand nature, calcination of magnetic adsorbents, and application of magnetic adsorbents as filtration. All POME sample collection was taken from a palm oil industry factory. POME was taken to the laboratory to separate the liquid and the particle based on the specific gravity of each cell component using a centrifuge at 3000 rpm, supernatant was separated and solid was used for stage.



(a) (b) (c)

Figure 1 POME before centrifugation (a); centrifugation results containing supernatant and solids (b); and solids from centrifugation of POME (c).

Natural iron sand was the main precursor. First, POME was stirred using a magnetic stirrer, with 25 mL HCl 37% until homogeneous for 30 minutes at room temperature, then filtered with Whatman filter paper no. 42. Next, natural iron sand was stirred using a magnetic stirrer with 100 mL HCl 37% on room temperature for 30 minutes, then filtered using Whatman filter paper no.42. After filtering, each filtrate was slowly dripped into a 2 M NaOH solution which was stirred using a magnetic stirrer with distilled water. Then solution stirrer was reversed during 1 hour until form a precipitate. The precipitate was washed with distilled water then 96% ethanol, and filtered with Whatman filter paper no. 42 using Buchner filtration method. Then results the residue was dried in an oven.

The powder obtained after synthesis was calcined at a temperature of 500 °C for 4 hours in the furnace. Furthermore, the calcination results were characterized by atomic absorption spectrophotometer (AAS), scanning electron microscope energy dispersive X-Ray (SEM-EDX), vibrating sample magnetometer (VSM), and X-Ray diffraction (XRD). Turbid and yellow well water was used for extraction during magnetic application as filtration. Magnetic adsorbent was packed into a paper filter tea filter in the form of kraft type. After that, it was dipped into polluted water for improve the quality of water to be a clean water, then tested for chemical oxygen demand (COD), biological oxygen demand (BOD) and color changes.

RESULTS AND DISCUSSION

Achievement of External Targets of POME Centrifugation Result

From 4 L of centrifuged POME, the solids obtained were 315.3 g. The water content of centrifuged POME was found to be 97.9 ± 0.3%. Even after centrifugation, the water content in the centrifuged POME solids was still high, almost the entire mass of the sample was water. Even so, the appearance of POME looked like a fibrous paste. The results of this study are in line with the study conducted by Davies (2020) as the results of POME centrifugation after the supernatant was removed, produced solids in the form of a fibrous paste.

Synthesis Results of POME and Natural Iron Sand

The results of the synthesis of POME and natural iron sand were obtained in the form of black powder. In this case, the carbon source was POME, a liquid resulting from the palm oil milling process which is rich in will carbon (Abdullah *et al.* 2020). According to Mohammad (2021), carbon which contained on POME is 51.0%. Natural iron sand is synthesized so that the high surface energy has super-paramagnetic properties, and has high absorption power (Nengsih 2021).

Figure 2 Synthesis results.

Calcination Process Results

Calcination at 500 °C for 4 hours resulted in a color change from jet black to reddish brown. Magnetism can be proven with existence mineral magnetite dark brown in color which is magnetic (Karbeka *et al*. 2020). Properties this magnetism is obtained from the material natural and synthetic like sand natural iron. Material magnetic which originate from natural have oxidation iron which strong characteristic magnetic (Ningsih 2019).

Figure 3 Results of calcination of magnetic adsorbent.

Magnetism Test

Separation using magnetic force is called magnetic separation. To increase the efficiency of separation, this system must increase the magnetic force acting on the particles by increasing the volume of the particles, the relative magnetization between the particles (dispersoids) and the dispersing medium or the magnitude of the magnetic field gradient (Ahdiaty 2022). Most element content from adsorbent was element with magnetic characteristic, so the adsorbent have own magnetic properties (Rettob and Carbide 2019). Magnetic fields can enhance the adsorption rate by increasing mass transfer and increasing the adsorption capacity. Similarly, the use of controlled magnetic fields can ensure the adjustment of important parameters, by ensuring the adsorption of specific ions.

