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E-Mail :
editor.ijasem@gmail.com
editor@ijasem.org

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"Integrated Environmental Monitoring of Sediment and Water Quality for Offshore Petroleum Operations".

Alok Kumar khore

Research scholar

Mirzapur Pole, Dist - Saharanpur, U.P. - 247121, India

Dr. Zeeshan Ahmad

Research supervisor

Mirzapur Pole, Dist - Saharanpur, U.P. - 247121, India

Abstract:

Offshore petroleum activities have turned out to be a major economic booster yet at the same time they emy with serious threat to coastal environments due to release of pollutants, especially hydrocarbons, heavy metals and chemical additives. Integrated environmental monitoring involves a plethora of measures to assess sediment and water quality in terms of physical, chemical and biological impacts. The research article will evaluate the effects of offshore petroleum activities on marine environments by performing an organized observation of critical parameters including concentration of hydrocarbons, concentration of heavy metals and level of nutrients and biologic indicators. Its use of in-situ measurement, laboratory analysis identifies the trend of contamination and assesses the possible ecological risks of such contamination and gives recommendations on sustainable offshore petroleum activities. It is pointed out that the results should contribute to the policies of environmental management, regulatory frameworks, and long-term ecological conservation.

Keywords:

Offshore petroleum operations, sediment quality, water quality, environmental monitoring, hydrocarbons, heavy metals, marine pollution, ecological risk assessment.

Introduction: Offshore petroleum activity including petroleum exploration and drilling is significant in providing the increasing energy demands in the world. All this is done in oceans and seas which are distant along the coast and it concerns the extraction of the oil and gas that is located underneath the seabed. Although such operations are beneficial to economic development, employment, and generation of energy, they may cause a negative impact on the marine environment in the event that they are not done well.

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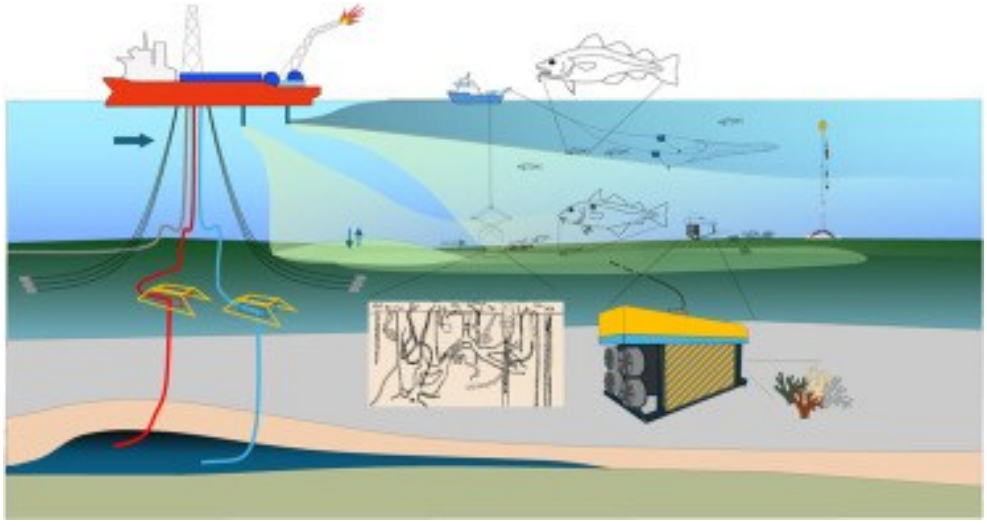
In the process of drilling and production, there might be flow of various forms of wastes and chemicals into the water around. These are oil, drilling flends and produced water (water released alongside with the oil and gas). Such effluents can be polluted with hazardous substances including hydrocarbons, heavy metals, and other chemicals that will pollute the water as well as the ocean floor (sediment).

