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기술보고

The Effectiveness of the Dispersant Use during the “Deepwater Horizon” Incident
-REVIEW of the Proceedings from 2011 International Oil Spill Conference-

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미국 멕시코만 기름유출사고에서 본 유처리제 사용의 효용성 고찰

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Abstract : *Once oil has spilled, oil spill responders use a variety of countermeasures to reduce the adverse effects of spilled oil on the environment. Mechanical methods of containment and recovery are preferred as the first response when the use of other methods fail or are ineffective. In these cases, the application of oil dispersants shall be use only as a last resort. While effectiveness of dispersants in removing oil form the sea surface is proven, the use of dispersants is controlled in almost all countries due to the toxicity of their active agents and the dispersed oil on the marine environment. However, according to reports, after dispersant application, no significant toxicity to fish or shrimp was observed in the field-collected samples. Moreover, the results also indicate that dispersant-oil mixtures are generally no more toxic to the aquatic test species than oil alone. During the Deepwater Horizon Incident, dispersants were applied to floating oil and injected into the oil plume at depth. These decisions were carefully considered by state and federal agencies, as well as BP, to prevent as much oil as possible from reaching sensitive shoreline habitats. Net Environmental Benefit Analysis for dispersant use assumed that dispersants appear to prevent long-term contamination resulting absence of oil in the substrate and will benefit marine wildlife by decreasing the risk of significant contamination to feathers or fur. Further study to use dispersants with scientific baseline is needed for our maritime environment which consistently threaten huge oil spill incidents occurrence.*

Key Words : *Marine Pollution, Dispersants, Deepwater Horizon(DWH), Oil Spill, Response Strategy, Toxicity, Net Environmental Benefit Analysis*

요 약 : 바다에 기름오염 사고가 발생하면 여러 가지 방제 방법 중 물리적 회수 방법을 우선적으로 사용하고 유처리제는 최후 수단으로 고려하는 경향이 있다. 유처리제는 수중으로 기름이 신속히 분산되도록 하여 해수면으로부터 제거하는 방법이다. 해수면으로부터 신속히 기름을 제거하는데 대한 유처리제의 효용성은 널리 증명되어 왔으나 아직도 대부분의 국가들은 해양환경에 미치는 독성을 우려하여 적극적인 사용을 하지 않고 있는 실정이다. 보고된 자료에 의하면 유처리제와 혼합된 기름이 기름 그 자체보다 독성이 더 크게 나타나지 않았다. 멕시코만 기름유출 사고시 미국 정부와 BP사는 최대한 해안에 기름이 도달하지 않는데 중점을 두고 해수면뿐만 아니라 수중의 기름에 대해서도 유처리제를 사용하였다. 유처리제에 대한 순환경편익을 분석하면 유처리제를 사용함으로써 기름이 생태계에 머무는 시간이 줄어들며 장기간 노출을 예방하고 야생동물에 심각한 오염을 방지하는 효과가 있는 등 다양한 연구가 진행되고 있다. 미국 멕시코만 유류오염 사고와 같은 대규모 해양오염사고의 위험이 상존하는 우리 실정에서도 과학적 결과를 바탕으로 한 유처리제 사용의 효용성과 안전성에 대한 검토가 이루어져야 할 시점이라 사료된다.

핵심용어 : 해양오염, 유처리제, 멕시코만, 기름유출, 방제전략, 독성, 순환경편익분석

1. Introduction

Deepwater Horizon(DWH) incident released a large quantity of light crude oil into the Gulf of Mexico, which threatened marine wildlife and sensitive coastal habitats. Response strategies to reduce the impact of the spilt oil included mechanical removal, controlled burning, and use of dispersants. Among them, dispersants were applied by aerial spray from low-flying aircraft, by boat spray on the water surface for volatile organic compounds(VOCs) control and by subsurface injection into oil released at the

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wellhead(BenKinney et al., 2011). The DWH blowout was a unique spill in that (a) it was a subsurface(near sea bottom) release(approximately 1,500 meters depth); (b) chemical dispersants were added at the release point as well as at the surface; and (c) the discharge continued from almost three months(from April 20 to July 15, 2010) until the well was plugged(Boehm et al., 2011).

Crude oil is a naturally occurring carbon-based substance made up of a complex mixture of thousands of chemical compounds. These include heavy metals, Polycyclic Aromatic Hydrocarbons(PAHs) and VOCs which are lower-molecular-weight aromatic hydrocarbons which readily evaporate when exposed to the air. When crude oil comes into contact with the atmosphere, it begins to evaporate. Within those evaporation molecules are VOCs that could be harmful to human health(Curd, 2011).

Spill response in the United States has historically relied primarily on mechanical recovery to mitigate the impacts of oil spills even though mechanical recovery is constrained by distance to spill site, encounter rate, sea condition, and temporary storage availability, especially when responding to offshore spills(Joeckel et al., 2011). Since 1990, dispersants have been used on small surface spills several times in the U.S. In other parts of the world the use of dispersants on small oil spills has been more frequent, but generally poorly documented(Coelho et al., 2011). Although the use of dispersants as a primary strategy in oil spill incidents has been effective a number of times and the effectiveness in removing oil from the water surface is proven, the use of dispersants is controlled in almost every countries because of its most noted disadvantage, the toxicity of its active agents and the dispersed oil on the marine environment and its inhabitants.

