Oil Spill Dispersants: A Literature Review

Prince William Sound
Regional Citizens Advisory
Committee

Overview

- Introduction and Dispersant Issues
- This Literature Review – 2017-2021
- Findings from Literature Review
- Effectiveness
- Toxicity
- Biodegradation
- NAS review and Other Issues
- Summary

Dispersants - further

- Most dispersants consist of a mixture of surfactants and solvents
- These ingredients vary in toxicity and fate in the environment
- Corexit 9500 – used extensively at Deepwater Horizon spill consists of 3 surfactants – DOSS, Span, Tween with 2 or 3 solvents
- Note dispersant formulations not changed over 25 years
- Each of these ingredients could be tracked separately during a spill

How are dispersants applied?

- Typically using aircraft

Basic Limitations

- Oil must be fresh and not viscous
- Must be able to deliver adequate dose to oil
- Oil must be thick – not light sheen
- Must be done early - within a time window

The Issues Regarding Dispersants

- Many – but three (five) primary ones at this time
- Effectiveness – Do dispersants really work on the oil under consideration?
- Toxicity – Does adding the dispersant make the oil more or less toxic?
- Biodegradation or Fate of the oil – How does adding dispersants affect the oil?

Further Issues Regarding Dispersants

- Two additional ones now
- 4 - The effect of dispersants and dispersed oil on human health
- 5 – The effect of dispersants on marine snow formation and sedimentation (i.e., do dispersants sink more oil that would occur without dispersants)

Effectiveness

- Will the dispersant and its application be effective on the target oil?
- Define effectiveness minimum – 50% - 100% - wouldn't it have to be effective enough to protect wildlife (birds and mammals) and the shoreline
- What if dispersants were applied and there still was massive oiling of wildlife and shoreline?

Special Issues for PWS

- Temperature – water temperatures are below most other waters
- Salinity – many regions have lower salinity – detrimental to effectiveness
- Sediment – sediment in water high in regions – would cause sedimentation if oil dispersed

Toxicity

- Major considerations 1. if dispersants are effective, much more oil is put into the water 2. PAHs (toxic to fish) are made soluble in water by dispersants
- Most toxicologists find that mechanically-dispersed oil is less toxic than chemically-dispersed oil
- Most toxicologists find that chemically-dispersed oil is more toxic to fish and aquatic life

Fate and Biodegradation

- Question is – Do Dispersants change or alter the fate of oil?
- Oil degrades to various other compounds – mostly oxygenated compounds – how do dispersants change this?
- Small part of oil goes to CO_2 - this complete biodegradation is called mineralization
- Are other fates changed with the use of dispersants?

Effects on Human Health

- Early in the studies – but there are findings that dispersants may impact human health – particularly the respiratory tract is harmed by aerosols

Effect on Marine Snow and Sedimentation

- Studies show that dispersed oil reacts with marine flora to increase marine snow formation and thus increases sedimentation by as much as 10-fold

A Short History of Use of Dispersants

- In USA – little use until the Deepwater Horizon spill where dispersants were injected at the well head - as well as used on the surface
- In Alaska – a few trial runs were carried out on the Exxon Valdez spill – little success – most dispersant ran off oil
- Elsewhere – used more in third-world countries and somewhat in United Kingdom
- Banned in some countries, prime response in others - in recent years less use all around

Initial Deepwater Horizon Dispersant Application was Outside Plume

Exxon Valdez – application to emulsified oil in Gulf of Alaska - unsuccessful

Before or after application – slicks appeared to be same

The Latest Literature Review

- Is the fifth in a series – dating back to 1997
- Literature review now includes more than 1700 papers
- The emphasis on topics changes over the years – depending on importance of issues at the time
- Number of papers increases for a few years after a major spill

