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Evaluation of physiochemical properties of crude oil and its impact on water quality

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Abstract

The Nigerian economy has improved overtime due to the prevailing role of Crude oil generation, but its spillage poses a big threat to agriculture and human health in all oil producing regions potentially causing damage to the structure and function of the ecosystem. In this investigation, the physiochemical properties of unrefined petroleum and its conductivity as its impacts on water quality was investigated. Series of tests performed using methods of American Standard for Testing Material (ASTM) to assess the various physiochemical properties of crude oil. Results from this finding reveal that at higher temperature, there is a corresponding increase in the API value across all the samples ranging from 30.70 to 43.70. All crude oil samples analyzed, showed API values greater than 31 with exception of sample C at 15^oC. The results also reveals ranges for the moisture content, freezing point, pour point, Flash point and Specific Gravity as 0.12% to 0.21%, -41.3^0C to -37.5^0C, -10^0C to -7^0C, $+42^0C$ to $+55^0C$ and 0.8364 to 0.9321 respectively. The change in Conductivity values, which varies with different degrees of crude oil contamination, reveals that as the percentage of contamination increases, the conductivity value decreases. This study is appropriately timed as the need to carefully clean crude oil contamination in oil producing areas has been on the increase; thus such research geared towards remediation of such oil contaminated environment should be encouraged towards developing a sustainable environment.

Keywords: Contamination, American standard for testing material (ASTM), crude oil, spillage, exploration.

Introduction

Organic compounds (hydrocarbons), form the major composition in the Crude oil complex mixture of many different chemical components[1]. The Nigerian economy has recorded tremendous growth in her foreign exchange and also having the required source of energy to drive the nation's economy since the discovery and production of crude oil[2]. Application of modern technology in its exploration and production has brought about the lingered damage on the ecosystem. The environmental hazard generated by oil production has been a major source of concern to the people living in such regions as large amount of this product are released into water body from natural and anthropogenic sources, hence threatening global and local environments[3]. Origin and conditions of formation are factors that determine the composition of crude oil[4]. The properties of crude oil, vary from one location to another even at different depths in the same well[5,6]. Certain factors such as permeability, adsorption and partition coefficient of the soil are responsible for such environmental pollution[7]. Thus, it is important that refiners are equipped with the basic knowledge of the composition of crude oil for its maximum usefulness in conversion into high value products[8]. This knowledge can as well enhance effective environmental impact assessment by environmentalist[9]. Crude oil in its sold form is converted to petrochemical feedstock's which forms the basis for most production industries[5,10]. Refining process uses various combinations of processes to rearrange the petroleum molecules into these products[8]. The various processes of cracking, hydro treating and reforming are employed to break large molecules into smaller fractions, create environmentally acceptable products and rearrange molecules to those with high values respectively[11-13]. The basis for exploration, transportation and refinement process is dependent on the knowledge of the physical properties of a particular crude oil[14]. Heavy oil as defined by the American Petroleum Institute has an API index equal to or smaller than 20 degrees[15]. Based on the API index, the Brazilian National Petroleum Agency identifies the various types of petroleum; Light (°API ≥ 31), Medium (22 ≤ °API < 31), Heavy (10 ≤ °API < 22), Extra-heavy (°API ≤ 10)[16]. These parameters are employed in refining and optimization process in crude oil production[17]. Producers depend on the basic physical parameters of crude oil for optimum utilization[18]. Progressive increase in energy demand as a result of economic development driven by population growth has caused the decline in the availability of petroleum resources[16]. Oil exploration impact negatively on the environment if not properly managed. The menace posed by oil spillage in the Niger Delta region is a course of concern; hence an understanding of the physiochemical properties is imperative in evaluating the behaviour of spilled oil in the environment and hence proffering solution. This study will examine some physicochemical parameters of crude oil and its impact on water sample.

Materials and methods

Sample collection and chemical analysis: Sample A, B, C and D are conventional crude oil from Warri, Delta State Nigeria. Evaluation of some physiochemical components of the various samples and also its impact on the electrical conductivity of river water from the area under consideration was carried out. These analyses were carried out using standard operating procedures from the American Standard for Testing Material (ASTM). These Properties include the following; flashpoint (ASTM, D93), Freezing Point (ASTM D2386), pour point (ASTM, D97), Density and Specific Gravity (ASTM, D1217), Distillation (ASTM, D86), API (ASTM, D287), Moisture Content (ASTM D 4298) and Electrical conductivity (ASTM D1125)[19]. Measured densities as a function of temperature was conducted in order to investigate the change in properties with respect to temperature.