The sea has a memory in the form of sediment. It is capable of holding the pollutants over a long duration of time and in some cases years before letting it out gradually into the water. The quality of the water is also a crucial point since this aspect immediately reflects on the life of marine beings like fish, corals and planktons. Bad water quality may lead to the depression of oxygen and upset the equilibrium of the ecosystem and be damaging to biodiversity.



Singular effort monitoring both the sediment and water exposes the full picture on the impact of petroleum activities on the environment. When we use water as a single test, then we can miss checking other contamination stored in sediments. On the same note, by simply looking at the sediments we might fail to detect the short-term changes taking place in the water. This is the reason why integrated monitoring checking simultaneously is the appropriate method to grasp the general health of the marine environment.

The area of concern in this research is to study water and sediment quality in sites adjacent to the offshore petroleum industries. The risks that the environment may face can be assessed through measures of the extent of pollution, against safe limits, and the sources to give us an idea of the hazard. The final purpose is to avail information that can guide both the policymakers, the industry operator, and environmental regulators to safeguard marine ecology and still enable viable petroleum development.

Literature Review:

Chouksey et al. (2004) made a close study into petroleum hydrocarbon deposits on the marine environment right in the Bassein-Mumbai area. They found out that oil-related activities lead to the accumulation of hydrocarbons in the sediments which may stay there for a long time, harming the benthic lives. In the research, they also indicated that Hydrocarbons concentration was at its highest close to the oil fields then diminishing as the distance increases I and thus a direct relationship was evident between offshore petroleum activities and marine pollution.

Reddy and Radha Krishnaiah (2007) evaluated the pollution of the heavy metals in the coastal waters and earth of the Bay of Bengal along the east coast of India. They have described high concentration of metals like lead, cadmium, and copper especially in urban shipping, and industrial zones. The paper stated that sediments tend to become long-term sinks of the heavy metals, and because of this, the degree of contamination can be correlated with the state of the environment.

The research undertaken by Jadhav et al. (2015) examines the western offshore region of India and its impacts on the environment due to offshore oil drilling. These drilling practices cause uncountable pollutants that are emitted into the sea such as, pollutants of hydrocarbons and residuals of drilling mud which may destroy the water quality and affect the marine life biodiversity. The results of the study implied that more rigid monitoring and enhancement of waste elimination operations should be used to reduce harm to the environment.

Zingde and Govindan (2000) discussed the coastal water health of the city of Mumbai and its effect on marine life in the coastal waters. Their research identified that water pollution is caused by industrial effluents, sewage wastes, and pollutants of petroleum nature leading to a poor water quality. Disappearance of fish and other marine life was strongly intertwined with this pollution and this necessitated stringent measures in curbing pollution.

Rajamanickam and Nair (2010) were interested in the distribution and enrichment of heavy metals in surface sediments along southwest Indian (west) coast with Arabian Sea having the focus. They found out that leading metals such as zinc, copper and lead were enriched in sediments along industrial centers and shipping routes. The investigation employed pollution indices to determine the level of contamination, which is a scientific point that facilitated the assessment of the risks in the environment.

Dutta and Sahu (2013) conducted an assessment on the sediment quality of heavy metals at the coastal waters off Visakhapatnam located at the east coast of India. They found out that levels of some metals were significantly contaminated and others moderately contaminated, which they attributed to natural sources as those related to human activities such as those that related to port and industrial discharges. They suggested that it should be monitored on a periodic basis in order to monitor the trend of pollution.

The article by Rao and Anjaneyulu (2012) gave an Indian response regarding the study of the impact on environment of oil exploration and production in the offshore areas. They argued about the ecological impacts which may arise due to oil spills, emission of produced water, and drilling wastes. The research highlighted the need to have full environmental management plans, stakeholder engagement and following of global best practices of sustainable offshore operations.

Objectives of the Study:

- To monitor the state of the sediments and water in effected regions due to offshore petroleum activities by physical, chemical and biological testing.
- To determine and quantify the level of such contaminants as hydrocarbons and heavy metals in the sediment and water samples and compare them to the safety standards established by the environment.
- To assess the possible ecological threats of observed pollutants and propose appropriate monitoring and control approaches in a form of pollution to attain sustainable offshore petroleum operations.

