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Remediation of Oil Spill Contaminated Water Using Spent Vegetable Oil

*T. M. Gesa, N. Surma& A. U. Itodo
Department of Chemistry, Joseph Sarwuan Tarka University, P.M.B 2373 Makurdi, Benue, Nigeria
*Correspondence E-mail: missyteci@gmail.com

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Abstract
This research investigates the remediation of oil spill-contaminated water using spent vegetable oil. The studies evaluated the efficiency liquid-liquid extraction process by comparing the physicochemical parameters including pH, conductivity, density, viscosity, acid value, total soluble solids (TSS), total dissolved solids (TDS), and turbidity, at different spent vegetable oil-to-oil spill water ratios of 100:10, 500:10, 1000:10, 1500:10 and 2000:10. The physicochemical anlysis results after the extraction with spent oil shows: pH (-52.386%), conductivity (99.311%), density (9.246%), viscosity (99.949%), acid value (99.907%), TSS (99.936%), TDS (99.838%), and turbidity (85.377%). These results indicate a promising approach for remediating oil spill-contaminated water to produce good-quality water suitable for domestic use.
Keywords: Remediation, oil spill, contaminated water, spent vegetable oil

Introduction

The majority of our surface water in oil-borne areas are severely contaminated with various contaminants, including dissolved and dispersed oils, as a result of crude oil activities [17]. An estimated 10 million metric tons of petroleum hydrocarbons are imported annually. Transportation-related activities, spills from tanker uploads or emptying, accidents in the oil industry, discharge during extraction, distribution, storage, and usage, and pipeline ruptures—which may be caused by industrial waste like leaks from engines, mishandled valves, vandalism of pipe lines, and the discharge of oily waste—account for the majority of these spills. This pollutant renders our soil unusable and endanger the lives of humans and aquatic wildlife. The effects of oil spills across oceans and seas on the environment and economy call for immediate action. There is always a chance that oil will spill during the production, storage, transportation, or use process, which could have a negative effect on the environment. Over time, spilled oil contaminates the food chain, posing a threat to human health and the environment. Thus, if oil spills are not cleaned up as soon as possible, they continue to endanger both people and animals and create serious environmental issues [6].

Despite efforts made by researchers to find solution to the menace of oil spill, sustainable oil clean up approach remains a massive challenge. Chemical dispersants, containment (oil booms), mechanical recovery (skimmers and separators), surface washing, solidifiers, trunk vacuums, enzyme, collecting agent, and bioremediation are some of the conventional methods that have been employed over time. Chemicals and traditional mechanical techniques were also embraced and applied for cleanup. Many elements, such as the temperature of the water, proximity to the shoreline, amount of the spill, kind of oil, density, waves, weather, currents, influence the methods and efforts for cleanup activities [8]. These factors create limitations for effective oil spill clean-up. The conventional methods use for oil spill clean-up are less effective in removing smaller oil droplets and oil emulsions. Hence, in the research work, spent oil from fried ice fish was employed for the remediation of oil spilled water. Spent vegetable oil contains chemical complex formed by emulsifiers called micelle, micelle is a spherical structure composed of emulsifier molecules typically surfactants that arrange themselves to enclose a core of one liquid phase within another liquid phase [11].

Materials and Methods

Materials

All materials and reagents used for this research work were of analytical/standard grades. These include oil spill water, spent vegetable oil, HCl, phenolphthalein indicator, ethanolic KOH, etc.

Sample collection

Oil spill water was collected from Bonny land and spent oil from fried vegetable oil was collected from fried fish sellers in the local markets in Makurdi (Benue State).

Treatment and physicochemical analysis of the spent vegetable oil

The spent oil was filtered with a mesh of 0.2 mm to remove particles and thereafter divided into two portions of 50 mL each. One of the portions was used in the physicochemical analysis of the oil. Then, the second portion (50 mL) was measured into a separation funnel and mixed with 100mL of water for 10 minutes and allowed to settle and the water allowed to let out. This was done many times to ensure that all the water-soluble minerals were dissolved and eliminated with the distilled water mixture.