Results and discussion

Effect of Temperature on Specific gravity and API values: The temperature variation of the various sample of crude oil as shown in Table-1 reveals that at higher temperature, the specific gravity of the various sample decreases resulting in the corresponding increase in the API value across all the samples ranging from 30.70 to 43.70. All crude oil samples analyzed, showed API values greater than 31 with exception of sample C at 15^{o}C (30.70). Sample C maintained a consistently low API value across the various temperatures for all the samples as shown in Figure-1. The implication of the results, indicates that all samples are classifies as light crude which makes it easy to float on water and also the possibility of containing more volatile components. Results from this finding are in agreement with reports from other study with corresponding increase in the API value with respect to increase in temperature[20].

Table-1: Specific Density and API values of crude Oil Sample (g/ml).

Temperatures	*n*	A		B		C		D	
		Density	API	Density	API	Density	API	Density	API
15^{o}C	3	0.8434±0.02	36.30	0.8312±0.01	38.70	0.8724±0.00	30.70	0.8645±0.11	32.18
30^{o}C	3	0.8391±0.00	37.10	0.8291±0.04	39.20	0.8618±0.12	32.70	0.8521±0.04	34.56
45^{o}C	3	0.8314±0.03	38.70	0.8276±0.13	39.50	0.8602±0.31	33.00	0.8436±0.21	36.23
60^{o}C	3	0.8271±0.01	39.60	0.8231±0.21	40.40	0.8594±0.07	33.15	0.8412±0.03	36.71
75^{o}C	3	0.8194±0.05	41.20	0.8186±0.00	41.36	0.8574±0.10	33.53	0.8378±0.11	37.40
90^{o}C	3	0.8079±0.11	43.70	0.8156±0.45	42.00	0.8531±0.00	34.36	0.8343±0.33	38.10

n = sample size. A, B, C, D = Sample type.

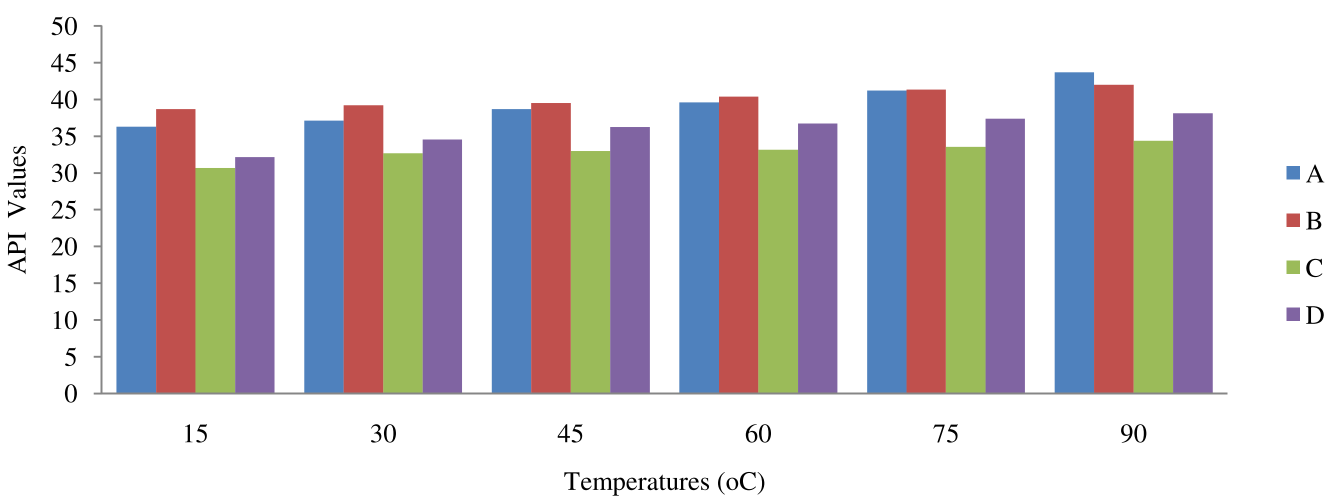

Figure-1: Chart of API value against Temperature.

