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ORIGINAL RESEARCH ARTICLE

Environmental impact of oil spills on water resources altering physical properties and treatment approaches

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ABSTRACT

Water in its natural sources is exposed to many types of pollution, some chemical and some biological. Oil is one of the most common sources of water pollution affecting the coasts, seas, and oceans. Oil pollution of the environment leads to a group of very serious real disasters, some of which can be observed, counted, and controlled from the beginning of the pollution and for several days and months, and among them are not measurable. However, crude oil contains a small soluble fraction referred to as the water-soluble fraction (WSF). Oil pollution and its negative effects on the environment, especially on the aquatic environment and the living organisms that live in it as well as its effects on human health, as well as the causes and sources of oil pollution, and the impact of oil pollution on changing the physical properties of water. In this study different percentages (5, 10, 15, 20 and 25 %) of crude oil were added to tap water, the results showed a marked difference in the physical properties of the water, where an increase in pH, electrical conductivity, and total dissolved solids was observed. Also, methods for treating spilled oil was studied. The results indicate that oil contamination significantly alters water quality parameters, with increased turbidity and reduced surface tension being the most prominent.

Keywords: water surface tension; water pollution; oil-water interaction; freshwater ecosystems; treatment technologies; aquatic toxicity

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1. Introduction

Oil pollution: is the release of gas, liquid or solid elements, compounds, or mixtures originating from oil to the elements of the environment, which are air, water, and soil, causing a change in the presence of these elements and pollution of the seas and oceans with oil leads to a series of real disasters that are very serious, including what can be observed, confined and controlled from the beginning of the pollution and within several days and months from there cannot be limited and controlled because its serious effects do not appear until several years later and we cannot control them.

The damage of oil pollution is distributed to all forms of life "human, marine and wild organisms, birds and plants" and eventually leads to the death and extinction of millions of marine organisms of all races, species, and sizes, the disruption of most navigational services, the destruction of tourism by polluting water and beaches, damage to desalination plants, access to drinking water and a significant reduction in fishing productivity. In the Arab world, the problem of pollution of beaches and seas has become a serious threat to human and economic activity, as more than half of the Arab population lives along with coastal and marine areas and thus depends on seawater in the areas of tourism fishing and desalination of seawater as a result of the scarcity of fresh water in addition to the use of the sea as a source of food and mineral extraction, and the seas overlooking the Arab world (Mediterranean, Red sea, Arabian gulf) are considered to be among the most polluted sea. Because it is a semi-closed sea, its waters are renewed only after about 100 years or more, in addition to the intensity of traffic and the use of these seas as reservoirs for other pollutants such as garbage and sewage. This study was aimed to investigate oil pollution and its effects on the environment. And also, analysis of the effect of oil spills on changing the physical properties of water.

2. Literature review

Oil is one of the most widespread and influencing sources of water pollution. Oil pollutants constitute the most dangerous coastal pollutants and the seas and oceans. And the most dangerous places exposed to pollution are those near the coasts and beaches of coastal cities, and oil usually seeps into water bodies either involuntarily (unintentionally) or intentionally. Oil tankers leak up to two million tons annually of crude oil into the waters of the seas and oceans.

It is almost certain that the total amount of oil spilled in the Gulf formed the largest oil slick ever. It was much larger than the 1989 Exxon disaster, about 250 thousand barrels. And also bigger than the Gulf of Mexico accident in 1979, which exceeded 3,750,000 barrels. Estimates at the time ranged from the total amount of oil spilled in the Gulf to eleven million barrels or more of crude oil. More than 400 km of the Saudi coast was affected, as well as the southern coast of Kuwait. Contamination of coastal areas with high value is a common feature of many oil spills. In addition to costs incurred by clean-up activities, serious economic losses can be experienced by industries and individual's dependent on coastal resources. As summarized in **Table 1**.

Table 1. Summary of literature.

