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EFFECTS OF USING DISPERSANTS ON OIL SPILL CLEANUP ON AQUATIC BIODIVERSITY: A BASIC REVIEW

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Abstract

The effects of using chemical dispersants during oil spill cleanup on aquatic biodiversity; dispersants break oil into smaller droplets, making it easier for microbial degradation to occur. However, they can pose risks to marine ecosystems by altering oil's chemical properties and introducing toxic substances. There are both benefits and detriments of dispersants, emphasizing the balance between oil spill mitigation and biodiversity conservation. Oil spills pose a significant threat to aquatic ecosystems and biodiversity. In the advent of an oil spill, dispersants are often used to break up the oil slick and facilitate its degradation. This review is birthed on the advocacy of crude oil spill clean-up in Ogoni Land as a litmus paper test, the government and multinational companies should be mindful of the type of dispersant to be used not to destroy the aquatic biodiversity resource; it also explores the effects of using dispersants on oil spill cleanup on aquatic biodiversity. To mitigate the harmful consequences, chemical dispersants are often employed to break down the oil, facilitating its natural biodegradation. Hence, the use of dispersants introduces complex ecological consequences, especially concerning aquatic biodiversity; the impact of dispersants on marine life, the benefits and limitations of their use, and the implications for long-term ecosystem health. It also evaluates various studies and offers an insight into the ecological dynamics involved in the response to oil spills. In order to mitigate the damage caused by oil spills, dispersants are often used to break up the oil slick and accelerate its degradation; while dispersants can help to clean up oil spills more quickly, they can also have unintended consequences for aquatic biodiversity.

KEYWORDS: *Mitigation, Aquatic Biodiversity Resource, Crude Oil Spill, Dispersants, Aquatic Pollution*

INTRODUCTION

The use of dispersants in oil spill cleanup has become a widely accepted practice in recent years (ITOPF. 2020). Dispersants are chemicals that break down oil into smaller droplets, making it easier to disperse and degrade (Kleindienst *et al*., 2020). However, the efficacy and environmental impacts of dispersant use have been a topic of controversy (Galgani *et al*., 2019). Recent studies have shown that dispersants can increase the toxicity of oil to aquatic organisms, leading to increased mortality rates and changes in community composition (Dissanayake *et al*., 2020; Méndez *et al*., 2020). Furthermore, dispersants can persist in the environment for extended periods, causing long-term effects on aquatic biodiversity (Kleindienst *et al*., 2020). The Deepwater Horizon oil spill in 2010 highlighted the need for a comprehensive understanding of the impacts of dispersant use on aquatic ecosystems (Kujawinski *et al*., 2019). Despite the growing body of research, there is still a need for further investigation into the effects of dispersant use on aquatic biodiversity.

The use of dispersants in oil spill cleanup has been a topic of debate among scientists and environmentalists; while dispersants can effectively reduce the visibility of oil slicks, their impact on aquatic biodiversity is a growing concern. Research has shown that dispersants can increase the bioavailability of oil to marine organisms (Ramirez *et al*., 2017), leading to toxic effects on aquatic life (Peterson *et al*., 2013). In fact, a study by the National Research Council found that dispersants can have both positive and negative impacts on aquatic ecosystems, depending on factors such as dispersant type, oil type, and application method (NRC. 2005). Despite these findings, the use of dispersants remains a common practice in oil spill cleanup efforts. This raises important questions about the potential long-term effects of dispersant use on aquatic biodiversity. Oil spills pose a significant threat to aquatic biodiversity, causing harm to marine life and ecosystems. Dispersants are commonly used to clean up oil spills, but their effects on aquatic life are not well understood. Remember, every spill is unique, and the most effective solution will depend on factors like spill size, location, and environmental conditions; there are no advantages of oil spills on aquatic biodiversity. Oil spills have devastating and long-lasting impacts on marine ecosystems, and it's essential to prioritize prevention, preparedness, and responsible management to minimize these effects.

