American Journal of Environment and Climate (AJEC)

ISSN: 2832-403X (ONLINE)

VOLUME 4 ISSUE 2 (2025)

PUBLISHED BY
E-PALLI PUBLISHERS, DELAWARE, USA

American Journal of Environment and Climate (AJEC)

Volume 4 Issue 2, Year 2025
ISSN: 2832-403X (Online)
DOI: https://doi.org/10.54536/ajec.v4i2.4648
https://journals.e-palli.com/home/index.php/ajec

Coastal Water Quality Assessment of Partially Remediated Oil Spill Site

Regine A. Albios[1*], Judy Marie R. Zoleta[1]

Article Information

Received: March 02, 2025
Accepted: April 06, 2025
Published: May 17, 2025

Keywords
Coastal Water Quality, DENR Compliance, Marine Ecosystem, Oil Spill, Remediation

ABSTRACT

Oil spills are a major environmental catastrophe that poses significant threats to marine life and coastal communities. This study assesses the coastal water quality of a partially remediated oil spill site in Jasaan, Misamis Oriental. Water samples were collected from Kimaya, Luz Banzon, and Solana stations to analyze key physico-chemical parameters, including temperature, pH, salinity, nitrate, total suspended solids, biological oxygen demand, dissolved oxygen, and oil and grease using descriptive comparative research design. According to the findings, the water quality parameters remained within acceptable limits. However, salinity in Station 3 was lower on average and not normally distributed, likely due to local activities. Among all the parameters, only temperature did not significantly differ between stations. However, it stayed within the allowable limits for Class SC waters, as defined by DENR Administrative Order 2016-08. Successful cleanup activities were indicated by oil and grease concentrations that were continuously below the reporting limit (<1 mg/L). The water quality after cleanup has remained stable throughout time, ensuring that it is suitable for marine life and recreational activities. The study emphasizes the importance of community involvement, sustained enforcement policies, and long-term monitoring in maintaining water quality in areas affected by oil spills.

INTRODUCTION

Oil spills from maritime transportation have a huge effect on the economy and environment which can persist for years even with remediation efforts. Accidents involving oil tankers, offshore platforms, pipelines, and even smaller vessels are often the cause of these disasters. The MV Tower 1 vessel, formerly known as the MV Racal IV, had a hole in its hull, resulting in an oil spill incident that occurred on April 3, 2021, which affected the livelihoods of most residents in the barangays of Jasaan. The residents in the said barangays have expressed concern that the poisoning of seas and shorelines can cause significant losses whose coastal economies rely heavily on fishing and tourism. Hence, it threatened their primary sources of income—fishing and tourism. When oil spills get into the environment, it wreaks havoc on ecosystems. In the ocean, it spreads across the water's surface, polluting habitats and putting marine life at serious risk (Solo *et al.*, 2021). Coastal areas, including fragile ecosystems like mangroves and estuaries, can suffer lasting damage.

The toxic oil contaminates their habitats and disrupts their feeding patterns and reproduction. Thus, the harm doesn't stop at wildlife but also create significant challenges for human communities that rely on these environments. Beyer *et al.* (2016) supports this claim. A recent oil spill incident from the MT Terra Nova, which capsized off the coast of Manila Bay, also prompted urgent efforts to contain and clean up the spilled fuel (Villamor, 2024).

Based on the assessment, the EMB-Region 10 reported that 80 percent of the spilled oil was already removed in the affected areas through remediation. The villagers collected at least 2,000 liters of oil-contaminated seawater from the seafloor using sawdust and mosquito net. As a source of nourishment and food as well as a source of revenue, the locals had to wait until the spill was completely contained before taking a bath or going fishing (Jerusalem, 2021).

Water quality assessment is a vital component of environmental monitoring, providing crucial information on the physicochemical and biological status of aquatic ecosystems. These parameters play a crucial role in evaluating ecological health and determining areas that are partially remediated and may need additional interventions, including the level of environmental awareness (Zoleta & Nawang, 2015).

To evaluate environmental recovery and direct cleanup operations, it is crucial to analyze and monitor the quality of coastal water following oil spills. This study set out the current state of the coastal water quality after the post-oil spill incident.

LITERATURE REVIEW

This study utilized Suter's framework to evaluate water quality post-cleanup, examining residual pollutants and ecological impacts on marine life. By applying the TEA framework, the study provided a systematic understanding of the ongoing ecological risks and recovery stages of the affected ecosystem. The Environmental Monitoring Theories which proposed that water bodies are dynamic systems influenced by both natural and anthropogenic factors, and requires continual monitoring to track variations in water quality over time supported the framework (Jørgensen & Fath, 2011).

To track long-term changes in the quality of coastal water, this study assessed the physical, chemical, and biological

[1] College of Engineering, Liceo de Cagayan University, Philippines
[*] Corresponding author's e-mail: ralbios98272@liceo.edu.ph

properties of water samples including pH, temperature, dissolved oxygen (DO), biological oxygen demand (BOD), total suspended solids (TSS), salinity, nitrate, and oil and grease.