Physicochemical parameters of oil spill water and the treated water

The following physicochemical parameters were done on both the untreated and treated oil spill water samples.

a) Iodine value

About 0.2g of spent oil was dissolved into 15 mL carbon tetrachloride in a conical flask and 25 mL WIJS solution was added and stoppered. The content was mixed vigorously and 20 mL of 10% potassium iodide solution and 15 mL water was added. A blank was also prepared concurrently, both were placed in a dark room and allowed to stand for at least 1hr. this was to allow for complete reaction between the double bonds of the oil and the liberated iodine to a pale yellow colour. At this point, a few drops of starch indicator solution were added and titrated against standard 0.1 sodium thiosulphate to a blue end point. The iodine value was then calculated using the expression [3]:

Iodine value =m (a-b)* 126.9*100/1000/w. (1)

b) Acid value

About 3g of the spent oil was weight into a conical flask and 50 mL of absolute alcohol added. This was heated on a water bath at 40^{o}c for half an hour to dissolve the oil completely.it was allowed to cool and then titrated against 0.1M ethanolic KOH using phenolphalein indicator until a pink colour which lasted for at least 30 second was observed. A blank titration was carried out concurrently. The acid value was then calculated using the expression:

AV (*mgKOH*/*g*) = (a-b) m*56.1/w (2)

Where a is volume of KOH in mL for blank, b is volume of KOH in mL for test M is molarity of KOH, w is weight of the spent oil sample (g)and molar mass of KOH=56.1 [2].

c) Viscosity

Red alcohol thermometer with a range of -10 to 120^{o}c was inserted into 50cm3 of spent oil sample for 5 minutes and the temperature was recorded, then a digital viscometer with appropriate spindle at 60rpm was used to determine the viscosity of the respective samples [13].

d) Density

The specific gravity of the oil was determined by conventional method. The oil was vacuum filtered to remove any suspended particles. The weight of 50 mL empty density bottle will be taken and recorded as W_o. The density bottle was first filled with water, weighed and recorded as w_i. An equivalent quantity of spent oil weighed as w_q, the density of the oil was determined using the expression:

Specific density = $(w_i - w_0)/(w_q - w_0)$ (3)

Where w_0 is weight of empty density bottle (g), w_i is weight of empty density bottle with water (g) and w_q is weight of density bottle filled with spent oil (g) [13].

e) Oil water percentage

The spent oil was shaken to homogeneous and 50 mL was loaded into a funnel of known weight. The water after settlement, was eluted leaving only the oil in the funnel. The funnel with the left oil was weighted and the percentage calculated [5].

f) Total solids (TS) and Total suspend solids (TSS)

A 250 mL beaker was rinsed and labeled, spent vegetable oil sample was mixed thoroughly on a magnetic stirrer for 2 hours at ambient temperature which was later poured into the labeled beakers. 100 mL of homogenized spent oil sample was poured into a 250 mL beaker. The solution was filtered on a screen filter paper into a cleaned grease free weighed Pyrex beaker bit by bit. The filtrates were evaporated on a water bath, dried in the oven at 60^{o}c, cooled in a desiccator avoiding stain and the beaker was re-weighed. The gain in weight of beaker is equal to the total soluble solid per one gram of sample. (TSS) readings was taken and recorded, the unit of measurement is mg/l. Total solid test was conducted to determine the concentration of both suspended and dissolved solids in spent oil sample, the TSS and TS was determined using the mathematical formula below [13].

TS= TSS+TDS (4)

g) *pH value*

A pH meter was activated in deionized water and was calibrated with buffer solution of pH 4.2 and 9.2. The pH of the spent oil was measured at ambient temperature of solutions by dipping the pH meter electrodes into the solution till a stable reading was observed and recorded [16].

h) *Odour test*

A clean glass was fill with spill water and a good swirl was taken to releases any possible odour, then a deep sniff was taking to determine if there is any noticeable smell. If there is, it might be an indication of impurities or contamination in the water.

i) *Electrical conductivity*

This test was carried out to determine the concentration of the dissolve mineral salt and to determine the ionic effecting spill water sample. The conductivity was determine using conductivity meter (Starter model 300). Spill water sample of 20 mL was measured and dispensed into the labelled beakers. The meter will be switched on and its probe rinsed with de-ionised water, and probe was inserted into the spill water samples, and the read button was pressed on the meter to take the reading. The unit is us/cm (micro-Siemens per cm) [17].