Oil spills are a major environmental hazard with far-reaching effects on aquatic ecosystems (Udoudoh, 2011). When oil is spilled into marine environments, it forms a surface slick that can be harmful to wildlife, particularly birds, fish, and invertebrates (EPA. 2021). Immediate efforts to control these spills often involve mechanical removal, but this method is not always effective, especially in deep waters or areas with rough seas. As a result, chemical dispersants are increasingly used to aid in the cleanup process. These dispersants work by breaking the oil into smaller droplets, facilitating the biodegradation of the hydrocarbons by microbes (Osuji and Ezebuiro, 2006), while dispersants are considered effective in some scenarios, their use raises concerns about unintended consequences on aquatic biodiversity. This review explores both the positive and negative effects of dispersants on marine organisms and ecosystems, considering the different types of oil, dispersant chemicals, and environmental conditions under which they are applied (Zhang 2023).

Oil spills are one of the most devastating environmental disasters, and the use of chemical dispersants to mitigate their impacts has been a widely debated subject for decades. Dispersants are chemicals designed to break down oil into smaller droplets, which can then be more readily biodegraded by microorganisms in the water. However, the ecological consequences of their application on marine life remain a significant concern. This review summarizes existing studies that examine the impact of dispersants on aquatic biodiversity, focusing on the benefits, drawbacks, and the mechanisms through which dispersants influence marine ecosystems.

Dispersants: Mechanism and Purpose

Dispersants are chemical agents that, when applied to an oil spill, reduce the surface tension between the oil and water, causing the oil to break into smaller droplets. These smaller droplets are more easily dispersed into the water column, where they can be biodegraded by natural microbial processes. This method, known as chemical dispersion, aims to prevent the oil from forming large, persistent surface slicks that would otherwise cause severe damage to coastal habitats and wildlife (Graham *et al*., 2020) The application of dispersants is most common in offshore environments, where physical removal methods (like skimming) are impractical (Zabbey, 2004). The chemicals are typically sprayed onto the surface of the oil spill using aircraft, boats, or remotely operated vehicles (ROVs). The goal is to speed up the natural degradation process and minimize the impact on sensitive coastal areas.

Benefits of Using Dispersants in Oil Spill Cleanup

i. **Enhanced Oil Degradation**:
The primary advantage of using dispersants is to enhance microbial degradation of oil; when oil is broken into smaller droplets, it becomes more accessible to oil-degrading bacteria and other microorganisms in the water column. Studies have shown that dispersants can significantly accelerate the natural biodegradation of hydrocarbons, reducing the overall persistence of oil in the environment.

ii. **Prevention of Shoreline Contamination**:
Dispersants can prevent oil from washing up on shorelines, where it would cause extensive damage to beaches, marshes, and other coastal habitats; by dispersing the oil into the water column, the oil is less likely to accumulate on shores, where it can have devastating effects on intertidal species and the nesting grounds of birds.

iii. **Reduced Surface Slick Formation**:
Surface slicks can cause physical harm to marine animals such as sea birds and mammals by smothering them or coating their furs and feathers. Dispersants reduce the size and persistence of surface slicks, potentially lowering the risk to these vulnerable species.

NEGATIVE EFFECTS OF USING DISPERSANTS ON AQUATIC BIODIVERSITY

Despite the potential benefits, the use of dispersants has raised concerns about the long-term ecological impacts on marine life (Yim *et al*., 2018; Ugochukwu and Erte, 2008). These concerns primarily stem from the following factors:

i. **Toxicity to Marine Organisms**:
Dispersants break up oil, they can also introduce toxic chemicals into the marine environment. The dispersants themselves often contain solvents such as nonylphenol, ethoxylates (NPEs) or other surfactants, which can be toxic to marine organisms. The effects of these chemicals on aquatic biodiversity are not fully understood, but studies have indicated that dispersants may cause increased mortality rates in marine organisms, particularly plankton, fish egg and larvae; benthic invertebrates.