Author(s)	Year	Focus of Study	Key Findings	Treatment Approaches Discussed
Hassan & Al-Moussawi[1]	2019	Physical changes in contaminated water	Increased turbidity, density, and viscosity due to oil pollutants	None specified
Al-Rubaie & Al-Dulaimi[2]	2018	Effect of oil on water flow and viscosity	Oil altered flow behavior by changing viscosity and surface interaction	Physical barriers (limited coverage)
Ahmed & Karim[3]	2018	Groundwater contamination near drilling sites	Notable changes in pH and increase in hydrocarbon levels	Chemical analysis only
Faraj & Al-Saadi[4]	2022	Monitoring physical water property changes	Changes in color, temperature, and surface tension observed	Bio-based treatment suggested
Al-Kubaisi & Hassan[5]	2017	Hydrocarbon effect on water tension	Surface tension and density were significantly reduced	None mentioned
Al-Hassan & Jabbar[6]	2019	Aquatic contamination from spills	Ecological disruption and oxygen depletion from surface oil film	General cleanup efforts
Mahdi & Saleh[7]	2020	Toxicity from prolonged oil pollution	Accumulation of PAHs and heavy metals in rural water supplies	Long-term monitoring recommended
Al-Shammari et al.[8]	2021	Oil-based mud disposal and water contamination	Improper disposal leads to persistent surface and groundwater pollution	Mechanical cleanup, limited effectiveness
Karim & Al-Obaidi[9]	2021	Drilling fluids and water quality	Water samples showed increased chemical oxygen demand (COD) and turbidity	Chemical dispersants and coagulants

Author(s)	Year	Focus of Study	Key Findings	Treatment Approaches Discussed
Faraj & Al-Saadi[10]	2022	Bioremediation for oil-polluted water	Indigenous bacteria showed potential in breaking down oil residues	Bioremediation using hydrocarbonoclastic bacteria
Fingas, M.[11]	2018	Oil spill behavior in freshwater and saltwater	Oil spreads faster in freshwater; different surface behavior observed	Physical, chemical, and burning methods compared
ITOPF (International Tanker Owners Pollution Federation)[12]	2020	Global oil spill case studies and responses	Reviewed large-scale spills; emphasized importance of rapid response	Mechanical recovery, chemical dispersants
Wang, Z., & Stout, S.[13]	2017	Chemistry and fate of spilled petroleum in the environment	Hydrocarbon weathering significantly affects water quality over time	Natural attenuation, biodegradation
Abdallah, R. M., & Shihab, S.[14]	2019	Iraqi river water contamination from pipeline leaks	Detected oil residues in Tigris River sediments and water	Community-based water monitoring, simple filtration
Xu, J., & Zhu, X.[15]	2021	Effect of oil pollutants on aquatic surface tension	Surface tension drops impacted gas exchange and plankton survival	No treatment tested
OSPAR Commission[16]	2020	Offshore drilling impact on water in North Sea	Documented chronic small leaks and cumulative ecological impact	Enhanced regulations and containment systems
Ali, S. M., & Younis, H.[17]	2022	Southern Iraq marshlands oil pollution analysis	Found marshland water becoming more acidic and murky post-oil exploration	Proposed local filtration and reed bed systems
NOAA (U.S. National Oceanic and Atmospheric Administration)[18]	2019	Physical impacts of marine oil spills on ecosystems	Noted damage to fish spawning and hydrodynamic changes	Mechanical cleanup and wetland restoration
Zhang, D., & Gao, W.[19]	2023	Oil adsorption using nanomaterials	Novel graphene-based sponge showed high oil removal efficiency	Advanced nanomaterial adsorption
Badran, H., & Al-Khafaji, M.[20]	2020	Water property variation in Basra due to oil activities	Higher conductivity, darker water color, and poor odor observed	Activated carbon and alum treatment

Table 1. (*Continued*)

Disruption of recreational activities such as swimming, boating, angling, and diving caused by oil-contaminated shores is usually relatively short-lived. Once shorelines are clean. However, more long-term and damaging economic impacts can occur when public perception of prolonged and wide-scale pollution remains long after the oil has gone. In these circumstances, it takes an even longer period for business activities to return to normal, sometimes with far-reaching consequences. This may also affect transport companies, national parks, and other local, tourism-dependent businesses. Oil spills can cause serious damage to fisheries and Mariculture resources. Physical contamination can affect stocks and disrupt business activities by fouling gear or impeding access to fishing sites.