Physicochemical Properties of Crude Oil Sample: Result shown in Table-2 shows the moisture content value of the various crude oil samples ranging from 0.12% to 0.21%. The results also reveals ranges for the freezing point, pour point, flash point, specific gravity as -41.3^{0}C to -37.5^{0}C, -10^{0}C to -7^{0}C, +42^{0}C to +55^{0}C and 0.8364 to 0.9321 respectively. Also the total distillation reveals results of the Initial Boiling Point (IBP) and End Boiling Point (EBP) ranging from 145^{0}C to 197^{0}C and 309^{0}C to 395^{0}C respectively. The result from this finding reveals low pour point, which could be a clear indication of the presence of low paraffin content and a corresponding high content of Aromatics. Results for the flash point from the findings are higher than results reported in other study[21], likewise the results for the flash point were lower than values reports in other findings[22]. Report from other study stated that the quality specification requires that water content should be < 0.5 vol % to prevent corrosive contaminant of the crudes[23-25]. It can thus be concluded from the result of this finding that the crude oil analyzed is good for pipeline transportation as all the measured crude oil values were found to be below the benchmark of 0.5 vol %.

Effect of degree of contamination on conductivity and pH values of water sample: The results recorded changes in values with respect to change in the percentage of crude oil contamination indicating that as the percentage of contamination increases, the conductivity value decreases. The result from the study as shown in Table-3 reveals progressive changes in conductivity with respect to the degree of crude oil contamination as shown in Table-3. Results from this study also agree with report from other study that describes the purity of water in terms of its decrease conductivity[26]. The trend in the results also indicates that an increasing the percentage of crude oil content in water resulted in a decrease in the conductivity and pH respectively. This relationship could be as a result of the water content acting as a bond droplets and a dispersed phase in the continuous crude oil phase. The result from water-oil emulsion correlation reveals that there is a strong positive correlation at $p<0.05$ with an R^2 value of range 0.983, 0.947, 0.987 and 0.933 as shown in Figure-2, 3, 4 and 5 respectively. The result for the conductivity falls below 1000 µS/cm in other report[27-29]. Conductivity of water is affected by the presence of dissolved inorganic compounds, while the presence of organic compounds do not conduct electrical current very well but responsible for retarding the movements and immobilizing of ions present in the solutions, resulting in low ionic mobility, velocity and electrical conductivity when in water[27]. The pH value from this study falls within the range of 6.5 and above suitable for drinking water to prevent corrosion as recommended by WHO[30].

Table-2: Physicochemical properties of Crude Oil samples.

Sample	Moisture Content (%wt)	Freezing Point (°C)	Pure Point (°C)	Flash Point (°C)	Specific Gravity (60°F)	Total Distilling Unit	
						FBP (°C)	EBP(°C)
A	0.15±0.71	-37.5±0.13	-8±0.02	45±1.45	0.8364±0.01	197±0.34	390±2.34
B	0.21±0.41	-41.3±0.02	-7±0.11	42±0.97	0.9321±0.00	195±0.67	309±1.86
C	0.17±0.31	-40.7±0.11	-10±0.08	55±2.34	0.8745±0.45	145±0.91	395±0,95
D	0.12±0.61	-38.4±0.02	-7±0.04	51±1.56	0.8674±0.33	184±1.23	346±4.23

A, B, C and D = Crude oil Sample, FBP = First Boiling Point, EBP = End Boiling Point .

Table-3: Conductivity and pH Change of drinking water sample contaminated with crude oil.