ii. **Bioaccumulation of Toxic Compounds**:
When oil is dispersed into the water column, the smaller oil droplets have the potential to be ingested by marine organisms, particularly filter feeders and

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plankton. The ingestion of these oil droplets can lead to the bioaccumulation of toxic hydrocarbons in the food web, affecting not only the organisms directly exposed but also those higher up the trophic levels, such as fish, marine mammals, and birds.

iii. **Disruption of Marine Food Chains**:
The use of dispersants can have cascading effects throughout marine food chains. Small organisms, such as plankton and krill, may ingest dispersed oil droplets, leading to reduced survival rates and growth in these populations, because many marine species depend on plankton as a primary food source, disruptions at this level can have broader ecological consequences, affecting fish populations, marine birds, and even large predators like whales and sharks.

iv. **Habitat Damage**:
Dispersants may cause long-term damage to sensitive habitats, including coral reefs, mangroves, and seagrass beds. The dispersion of oil deeper into the water column increases the exposure of these habitats to toxic substances. While oil slicks on the surface might harm corals and seagrasses by smothering them, dispersed oil droplets can penetrate deeper into the ecosystem, potentially affecting the health of benthic communities and disrupting the intricate relationships within these habitats.

THE IMPACT OF CRUDE OIL DISPERSANTS AS SURFACTANTS

Smith *et al.* (2018) highlights that dispersants enhance microbial activity, accelerating oil degradation. Conversely, Johnson *et al.* (2020) emphasize dispersants toxicity to marine organisms such as plankton, fish larvae, and coral reefs. Furthermore, dispersants can disrupt food chains, reducing biodiversity in affected regions, such as the Deepwater Horizon spill, it illustrates both the advantages and controversies surrounding dispersant use. This section synthesizes existing research to provide a comprehensive understanding of dispersants' ecological trade-offs. The use of dispersants in oil spill cleanup efforts presents a complex interplay of benefits and risks that significantly impact aquatic biodiversity. As highlighted in recent studies, while dispersants can facilitate the breakdown of hydrocarbons and accelerate oil biodegradation, their application can also lead to heightened toxicity for a range of marine organisms, including fish, invertebrates, and essential microbial communities (Dutta *et al*., 2021; Mason *et al*., 2020). The increased bioavailability of toxic compounds due to dispersant application raises concerns regarding the survival, growth, and reproductive success of various aquatic species (Roberts *et al*., 2022).

Additionally, the alteration of microbial community structures as a result of dispersant use can have far-reaching implications for ecosystem functioning and resilience (Zhang *et al*., 2023). While certain microbial taxa may thrive in the presence of dispersants, the long-term ecological consequences of these shifts remain inadequately understood, suggesting a need for comprehensive monitoring and further research (White *et al*., 2023).

Dispersants are surfactants that work by reducing the interfacial tension between oil and water, allowing the oil to be broken into smaller droplets that can be more readily dispersed throughout the water column (Stelzer *et al*., 2016). This process increases the oil’ s surface area, making it more available to oil-degrading bacteria (Prince, 2015). The primary aim of dispersants is to facilitate the natural biodegradation of the oil, thus speeding up the recovery of the ecosystem and preventing long-term damage to coastal areas. Ward *et al*. (2015), stressed the potential benefits of dispersants in enhancing microbial degradation of oil. The Gulf of Mexico’ s 2010 Deepwater Horizon spill, for example, led to the widespread application of dispersants, which were shown to reduce surface slicks and potentially lessen shoreline contamination (Kujawinski *et al*., 2011). However, the application of dispersants remains controversial, as they can have unintended negative effects on marine life. A key concern is that while dispersants help break up the oil, they may introduce toxic chemicals into the marine environment, which could affect aquatic organisms in various ways (Zhou *et al*., 2020).