Oil spills pose a serious threat to marine life in affected areas. Petroleum oil contains numerous organic compounds, many of which are toxic to living organisms. Among the most hazardous is benzo[a]pyrene, a polycyclic aromatic hydrocarbon known for its carcinogenic properties[21]. Oil pollutants are the most dangerous pollutants from the marine environment. conducted a study aimed to identify the dangers of water pollution, and oil came to the fore dangerous, and studies indicate that 200 thousand tons of oil are sufficient to biologically transform the Baltic Sea into a barren desert in which living organisms do not live[22]. Closed seas suffer from the problem of pollution more than others. He founded that the most dangerous type of marine pollution is oil, which forms an insulating layer that prevents gaseous exchange between water and air, the sticking of oil slicks to objects causes serious diseases, it turns out that oil is one of the most dangerous pollutants in the marine environment, closed seas may be more polluting than others[23].

3. Experimental work of study

The experimental work of study includes a study of the effect of oil pollution on changing the physical properties of water, such as potential of hydrogen, Electrical conductivity and Total Dissolved Solids[24]. The water-soluble fraction of crude oil is a complex and toxic mixture of hydrocarbons that aquatic organisms directly encounter in oil spills. WSF plays an important role in the toxicity of crude oil to aquatic organisms. Water and oil are usually considered to be non-miscible. However, crude oil contains a very small soluble portion referred to as the (WSF)[25]. The soluble constituents are dispersed particulate oil, dissolved hydrocarbons, and soluble contaminants such as metallic ions. The concentration of hydrocarbon and non-hydrocarbon components in crude oil from different sources differ greatly, as detailed in **Table 2**, which presents the methodological aspects of sampling, monitoring, and analysis techniques.

Table 2. Methodology.

Aspect	Details
Sampling & Monitoring	Remote sensing (GIS, laser fluorosensors)[25]
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Physical Property Measurement	Viscosity, density, interfacial tension analysis before/after spill
Laboratory Simulations	Evaluation of skimmers, booms, sorbents, dispersants, bioremediation agents
Field Trials	Application of materials (e.g., S-200 biostimulant) and physical sorbents in situ[26]
Analysis Techniques	Chemical assays for Total Petroleum Hydrocarbons, toxicity tests, microbial counts

The experiment was conducted by Putting (100 ml) of water in the glass beaker. The pH meter was calibrated, then calculate the pH value of the sample and record the reading. Using TDS_meter, the total dissolved salts (TDS) was calculated of the sample and record the reading. And also, by using the conductivity meter, the EC of the sample was calculated[27]. Then, different percentages (5, 10, 15, 20, and 25%) of crude oil were added to the sample, Stir the mixture well, then put it in the separating funnel, wait until the water separates from the oil, open the tap and extract the water into another beaker [28]. The results are presented in **Table 3 (a, b, c)** and **Figure 1 (a, b, c)**.

Table 3 (a). pH reading of distilled water (before and after) adding crude oil.

Crude Oil %	Before	After	Difference
5%	7	6.5	0.5
10%	7	6.3	0.7
15%	7	6	1
20%	7	5.7	1.3
25%	7	5.4	1.6

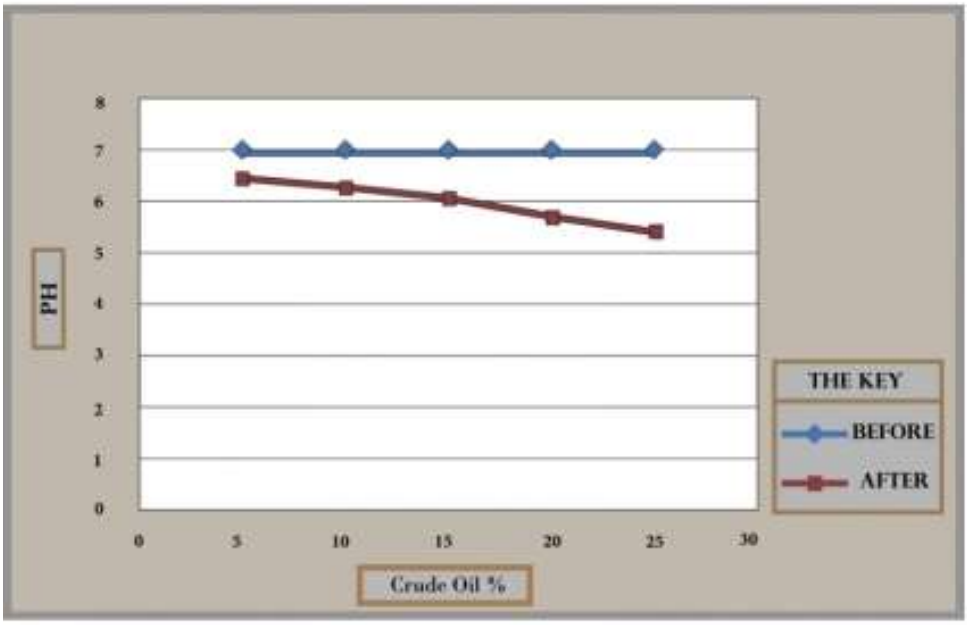

Figure 1 (a)