Iloabuchi *et al.* (2024) emphasize that strengthening regulatory frameworks, improving spill response capabilities, and promoting transparency are essential for advancing responsible practices in the petroleum sector. While most of the oil spill incidents are the result of human mistakes, the negative impacts on water quality, such as elevated pollution levels, altered physicochemical characteristics, and disturbances to marine ecosystems, are regularly noted in the literature (Peterson *et al.*, 2003; Whitehead, 2013). Depending on how the oil spill's effects were handled, the influence on water quality was only temporary (Effendi *et al.*, 2022). The study of Bacusa *et al.* (2022) emphasized the importance of bioremediation in this case. Biodegradation and other oil weathering mechanisms play a major role in reducing the amount of oil in the environment. Although biodegradation can mitigate the effects of oil spills, it is still influenced by several physicochemical and environmental parameters.

Low pH values are indicative of both contaminated acid drainage and water that is rich in dissolved organic matter (Ololade & Lajide, 2010). At low temperatures, enzymatic activities associated with oil biodegradation decrease (Bacosa *et al.*, 2018). The greatest bioremediation efficacy was reported in the summer, followed by spring, autumn, and winter, in a study on hydrocarbon bioremediation in seawater that has been simulated to be contaminated by petroleum taken from Tokyo Bay (Aung *et al.*, 2018). Temperature has an impact on the makeup of the microbial community since various bacteria have temperature tolerance (Lui *et al.*, 2017). There are oil spills from boats and residential trash in the water, which will hinder the growth of aquatic plants and the photosynthetic rate, which will lead to low DO (Best *et al.*, 2007). Because the oil coating obstructs the air's diffusion mechanism, it can also directly result in low levels of dissolved oxygen in the water (Ifelebuegu *et al.*, 2017). A large amount of crude oil causes a sudden rise in BOD due to the activity of hydrocarbon-degrading organisms and the reduced oxygen dissolution in the water (Enujiugha & Nwanna, 2004). Because of this, water with a low BOD is of good quality, but water with a high BOD is considered contaminated. Typically, unpolluted natural water has a BOD of 5 mg/l or below. Also, different organic and inorganic elements can be introduced into the water by oil spills, changing the natural equilibrium and raising the total dissolved solids, in turn, will also realize the turbidity of the water (Andalecio *et al.*, 2014).

Most of the time, low to intermediate-salinity waters have the highest rates of oil and mineral flocculation (Daly *et al.*, 2016). Hence, salinity was considered as another important parameter. Nutrients, on the other hand, play a crucial role in the biodegradation of spilled oil. According to recent research, adding nutrients improves the rate at which oil breaks down. For instance (Chen *et al.*, 2020). Oil and grease degrade extremely slowly. Even the smallest film of oil or grease can have an impact on aquatic life (Pintor *et al.*, 2016).

Monitoring a range of criteria, such as chemical contaminants, biological indicators, and physical qualities, is necessary to assess the quality of the water in partially remediated oil spill sites. A thorough picture of the state of the ecosystem and the status of recovery is provided by this multifaceted approach (Owens *et al.*, 2005).

To evaluate the success of cleanup measures and the restoration of water quality, ongoing monitoring is necessary. The significance of a thorough monitoring program that considers physical, chemical, and biological characteristics is emphasized by research conducted by Li *et al.* (2020). These kinds of systems could recognize patterns, spot new problems, and direct adaptable management techniques.

MATERIALS AND METHODS

The descriptive–comparative assessment method was utilized in this study. The research study approaches to obtain the water quality by measured factors include pH, temperature, dissolved oxygen (DO), biological oxygen demand (BOD), total suspended solids (TSS), salinity, nitrate levels, and oil and grease. Chang *et al.* (2021) conducted a study using descriptive-comparative to evaluate the quality of coastal water.

This study was conducted in Jasaan, Misamis Oriental, specifically in the fishing communities where the oil spill disaster occurred three years ago. These communities reside in the coastal barangays of Kimaya, Luz Banzon, and Solana and predominantly depend on marine resources for their livelihoods. Jasaan is located on the island of Mindanao at around 8.6516, 124.7535. It is estimated that the elevation at these coordinates is 19.8 meters, or 64.9 feet, above mean sea level. The research sites' precise locations are shown in Table 1. Figure 1 and 2 on the other hand, shows the locations of the sampling sites and the oil spill sites, respectively.

Table 1: Overview of the locations and characteristics of the sampling stations

Station	Area	Geographic Location	Area Description
1	Kimaya, Jasaan Misamis Oriental	8° 38'41" N, 124° 45'21" E	Less populated but settlements are near the coastline
2	Luz Banzon, Jasaan, Misamis Oriental	8° 38'21" N, 124° 45'41" E	Less populated but settlements are near the coastline
3	Solana, Jasaan, Misamis Oriental	8° 37'26'" N,124° 45' 39" E	Less populated but settlements are near the coastline. Construction and Industrial are also occur near-by the area.