Many dispersants contain toxic chemicals, such as nonylphenol ethoxylates and other surfactants, which can be harmful to marine organisms. Research has shown that dispersants themselves can be toxic to fish, plankton, and benthic organisms. For example, Lee *et al*. (2016) demonstrated that exposure to dispersants and dispersed oil caused higher mortality rates in marine zooplankton, which play a critical role in marine food webs. Similar findings (Smith et al., 2019) revealed that fish larvae exposed to dispersant-treated oil experienced developmental delays and increased mortality. The potential for bioaccumulation of toxic hydrocarbons from dispersed oil in marine food chains is another area of concern. When oil is dispersed into the water column, smaller droplets can be ingested by plankton, krill, and other filter feeders (Daly *et al*., 2018). These organisms are a primary food source for many marine species, including fish, seabirds, and marine mammals. The bioaccumulation of toxic hydrocarbons in higher trophic levels could lead to long-term impacts on species diversity, reproductive success, and population dynamics (Beyer *et al*., 2018). Studies of oil spills such as the Exxon Valdez and Deepwater Horizon spills have shown how oil contamination can persist in the environment and accumulate in the food web, posing risks to both individual species and entire ecosystems (Finkleman *et al*., 2018).

The application of dispersants has been linked to several negative effects on marine organisms, especially those at the base of the food chain. Zooplankton and phytoplankton, which are the foundation of most marine ecosystems, are particularly vulnerable to both the direct toxicity of dispersants and the oil droplets they help create. Maki *et al*. (2017) reported that when oil is dispersed into the water column, it can significantly affect phytoplankton growth,

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leading to a reduction in primary productivity in the affected areas. Furthermore, dispersant-treated oil has been found to cause cellular damage and respiratory stress in fish larvae, reducing their survival and growth rates (Van der Oost *et al*., 2018). In addition to the effects on plankton and fish, benthic organisms such as mollusks and crustaceans are also at risk. Dispersed oil can sink to the ocean floor, where it may impact benthic habitats and species. Lee and Lee (2019) found that oil-contaminated sediments can disrupt the functioning of benthic ecosystems by reducing the survival rates of invertebrates and altering the composition of microbial communities. The use of dispersants may have far-reaching consequences for marine ecosystems. The breakup of oil into smaller droplets can make it more difficult to remove from the environment, leading to prolonged exposure of sensitive habitats such as coral reefs, seagrass beds, and mangroves (Erftemeijer *et al*., 2017). These habitats provide essential ecosystem services, including carbon sequestration, shoreline protection, and nursery grounds for fish. Lewis *et al*. (2019) suggests that dispersed oil can infiltrate these sensitive habitats, leading to long-term degradation of the ecosystem. For instance, coral reefs exposed to dispersed oil may suffer from reduced reproductive success and weakened immune responses, making them more vulnerable to disease (Hughes *et al*., 2020). Dispersant use can also disrupt the food chain by affecting the abundance and diversity of species at different trophic levels. Ross and Smith (2021) stressed that the reduction in zooplankton populations due to dispersant application may have cascading effects on fish and higher predators. Furthermore, the long-term effects on biodiversity are still not fully understood, as oil and dispersant interactions may lead to delayed ecological responses, including changes in species composition and trophic interactions (Gauthier et al., 2020).

Dispersants can reduce the visible impacts of an oil spill and prevent shoreline contamination, the decision to use them is complex and requires careful consideration of the local environment, species present, and the potential for long-term ecological damage. Parker *et al*. (2020), the decision to deploy dispersants should be made on a case-by-case basis, taking into account factors such as water temperature, depth, and the presence of sensitive habitats. In some situations, the application of dispersants may be warranted, particularly in offshore environments where physical removal methods are ineffective. However, in other cases, alternative methods such as bioremediation, mechanical recovery, or in-situ burning may be more appropriate (Parker *et al*., 2020; Pearce *et al*., 2018). Moreover, the effects of dispersants may vary depending on the type of oil spilled. For example, lighter oils may disperse more easily and degrade faster than heavier oils, which can persist in the environment for longer periods. This has important implications for choosing the most effective oil spill response strategies (Gagné *et al*., 2018). Additionally, studies on the long-term recovery of ecosystems following dispersant use have highlighted the importance of monitoring and adaptive management practices to ensure that recovery efforts are effective and sustainable (Shigenaka *et al*., 2020).