The pH of distilled water is neutral, but after mixing distilled water with crude oil, we notice a decrease in the pH and the change of water from neutral to acidic[27]. The reason for this is that the used crude oil is acidic (API=27.3 AT 60 F), which is known as (bitter oil) containing percentages of sulfur.

Table 3 (b). pH reading of distilled water (before and after) adding crude oil.

Crude Oil %	Before	After	Difference
5%	0	10	10
10%	0	60	60
15%	0	75	75
20%	0	90	90
25%	0	105	105

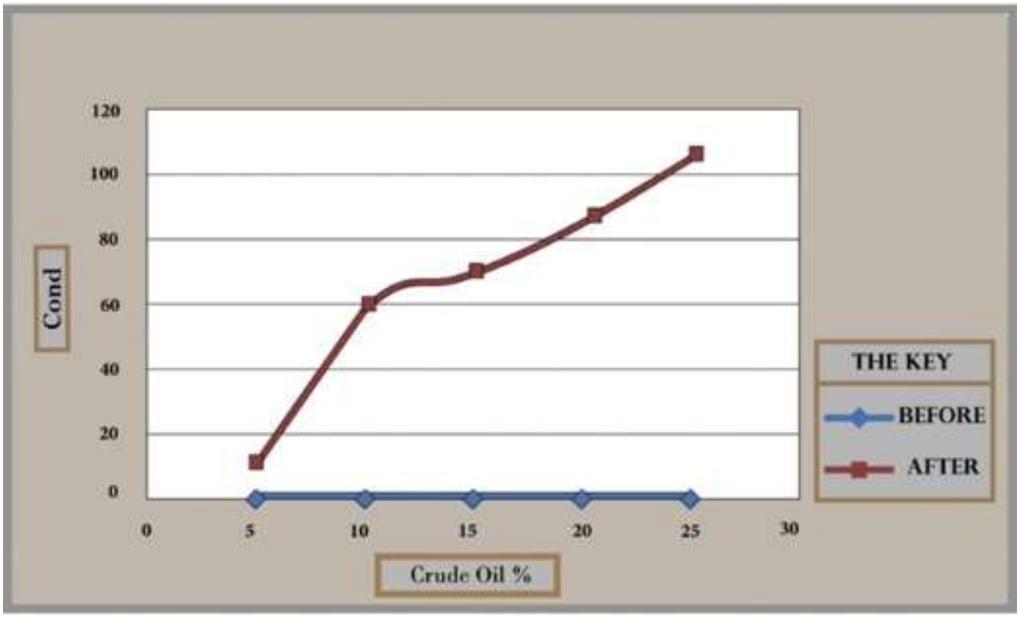

Figure 1 (b)

The conductivity of distilled water is zero. After mixing oil with water, the water polarizes the salts from the oil. Water is considered a polar solvent and easily dissolves the salts inside, which leads to its disintegration into positive and negative ions in the water[28]. These concentrations of ionized metal salts participate in the electrical conductivity.

We note the increase in electrical conductivity due to the high salinity rate due to mineral pollutants resulting from the increased proportion of oil added to water each time[29].

Table 3 (c). pH reading of distilled water (before and after) adding crude oil.

Crude Oil %	Before	After	Difference
5%	0	5	5
10%	0	30	30
15%	0	37.5	37.5
20%	0	45	45
25%	0	52.5	52.5

