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# Treatment of Water Polluted by Oil Spill by Ferromagnetic Particles

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**ABSTRACT**

Water constitutes 71% of the Earth's surface, and up to 60% of the human body. The amount of water that humans consume, and need depends on the age, gender and the location. According to many studies, oil spill is considered as one of the most common environmental disasters, resulting in the destruction of ecosystems and significant losses for the economies of the countries that suffer from leaked oil, not only because of the price of the leaked oil but also because of the extinction of many marine organisms that live in these environments. The Kingdom of Saudi Arabia exports a huge amount of crude oil, varies between 6.935 and 7.737 million barrels per day, leading to rise oil pollution that may harm the vital marine environment. The current paper aims to examine the effect of micro and nano-ferromagnetic in the treatment of water polluted by oil spill. The method is based on mixing the oil with ferromagnetic particles and using the neodymium magnets to separate the particles from the oil. The experiment was repeated by changing the concentration of ferromagnetic particles, that are able to purify water from oil at rates ranging from 154 for microparticles to 185 for nanoparticles. The properties of seawater treated with ferromagnetic particles were identified in both parts by measuring the acidity value and identifying the compounds present in the samples, followed by mechanical experimentation. Results showed the efficacy of purifying seawater from oil leakage using ferromagnetic nanoparticles as well as the extent to which ferromagnetic materials can be separated from oil by examining the components of the water after purification. Also, this method is safe, highly efficient, and cheap for purifying sea water from oil pollution. In addition, the acidity of the water was not affected using ferromagnetic particles, as it ranged around 8.5 for all samples.

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## Introduction

Water is of paramount significance for the existence of life on earth and all life depends upon the availability of it. According to the recent report of united nations sustainable development goals 2022, 1.6 billion will not have access to clean water and with 1.9 billion people that will not have the access to basic hygiene [1]. Devastating effects on the environment might result from high water stress. Additionally, it can slow down or even stop social and economic progress, fostering increased competition and the possibility of user conflict. In 2019, the amount of water stressed on a global scale rose to 18.6%. Although it stayed below the acceptable threshold of 25%, these average hides significant regional variances.

With the increasing annual population rate and migration towards urban areas also puts another pressure on the availability of water according to [2]. While the climate change is also coupling the effect of human water usage and demand, climate change also has an impact on groundwater resources. The study finds that groundwater levels will either increase (or decrease, depending on the scenario) by almost 33% in 2100 [3].

The massive deposits of the oil in the world represents the threat to the environmental and ecological populations with the rate at which it is being extracted is alarming [4]. This is especially true in areas like the Gulf of Mexico, the Gulf of Paria, the Bohai Sea, the North Sea, and many other places across the world where oil exploration and extraction play a substantial role in the local economy. Unintentional emissions are frequently traceable to drilling rigs, pipeline networks, storage facilities, tankers, refineries, or other petroleum industry infrastructure components. Regardless of the source, the foundation for response planning depends on knowing the potential effects of the spill.

Oil spills continue to pose a hazard to marine and coastal ecosystems, encouraging the creation and use of oil spill models to create more effective response and preparedness strategies. Up until this moment, there had been several recent spills of sizable proportions in the previous five years.

**Figure 1:** The Picture Sanchi Tanker Incident in the South China Sea

For instance, approximately a million barrels of fuel oil were released after the Sanchi tanker incident in the South China Sea [5]. The water quality criteria (WQC) of the river or seawater defines the existence of structures in the water [6].

The Kingdom of Saudia Arabia petroleum export value in 2021 was 202,166 ((million $), crude oil production per day is 9,125(1,000 b/d) barrels per day according to OPEC. According to global oil demand will increase 286 million barrels/day from 2021 to 2045, a rise of 23% with a higher percentage of increase in the India of 28% in the global economy [7]. Oil tend to be the largest share in the world economy with its 29%.

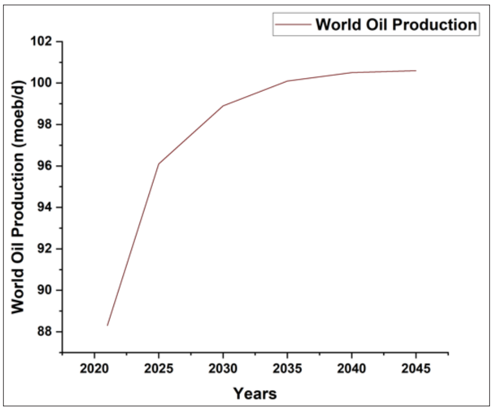


**Figure 2:** World Oil Production (moeb/d) by OPEC

Light aromatic hydrocarbons and their derivatives, which are present in oil, are primarily referred to as oil pollutants [8]. Aquatic species may become acutely or chronically harmful depending on the level of oil exposure in the water. Oil leak catastrophes have occurred often in recent years because of the rapid development of offshore oil resources and the ongoing expansion of global oil transportation, damaging aquatic habitats and having major harmful impacts on aquatic life) [8,9].