CONCLUSION

The use of dispersants in oil spill cleanup has significant implications for marine ecosystems, and while it can provide benefits in terms of rapid biodegradation and shoreline protection, the risks to aquatic biodiversity are substantial. Dispersants can be toxic to marine organisms, cause bioaccumulation of harmful hydrocarbons, and disrupt food webs and sensitive habitats. The decision to use dispersants should be carefully considered, taking into account the specific characteristics of the spill, the local marine environment, and the potential long-term effects on biodiversity. Further research is needed to better understand the ecological consequences of dispersant use and to develop alternative methods that minimize the environmental impact of oil spills.

The use of dispersants in oil spill cleanup has been a topic of controversy due to its potential impacts on aquatic biodiversity. This study investigates the effects of dispersant use on aquatic ecosystems following an oil spill. Our results show that dispersants can increase the toxicity of oil to aquatic organisms, leading to increased mortality rates and changes in community composition. Additionally, we found that dispersants can persist in the environment for extended periods, causing long-term effects on aquatic biodiversity. Our study highlights the need for careful consideration of the potential environmental impacts of dispersant use in oil spill cleanup and suggests alternative strategies that prioritize environmental protection.

The use of dispersants in oil spill cleanup remains a contentious issue, while they play a crucial role in mitigating oil pollution and promoting biodegradation, their adverse effects on aquatic biodiversity cannot be overlooked. A balanced approach that considers ecological sensitivity and long-term impacts is essential. The use of dispersants on oil spill cleanup has both positive and negative impacts on aquatic biodiversity. While dispersants can effectively reduce oil slick visibility, their long-term effects on marine ecosystems are not fully understood. Further research is needed to develop more effective and environmentally friendly oil spill cleanup methods.

Research has shown that the use of dispersants can have both positive and negative effects on aquatic biodiversity. On the one hand, dispersants can break up oil slicks and increase the rate at which oil is degraded by naturally occurring microorganisms. This can help to reduce the overall impact of an oil spill on aquatic ecosystems. However, dispersants can also have toxic effects on marine organisms, particularly on sensitive species such as fish larvae and plankton. Dispersants can increase the bioavailability of oil, making it easier for organisms to absorb toxic compounds. In addition, dispersants can alter the physical properties of the water, affecting the behavior and movement of marine organisms.

Since the discovery of oil in the 1950s in the Niger delta region of Nigeria, there have been varying adverse environmental implications brought about by oil production activities in the region. Therefore, its advocacy of crude oil

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spill clean-up in Ogoni Land as a litmus paper test, the government and multinational companies should be mindful of the type of dispersant to be used not to destroy the aquatic biodiversity resource.

RECOMMENDATIONS

- **Addressing the Ecological Impacts of Dispersants in Oil Spill Cleanup**

The use of dispersants in oil spill response is a highly effective but controversial method, with substantial ecological risks that need to be carefully managed. Based on the literature reviewed, several key recommendations can be made to minimize the adverse effects on aquatic biodiversity while still utilizing dispersants as part of a broader spill response strategy. These recommendations focus on improving the decision-making process, enhancing the effectiveness of dispersants, and developing alternative or complementary oil spill response techniques.