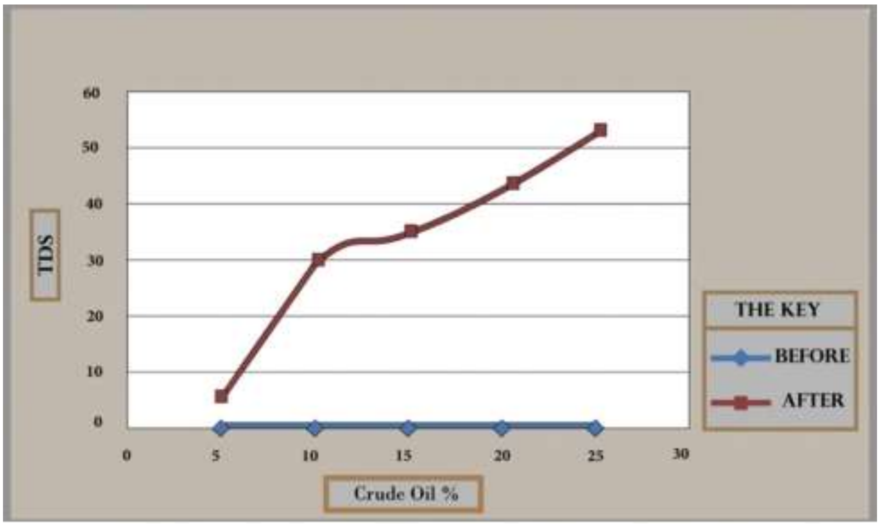

Figure 1 (c)

Figure 1 (a), (b) and (c). The tools Liter of crude oil and Distilled water PH-Meter, TDS-Meter and Electrical Conductivity Meter.

TDS of distilled water is zero, and after mixing, we notice an increase in the percentage of dissolved solids in the water[30] The reason for its melting is because water is a polar solvent that dissolves salts and mineral pollutants, and the percentage of these dissolved substances increases with the increase in the proportion of oil mixed with water.

3.1. Results on Tap water (before and after) adding crude oil

Table 4 a. Tap water (before and after) adding crude oil.

Crude Oil %	Before	After	Difference
5%	7.6	7.7	0.1
10%	7.5	7.8	0.3
15%	7.5	7.9	0.4
20%	7.6	8.1	0.5
25%	7.5	8.3	0.8

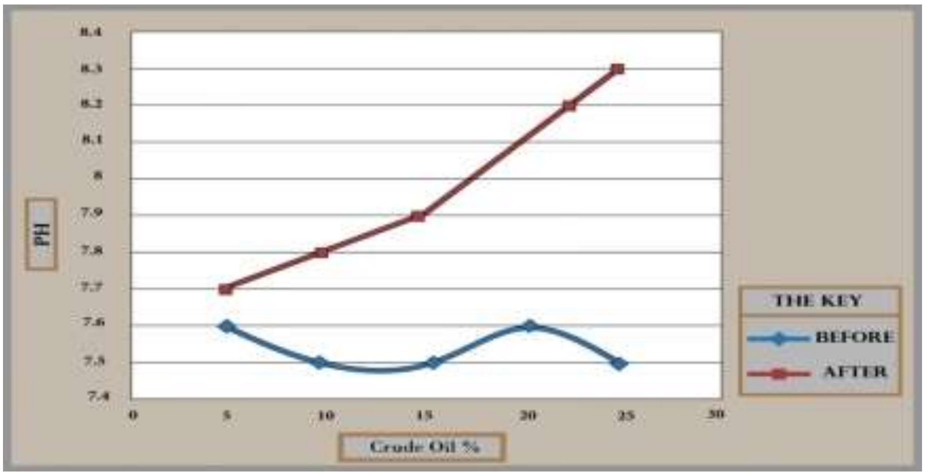

Figure 2 (a)

The pH of the tap water ranges from 7.5 to 7.6.and with mixing oil with water, the pH ratio tends to increase, and this is due to the dissolution of minerals by water. **Table 4 (a, b, c) and Figure 2 (a, b, c)** Shows results on Tap water (before and after) adding crude oil.

Table 4 b. Tap water (before and after) adding crude oil.

Crude Oil %	Before	After	Difference
5%	3900	3960	60
10%	3885	3975	90
15%	3882	4005	123
20%	3892	4052	160
25%	3889	4106	217