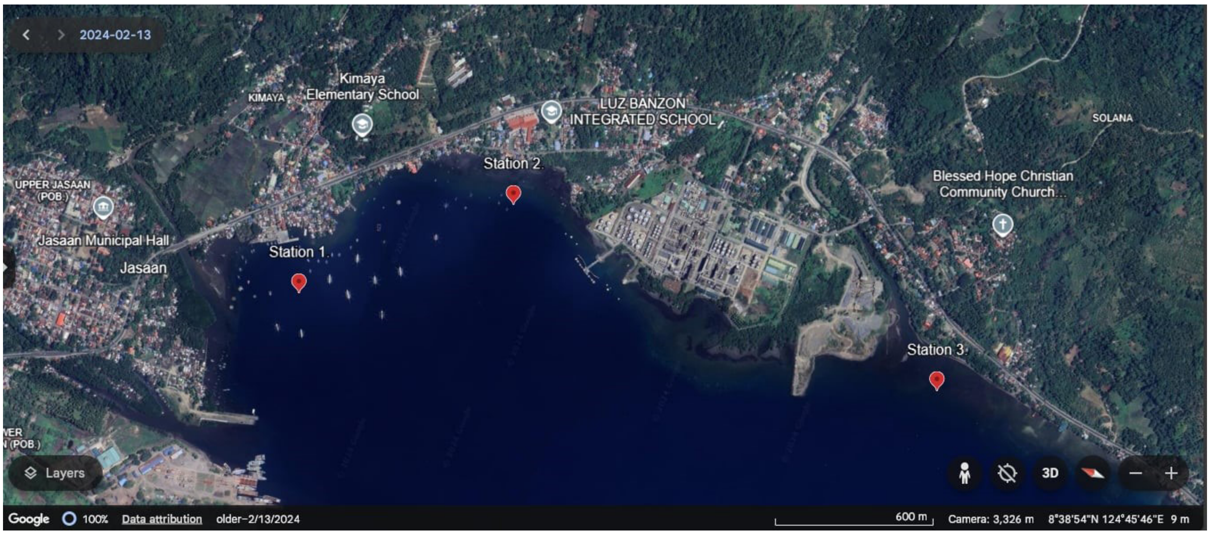

Figure 1: Sampling locations in Jasaan, Misamis Oriental

Figure 2: Oil spill incident in Jasaan, Misamis Oriental

Water samples were collected from the designated sampling sites in Jasaan, Misamis Oriental namely: Station 1 (Kimaya), Station 2 (Luz Banzon), and Station 3 (Solana). The process of collecting water samples was anchored from the study of Suarez and Zoleta (2024) in which sampling was carried out in replicates at each sampling site. Key water quality parameters such as pH, temperature, dissolved oxygen (DO), biological oxygen demand (BOD), salinity, total suspended solids (TSS), nitrates, and oil and grease were measured. The data obtained were compared to DENR administrative standards 2018-06 and consequently subjected to statistical analysis for validation.

The set of data obtained was compared with the DENR-EMB guidelines. The Analysis of Variance (ANOVA) was utilized to validate the results.

RESULTS AND DISCUSSION

Problem 1. To what extent do the water quality parameters vary among the three (3) stations in Jasaan in terms of:

1.1 Physical

1.1.1 Temperature

1.2. Chemical

1.2.1 pH

1.2.2 Salinity

1.2.3 Nitrate

1.2.4 Total Suspended Solids (TSS)

1.2.5 Biological Oxygen Demand (BOD)

1.2.6 Dissolved Oxygen

1.2.7 Oil and Grease?

The mean values for the three Jasaan stations vary during each sampling period, as seen in Figure 5. Additionally, Table 3 shows the summary matrix for both water quality samplings which is a reliable indicator of compliance with DAO 2016-08's criteria for water quality class SC.

The mean temperature across sites is 27.51°C, which is within the acceptable range of 25-31°C, indicating stable thermal conditions that are unlikely to stress aquatic life. The average pH of 8.11 falls well within the permissible range of 6.5-8.5, suggesting no significant acidic or alkaline pollution, thus supporting biodiversity. Salinity averages at 1.82 ppt, significantly below the DENR standard of 30 ppt, which may indicate freshwater inflows or dilution effects from remediation efforts, potentially altering the saline habitat and making it less saline. Nitrate concentrations are low at 0.16 mg/L, well below the allowable 10 mg/L, reflecting minimal nutrient loading and reducing eutrophication risk. The level of total suspended solids (TSS) is 9.67 mg/L, which is much lower than the 80 mg/L threshold that is advised. This implies that remediation is effective in reducing sediment-related contaminants. The average Biochemical Oxygen Demand (BOD) is 5.27 mg/L, compliant with standards and suggesting a manageable organic load for oxygen recovery essential for aquatic life. Dissolved Oxygen (DO) measurements show an average of 5.24 mg/L, compliant with the minimum standard of 5 mg/L.

Additionally, the Oil and Grease (O/G) test results reported as less than the reporting limit or less than 1mg/L, suggest that concentrations are minimal or undetectable. This is a positive indicator of the remediation's effectiveness in addressing hydrocarbon contamination, which is a primary concern following an oil spill.