General Findings

Effectiveness

- In the last review period (2017-2021) not much activity in area

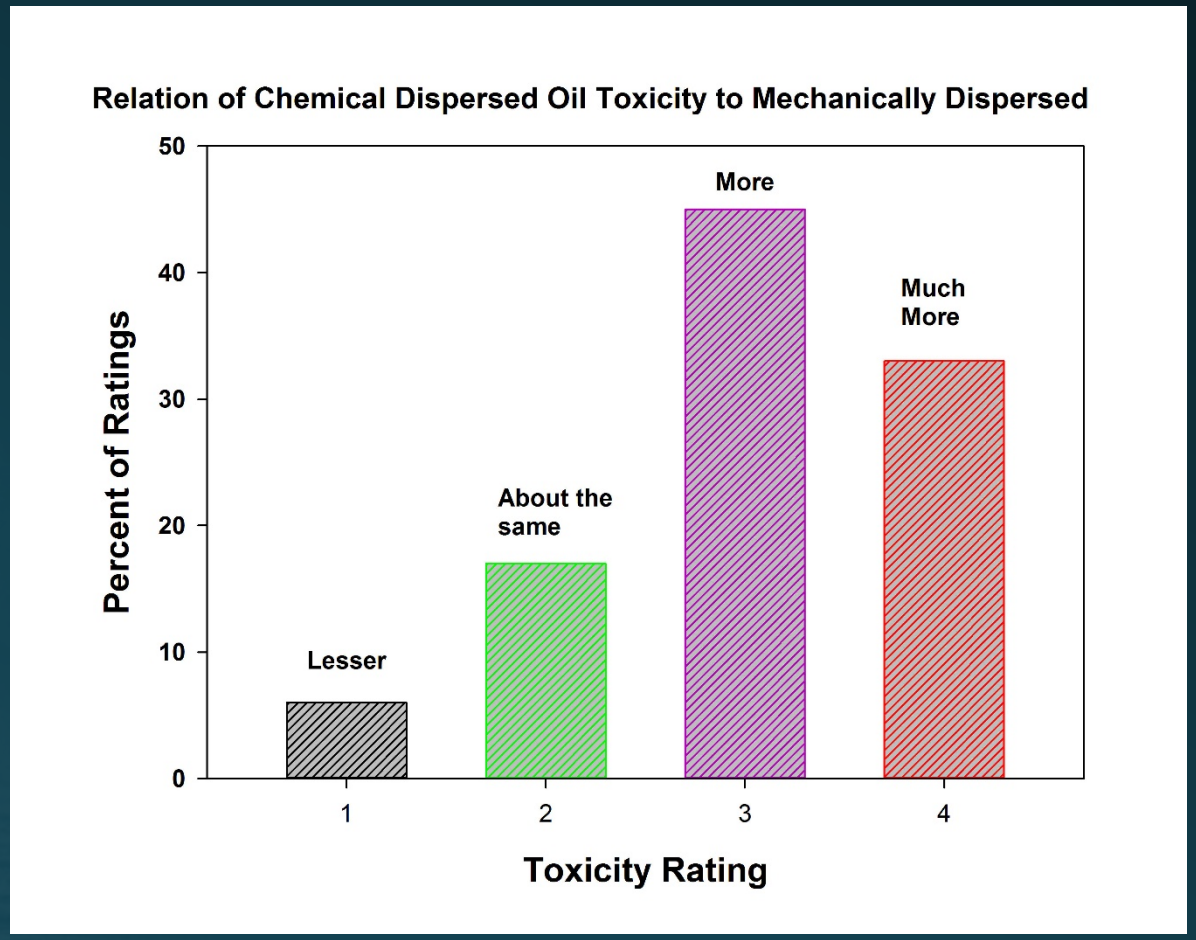
Question re: Deepwater Horizon

- If dispersants were so effective, why did so much shoreline oiling take place and why were so many birds and other wildlife oiled?
- No specific studies done on effectiveness either subsea or on-sea
- NAS study says only a few percent of deep oil remained in water
- The effectiveness on DWH remains open to question
- Analytical techniques for at-sea, laboratory and tank tests need improvement