Magnetic nanoparticles are very useful because they can be used alone, functionalized, or combined with various conventional adsorbent materials and have the benefit of being quickly removed from solutions after being exposed to a magnetic field [10,11]. A study used the composite material of polyurethane foams with the iron oxide nanoparticles and used to clean the water from the oil spill [10,9]. Another study used the Polyacrylonitrile (PAN) nanofiber and nanoparticles with a coating of Titanium oxide to help the efficiency of oil adsorption while it has been increased with the increased area [11,12].

This study investigates the micro vs nano ferromagnetic particles strength in the removal of oil contaminants and its efficiency that can improve the aquatic marine life and restore ecosystem. Moreover, the validity of removal can be evaluated through the acidity and other pollutants removal from the wastewater.

**Methodology**

The study is conducted according to the figure 3 with a start from characterization of seawater, ferromagnetic particles preparation, followed by preparation of ferromagnetic particles that generate magnetic field which separate the particles, then to count the percentage % of purification. The treated water then characterizes according to properties and coparison with the initial parameters.

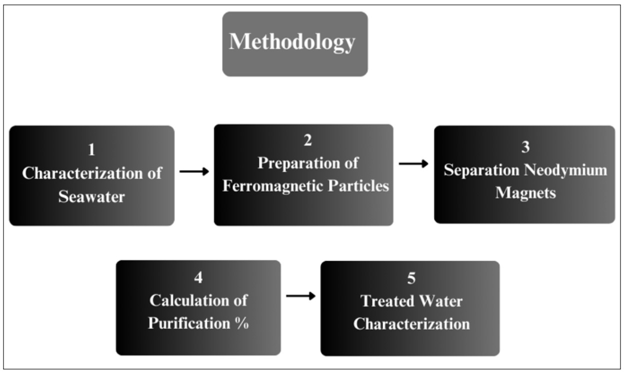


**Figure 3:** Flowchart of for Spill Oil Water Treatment

**Characterization of Seawater**

The parameters of the seawater analyzed include pH, COD, EC, Turbidity, DO and heavy metals (cadmium, lead, nickel). A pH meter (model: HANNA HI8424) used to measure the acidity value (pH), for turbidity (model:tb1 portable turbidi meter),electrical conductivity by (Model: conductivity meter cond 720) and dissolved oxygen (DO) by (model: HANA HI9146) was measured. For chemical oxygen demand (COD), potassium dichromate ($K_2Cr_2O_7$) from Duksan International and sulfuric acid ($H_2SO_4$) from Sigma Aldrich used and the sample was then added and digested for two hours. The sample was titrated against ferrous ammonium sulphate $(NH_4)_2Fe(SO_4)_2{\bullet}6H_2O$) till the reddish brown color appeared.

An atomic absorption spectrophotometer (AAS) equipment was also used to analyze the composition of the seawater samples, revealing the presence of different chemicals in the samples. All the initial parameters values of oil spilled seawater are given in Table.1.

**Table 1: Initial Parameters of Seawater**

| Initial Seawater Parameters | | |
|---|---|---|
| **Parameter** | **Value after Spill** | **Unit** |
| pH | 6.7 | pH units |
| COD | 125 | mg/L |
| DO | 4.3 | mg/L |
| Turbidity | 125 | NTU |
| Lead | 11 | ppm |
| Cadmium | 13 | ppm |
| Nickel | 13 | ppm |

**Preparation of Ferromagnetic Particles**

For the experiment measuring both components, oil and micro-ferromagnetic particles, a 1:1 concentration of both was prepared. The micro-ferromagnetic particles and oil were added to two liters of seawater, which had been put in a container. To achieve equitable distribution, the mixture was thoroughly homogenized using a glass rod. The aggregate weight of the mixture of oil, water, and micro-ferromagnetic particles was then calculated on a scale with extreme sensitivity.

**Separation by Neodymium Magnets**

Neodymium magnets are used to create a magnetic field in the mixture. The magnets were placed within a plastic insulator, keeping isolated from water. Then the magnetic field generated by neodymium magnets helped in the detachment of oil and ferromagnetic particles from water.