Remediation Procedure

The separation technique in the setup containing a separation funnel was connected end-to-end. The top separation funnel (1) was fill with the petroleum oil spillage water and with opening for drop – to – drop of the waste water into the down funnel, (2) which was half filled with treated spent oil. The funnel 2 was open to dropping at controlled rate into a beaker. The procedure is presented in Figure 1.

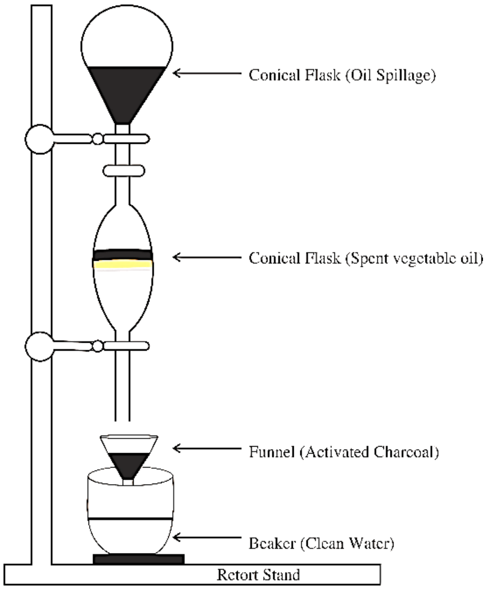

Figure 1: Remediation experiment using liquid - liquid extraction technique

The conical flask which contains the oil spill contaminated has a control outlet which is been let out drop by drop into the flask containing the spent vegetable oil. Spent vegetable oil contains chemical complex formed by emulsifiers called micelle, micelle is a spherical structure composed of emulsifier molecules typically surfactants that arrange themselves to enclose a core of one liquid phase within another liquid phase. Here is how the micelle structure work in terms of clean-up process. The micelle contains hydrophilic head which is the polar – loving part of the emulsifier molecule, this faces outward interacting with the surrounding water phase.; the hydrophobic tail which is the non-polar water repelling part of the molecule which faces inward interacting with the core liquid phase, and the core; which as the last phase, is the inner phase which can be oil or another non-polar liquid which encapsulated by the emulsifier molecules.

The remaining part of the oil spill water which cannot be removed by this process is then passed through the funnel which contains the activated charcoal to give clean water.

This micelle can form various shapes such as: spherical micelles, cylindrical, vesicles (hollow spheres) and liposomes (bilayer vesicles). These emulsifiers form micelles to stabilize emulsions, reduce surface tension, increase solubility and enhance chemical reaction.

Results and Discussion

These results include their pH value, conductivity, density, viscosity, acid value, total soluble solid and total dissolved solid. The oil spill contaminated water was kept constants at ratio of 10, while the spent vegetable oil was given the ratios 100, 500, 1000, 1500 and 2000 respectively.

Table 1: Physicochemical parameters of treated oil spill water using treated spent vegetable oil ratios