Aquatic Toxicity

- Very extensive studies carried out – not only involving basic toxicity tests but also chronic testing with many different end-points
- Deepwater Horizon resulted in extensive funding – mostly to established research groups
- There were about 220 individual tests by 25 research groups
- Most studies showed that the chemically-dispersed oil was more toxic than the mechanically-dispersed oil

Findings: most find chemically-dispersed oil more toxic than mechanically-dispersed



Why would chemically-dispersed oil be more toxic than mechanically-dispersed

- The use of dispersant drives PAHs into the water column
- These PAHs are aquatically-toxic
- This does not occur with mechanically-dispersed oil
- Some researchers also indicate that chemically-dispersed oil may be more bioavailable
- In most studies, it was found that CEWAF (Chemically-Dispersed) was from slightly to 1.5 to 100 to as much as 500 times more toxic than the WAF (Mechanically-dispersed)

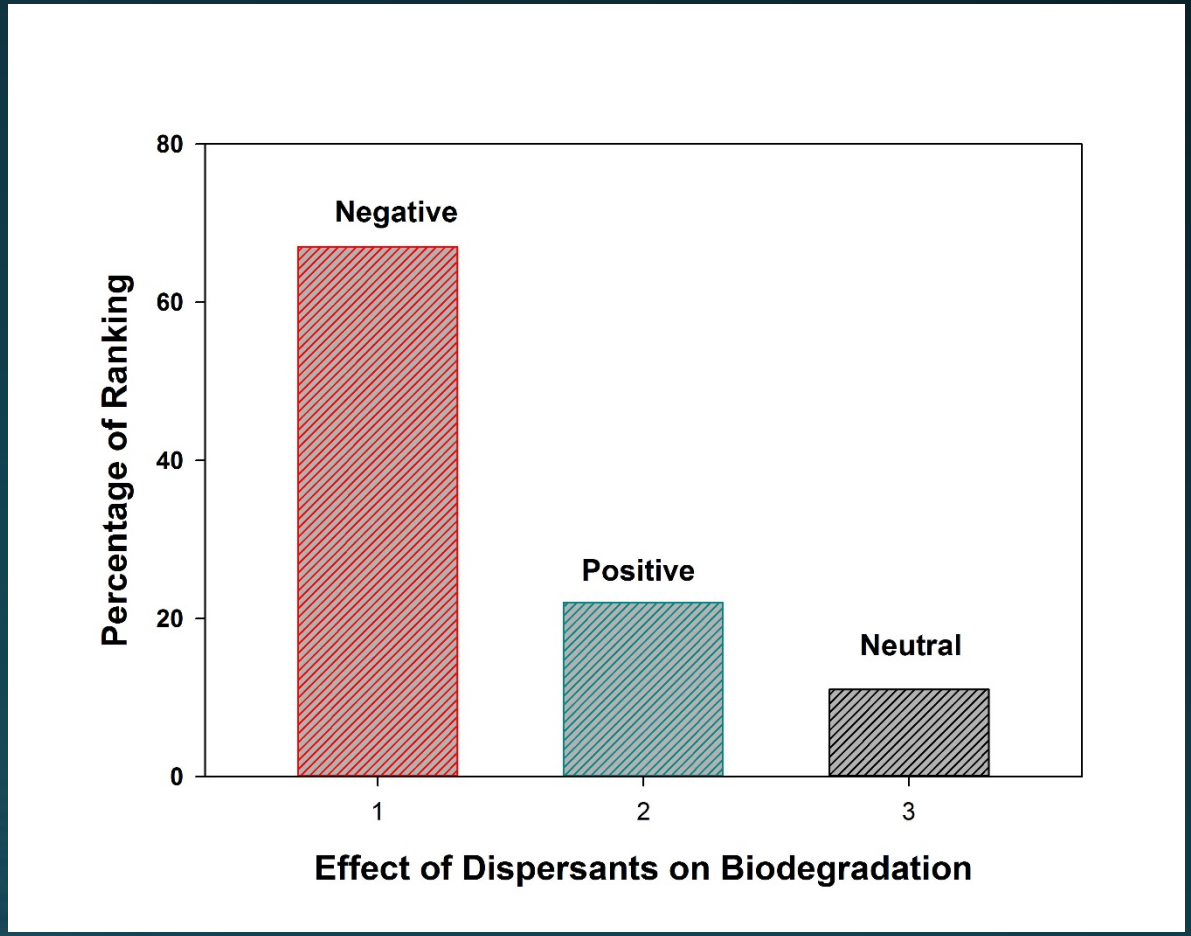
Biodegradation & Fate of Spilled Oil

- Was extensively studied in this time period
- Biodegradation which is degradation to any carbon species is often confused with degradation to CO_2 which is called 'mineralization'
- Mineralization is true conversion of oil to harmless species
- Most biodegradation results in conversion of oil components to other species, usually oxygenated, which are sometimes more toxic than the starting oil

Results of Recent Studies

- Most authors conclude that that dispersants suppress biodegradation.
- The reason suggested is that some components of dispersants are toxic to some biodegrading bacteria and not others
- This results in a species shift and a delay in biodegradation

Results of Studies – most studies show that dispersants slow biodegradation



Shift of Species

- Several studies show that the presence of dispersants alters both the numbers and succession of hydrocarbon degrading organisms
- This is the result of selective toxicity of dispersants to some species while other species are tolerant of dispersants
- The end result of this number and succession shift is generally a reduction in biodegradation compared to a situation where dispersants are not used
- Another result is that certain components of oil are degraded faster or slower than they would be if dispersants were not used

Marine Snow Formation

- Marine snow is the formation of mucous-like agglomerates including oil
- Marine snow is enhanced by spills and is increased by the presence of dispersants
- As much as 14% of all the DWH oil may have been sedimented to the sea floor as marine snow in a spill