We reviewed several proceedings from International Oil Spill Conference, which was held in US, May 2011, especially dealing with DWH incident. According to the reviews, we suggest more positive utilization of dispersants as primary response strategy to oil spill incidents based on some scientific data which were reported in the conference.

2. Overview of DWH incident and dispersants' application

On the evening of April 20, 2010 a gas release and subsequent explosion occurred on the DWH oil rig working on the Macondo exploration well for BP in the Gulf of Mexico. The fire burned for 36 hours before the rig sank, and about 4.9 million barrels of crude oil had leaked into the Gulf of Mexico for 87 days before the well was closed and sealed.

The spill was the largest marine oil spill in the history of the petroleum industry and caused extensive damage to marine and wildlife habitats, and to the Gulf's fishing and tourism industries. In an attempt to protect hundreds of miles of beaches, wetlands, and estuaries from the spreading oil, skimmer ships, floating containment booms, anchored barriers, sand-filled barricades along shorelines, and dispersants were used.

About 1.84 million gallons of dispersants were applied either on the surface or subsea - by far the largest use of dispersant in the oil spill response history. The dispersants used in the incident are Corexit 9500 and Corexit EC9527A.

According to the revised oil budget for Gulf of Mexico oil spill response released by the Federal Interagency Solutions Group in November, 2010, dispersants' application was evaluated to be very effective; about 16% of total spillage was chemically dispersed, while in situ burning and offshore and near-shore skimming were 5% and 3%, respectively.

3. Dispersants' Work on Spilled Oil

Surface oil can be especially harmful to birds, mammals and other organisms that come in contact with the water surface. During the response, oil on the surface may also have posed a hazard to workers on stationary vessels. Therefore, it is important to remove or disperse oil from the surface as quickly as possible. Once oil has spilled, responders use a variety of oil spill countermeasures to reduce the adverse effects of spilled oil on the environment. Dispersants are one kind of countermeasures used to increase the rate of dispersion of oil into the water column(Levine et al., 2011).

Dispersants are chemicals applied directly to the spilled oil in order to remove it from the water surface. Oil on the surface is often cohesive and its natural degradation processes are slow. When dispersants are effectively applied to surface oil slicks, tiny dispersant-oil droplets then separate from the slick and mix into the water column, reducing the size and volume of the surface slick. The tiny droplets are too small to refloat to the surface.

Bacteria and other microscopic organisms are able to act quickly to degrade the oil. Dispersants are commonly applied through specialized equipment mounted on airplanes, helicopters and ships(Levine et al., 2011).

Aerial dispersant applications have the benefit of being able to respond quickly in a matter of hours from activation, increase encounter rates, treat oil slicks that measure square miles in area and operate over a wider range of wind and sea conditions than mechanical recovery and burning operations. Dispersants break up the oil slick into fine droplets and disperse these droplets into the water column where they can be consumed by naturally occurring microbes(Joeckel et al., 2011).

4. Several Reasons of Limited Use of Dispersants

The use of dispersants as a primary strategy, especially in large oil spill incidents, has been effective a number of times when used in a timely and appropriate manner. However, it has its noted disadvantage- the acute toxicity of its active agents and the effects of the dispersed oil on the marine environment and its inhabitants. This is why the use of dispersants is controlled in almost every country(Guevarra, 2011).

Considering the fact that dispersants are the accepted response strategies and have been used in major spills, many countries still take a precautionary approach with their use. This is primarily due to concerns on toxicity and the growing influence of the environmental movement on the public's perception. The use of dispersants to combat large spills, especially offshore, is tried and tested and generally accepted worldwide. But in many cases the decisions are based on political rather than scientific considerations(Guevarra, 2011).

Nowadays, dispersant utilization as a response strategy to treat oil spills has been gaining an increasing level of acceptance from worldwide authorities. The reason for this is in part because new dispersants have been developed which are significantly less toxic than their precedents, and in part because current mechanical methods have definite limitations. Several countries have expressed positive attitudes towards dispersants and have therefore softened their views on the use of such products(Guevarra, 2011).

5. Effectiveness of Dispersant Utilization

The purpose of any oil spill response is to minimize the damage that could be caused by the spill. Dispersants are one of the limited number of practical responses that are available to respond to oil spills at sea(Guevarra, 2011).

To alleviate marine and coastal impacts, consideration should be given to enhance the dispersion of oil slicks at sea into small droplets($<70\,\mu m$) in the water column, to facilitate oxygen transport at the air-water interface, and to encourage the biodegradation of the oil by micro-organism. This process may be enhanced by applying chemical dispersants, which are surfactants in carrier solvents, that reduce interfacial tension at the oil-water interface. Dispersant use is predicated on the concept of dilution of oil to reduce its concentration below toxicity threshold limits and the enhancement of natural microbial degradation, as small oil droplets offer greater surface area for access to nutrients and oil degrading microbes(Lee et al., 2011).