Figure 4 Magnetic test process

Atomic Absorption Spectrophotometer (AAS) Results

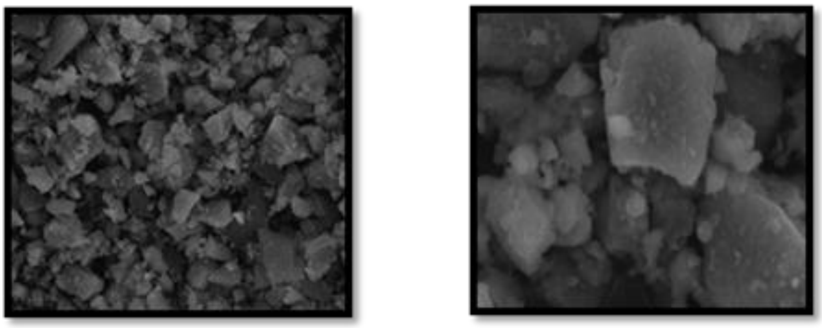
The presence of heavy metal components in magnetic adsorbents, and the application of external magnetic fields can easily separate the adsorbent from the solution and recycle or regenerate it for further use. In Table 1, the results of iron (Fe) magnetic adsorbents from variations A, B, and C are 31.5%, 38.2%, 37.56% respectively, which indicates that with the presence of iron metal oxide (Fe) in magnetic adsorbents, it can absorb water pollutants such as heavy metal ions dissolved in water.

Table 1 Atomic Absorption Spectrophotometer (AAS) results.

No.	Variation	Parameter	Results (%)
1.	A	Fe	31.50
2.	B	Fe	38.20
3.	C	Fe	37.56

Characterization of *Scanning Electron Microscope-Energy Dispersive X-Ray* (SEM-EDX)

Characterization of magnetic adsorbent Fe_2O_3/POME activated carbon was carried out using SEM-EDX aims to determine the morphology of the surface of the Fe_3O_4/POME activated carbon adsorbent sample, and to determine the element content and its distribution. The image showed the SEM-EDX micromorphology of POME synthesis on the 3000x magnification that forms irregular crystal sizes. While on the morphology image of the magnetic adsorbent on the 20000x magni-



(a) (b)

Figure 5 Morphological form of POME synthesis(a); and morphological form of magnetic adsorbent (b).

Table 2 EDX characterization results on magnetic adsorbents.

Element	Concentration (%)
C	30.85
O	50.08
Fe	19.07

fication, it formed square chunk crystal sizes. In Fe_3O_4/POME activated carbon there are several elements contained, listed in Table 2 including carbon (C), oxygen (O), and iron (Fe). The largest element content in Fe_3O_4/POME activated carbon is oxygen with a per-centage of 50.08% where this oxygen element comes from the active group in activated carbon and its metal oxide produced from the pyrolysis process. The percentage of iron (Fe), carbon (C) and oxygen (O) elements obtained showed that the Fe_3O4 metal was successfully loaded on activated carbon.

Characterization of Vibrating Sample Magnetometer (VSM)

Magnetite Fe_3O_4 is one of the iron oxides that has the strongest magnetic properties among other iron oxides. Fe_3O_4 material is ferromagnetic in its pure state (Anbarasu *et al.* 2015). Therefore, the characterization of Fe_3O_4/POME activated carbon was carried out using VSM to determine the magnetic saturation value of a material. Figure 6 showed the measurement results of Fe_3O_4/POME activated carbon using VSM which was carried out at room temperature with the Hc value in range of 0 to 1T. The hysteresis curve obtained showed that the adsorbent was superparamagnetic as indicated by the Hc value approaching 0. From the curve it showed that the magnetization versus magnetic field data of Fe_3O_4/POME activated carbon obtained magnetic saturation value (Ms) is 10.13 emu/g. However, the saturation magnetization value (Ms) obtained is lower than the maximum saturation magnetization value