While tracking the material that separated, weight of water measured and by subtracting this from the initial weight of mixture, micro-ferromagnetic particles was determined.

**Purification Percentage Calculation**
The purification % was calculated using the equation 1:

Equation 1

$$\text{Purification \%} = \frac{\text{Weight of Purified Oil and Microferromagentic Particles}}{\text{Initial Weight of Oil}} \times 100$$

To explore the impact of different micro-ferromagnetic particle concentrations, the experiment was repeated using ratios of micro-ferromagnetic particles to oil at 5:1, 3:1, and 1:1.The same procedures was followed for each concentration.

**Characterization of Treated Seawater**
Then the properties of seawater that had been exposed to micro-ferromagnetic particles.To evaluate any changes in acidity, pH readings were recorded at concentrations of 1:1, 3:1, and 5:1. The chemicals in the treated water sample samples were identified using the atomic absorption spectrophotometer (AAS).

Now to further investigate, ferromagnetic nanoparticles were utilized to see the effectiveness of water treatment. To examine the effects of various oil-to-water ratios and separation times (5 minutes), the method was performed with a fixed amount of oil (10 ml) and varying concentrations of ferromagnetic particles (202 grams, 4 grams, and 6 grams).

**Results and Discussion**
**Efficiency of Micro vs Nano Ferromagnetic Particles**
The maximum reported purification percentage of 58% was found at a particle-to-oil ratio of 5:1, demonstrating the impressive purifying powers of micro ferromagnetic particles. However, the efficiency of filtration noticeably decreased to 45% as the ratio shifted toward 3:1. At a particle-to-oil ratio of 1:1, this tendency was maintained, and the purification percentage further dropped to 30% as shown in figure 4. It was observed by that ferromagnetic possesses collection power and also utilized as the sponge to clean the oil as well [13,14].

While nano-ferromagnetic particles showed noticeably better performances than their micro-ferromagnetic particles. Nano-ferromagnetic particles demonstrated enhanced oil-separation efficiency by achieving an excellent purification percentage of 67% at a particle-to-oil ratio of 5:1. Despite a 3:1 reduction in the particle-to-oil ratio, 50% purification efficiency was still achieved. Amazingly, nano-ferromagnetic particles maintained a substantial purification percentage of 40% even at a 1:1 ratio, highlighting their effectiveness in the treatment of oil-contaminated water.

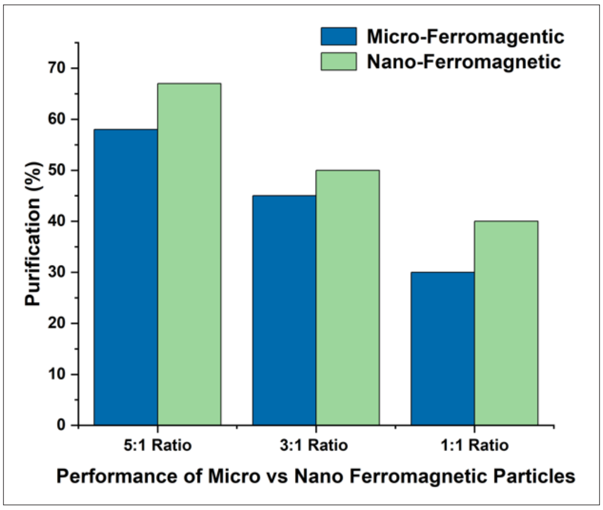


**Figure 4:** Performance Efficiency of Micro vs Nano Ferromagnetic Particles

The observed decrease in purification percentages with micro-ferromagnetic particles as the particle-to-oil ratio approaches 1:1 highlights the ineffectiveness of larger particles in removing oil under such circumstances. Nano-ferromagnetic particles, on the other hand, were able to maintain a significant level of efficiency even at a 1:1 oil-to-water ratio, highlighting their adaptability and applicability for a wider variety of oil-to-water ratios. Similarly find out that small size of nanoparticles are efficient in separation and proposed an iron mesh as solution [15-17].

