OIL ON WATER SHEENS

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1. INTRODUCTION

When any liquid is poured onto another liquid, there are four possible events that can occur depending on the properties of the two liquids.

a. The two liquids are miscible and completely mix together. An example of this is water and alcohol.

b. The two liquids chemically react and form a new compound.

c. The first liquid is non-miscible and heavier than the second. In this case the first liquid sinks to the bottom. This is the case for some very heavy crude oils, with an API gravity of less than 10, in fresh water. API gravity is a measure of the density of oil, the greater the API gravity the lighter the oil.

d. The two liquids are non-miscible and the first is lighter than the second. The first liquid then spreads on the surface of the second liquid forming a thin layer. The thickness of this layer depends on the properties of the two liquids. This is the case for most hydrocarbons, including both refined products and crude oil of API gravity greater than 10.

2. APPEARANCE OF SHEEN

In the case of most hydrocarbons, the oil continues to spread and eventually becomes a very thin film known as sheen. The thickness of this film is less than one micron (1µm). In comparison, the thickness of a human hair varies from 20-180 µm, depending on the hair colour and the age of the person. This film is transparent and has a silver to silver-grey appearance. Sheen contains very little oil, less than one cubic metre in a square kilometre, or about one cup of oil will cover the area of a typical house. As oil spreads on water, the oil slick changes in colour from black or brown to a rainbow of colours and finally to the silver or silver-grey of sheen.

Figure 1. Sheen and Rainbow Oil

The later two stages are shown in figure 1. The colour of the oil can be related to oil thickness in the rainbow phase since the colours are caused by thin-film interference. Otherwise, for grey sheen or black oil the thickness cannot be related to the appearance of the oil.

3. FORMATION OF SHEEN

Nearly all hydrocarbons when spilled on water will eventually form a sheen, but the timing and mechanism will vary depending on the properties of the spilled material. Viscosity, which is a measure of the ability of the oil to flow, is the main characteristic that controls the formation of sheen. Refined products such as gasoline and diesel fuel have low viscosities, and thus spread quickly. They generally only form rainbow colours blending into a sheen. The only exception is diesel fuel under very cold conditions and if the slick is thickened against a barrier. For most crude oils, the oil spreads out quickly and after a few minutes forms a dark slick. Under undisturbed conditions, the slick will be black and circular as shown in figure 2. Surface disturbances such as wind, waves or currents will cause this circular slick to break up into smaller sizes with sheen forming in between the individual slicks. For crude oils with an API gravity of greater than 30, the slick will generate a sheen during the early stages of spreading as shown in figure 3.