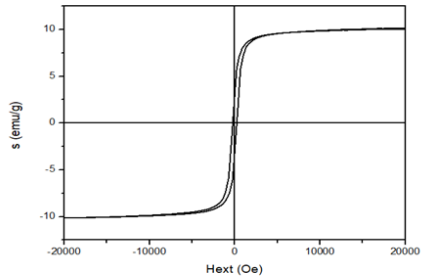


Figure 6 Results of Fe_3O_4 analysis/POME activated carbon.

of Fe_3O_4 which is 92 emu/g. This can be caused by the formation of a lower degree of Fe_3O_4 crystallinity. The saturation magnetization value decreases due to the presence of non-magnetic fractions such as activated carbon in the adsorbent. The higher the non-magnetic fraction contained, the saturation value (Ms) will also decrease.

X-Ray Diffraction Characterization

The following is the spectrum of the X-Ray Diffraction (XRD) test results on raw material. Interpretation of the XRD pattern in the Figure 7 can ensure the crystal plane and peak of the XRD spectrum. The images are the results of X-Ray Diffractometer (XRD) measurements of activated carbon, iron oxide-activated carbon composite, and iron oxide. The synthesized iron oxide has a diffraction pattern similar to the XRD database from JCPDS.

Application of Magnetic Adsorbent in Filtration

Water quality testing is needed to ensure the quality of drinking water. According to the law of the Ministry of Health of the Republic of Indonesia No. 32 of 2017, water quality testing includes physical and chemical parameters. The well water samples used were turbid and yellow with acidic pH. Figure 8, showed 8 applications of 0.50 g of magnetic adsorbent to 250 mL of turbid and yellow well water, and changes in producing clean water were seen overnight.

Chemical Oxygen Demand (COD) and Biological Oxygen Demand (BOD) tests on Well Water

COD and BOD tests in Table 3 showed that COD values are higher than BOD, this indicates the amount of organic matter that is chemically oxidized but cannot be oxidized biologically. Similar results were obtained by Syahrina *et al.* (2021) who stated that COD levels were higher than BOD. The test results proved a decrease in COD and BOD levels in well water before and after filtration with a large range, and this indicates success in the filtration process.

Atomic Absorption Spectro-photometer (AAS) Test on Well Water

The AAS test in Table 4 showed a decrease in iron levels in well water before and after filtration. This proved that magnetic adsorbents have the potential to reduce iron levels in water.

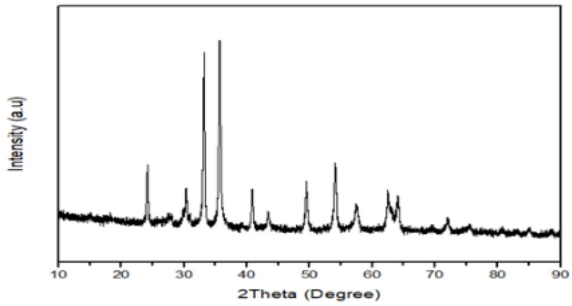


Figure 7 Diffractogram results of Fe_3O_4/ POME activated carbon.

(a) (b) (c)

Figure 8 Cloudy and yellow well water (a); application of filtration to cloudy and yellow well water (b); and well water after filtration (c).

Table 3 COD and BOD of well water.

Parameter	Before filtration (mg/L)	After filtration (mg/L)
Fe	0.01	< 0.00206

Table 4 AAS test on well water.

Parameter	Before filtration (mg/L)	After filtration (mg/L)
COD	151.78	35.41
BOD	75.68	19.36

CONCLUSION

In the results of the synthesis of POME/narural sand, the results of iron (Fe) magnetic adsorbents from variations A, B, and C were 31.5%, 38.2%, 37.56% respectively, which indicates the presence of iron metal oxide (Fe) in the magnetic adsorbent. The largest element content in Fe_3O_4/activated carbon POME is oxygen with a percentage of 50.08%. This oxygen element comes from the active group in activated carbon and its metal oxide produced from the pyrolysis process. XRD pattern interpretation test, ensured the crystal plane and the peak of the XRD spectrum. From the AAS test for identified the Fe metal in well water samples, Fe metal becomes very low <0.00206 (mg/L).