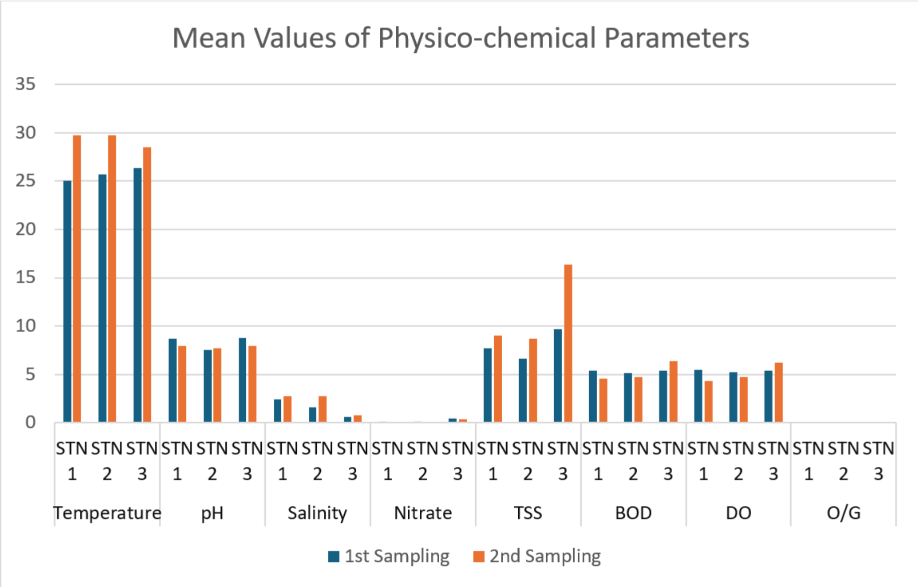

Figure 3: Summary results of the Physico-chemical parameters

Table 3: Summary Matrix of Overall for both Sampling of Water Quality Results versus DENR Water Quality Standards

Parameter	Station 1	Station 2	Station 3	Avg. Mean	DAO2016-08	Remarks
Tempera-ture (°C)	27.38	27.72	27.42	27.51	25-31	Compliant
pH	8.32	7.62	8.38	8.11	6.5-8.5	Compliant
Salinity (ppt)	2.59	2.17	0.70	1.82	30	Compliant
Nitrate (mg/L)	0.023	0.047	0.408	0.159	10	Compliant
TSS (mg/L)	8.33	7.67	13.00	9.67	80	Compliant
BOD (mg/L)	5.01	4.93	5.88	5.27	7 (C)	Compliant
DO (mg/L)	4.92	4.99	5.82	5.24	Min. 5	Compliant
O/G (mg/L)	<1**	<1**	<1**	<1**	3	Compliant

***Reporting Limit*

Salinity and Biochemical Oxygen Demand (BOD) measurements were included in the current parameters, providing a more comprehensive assessment of water quality of partially remediated oil spill site. While some of the values for all parameters are in their normal range, some are extremely low, and some are near the recommended maximum limit. As to the Oil and Grease, the values are the same as the when the water body was remediated. Table 4 shows the results of the analysis of

Table 4: Results of Jasaan Sea Water Analysis in 2021

Parameter	Station 1	Station 2	Station 3
Temperature (°C)	30	30.5	30.5
pH	8.3	8.3	8.3
Salinity (ppt)	—	—	—
Nitrate (mg/L)	0.27	0.19	1.20
TSS (mg/L)	9	9	5
BOD (mg/L)	—	—	—
DO (mg/L)	8.4	8.5	7.5
O/G (mg/L)	<1**	<1**	<1**

Source: DENR-EMB Region X

Jasaan sea water after oil spill incident. Overall, it can be inferred that the oil spill site was perfectly maintained from the time it was remediated until the time of sampling

Problem 2. Is there a significant difference in the water quality of Jasaan coastal waters across stations in terms of the parameters?

Table 4: Results of Jasaan Sea Water Analysis in 2021

Parameter	Source	Sum of Squares	df	Mean Square	F	Sig.	Remarks
Tempera-ture	Between Groups	0.404	2	0.202	0.046	0.955	No Significant Dif-ference ($p > 0.05$)
	Within Groups	66.045	15	4.403			
	Total	66.449	17				
pH	Between Groups	2.164	2	1.082	6.091	0.012	Significant Differ-ence ($p < 0.05$)
	Within Groups	2.665	15	0.178			
	Total	4.829	17				
Salinity	Between Groups	11.917	2	5.959	39.197	0.0001	Significant Differ-ence ($p < 0.05$)
	Within Groups	2.280	15	0.152			
	Total	14.197	17				
Nitrate	Between Groups	0.559	2	0.280	74.952	0.0001	Significant Differ-ence ($p < 0.05$)
	Within Groups	0.056	15	0.004			
	Total	0.615	17				
TSS	Between Groups	101.333	2	50.667	7.862	0.005	Significant Differ-ence ($p < 0.05$)
	Within Groups	96.667	15	6.444			
	Total	198.000	17				
BOD	Between Groups	3.368	2	1.684	9.144	0.003	Significant Differ-ence ($p < 0.05$)
	Within Groups	2.762	15	0.184			
	Total	6.131	17				
DO	Between Groups	3.008	2	1.504	6.239	0.011	Significant Differ-ence ($p < 0.05$)
	Within Groups	3.615	15	0.241			
	Total	6.623	17				