S/N	Parameter	Oil spill water/Treated spent oil						
		Oil spill waters Mean ±S.D.	*100:10* Mean ±S.D.	*500:10* Mean ±S.D.	*1000:10* Mean ±S.D.	*1500:10* Mean ±S.D.	*2000:10* Mean ±S.D.	WHO Permissible limit
1	pH(32∘C)	4.466±0.0	6.900±0.0	6.800±0.0	6.833±0.0	6.7666±0.0	6.7333±0.0	6.5-8.5
2	Conductivity (µs/cm) (32∘C)	27412.670±9.0	183.333±1.5	185.660±2.3	186.660±1.1	190.330±1.5	198.333±5	180 -1000
3	Density (g/V) (32∘C)	1.096±0.0	0.998±0.0	0.997±0.0	0.994±0.0	0.994±0.0	0.992±0.0	0.9970
4	Viscosity (Pa.S) (32∘C)	47.273±0.1	0.020±0.0	0.020±0.0	0.020±0.0	0.030±0.0	0.030±0.0	0.89
5	Acid Value (1.0 mg NaOH)/g	15.036±0.0	0.010±0.0	0.011±0.0	0.014±0.0	0.016±0.0	0.018±0.0	6.5-8.5
6	Iodine Value (mg/100l)	10.996±0.1	-	-	-	-	0.200±0.0	90-200
7	Total Suspended Solid (TSS) (g/100mL)	40.301±0.0	0.011±0.0	0.012±0.0	0.012±0.0	0.014±0.0	0.078±0.1	25
8	Total Dissolved Solid (TDS) (g/100mL) (32∘C)	19.510±0.0	0.113±0.0	0.011±0.0	0.011±0.0	0.011±0.0	0.009±0.0	10
9	Turbidity (NTU)	0.350±0.0	0.163±0.0	0.018±0.0	0.021±0.0	0.033±0.0	0.020±0.0	5

Discussion

Physicochemical parameters of remediated oil spill water using treated spent vegetable oil

pH: According to results, the water contaminated by the oil spill had an average pH of 4.4666, with a standard variation of ±0.0. Because the pH of the water is lower than the WHO permissible limits of 6.5 to 8.5, thus it may have a terrible taste and smell and may damage pipes or other water-carrying appliances, making it not suitable for use [7]. But after the treatment with spent vegetable oil with the result in Table 1 at various ratios of 100:10, 500:10, 1000:10, 1500:10, and 2000:10. The average pH values of 6.900±0.0, 6.800±0.0, 6.833±0.0, 6.766±0.0, and 6.733±0.0 were noted, indicating that all samples are within the WHO's acceptable range of 6.5-8.5.

***Electrical conductivity**:* The findings indicate that the water contaminated by the oil spill has a very high electrical conductivity of 27412.67 ±9.00 µs/cm. Nonetheless, 180-1000 µs/cm is the conductivity range that the WHO permits. A high electrical conductivity means that there are a lot of dissolved ions in the water, including salt, minerals, or other materials that may conduct electricity. According to [4], its high electrical conductivity makes it unsuitable for use. However, from the results in Table 1,after treating the oil spill contaminated water with spend vegetable oil the average value of electrical conductivity gotten was 183.330, 185.666, 186.666, 190.330, 198.330 µs/cm at the ratios of 100:10, 500:10, 1000:10, 1500:10 and 2000:10 respectively. This indicates that all the mean value is within. The WHO permissible limits and the water can be suitable for domestic used but not for drinking.

***Total suspended solids (TSS)**:* The mean value of total suspended solids is 40.30107±0.0 g/100 mL. In comparison to the WHO permitted limit of 25 g/100 mL, max. This is high. It follows that elevated TSS levels may lessen light penetration through the water columns, which may have detrimental effects on photosynthesis in aquatic plants and algae and ultimately damage aquatic food chains as a whole. In a similar vein, elevated TSS can lead to water oxygen depletion, which harms fish. According to Muhammad *et al*., 2020; high TSS can have a detrimental effect on taste, fragrance, and appearance. It can also clog filtration systems, which increases the danger of flooding situations .nevertheless from the analysed results in Table 1, the mean values of TSS are 0.012±0.0 g/mL, 0.012±0.0 g/mL, 0.014±0.0 g/mL, 0.078±0.0 g/mL using the ratios of 100:10, 500:10, 1000:10, 1500:10 and 2000:10 thus indicating that all the values are within the WHO permissible limits and caused lower growth medium for bacterial and microorganisms in water.