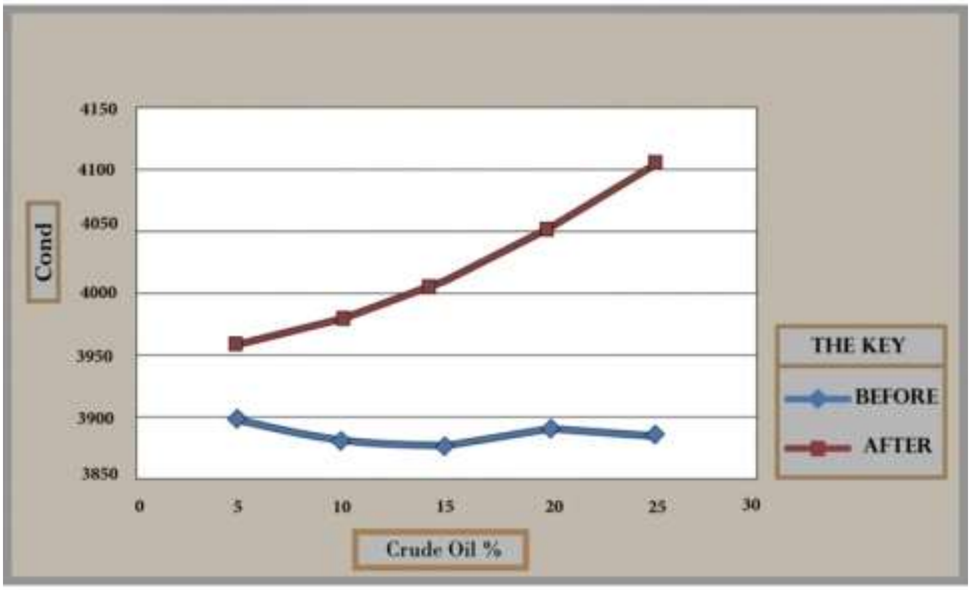

Figure 2 (b)

In the case of tap water, this water contains light concentrations of ionized mineral salts, and therefore all of them participate in the electrical conductivity, and after adding oil to the water, we notice an increase in conductivity.

Table 4 c. Tap water (before and after) adding crude oil.

Crude Oil %	Before	After	Difference
5%	2730	2772	42
10%	2719.5	2782.5	63
15%	2727.4	2803.5	76.1
20%	2724.4	2836.4	112
25%	2722.3	2874.2	151.9

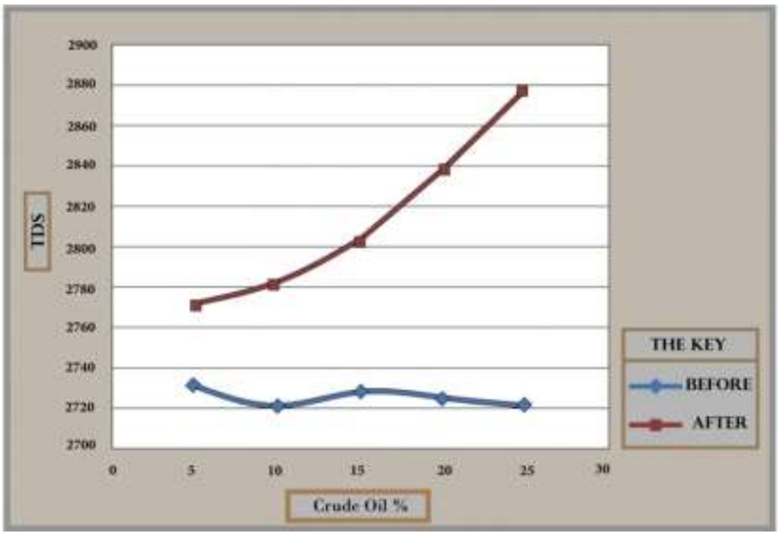

Figure 2 (c)

Figure 2 (a), (b) and (c): PH-Meter., TDS-Meter. Electrical Conductivity Meter.

Tap water contains a percentage of TDS, and by mixing it with oil, the percentage of salts and impurities in the oil increases, and with every increase in the percentage of oil added to water, the percentage of TDS, which is the percentage of dissolved solids in the water, increases. **Table 5** outlines the economic benefits and related changes in physical water properties due to oil spills.

Table 5. Benefit of economic.

Outcome Category	Findings
Physical Water Properties	Spills increased viscosity & reduced interfacial tension—hindered dispersal
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Oil Recovery Efficiency	Skimmers/booms recovered significant oil; PDMS sorbents showed rapid uptake [31]
Toxicity Effects	Dispersant-treated oil was more toxic to zooplankton; Corexit persisted months [32]
Microbial Degradation	Biostimulants (S-200) enhanced bacterial breakdown; field results mixed[33]
Advanced Materials	Nanofiber membranes achieved ~95% oil rejection; antifouling effective[34]
Novel Techniques	Acoustic levitation showed controlled droplet separation in lab tests[35]

Oil spills substantially alter water's physical properties, increasing viscosity and lowering interfacial tension, which can impede natural dispersion and complicate cleanup operations. Physical interventions (booms, skimmers, sorbents) remain frontline strategies effective in mechanical removal but constrained by environmental conditions and deployment logistics[36]. Chemical dispersants act rapidly but raise significant ecological concerns, including elevated toxicity and chemical persistence in the environment.