The findings shown in Table 3 indicated that, except for temperature, there is a statistical difference in stations. This indicates that there are no appreciable differences in temperature among the three stations. Additionally, it shows values that are substantially distinct from one another but still fall within the normal range. As a result, certain values are both higher and within the range. These discrepancies are explained by the different activities and conditions in each sampled site.

A significant spatial variation in pH values ($p = 0.012$) occurred across all sampling sites. A pH variation can result from natural buffering, pollution, or industrial discharges. As highlighted by De-la-Cruz and Quijano (2021), a stable pH within this range is essential for biological functions such as respiration and reproduction in aquatic organisms. The salinity levels measured have high variation between stations but stable and within limit. Salinity shows a highly significant difference among stations, as indicated by a p-value of 0.0001 ($p<0.05$). Stable salinity is crucial for species sensitive to salinity fluctuations, such as corals and mangroves (Jiang *et al.*, 2020).

With nitrate, the results show a significant difference across stations ($p=0.0001$), with a high F-value of 74.952. Nitrate concentrations remained well below the DAO 2016-08 standard of 10 mg/L for marine waters. Low nitrate levels are crucial to prevent eutrophication, a process that can lead to algal blooms, hypoxia, and biodiversity loss (Anderson *et al.*, 2021). TSS levels indicate significant differences ($p=0.05$) and were observed to be below 80 mg/L. Low TSS is essential for reducing turbidity, which enhances light penetration needed for photosynthesis in aquatic plants like seagrasses and corals (Li *et al.*, 2021).

As for BOD, it exhibited significant differences across the stations (p=0.003), indicating that differences in organic load and decomposition processes between stations are substantial. Low BOD is critical for maintaining oxygen availability for aquatic organisms. Excessive BOD levels, often linked to organic waste, can deplete oxygen and disrupt ecological balance (Rehman *et al.*, 2021). Dissolved oxygen on the other hand, shows significant variation across stations (p=0.011) but within standard limits. DO levels support aquatic life and are a positive indicator of water quality and ecosystem health. Adequate DO is fundamental for the survival and reproduction of marine species and indicates healthy ecosystem processes like nutrient cycling and organic matter breakdown (Nguyen *et al.*, 2022).

Oil and grease levels were recorded at below 1 mg/L in all stations across months, complying with the DAO 2016-08 standard of 3 mg/L for class SC. This result indicates successful remediation efforts to remove hydrocarbon contaminants. This statement is supported by Kose et. al (2021) that low oil and grease levels are essential to prevent bioaccumulation and toxicity in marine organisms, particularly in fish.

Problem 3. How does the current water quality compare to the conditions after the remediation of the oil spill, and to what extent does it comply with DENR standards? From the results of the laboratory analysis conducted based on the current data collected, it can be inferred that the present condition shown revealed no variances and is as good as when the coastal area was remediated particularly in S1 (Station 1) - Kimaya, S2 (Station 2) – Luz Banzon, and S3 (Station 3) - Solana.

CONCLUSIONS

The extent to which water quality parameters vary in their value is low because all of them are within normal range. Oil and Grease are constantly less than the reporting limit across months in all stations, this signifies a condition that has been the same since after remediation in April 2021. The coastal water quality physical and chemical parameters of the partially remediated oil spill site in Jasaan are compliant with DENR Administrative Order 2016-08 suggesting normal water quality. The analysis of water quality parameters across the three stations demonstrates that while the temperature remains consistent, other key indicators such as pH, salinity, nitrate, TSS, BOD, and DO exhibit significant variability. Incorporating Salinity and Biochemical Oxygen Demand (BOD) as additional parameters in the present evaluation provides a more precise assessment of water quality, enabling a comprehensive understanding of the site's ecological status. These results emphasize the importance of integrating ecological rehabilitation with continuous long-term monitoring to ensure sustained recovery and to identify and address changes in environmental conditions over time.

Recommendations

Based on the findings and conclusion presented, the following recommendations are suggested:

Management Implications

1. The researcher recommends establishing a long-term, comprehensive monitoring program on biological indicator, including heavy metals parameter.
2. The researcher recommends for community engagement by training local communities in pollution monitoring and coastal management.
3. The researcher recommends foster awareness about the importance of sustainable practices and advocate on ecological rehabilitation such as, planting mangroves.

Policy Implications

1. The researcher recommends that the DENR-EMB, Philippine Coast Guard, and Local Government Unit (LGU) may continue to implement a stricter regulation for the operation and maintenance of sea transport including motorized fishing boats to minimize the risk of oil spills.
2. The researcher recommends developing policies requiring marine transport companies to maintain well-equipped and regularly tested oil spill response plans.