Dispersant should be considered one of the primary response technologies, because dispersant can significantly reduce potential sensitive shoreline damage and can be effective over a wider range of wind and sea conditions that may constrain the ability and use of mechanical recovery or burning operations(Joeckel et al., 2011).

6. Consideration of Using Dispersants More Positively Based on Scientific results

As the extent of the dispersant use increased during the DWH spill response, these factors resulted in a steadily increasing concern over dispersant use, focusing attention on the potential for using a “less toxic” dispersant(Coelho et al., 2011).

According to McFarlin and Perkins(2011), per unit total petroleum hydrocarbon(TPH), physically dispersed oil is more toxic than chemically dispersed oil to copepods and arctic cod from the Beaufort and Chukchi Seas. Based on measured petroleum, the relative toxicity of the physically dispersed petroleum(breaking wave-water accommodated fraction of oil, BWWAF) was consistently higher than that of the chemically-dispersed petroleum(CEWAF). For larval sculpin the mean LC_{50} of CEWAF was 27 mg/L TPH. The sculpin mean LC_{50} for BWWAF was 3.3 mg/L TPH. As with copepods and sculpins, the LC_{50}s for physically dispersed petroleum were substantially lower than those of the chemically dispersed petroleum.

Guevarra(2001) also reported that when the eight dispersants were mixed with Louisiana Sweet Crude, the results indicated that dispersant-oil mixtures were generally no more toxic to the aquatic test species than oil alone.

Benkinney et al.(2011) collected water samples for analytical characterization and toxicity testing at 1 and 10 meter depths below the slick prior to and following dispersant application to evaluate the distribution of the dispersed oil through the water column. Results of chemical analyses during the DWH response indicate that total polycyclic aromatic hydrocarbons(tPAH) and TPH measurements were greater below the slick after dispersant application. Hydrocarbon concentrations at 10 meter depths were consistently lower than those measured at 1 meter in both pre- and post-dispersant application samples. No significant toxicity to fish or shrimp was observed in the field-collected samples, while alged test results were inconsistent, but did not show a correlation between toxicity and dispersant application.

In the aspect of physical benefits of using dispersants, Belore et al.(2011) observed persistent emulsions formed sheen more quickly when treated with dispersants, whose results demonstrate that dispersants may be useful in treating even the most viscous of the emulsions.

Even though not from the data in the DHW, DeMicco et al.(2011) provide baseline scientific data for addressing Net Environmental Benefit Analysis(NEBA) for dispersant use decision-making in near-shore tropical ecosystems. Dispersants appeared to prevent long-term contamination to mangrove forests. They investigated a spilled area for 25 years and observed that components of non-dispersed crude oil, specifically aromatic hydrocarbons, remain in the mangrove substrate in the non-dispersed site, where chronic exposure continues to inhibit recovery and repopulation. According to Duerr et al.(2011), NEBA also assumed that removing oil from the water surface and dispersing it into the water column by the use of chemical dispersants will benefit marine wildlife by decreasing the risk of significant contamination to feathers or fur.

7. Conclusion

Dispersants are known to be an appropriate solution for offshore spill response when dilution conditions are high and dispersed oil concentrations decrease rapidly below levels that could potentially harm the environment. In coastal areas, however, where dilution can be restricted due to limited depth and proximity to various coastal resources, dispersant use requires further consideration. In certain cases, the use of dispersants could be beneficial to these regions while in others their use may be more problematic. In response to these situations, it is necessary to analyze and assess the advantages and potential risks of dispersing oil in these sensitive regions(Dussauze et al., 2011).

As suggested by Joeckel et al.(2011), recognizing that dispersants can be misunderstood and misjudged by those unfamiliar with them including regulators, academic scientists, elected officials, fishermen, the media and the public, realistic expectations about dispersants should be cultivated during response, preferably using knowledge-based outreach and risk communication methods.

DeMicco et al.(2011) concluded that dispersed oil did not become trapped in the substrate and consequently allowed for short-term recovery at the dispersed oil site. Conversely, at the non-dispersed crude oil site, oil penetrated and adhered to the substrate and became trapped, where it remained, albeit in small quantities. In addition, the spike in PAHs at the non-dispersed site raises the specter that oil trapped in the substrate may naturally degrade into more toxic compounds. Their observations underline the importance of considering the nearshore use of dispersants.

We have been reluctant to use dispersants in oil spill incidents in Korea by means of the negative public opinion on dispersant utilization or worker's hesitation from lack of scientific data. Immediate use of dispersants is advantageous under inappropriate conditions, such as harsh weather, difficult access to the area in time, huge scale of oil accidents, etc.

The decision to use dispersants in response to oil spills revolves around an evaluation of the potential costs and benefits. Once oil spills onto the sea, all artificial subjects including aquacultural products are badly affected by the floating oil slicks or physically dispersed oil droplets, even without dispersant utilization. Therefore, it must be meaningful if we begin to change our attitude to use dispersant more positively in oil spill incidents based on the scientific data. In an attempt to seek social consensus on the issue, further studies on dispersants and continuous information service to the public are needed.

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