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Hypothesis:

- Offshore petroleum operations significantly alter sediment and water quality in the surrounding marine environment.
- Hydrocarbons and heavy metals from petroleum activities accumulate in sediments and water at concentrations exceeding environmental safety limits.

Research Methodology:

This experiment will be conducted in some of the selected zones of offshore petroleum operations and the sampling points will be selected on the basis of its distance to drilling platforms, direction of ocean currents, and the presence of control point devoid of any industrial activity. A Van Veen grab sample will be used to collect samples of the sediment with the top 0-5cm layer being sampled as this is where the most recent deposit of pollutants is likely to be noticed. Niskin bottles will be used to collect water samples at both bottom and surface level, in order to sample water quality with depth. Parameters to be analyzed in the sediment samples relate to grain size, total organic carbon (TOC), heavy metals (or Hg, Pb, Cd, Cu and Zn) and total petroleum hydrocarbons (TPH), whereas parameters to be analyzed in the water samples refer to pH, salinity, dissolved oxygen, turbidity, nutrient concentration (nitrate and phosphate), heavy metals and TPH. Standard methods will be used by way of laboratory analysis of the heavy metals by Atomic Absorption Spectrophotometry (AAS) or Inductively Coupled/Plasma Mass Spectrometry (ICP-MS) hydrocarbons by Gas chromatography-mass spectrometry (GC-MS) and nutrients by UV-visible spectrophotometry. Analysis of the data will be carried out by statistical procedures to establish the extent and trend of pollution with pollution indices like Geo-accumulation Index (Igeo) and Contamination Factor (CF) being used in Sediment analysis data and ecological risk assessment done through Hakanson method. The GIS software will be used to map the extent to which the pollutants are spread in space. The quality assurance will be maintained using duplicate tests, blank and standard reference material. All the procedures will be in accordance with the national and global regulations of environmental surveillance as a way of reducing environmental disruption in the field research.

Table 1: Sampling Details for Sediment and Water Analysis

Sampling Site Code	Location Description	Distance from Platform (km)	Depth (m)	Sample Type Collected

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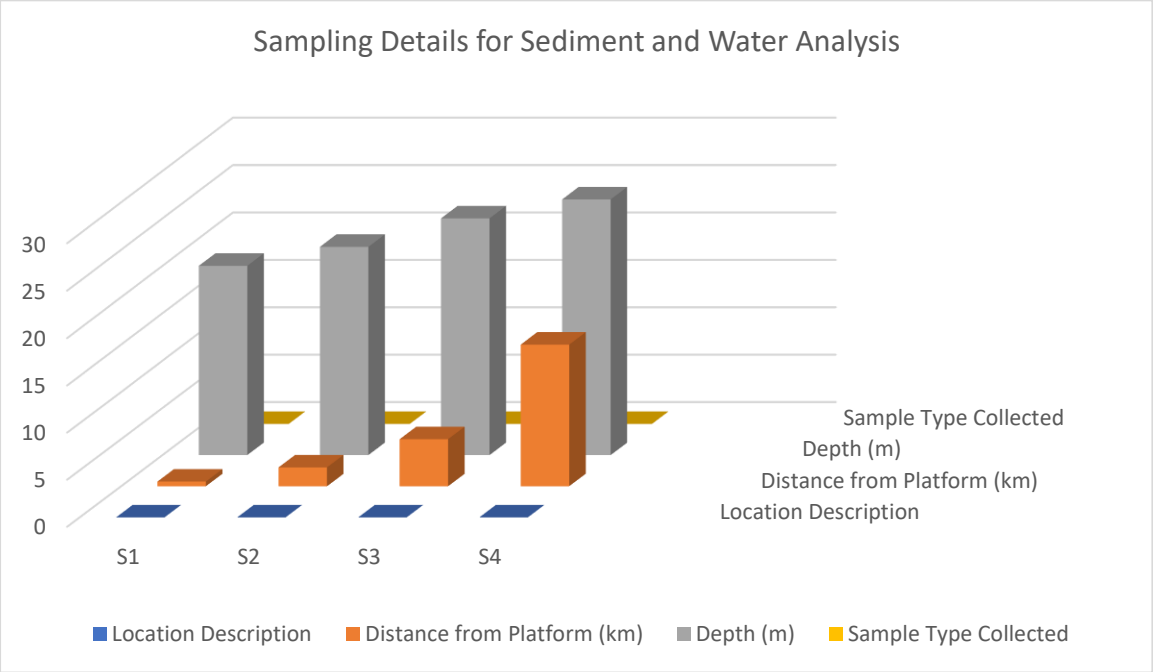
S1	Near drilling platform	0.5	20	Sediment + Water
S2	2 km downstream	2.0	22	Sediment + Water
S3	5 km downstream	5.0	25	Sediment + Water
S4	Reference site (control)	15.0	27	Sediment + Water