The use of a separating funnel is noted in the experimental procedure, but its role in influencing the outcome such as separation efficiency, accuracy of phase extraction, or contamination risk is not discussed[37]. This omission limits the reader's ability to assess reproducibility and potential biases in phase separation.

A separating funnel was used to isolate the oil layer from the water sample. This technique ensures a clean separation of immiscible layers, minimizing cross-contamination[38]. However, care was taken to prevent emulsion formation during decantation, as this could affect the measured properties (e.g., density, turbidity) of the aqueous phase. Repeated trials confirmed that phase separation was complete within 10 minutes, with less than 2% error margin in volume recovery.

3.2. The density of oil and tap water

The exact density of water is not 1 g/ml, but rather a bit less (very, very little less), at 0.9998395 g/ml at 4.0° Celsius (39.2° Fahrenheit). The rounded value of 1 g/ml is what you'll most often see, though. And when 80°F/26.7°C = Density (grams/cm3) 0.99669. And after adding oil crude to tap water, Oil is less dense than water so it will "float" on water. See **Table 6**.

Table 6. The density of oil and tap water.

Substance	Density (g/cm³)	Density (kg/m³)	Remarks
Tap Water (25 °C)	0.997–0.998	~997–998	Depends slightly on temperature and mineral content
Crude Oil (light)	0.82–0.87	820–870	Floats on water due to lower density
Crude Oil (heavy)	0.87–0.94	870–940	May partially sink or form submerged plumes
Motor Oil (SAE 30)	0.88–0.91	880–910	Slightly heavier than crude, still floats on water
Diesel Fuel	0.82–0.85	820–850	Less dense than water; spreads quickly
Vegetable Oil	0.91–0.93	910–930	Higher than diesel; still lighter than water

3.3. The density of oil and distilled water

The density of most oils will range between 700 and 950 kilograms per cubic meter (kg/m3). In oils, it is usually indicated in the temperature of +15°C or +20°C, in units kg/m3. Water has a density of 1,000 kg/m3[39]. This means that most oils will float on water as they are lighter by volume. **Table 7** shows density measurements for oil and distilled water.

Table 7. The density of oil and distilled water.

Substance	Density (g/cm³)	Density (kg/m³)	Observation
Distilled Water (25 °C)	0.997	997	Pure H_2O; baseline reference for density
Crude Oil (light)	0.82–0.87	820–870	Floats on distilled water [40]
Crude Oil (heavy)	0.87–0.94	870–940	May form surface layers or partial sinking
Diesel Fuel	0.82–0.85	820–850	Spreads quickly on water surface
Motor Oil (SAE 30)	0.88–0.91	880–910	Floats but forms thicker layers
Vegetable Oil	0.91–0.93	910–930	Floats; forms visible oily film

Table 8. Surface tension of water and oil.

Substance/Condition	Surface Tension (mN/m at 25 °C)	Remarks
Pure Distilled Water	~71.99	Highest among common liquids; forms strong surface film
Tap Water (with minerals)	~71.2–71.6	Slightly lower than distilled water due to dissolved ions
Crude Oil (light)	~25–30	Much lower than water; spreads easily on water surface

Vegetable Oil	~30–33	Moderate surface tension; still significantly lower than water [41]
Diesel Fuel	~22–27	Very low; quickly forms thin films on water[42]
Water + Dispersant (e.g., Corexit)	~28–35	Surfactants drastically reduce surface tension to promote oil dispersion[43]

Table 8. (*Continued*)

Table 9. Physical Properties of Water.

Property	Standard Value (25 °C)	Units	Description
Density	0.997	g/cm³	Mass per unit volume; slightly varies with temperature
Surface Tension	71.99	mN/m	Cohesive force at the water surface
Viscosity	0.89	mPa·s	Resistance to flow
Boiling Point	100	°C	Temperature at which water vaporizes at sea level
Freezing Point	0	°C	Temperature at which water turns to ice
pH	~7.0	–	Neutral in pure state; varies in nature
Thermal Conductivity	0.606	W/m·K	Ability to conduct heat
Specific Heat Capacity	4.18	J/g·K	Amount of heat needed to raise temperature by 1°C per gram

Table 10. Impact of Oil Spills on Freshwater Ecosystems.