Degree of Contamination (%)	*n*	pH				Conductivity (µS/cm)			
		A	B	C	D	A	B	C	D
0	3	6.97	6.89	7.01	6.99	71.33	69.88	70.34	72.55
1	3	6.97	6.78	6.96	6.81	68.04	67.56	68.45	62.55
2	3	6.64	6.88	6.88	6.77	59.13	64.89	65.34	54.61
4	3	6.34	6.54	6.79	6.55	50.44	46.24	58.56	46.24
6	3	6.32	6.52	6.57	6.43	42.56	43.78	56.45	43.42
8	3	5.98	6.33	5.99	6.23	34.35	39.21	48.94	39.33
10	3	5.97	6.11	5.89	5.99	29.11	30.77	42.12	27.43

n = sample size

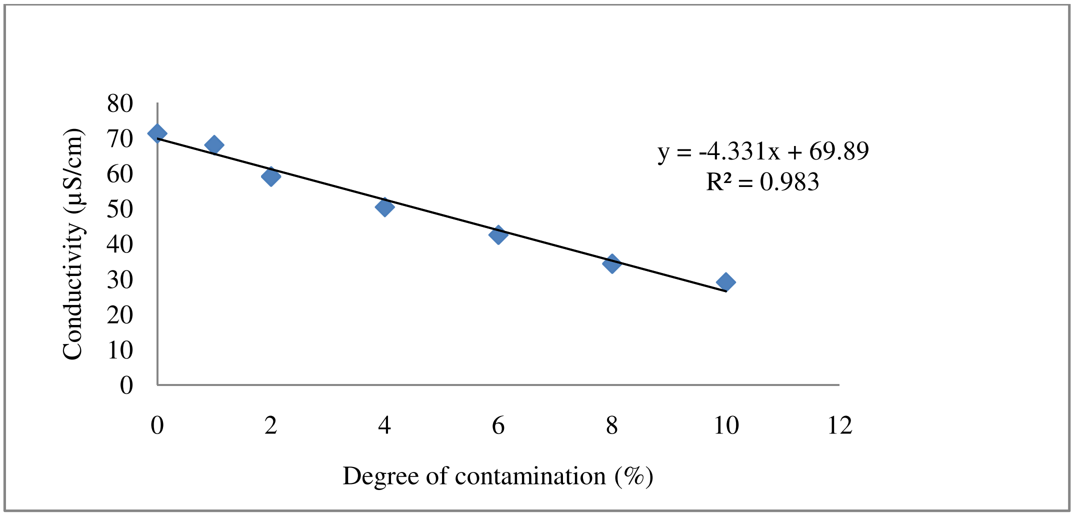

Figure-2: Graph of Conductivity against Crude oil Contamination with sample A.

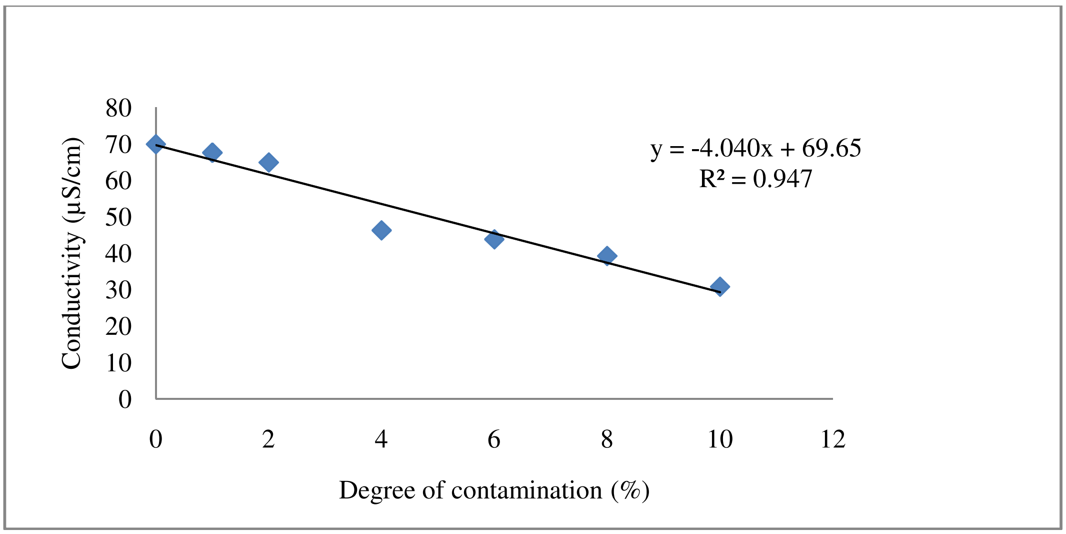

Figure-3: Graph of Conductivity against Crude oil Contamination with sample B.