**Physicochemical Parameters Removal from Seawater**
In the graph below, the seawater's pH was 8 at a 5:1 ratio, indicating a marginally alkaline environment. The pH levels plummeted to 7.8 and 6.2, respectively, suggesting increased acidity as the ratio reduced to 3:1 and 1:1. These modifications may affect the availability of nutrients and marine life. COD was 19 mg/L at a 5:1 ratio, indicating a decreased organic load. However, the COD increased to 42 mg/L and 50 mg/L at the 3:1 and 1:1 ratios, respectively, indicating greater organic molecules, possibly from oil contamination. Increased COD levels have an impact on ecosystem health and oxygen demand. Oxygen availability was indicated by DO levels. DO was 0.6 mg/L at 5:1, indicating possible oxygen shortages. At a ratio of 3:1 and 1:1, respectively, DO increased to 1.4 mg/L and 1.7 mg/L, indicating improved oxygenation and its significance for aquatic species while found effective removal of COD and other parameters [18].

As ratios decreased turbidity values increased. Water clarity was 19 NTU at a 5:1 ratio, but increased to 41 NTU and 50 NTU at a 3:1 and 1:1 ratio, respectively, suggesting more suspended particles and less clear water as shown in figure 5 below. Our findings emphasize the complex relationship between particle-to-oil ratios and seawater parameters. Lower ratios led to increased acidity, higher organic loads, improved oxygen availability, and decreased water clarity. These results highlight the importance of considering these factors in oil spill remediation efforts and understanding their ecological impacts.

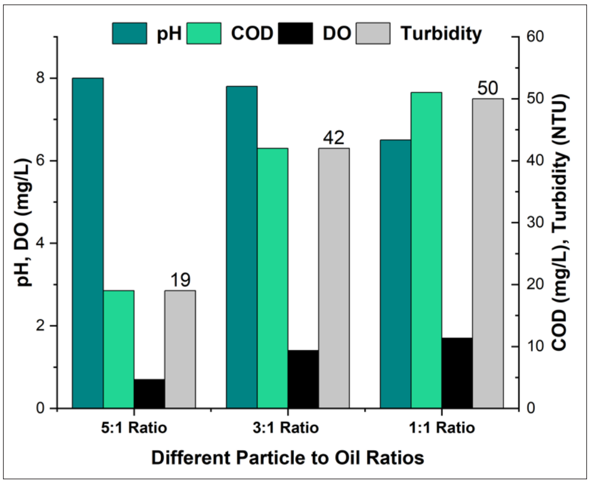


**Figure 5:** Physicochemical Parameters Removal with Respect to Different Particle to Oil Ratio

A 5:1 particle-to-oil ratio is used to assess the physicochemical properties of oil-contaminated water before and after treatment as showed in figure 6. Significant changes in critical parameters were found in the results. After treatment, the pH increased from 6.5 to 8, showing that the acidity brought on by the oil spill had been successfully reduced. Chemical Oxygen Demand (COD) significantly dropped from 125 mg/L to 20 mg/L, indicating that the oil spill's organic contaminants had been effectively removed. The environment for aquatic life became more friendly when the level of dissolved oxygen (DO) increased from 6.5 mg/L to 8 mg/L. Reduced turbidity suggests increased water clarity and fewer suspended particles.

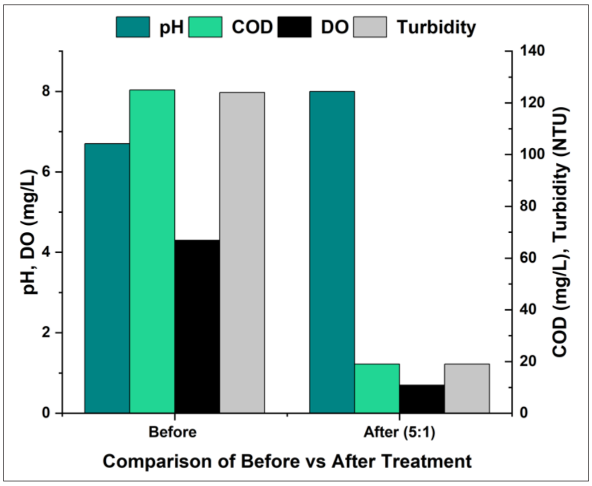


**Figure 6:** Comparison of before Treatment with Ferromagnetic Particles vs after

**Heavy Metals Removal at Different Ratios**

Using an advanced Atomic Absorption Spectrophotometer (model: Novaa 800 AAS) at three different particle-to-oil ratios, for the presence of heavy metals in seawater. The following heavy metal concentrations were found at a 5:1 ratio: Pb at 1.7 parts per million (ppm), Cd at 3.6 ppm, and Ni at 4.4 ppm. These numbers reveal the level of heavy metal contamination in the polluted seawater at the start of any treatment. At 3:1, the amounts of Pb (1.9 ppm), Cd (4.3 ppm), and Ni (5.1 ppm) all slightly increased. This figure 7 shows that treatment might have an impact on the levels of heavy metals. The heavy metal concentrations continued to increase at the 1:1 particle-to-oil ratio, reaching Pb levels of 2 ppm, Cd levels of 4.3 ppm, and Ni levels of 5.2 ppm. The conclusion of treatment effects on heavy metal removal from seawater is shown by these results.