Result:

Information about the sampling as indicated in Table 1 indicates that this study sampled four sites, which varied to reflect differences in distance with the offshore drilling platform. The location of Site S1 was extremely near the drilling platform at a distance of 0.5 km and with a water depth of 20 meters whereas site S2 was 2 km downstream with a water depth of 22 meters. The Site S3 was down stream at a distance of 5 km and 25 meters in depth and the reference site S4 was called the control site at a distance of 15 km away to the platform and this site stood at a depth of 27 meters. Integrated environmental monitoring was done in both sediment and water samples at each of the sites; thus the study encompassed an area that is directly affected by the petroleum activities and a relatively unaffected location.

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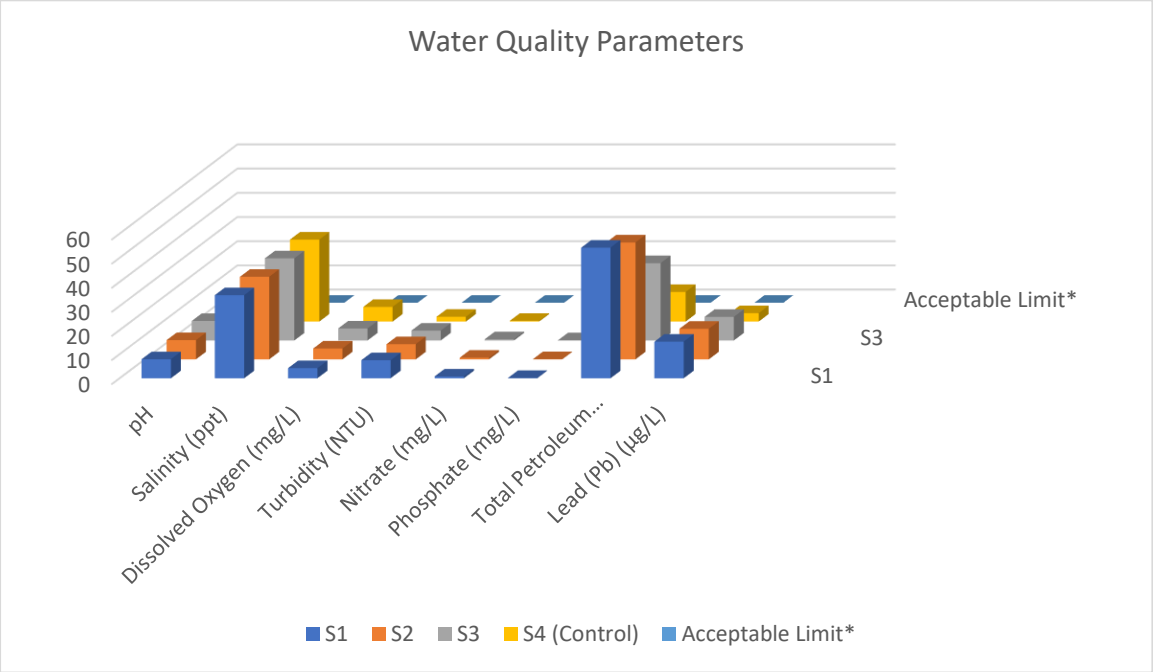
Table 2: Water Quality Parameters