Total dissolved solids (TDS): Table 1 shows that, the water has a total dissolved solid (TDS) of 19.51067±0.0 g/100mL compare to WHO permissible limits which is10 g/100mL max. High TDS levels can affect the corrosion of infrastructure and pipes, particularly in systems that use metal pipes and equipment. High TDS concentration can also cause suspended solids to precipitate out of the water and settle in tanks or pipes. Drinking such water may cause health problems like gastro-intestinal discomfort, dehydration and other adverse health impacts. Hence, TDS analysis can help determine the appropriate treatment method such as filtration, distillation or reverse osmosis required to purify drinking water [15]. Thus, the mean value of TDS value gotten was 0.011±0.0, 0.113±0.0, 0.113±0.0, 0.011±0.0, 0.001 ±0.0, 0.009±0.0 g/100mL from the treated water which is within the WHO limit.

***Turbidity**:* From Table 1, the oil spill contaminated water has a mean turbidity value of 0.35 ± 0.0 NTU which shows that the value is within that of WHO permissible limits (5 NTU) max. This indicates that the oil contaminated water is relatively clear and had low levels of suspended particles or solids. This is generally considered safe for consumption and other uses. It also suggests that the water is less likely to contain harmful microorganisms, as they are often associated with particulate matter. However, turbidity is not the only parameter used to determine water quality [15].

***Iodine value**:* The recommended iodine value for drinking water is 10 mg/100l [14]. This guideline takes into account the daily iodine intake from all sources including food and water. From the results, the iodine mean value was not detected in all ratios of Oil spill water except 2000:10 for which the iodine value of 0.2000 mg/100l was obtained. This value is within the WHO permissible limits, hence the water might be suitable for domestic and agriculture purposes but not for drinking.

***Acid value**:* the acid value obtained from the results in Table 1 shows that the mean acid value obtained from the results are 0.010±0.0, 0.011±0.0, 0.014±0.0, and 0.061±0.0 and 0.0186±0.0 g/mL respectively. Using the ratios of 100:10,150: 10,100:10, 1500:10, 2000:10 The acid value increase as ratios increases even though did not meet the WHO permissible limits standard of 6.5-8.5 g/mL, but believe that with higher ratio a suitable result can be obtained.

***Viscosity**:* The mean viscosity value of the oil spill polluted water in Table 1 is extremely high 47.2733 pa.s, WHO allowed limit of 0.89 pa.s. max Due to its high viscosity, less flow results in higher pumping energy consumption, increased equipment wear and tear, and the addition of chemicals or additives that may alter the buoyancy of aquatic life and objects like ships and submarines [10]. From the results, when the oil spill contaminated water was treated with spend vegetable oil, The mean value of viscosity obtained were 0.020±0.0, 0.020±0.0, 0.020±0.0, 0.030±0.0, 0.030±0.0 pa.s respectively with the ratios of 100:10,500:10.1000:10, 1500:10, 2000:10 this indicate that as the ratios increases the mean value also increase. All the mean values together with their respective ratios are suitable for the treatment of oil spill contaminated water with the best been 0.020±0.0 pa.s at the ratio of 100:10.

Density: Table 1 had a density of 1.0968±0.0g/l, which is higher than the WHO's allowable limit of 0.9970g/l. This suggests that the water tainted by the oil spill has a high concentration of dissolved minerals or other contaminants, which alter the water's flavor and make it less appetizing for domestic use. [1]. The density of water set by WHO permissible limit is 0.997g/mL. the results show that the mean value of density gotten were 0.998±0.0, 0.997±0.0, 0.994±0.0, 0.994±0.0, 0.992±0.0 g/mL respectively using the ratios of 100:10, 500:10, 1000:10, 1500:10, 2000:10 as the ratios kept increasing from 100:10 - 2000:10, the density has a slight decrease but was still within the standard but the best ratio for obtaining the density of water is 500:10 which has the value of 0.997 g/mL same as that of the WHO permissible limits standard.

Conclusion

In conclusion, the result in this study demonstrates the effectiveness of using spent oil to remediate oil spill water. Overall, the findings suggest that spent vegetable oil has significant potential for use in oil remediation and could potentially yield suitable water for domestic purposes on additional treatment. Further research and scaled up studies are recommended to fully realize the potential of spent vegetable oil in this application.

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