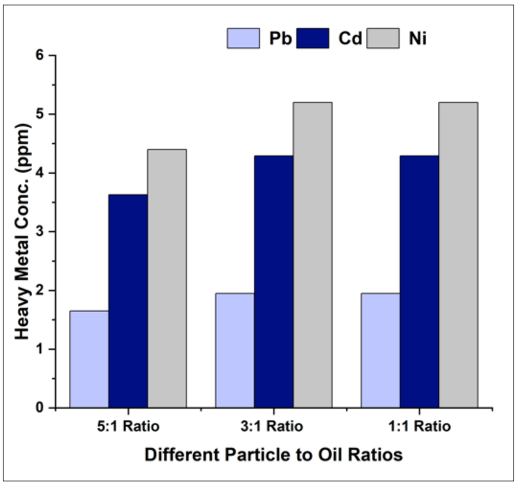


**Figure 7:** Heavy Metal Concentration at Different Particle to Oil Ratio

Alarming amounts of heavy metal contamination in the seawater were found, Pb was present in amounts of 11 (ppm), Cd at 13, and Ni at 13. These results highlighted how serious the oil spill's impact on heavy metal pollution was. Following treatment with the particle-to-oil ratio of 5:1, a decrease in the concentration of heavy metals happened. Pb dramatically declined to 1.7 ppm, Cd decreased to 3.6 ppm, and Ni fell to 4.4 ppm as shown in figure 8. This presents the solution as it is one of the environment friendly way studied by due to high removal efficiency of nanoparticles and more surface area [19-21].

This result is especially important for water treatment and oil spill cleanup applications where quick and comprehensive filtration is essential and considered as green approach as it also effects the bacterial population [22,23]. As this study given the excellent results in terms of removal efficiency, slightly different result from another approach was found by dodecanoyl chloride modified starch particles [24].

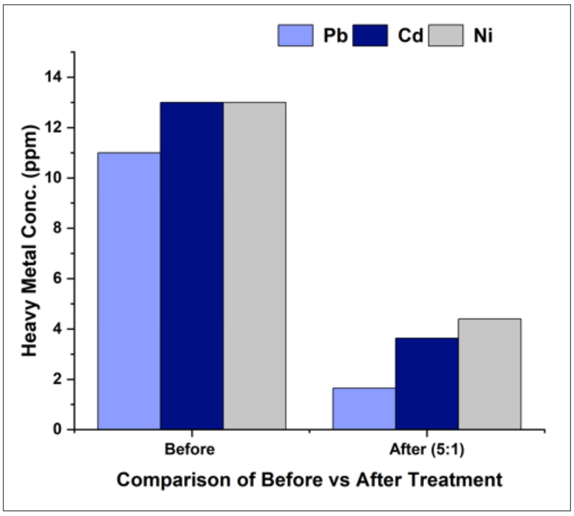


**Figure 8:** Comparison of Heavy Metal conc. before Treatment of Water vs after Treatment with Ferromagnetic Particles

## Conclusion

Our research has conclusively shown that ferromagnetic particles, both in micro and nano forms, showed outstanding capacities in removing oil from water. Notably, despite various particle-to-oil ratios, nano-ferromagnetic particles have emerged as a prominent option, constantly reaching outstanding purification percentages. These results provide a sustainable method of reducing the negative effects of oil spills on our aquatic ecosystems and have enormous potential for use in the real world.

- The pH of treated seawater with the micro and nano ferromagnetic particles remained between the range is 7 to 8 which is suitable for the marine life.
- Nano-ferromagnetic particles showed an exceptional performance with the highest on the 5:1 ratio in terms of purification rate and physicochemical parameters of water
- Hight amount of particles in the particle to oil ratio showed an increase in the removal of heavy metals including (Pb, Cd & Ni)
- This study paves the way for a revolutionary method of treating water in oil-rich areas, encouraging a harmonious coexistence of business, the environment, and sustainability. The results of this study could have a significant impact outside of the lab and provide a workable answer to one of the greatest environmental problems of our day.
- Oil-exporting countries like the KSA may embrace ferromagnetic-based water treatment to protect natural resources, improve their international standing, and encourage responsible environmental stewardship.

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