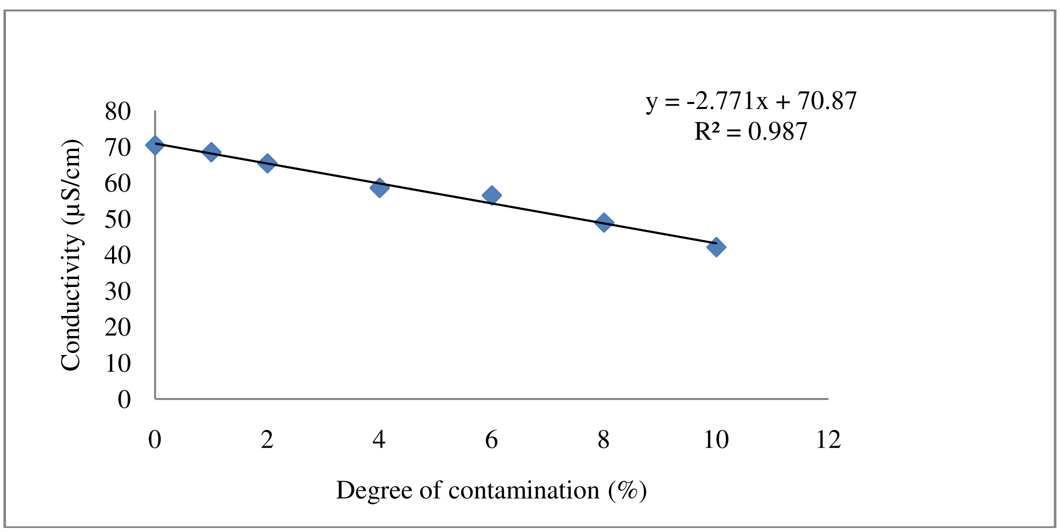

Figure-4: Graph of Conductivity against Crude oil Contamination with sample C.

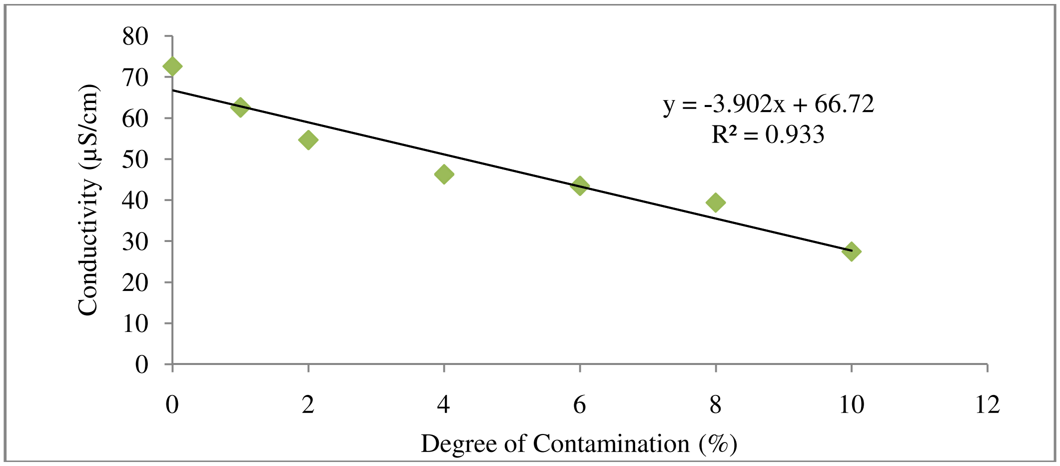

Figure-5: Graph of Conductivity against Crude oil Contamination with sample D.

Conclusion

The problem of oil spillage has been a big threat to both plants and animals in all oil producing countries. Physicochemical parameters are key indicators that are used to monitor and express the level of its applications. The menace caused by oil spillage has been found affecting negatively the regional environment and thus the need to address the problem urgently. The A.P.I value is one of the properties used to measure the economic value of any crude, which was found to be on the increase with increase in temperature, indicating that the crude oils are generally light. In conclusion, appropriate measures should be taken by oil producing companies to reduce the potential risk of water contamination to people living near these drinking water sources.

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