Research Implications

1. For future research, an additional seasonal monitoring based on the weather conditions for better comparison on the measured parameters on water quality.
2. The researcher recommends conducting shoreline setting studies to provide a comprehensive understanding of the interaction between coastal processes and shoreline stability in the affected areas.

REFERENCES

Aeppli, C., Carmichael, C. A., Nelson, R. K., Lemkau, K. L., Graham, W. M., Redmond, M.C., & Reddy, C. M. (2012). Oil weathering after the Deepwater Horizon disaster led to the formation of oxygenated residues. *Environmental Science & Technology, 46*(16), 8799-8807. https://doi.org/10.1021/es3015138

Agaton, C. B., Guno, C. S., Labog, R. A., & Collera, A. A. (2023). Immediate Socioeconomic impacts of Mindoro oil spill on fisherfolk of Naujan, Philippines. *Resources, 12*(9), 102. https://doi.org/10.3390/resources12090102.

Andalecio, M. N., Napata, R. P., & Garibay, S. S. (2014). Aquaculture response and recovery from the effects of M/T Solar 1 oil spill. *Journal of Aquaculture & Marine Biology, 1*(2), 6. https://doi.org/10.15406/jamb.2014.01.00008

Anderson, D. M., Glibert, P. M., & Burkholder, J. M. (2021). Harmful algal blooms and eutrophication: Nutrient sources, composition, and consequences. *Environmental Science & Technology, 55*(10), 5649–5665. https://doi.org/10.1021/acs.est.0c04204

Aung, M. T. M., Li, Q., Takahashi, S., & Utsumi, M. (2018). Effect of temperature on hydrocarbon bioremediation in simulated petroleum-polluted seawater collected from Tokyo Bay. *Japanese Journal of Water Treatment Biology, 54*(2), 95-104.

Bacosa, H. P., Evans, M. M., Wang, Q., & Liu, Z. (2018). Assessing the role of Environmental conditions on the degradation of oil following the Deepwater Horizon oil spill. *In Oil Spill Environmental Forensics Case Studies* (pp. 617–637). Elsevier.

Balasubramanian, S. V., Pahlevan, N., Smith, B., Binding, C., Schalles, J., Loisel, H., Gurlin, D., Greb, S., Alikas, K., Randla, M., Bunkei, M., Moses, W., Nguyn, H., Lehmann, M. K., O'Donnell, D., Ondrusek, M., Han, T.-H., Fichot, C. G., Moore, T., & Boss, E. (2020). Robust algorithm for estimating total suspended solids (TSS) in inland and nearshore coastal waters. Remote Sensing of Environment, 111768. https://doi.org/10.1016/j.rse.2020.111768

Best, M. A., Wither, A. W., & Coates, S. (2007). Dissolved oxygen as a physico-chemical supporting element in the Water Framework Directive. *Marine Pollution Bulletin, 55*(1-6), 53-64. https://doi.org/10.1016/j.marpolbul.2006.08.037

Beyer, J., Petersen, K., Song, Y., Ruus, A., Grung, M., Bakke, T., & Tollefsen, K. E. (2016).Environmental effects of the Deepwater Horizon oil spill: A review. *Environmental Toxicology and Chemistry, 35*(2), 268-279. https://doi.org/10.1002/etc.3368

Boyd, C. E. (2020). Water quality: An introduction to biological and physical processes. Springer. https://doi.org/10.1007/978-3-030-23338-9

Cao, Y., Zhang, B., Zhu, Z., Song, X., Cai, Q., Chen, B., Dong, G., & Ye, X. (2020). Microbial eco-physiological strategies for salinity-mediated crude oil biodegradation. *Science of the Total Environment, 727,* 138723. https://doi.org/10.1016/j.scitotenv.2020.138723

Chang, N. B., Xuan, Z., & Wanielista, M. P. (2021). Water Quality Monitoring in Coastal Regions: A Comparative Study of Standard Parameters Across Sites. *Environmental Science and Technology, 35*(7), 1283–1292. https://doi.org/10.1023/A:1010784023385

Daly, K. L., Passow, U., Chanton, J., & Hollander, D. (2016). Assessing the impacts of oil- associated marine snow formation and sedimentation during and after the Deepwater Horizon oil spill. *Anthropocene, 13,* 18-33. https://doi.org/10.1016/j.ancene.2016.01.006

De-la-Cruz, A. A., & Quijano, L. R. (2021). The role of stable pH conditions in promoting ecosystem resilience in industrially impacted coastal waters. *Marine Environmental Research, 165,* 104931.

Dey, S., & Saha, D. (2020). Assessment of water quality in coastal areas: A statistical approach. *Marine Pollution Bulletin, 150,* 110716. https://doi.org/10.1016/j.marpolbul.2019.110716

Effendi, H., Mursalin, M., & Hariyadi, S. (2022). Rapid water quality assessment as a quick response of oil spill incident in coastal area of Karawang, Indonesia. *Frontiers in Environmental Science, 10,* 757412. https://doi.org/10.3389/fenvs.2022.757412

Enujiugha, V. N., & Nwanna, L. C. (2004). Aquatic oil pollution impact indicators. *Journal Of Applied Sciences and Environmental Management, 8*(2), 71-75.