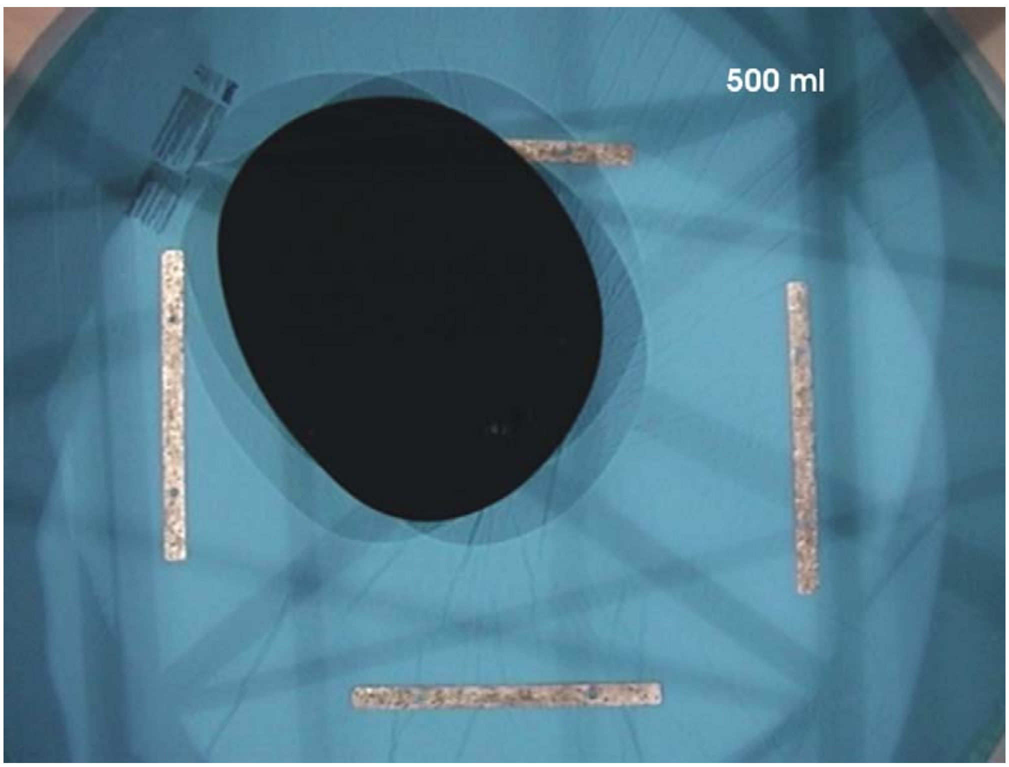

Figure 2. Initial spreading of oil on water API 25

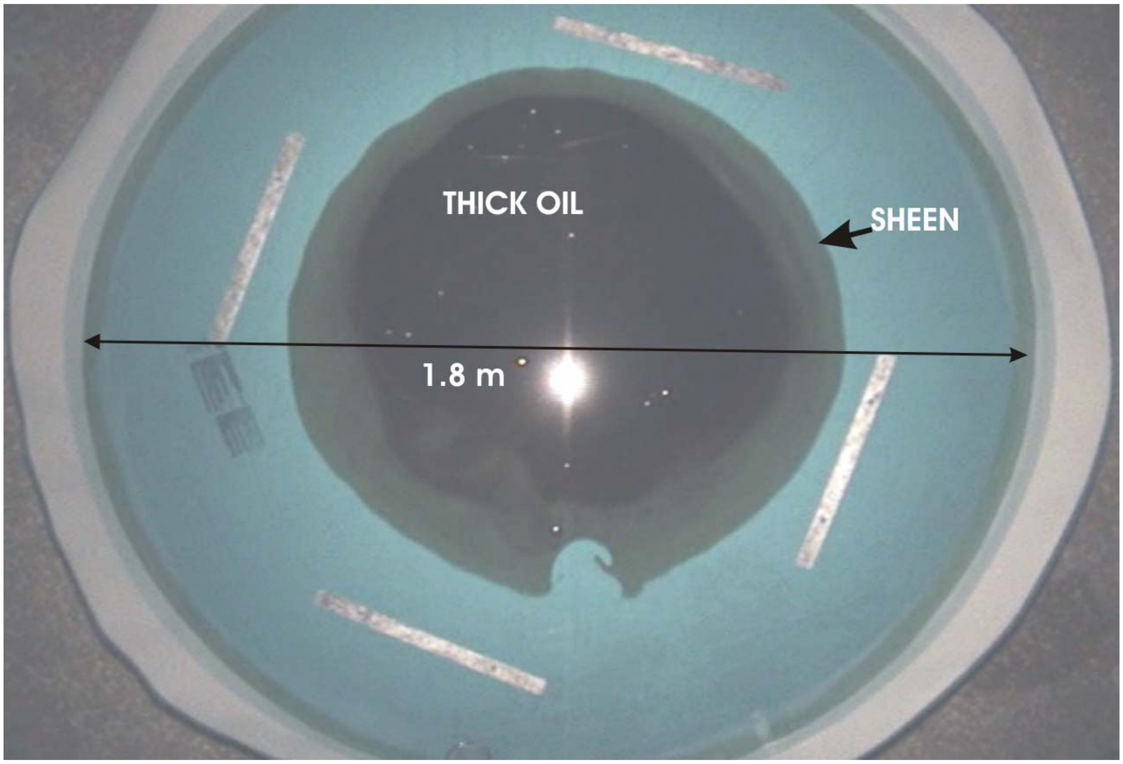

Figure 3. Initial Spreading of Oil API 34

4. DETECTING SHEEN

It is difficult to detect sheen at low angles such as from a boat or on shore. It is best to use a fixed-wing aircraft or a helicopter as an observing platform. In some situations, the oil slick can be identified from a bridge or other structure crossing the river. The closer to vertical the observation, the better the chance of detection. If possible the observation should be made with the sun over your shoulder. The sheen will appear as a grey film with indistinct edges. If there are ripples on the water, they will be propagated through the sheen with very little change in appearance.