Marine Snow with Oil

Oil-Sediment Interaction

- Studies now show that dispersants enhance the formation of oil-sediment aggregates
- Thus dispersant use will enhance the sedimentation of oil to the sea floor

Dispersion Stability

- It is known that oil dispersions are not stable and will resurface
- Some study and notes of this topic in this review period

Human Health Studies

- Many health studies conducted during previous review period
- Results follow:
- Largest health effect was from inhalation of aerosols which are increased by the use of dispersants
- The health risk from approved sea food was low and maybe less than the risk from inland sea food
- There was low risk to cleanup workers of exposure to inhalation of high levels of toxicants however blood levels of some oil components were found

Fate of Oil/Dispersants

- Some dispersant components may be subject to photolysis and photodegrade in near-surface waters
- The dispersant Corexit 9500 appears to inhibit the photodegradation of PAHs
- One surfactant ingredient in Corexit 9500, may increase the aerosolization of oil
- Dispersants increase the sediment uptake of PAHs

Summary

- This period review (2017-2021) saw a steady amount of papers – mostly peer-reviewed
- Many studies in last review period were very scientific– much better than before

NAS Review of Dispersants

- Completely out of step with literature –especially that of aquatic effects and biodegradation – literature was not reviewed
- Summary not in line with internal contents e.g. main report has fact that less than 2% of oil retained in deep water – but summary claims deep injection worked !
- Most of participants were dispersant proponents, completely out-of-step with current knowledge

Conclusions

- Toxicity and effects – Most studies found that chemically-dispersed oil was more toxic to aquatic life than mechanically-dispersed oil
- Dispersants increase PAHs and BTEX in the water column
- Biodegradation and fate – Most studies found that dispersants slow the biodegradation of oil
- Dispersants change the population of different degrading genotypes and thus results in a biodegradation rate and type change

Conclusions …

- Effectiveness – still a question of 'is a dispersant application effective if there is massive shoreline oil and massive bird and mammal oil'?
- Many new case studies show minimal effectiveness
- Marine Snow – results in large amounts of oil on the sea floor, accelerated by use of dispersants
- Oil-Sediment Aggregates – also results in amounts of oil on the sea floor, accelerated by use of dispersants