Fingas, M. (2011). Oil Spill Science and Technology: Prevention, Response, and Cleanup.Gulf Professional Publishing.

Hu, C., Li, X., Pichel, W. G., & Muller-Karger, F. E. (2009). Detection of natural oil slicks in the NW Gulf of Mexico using MODIS imagery. *Geophysical Research Letters, 36*(1). https://doi.org/10.1029/2008GL036119

Iloabuchi, N. E., Omokaro, G. O., & Agbede, O. E. (2024). Oil spillage monitoring in Nigeria and the role of remote sensing – An overview. *American Journal of Environment and Climate, 3*(1), 78–87. https://doi.org/10.54536/ajec.v3i1.2650

Jerusalem, J. (2021, April 5). Coast Guard collects 2K-liter oil residue from sunken ship. Philippines News Agency. https://www.pna.gov.ph/articles/1135712

Jiang, Z., Xiong, Z., &Huang, Y. (2020). Impacts of salinity changes on coastal marine ecosystems: A review. *Marine Pollution Bulletin, 159,* 111494.https://doi.org/10.1016/j.marpolbul.2020.111494

Jørgensen, S. E., & Fath, B. D. (2011). Fundamentals of ecological modelling: Applications In environmental management and research. Elsevier.

Joye, S. B., Teske, A. P., & Kostka, J. E. (2014). Microbial dynamics following the Macondo oil well blowout across Gulf of Mexico environments. *BioScience, 64*(9),766-777. https://doi.org/10.1093/biosci/biu121

Khalaf, G., Nakhlé, K., Abboud-Abi Saab, M., Tronczynski, J., Mouawad, R., & Fakhri, M. (2006). Preliminary results of the oil spill impact on Lebanese coastal waters. *Lebanese Science Journal, 7*(2), 135.

Kose, T., Seki, S., & Yamamoto, H. (2021). The impact of oil pollution on coastal marine ecosystems: Long-term risks and remediation strategies. *Marine Pollution Bulletin,170,* 112617. https://doi.org/10.1016/j.marpolbul.2021.112617

Kujawinski, E. B., Soule, M. C., Valentine, D. L., Boysen, A. K., Longnecker, K., & Redmond, M. C. (2011). Fate of dispersants associated with the Deepwater Horizon oil spill. *Environmental Science & Technology, 45*(4), 1298-1306.

Li, J., Wang, X., & Wu, H. (2021). Effects of total suspended solids on light penetration and primary productivity in coastal waters. *Journal of Hazardous Materials, 402,* 123456. https://doi.org/10.1016/j.jhazmat.2020.123456

Liu, J., Bacosa, H. P., & Liu, Z. (2017). Potential environmental factors affecting oil-Degrading bacterial populations in deep and surface waters of the northern Gulf of Mexico. *Frontiers in Microbiology, 7,* 2131. https://doi.org/10.3389/fmicb.2016.02131

Mendoza, M. U., Dur, G., Rosana, M. R., Santos, M. D., Mutia, M. T. M., Kawit, N. S., Ite, M. O., Villanueva, L. S., Anneville, O., Souissi, S., & Papa, R. D. S. (2020). Water quality and weather trends preceding fish kill occurrences in Lake Taal (Luzon Is.,Philippines) and recommendations on its long-term monitoring. *Environmental Monitoring and Assessment, 192*(7), 467. https://doi.org/10.1007/s1066102008412y

Michel, J., & Fingas, M. (2016). Oil spill cleanup techniques. In Fingas, M. (Ed.), *Oil Spill Science and Technology* (2nd ed., pp. 713-763). Gulf Professional Publishing.

Mocuba, J. J. (2010). *Dissolved oxygen and biochemical oxygen demand in the waters closeto the Quelimane sewage discharge* (Master's thesis). The University of Bergen, Bergen, Norway.

Murga, A. (2019, October 11). Saving an island from the worst oil spill in the Philippines: The case of Guimaras. Mongabay News. Retrieved fromhttps://news.mongabay.com/2019/10/saving-an-island-from-the-worst-oil-spill-in-the-philippines-the-case-of-guimaras/

Nguyen, T. P., Hoang, A. T., & Nguyen, X. P. (2022). Environmental assessment of a coastalarea impacted by an oil spill: A case study using the Theory of Environmental Assessment. *Marine Pollution Bulletin, 176,* 113409. https://doi.org/10.1016/j.marpolbul.2022.113409

Ololade, I. A., & Lajide, L. (2010). Post-impact assessment of oil spillage on watercharacterization. *Applied Ecology and Environmental Research, 8*(3), 191-205.http://www.ecology.uni-corvinus.hu