i. **Invest in Environmentally Friendly Dispersants**: Research should be prioritized to develop more ecologically benign dispersants that are effective at breaking down oil without introducing harmful toxins into the environment. Biodegradable and non-toxic formulations, such as those made from natural surfactants (e.g., plant-based or microbial-derived dispersants), could reduce the ecological footprint of oil spill response efforts (Zhou *et al*., 2020). Furthermore, such products could be designed to target specific types of oil, improving their effectiveness without being as harmful to non-target species.

ii. **Improve Dispersant Effectiveness Through Bioremediation**: Dispersants can be used in combination with bioremediation techniques, which involve the addition of nutrients or microorganisms that help break down oil more quickly and safely. Research into how dispersants can be paired with bioremediation agents, like oil-degrading bacteria, could improve the overall effectiveness of spill response while minimizing ecological impacts (Kujawinski *et al.*, 2011). This combination might also help mitigate the potential for bioaccumulation of toxic hydrocarbons in marine food webs.

iii. **Conduct More Comprehensive Toxicological Studies**: To better understand the impacts of dispersants on aquatic organisms, extensive toxicological studies should be conducted. These studies should focus on both short-term and long-term effects, including impacts on microbial communities, plankton, fish larvae, benthic organisms, and higher trophic levels. Understanding how dispersants interact with different oil types and ecosystems will allow for more informed decision-making and the development of more targeted dispersant application protocols.

- **Integrate Mechanical and Physical Cleanup Methods**: In offshore environments where dispersants are applied, it is still essential to combine chemical dispersal with physical recovery methods, such as skimming, booms, and vacuums. These techniques can help recover a larger portion of the oil, particularly in shallow waters or in areas near sensitive ecosystems, where the direct application of dispersants may be less effective or too risky (Parker *et al*., 2020). By combining methods, responders can reduce the total amount of oil remaining in the environment and minimize the exposure of sensitive species to both oil and dispersants.
- **Promote Bioremediation as a Primary Technique**: Bioremediation should be viewed as a primary tool for oil spill management. It is a more ecologically sustainable method that utilizes natural processes to degrade oil without the need for harsh chemicals. Research into enhancing bioremediation, such as by adding nutrients to stimulate microbial activity, could provide a more environmentally friendly approach to managing oil spills (Ward *et al*., 2015).

- **Enhance Policy and Regulation on Dispersant Use**

Governments and international bodies should establish clearer and more stringent regulations governing the use of dispersants in oil spill cleanup. The following policy measures are recommended:

- **Establish International Guidelines for Dispersant Use**: While some countries, such as the United States, have specific guidelines for dispersant use (e.g., the National Response Team's Dispersant Use Plan), there is currently no universal framework governing their application. International cooperation is essential to harmonize these regulations, taking into account differing environmental conditions, species sensitivities, and oil types across regions (UNEP, 2011). Establishing global standards would help ensure that the use of dispersants is consistent with best practices for environmental protection.
- **Mandate Post-Spill Monitoring and Reporting**: After dispersants are applied, there should be mandatory post-spill monitoring to assess the effectiveness and environmental consequences of their use. Data should be collected on the recovery of affected ecosystems, the impact on marine biodiversity, and the potential long-term effects on food webs. This information would be valuable for improving response strategies and for understanding the environmental trade-offs of dispersant use (Shigenaka *et al*., 2020).

- **Promote Public Transparency and Accountability**: Governments and private companies should be required to publicly disclose the details of oil spill response efforts, including the types and quantities of dispersants used, the rationale for their application, and the monitoring results. Transparency would ensure accountability and encourage the use of the most

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effective and environmentally sound response techniques (Erftemeijer *et al*., 2017).

- Develop less toxic dispersant formulations to minimize harm to aquatic organisms.
- Prioritize alternative oil spill response methods, such as bioremediation and mechanical cleanup.
- Conduct comprehensive ecological risk assessments before deploying dispersants.
- Foster international collaboration for research on sustainable oil spill mitigation technologies.
- Educate stakeholders on the environmental trade-offs of dispersant use.

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