Parameter	S1	S2	S3	S4 (Control)	Acceptable Limit*
pH	7.9	8.0	8.1	8.2	6.5–8.5
Salinity (ppt)	34.5	34.3	34.1	34.0	–
Dissolved Oxygen (mg/L)	4.2	4.5	5.0	6.1	≥5.0
Turbidity (NTU)	7.5	6.3	4.1	2.0	≤5.0
Nitrate (mg/L)	0.75	0.68	0.52	0.30	≤0.5
Phosphate (mg/L)	0.12	0.10	0.08	0.05	≤0.1
Total Petroleum Hydrocarbons (µg/L)	54.2	48.5	32.1	12.3	≤30.0
Lead (Pb) (µg/L)	15.2	12.7	9.8	3.5	≤10.0



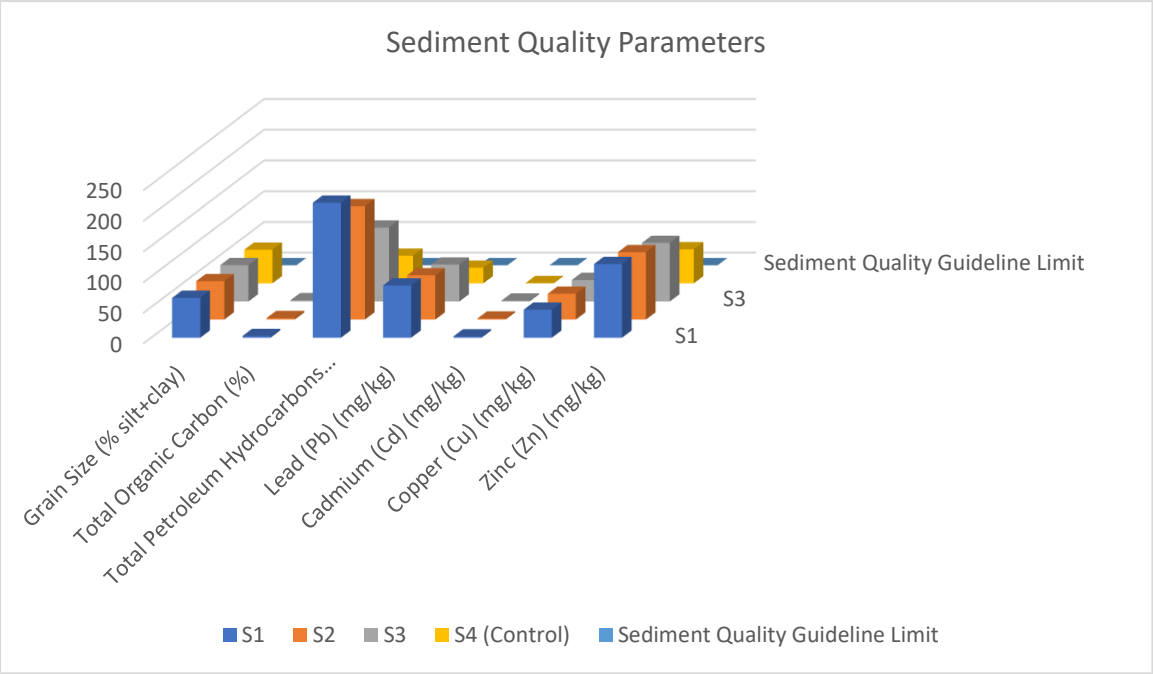
Result:

Analysis of Water Quality (Table 2) revealed that none of the sites deviated significantly in respect to pH and salinity that are within normal values in marine waters. Yet, the amount of dissolved oxygen at both S1 (4.2 mg./l) and S2 (4.5 mg./l) was not beyond the advised minimum of 5 mg./l, and it can be interpreted that depletion of oxygen was a possibility caused

as a result of the decomposition of organic matter and hydrocarbons. Turbidity values were greater at the platform (7.5 NTU at S1) than at the control site (2.0 NTU) which means more suspended materials. The S1 and S2 contained nitrate levels that were above the safe level and the phosphate levels at S1 were above levels allowed. Total Petroleum Hydrocarbons (TPH) water were top at S1 (54.2 0g/L) almost exceeding the maximum limit by 2 times, and as one moved farther away again back the platform, it went down. Of the heavy metals, there was contamination with lead, which surpassed the guideline at both S1 and S2 of water.

Table 3: Sediment Quality Parameters

Parameter	S1	S2	S3	S4 (Control)	Sediment Quality Guideline Limit
Grain Size (% silt+clay)	65.2	62.8	59.4	55.0	–
Total Organic Carbon (%)	2.8	2.5	2.1	1.5	–
Total Petroleum Hydrocarbons (mg/kg)	220.5	185.3	120.7	45.2	≤100
Lead (Pb) (mg/kg)	85.4	72.5	60.3	25.6	≤50
Cadmium (Cd) (mg/kg)	2.1	1.8	1.4	0.5	≤1.5
Copper (Cu) (mg/kg)	45.8	42.3	35.1	18.0	≤35
Zinc (Zn) (mg/kg)	120.4	110.2	95.7	55.6	≤100



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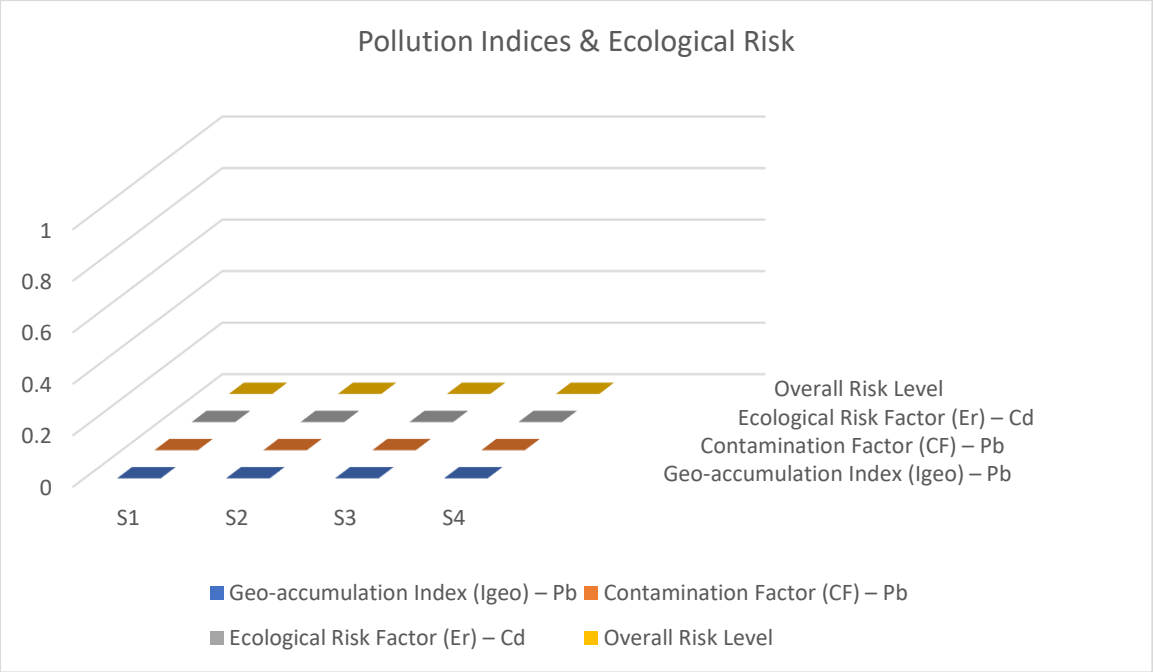
Result:

Results obtained with Sediment Quality (Table 3) showed higher levels of pollutants in the places nearest the drilling lines. Sediment was characterized by Total Petroleum Hydrocarbons which were above twice the safety threshold at S1 (220.5 mg/kg) but the value declined with the distance. The heavy metals under study, like lead, cadmium, copper and zinc were seemingly larger in S1 and S2 relative to the control site, with the Pb surpassing the maximum in all the affected sites. TOC at S1 (2.8) revealed that there was the accumulation of hydrocarbons and organic waste material in the sediment.

Table 4: Pollution Indices & Ecological Risk

Site	Geo-accumulation Index (Igeo) – Pb	Contamination Factor (CF) – Pb	Ecological Risk Factor (Er) – Cd	Overall Risk Level
S1	1.85 (Moderately Polluted)	1.71 (Moderate Contamination)	35.0 (High Risk)	High
S2	1.53 (Moderately Polluted)	1.45 (Moderate Contamination)	30.0 (Moderate Risk)	Moderate
S3	1.20 (Slightly Polluted)	1.20 (Low Contamination)	25.0 (Moderate Risk)	Moderate
S4	0.50 (Unpolluted to Slightly)	0.51 (Low Contamination)	8.0 (Low Risk)	Low



Result:

The results of the Pollution Indices and Risk Assessment (Table 4) proved that S1 had moderate pollution status of lead (Igeo = 1.85) and an ecological risk that was high over cadmium (Er = 35.0). Contamination factor of the lead at S1 (CF = 1.71) depicted moderate contamination. The low contamination and low ecological risk were recorded in the control site (S4).

On the whole, the findings imply that petroleum activity is leading to the build-up of hydrocarbons and heavy metals in water and sediment and contamination increases near to the position of the drilling platform and decreases with distance.

Conclusions Overall Results:

This paper has shown how offshore petroleum activities may affect the quality of the nearby sediment and water immensely. It is evident that the findings indicate high levels of Total Petroleum Hydrocarbons, heavy metals (lead and cadmium in particular), and nutrients around the drilling platform with a decreased level of dissolved oxygen and an increased turbid water. The disposal of pollutants in sediments constitutes a significant waste source, with the retention of the pollution higher than the level of ecological requirements and carrying consequences of the prolonged ecological danger to benthic organisms.

The higher contamination gradient that is evident by S1 to the control site also implies that the main contributor of these pollutants should be the petroleum operations. According to the ecological risk assessment, some heavy metals, especially cadmium is a high hazard to the marine environment and oxygen depletion and hydrocarbon cause organic enrichment.

Such combined monitoring of sediment and water has been critical in providing indication of the short-term and long-term trends of water quality and contamination of sediment. The findings show that the control and monitoring of pollution, constant surveillance of the environment, and enhancement of waste management activities is necessary in the operation of the offshore petroleum industry. Such measures will aid in reducing the ecological abuse, safeguard the biodiversity and the sustaining of the marine resources.

Future Scope of the study:

The research is informative reflecting the impacts of offshore petroleum's activities on sediment and water quality. Similar studies may be implemented in the future with an extended time interval in order to trace seasonal and annual changes of the pollution rate. To sample a broader area and ensure that several depths of water and sediment layers are available, more sampling locations also may be added. The use of more sophisticated monitoring methods like

remote sensing, underwater sensors, etc. can also be used in real-time tracking of pollution. It is also possible to extend the research to observe the effect that these pollutants have on marine flora, fishes and other creatures in order to gain a complete ecological knowledge. Secondly, the results may contribute to the establishment of more rigorous environmental regulations and pollution control techniques so that petroleum activities are practiced in a greener and more sustainable way.

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