REFERENCES

Abdullah MF, Jahim JM, Abdul PM, Mahmod SS 2020. Effect of carbon/nitrogen ratio and ferric ion on the production of biohydrogen from palm oil mill effluent (POME). Biocatal Agric Biotechnol. 23:101445.

Ahdiaty R. 2022. Anions adsorption in aqueous solution with magnetic nanocomposite Fe_3O_4/activated carbon. [Thesis]. Universitas Islam Indonesia, Yogyakarta.

Anbarasu M, Anandan M, Chinnasamy E, Gopinath V, Balamurugan K. 2015. Synthesis and characterization of polyethylene glycol (PEG) coated Fe_3O_4 nanoparticles by chemical co-precipitation method for biomedical applications. Spectrochim Acta A Mol Biomol Spectrosc. 135:536–539.

BPS (Central Bureau of Statistics). 2021. Plantation Crop Production of PTPN II, III, and IV By Plant (Ton). 2018–2021. North Sumatra: BPS Publishing.

Davies E, Deutz P, Zein SH. 2020. Single-step extraction-esterification process to produce biodiesel from palm oil mill effluent (POME) using microwave heating: a circular economy approach to making use of a difficult waste product. Biomass Convers Biorefin. 12:1–11.

Karbeka M, Koly FVL, Tellu NM. 2020. Characterization characteristic magnetism of iron sand of Puntaru Beach, Alor Regency-NTT. Lanthanida Journal. 8(2): 108–116.

Latuconsina H, Gadi ES, Isomudin A, Berlian HL, Ubaidillah Z, Azizah PN, Infant MA. 2022. Clean water filtration and water source rescue in Mulyoasri Village, Ampelgading District, Malang Regency. Agrokreatif: Scientific Journal of Community Service. 8(1):120–128.

Lee ZS, Chin SY, Lim JW, Witoon T, and Cheng CK. 2019. Treatment technology of palm oil mill effluent (POME) and olive mill wastewater (OMW): a brief review. Environ Technol Innov. 15:100377.

Mohammad S, Baidurah S, Kobayashi T, Ismail N, Leh CP. 2021. Palm oil mill effluent treatment processes – a review. Processes. 9(5):739.

Nainggolan AA, Arbaningrum R, Dear A, Dear DJ, Syaddad MA. 2019. Tool processing water baku simple with system filtration. Widyakala Journal.

6: 12–20.
Nengsih S. 2021. Literature review: synthesis of iron sand into magnetite nanoparticles through the application of coprecipitation method. Amina. 3(3): 112–122.
Ningsih F. 2019. Analysis of the effect of grinding time on resistivity and iron content (Fe_3O_4) in iron sand synthesized in the Regency Bima. [Thesis]. University State Islam Mataram, Mataram.
Putera DA, Matondang AR, Sembiring MT, Dermawan AA 2022. Application of seven tools to identify liquid waste (POME) levels in palm oil company. Sigma Teknika. 5(1):22–29.
Rettob AL, Karbeka M. 2019. Influence concentration solution hf on process preparation to level magnetic material elements of sand iron. Walisongo J Chemist. 2(1):6–9.
Sihombing M, Amiruddin E. 2020. Synthesis and characterization of nanoparticles Fe_2O_3 from Pasir Alam, Logas Village, Kuantan Singingi Regency. J Communication Physics Indonesia. 17(2): 68–73.
Syahrina E, Ilza M, Linggawati A. 2021. Analysis of wastewater contamination in boreholes around the ruminant RPH Cipta Karya Panam Pekanbaru. EcoNews. 4(1):9–15.
Winanti WS, Prasetiyadi P, Wiharja W. 2019. Palm oil mill processing effluent (POME) into biogas with fixed type anaerobic system bed without process neutralization. J Environ Technol. 20(1)143. DOI: 10.29122/jtl.v20i1.3248