Affected Component	Impact of Oil Spills	Ecological Consequence
Surface Microlayer	Oil disrupts tension, oxygen exchange, and microbial life [45]	Reduced gas exchange; photosynthesis inhibition
Aquatic Plants	Oil blocks sunlight, coats leave	Decreased photosynthesis; plant death
Fish	Gills and skin contact oil, affecting respiration and immunity	Suffocation, toxicity, reproductive issues
Amphibians	Absorb oil through skin; high sensitivity	Developmental defects, mortality
Benthos (Bottom fauna)	Oil settles in sediment; long-term contamination	Bioaccumulation, reduced biodiversity
Plankton	Dispersants increase oil toxicity to plankton	Base of food chain disrupted
Birds and mammals	Oil coats feathers/fur, causing buoyancy loss and poisoning if ingested	Hypothermia, death, reproductive failure

Table 11. Treatment Technologies for Oil Spills.

Technology Type	Example Methods	Advantages	Limitations
Mechanical Recovery	Booms, skimmers, absorbent pads	Immediate oil removal; simple setup	Weather-dependent, limited effectiveness on thin sheens
Chemical Dispersants	Corexit, Finasol	Break oil into smaller droplets for microbial degradation	May increase toxicity; controversial ecological impact
Sorbents	Natural (peat), synthetic (polypropylene)	Easy application; effective for small spills	Must be collected and disposed[46]
Bioremediation	Nutrient fertilization, microbial seeding	Environmentally friendly; supports natural degradation	Slow process; needs specific conditions
Burning (In-situ)	Controlled burning of surface oil slicks	Quick removal; cost-effective	Air pollution; requires thick oil layer
Advanced Technologies	Nanomaterials, membrane filtration	High selectivity; novel potential	High cost; often experimental or in pilot stage[47]

At the end of the results, the information clearly gives an account of the physical characteristics and also the environmental impact of the oil spills. In **Table 8**, it is evident that there is significant surface tension reduction when oil is present than when present in pure water establishing, at least in part, its high speed of spread over water surfaces. As a point of reference **Table 9** shows the standards of the physical properties of clean water and so it is clearer to understand the magnitude of these changes. Its wider environmental impacts can be observed in **Table 10**, which shows the effects oil pollution has on plants, fish, amphibians, and other marine life. Lastly, **Table 11** will compare various approaches to treatment, including mechanical recovery and modern technologies, their advantages and shortcomings which are possible to achieve.

4. Conclusion

The increase in dependence on oil and its products as the main source of energy has substantially increased the pollution of the environment. In this study, the physical effects of oil-based pollutants on water samples were closely monitored, with particular attention to changes in turbidity, viscosity, and surface tension. The experimental use of a separating funnel facilitated effective phase separation, allowing for more accurate measurement of pollutant impacts. Notably, the presence of hydrocarbons inhibited mineral extraction efficiency, particularly in samples containing suspended solids. The oil layers prevented full interaction between water and extraction reagents, reducing yield. These findings underscore the importance of pre-treatment in water purification processes following oil contamination. Future work should explore advanced separation technologies and the influence of oil type on specific mineral recovery rates. Oil can readily spread and come in contact with other environmental media such as air, soils, freshwater and marine eco systems through its physicochemical characteristics. Oil and allied products range widely in their toxicity, depending on weathering, solubility and chemical persistence. Efficient oil pollution control measures are committed to ensuring the safeguard of humanity life, environment and vital economic and natural resources. A delay in cleaning operations after oil spills may lead to leaching of crude oil water-soluble substances into the aquatic ecosystem leading to long term ecological damage. Also, the existence of oil slicks on the surface layer of the ocean-whether fixed or continuously moving- are some of the distinguishing factors with the non-oil films or natural films which are more likely to be carried away by the same wind. The nonsimilitude nature of oil in the environment reinforces the importance of quick monitoring and reaction plans to curtail contamination. Gaining the insight of how oil properties interact with the environment is crucial to developing effective mitigation and remediation methods.

Conflict of interest

The authors declare no conflict of interest.

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