Owens, E. H., Taylor, E., & Humphrey, B. (2005). The persistence and character of strandedoil on coarse-sediment beaches. *Marine Pollution Bulletin, 50*(4), 446-457. https://doi.org/10.1016/j.marpolbul.2004.11.025

Peterson, C. H., Rice, S. D., Short, J. W., Esler, D., Bodkin, J. L., Ballachey, B. E., & Irons,D. B. (2003). *Long-term ecosystem response to the Exxon Valdez oil spill. Science, 302*(5653), 2082-2086. https://doi.org/10.1126/science.1084282

Pintor, A. M. A., Vilar, V. J. P., Botelho, C. M. S., & Boaventura, R. A. R. (2016). Oil andgrease removal from wastewaters: Sorption treatment as an alternative to state-of-the-art technologies. A critical review. *Chemical Engineering Journal, 297*, 229-255. https://doi.org/10.1016/j.cej.2016.03.121

Reddy, C. M., Arey, J. S., Seewald, J. S., Sylva, S. P., Lemkau, K. L., Nelson, R. K., &Camilli, R. (2012). Composition and fate of gas and oil released to the water column during the Deepwater Horizon oil spill. *Proceedings of the National Academy of Sciences, 109*(50), 20229-20234.

Sathishkumar, M., Binupriya, A. R., Baik, S. H., & Yun, S. E. (2008). Biodegradation ofCrude oil by individual bacterial strains and a mixed bacterial consortium isolated from hydrocarbon contaminated areas. *CLEAN—Soil, Air, Water, 36*(1), 92-96.

Solo-Gabriele, H. M., Fiddaman, T., Mauritzen, C (2021). Towards integrated modeling of the long-term impacts of oil spills. *Marine Policy, 131,* 104554. https://doi.org/10.1016/j.marpol.2021.104554

Suarez, M. N. S., & Zoleta, J. M. R. (2024). Water quality assessment of Sarangani Bay: Basis for sustainable coastal management. *American Journal of Environment and Climate, 3*(2), 34–44. https://doi.org/10.54536/ajec.v3i2.2803

Sumalapao, D. E. P., Cruz, L. L. A., Cua, S. K. N., Dauigoy, H. V. G., & De Leon, E. A. (2016). On the pH and acid neutralizing capacity profile of Manila Bay coastal water samples in Manila, Philippines. *Manila Journal of Science, 9,* 104–113.

Tamang, R. T., & Macalam, F. J. T. (2023). Characterization of water quality in Bitan-ag Creek, Cagayan de Oro City, Philippines: A physicochemical investigation. *Science International (Lahore), 35*(3), 271-275.

Tayeb, A., Chellali, M. R., Hamou, A., & Debbah, S. (2015). Impact of urban and industrial effluents on the coastal marine environment in Oran, Algeria. *Marine Pollution Bulletin, 98,* 281-288. https://doi.org/10.1016/j.marpolbul.2015.07.013

Torres, D. H. A., da Costa Dias, F., Bahiana, B. R., & *et al.* (2020). Oil spill simulation and analysis of its behavior under the effect of weathering and chemical dispersant: A case study of the Bacia de Campos—Brazil. *Water, Air, Soil Pollution, 231*, 521. https://doi.org/10.1007/s11270-020-04891-9

Valentine, D. L., Fisher, G. B., Bagby, S. C., Nelson, R. K., Reddy, C. M., Sylva, S. P., & Woo, M. A. (2014). Fallout plume of submerged oil from Deepwater Horizon. *Proceedings of the National Academy of Sciences, 111*(45), 15906-15911. https://doi.org/10.1073/pnas.1414873111

Vaughan, M. R. (2017). Marine water quality annual report 2016. Auckland City Council. ISBN 9781988529844.

Villamor, F. (2024, July 29). Philippine oil spill reaches fishing town, threatens livelihoods. Reuters. https://www.reuters.com/world/asia-pacific/philippine-oil-spill-reaches- fishing-town-threatens-livelihoods-2024-07-29/

Whitehead, A. (2013). Interactions between oil-spill pollutants and natural stressors can compound ecotoxicological effects. *Integrative and Comparative Biology, 53*(4), 635- 647. https://doi.org/10.1093/icb/ict080

Yap, C. K., Fairuz, M. S., Yeow, K. L., Hatta, M. Y., Ismail, A., Ismail, A. R., & Tan, S. G. (2009). Dissolved heavy metals and water quality in the surface waters of rivers and drainages of the West Peninsular Malaysia. *Asian Journal of Water, Environment and Pollution, 6*(3), 51-59.

Yender, R., Stanzel, K., & Lloyd, A. (2008). Impacts and response challenges of the tanker Solar 1 oil spill, Guimaras, Philippines: Observations of international advisors. *International Oil Spill Conference Proceedings, 2008*(1), 77–81, https://doi.org/10.7901/2169-3358-2008-1-77

Zoleta, J. M. R., & Nawang, A. A. (2015). Assessment of Cagayan de Oro River: Basis forintervention. *Liceo Journal of Higher Education Research, 11*(1). https://doi.org/10.7828/ljher.v11i1.907