Most refined products, such as gasoline and diesel, form only sheen, and sheen is typically associated with boom failure due to entrainment, when oil resurfaces after the use of dispersants or due to a reduction in wave energy. Sheen is more prominent when the oil release is under water, than for a surface release.

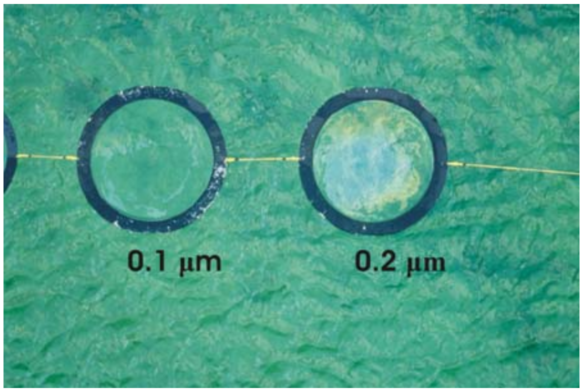

Figure 4. Visibility of sheen

There have been a number of studies of the minimum thickness of sheen that can be visually detected.

These experiments consisted of putting a known volume of oil in a small circular boom and determining whether the oil can be seen. These observations were made directly above the oil, at nadir, as shown in figure 4. The limit for the visual observation of sheen would seem to be between 0.1 and 0.15 µm, depending on the colour of the initial oil. Refined products such as gasoline and diesel fuel are more difficult to detect than sheens from black oil.

During recent flights in Atlantic Canada, by Environment Canada, sheens much thinner than 0.1 µm were detected using a state-of-the-art laser oil detection system called SLEAF (Scanning Laser Environmental Airborne Fluorosensor).

5. THEORY OF SHEEN

The presence of sheen is a nearly universal characteristic of an oil spill on water, and there have been a number of experiments that have studied the spreading of oil on water. Since sheen is very thin, and thus contains little oil, little attention has been paid to the characteristics of sheen. The commonly used models of oil spreading predict that the oil will spread continuously, forming an ever-thinning oil slick. Many observations have in fact shown that the oil spreads as a thick patch from which sheen is generated as shown in figure 3. This so called "fried egg" appearance is commonly observed but has not been successfully modeled, despite many attempts to provide a mathematical description of this fried egg effect.

There is only a limited understanding of the thin-thick oil system and the mechanism that causes this separation. While it is unlikely that the sheen and the thick oil have the same chemical composition, there is little experimental information on the possibility of fractionation of the oil. Evaporation is a major source of loss of oil volume to the atmosphere. The greater area to volume ratio of sheen increases that rate of evaporation, which primarily affects the lighter ends of the oil. Thus, after a short time, there will be fewer light ends in the sheen when compared to the thicker oil. Refined products, which contain only a limited number of fractions, will evaporate completely with little or no residue.

6. REMOVAL OF SHEEN

Figure 5. Sorbent pad and boom

Since the sheen is very thin, it is not practical to use mechanical systems such as skimmers to remove the oil from the water. The most practical method is to use a combination of oil boom and sorbent pads as shown in figure 5. Sorbent pads can be made of either natural materials such as straw or activated peat moss, or synthetic materials like polypropylene. Under field conditions, it is very difficult to remove sheen from the water due to the large area involved and the small amount of oil contained by sheen. If there is a current, the oil is moved into the boomed area, where it is sorbed on the white sorbent pads. It is possible to use booms that are constructed only of sorbent materials if environmental conditions permit.

Figure 6. Sorbent pads used in calm conditions

If there is no water movement, then sorbent pads can simply be placed on the water surface, as shown for an experimental test program in figure 6.

If the sheen is trapped within a complex environment such as a marsh or under a peer, it can be moved into a more convenient location using a number of techniques including the use of leaf blowers to move the oil, or in some situations oil-herding agents can be used.

7. ENVIRONMENTAL IMPACT OF SHEEN

The most dramatic impact of an oil spill is the lethal coating of birds, marine mammals, fish and shoreline vegetation with black oil. The cause of death is by smothering or a significant reduction of the ability of the critters to hunt. Ingestion due to cleaning or preening is frequently a cause of mortality. The small amount of oil in sheen does not cause such a dramatic effect, but still there is the potential of an environmental impact. Early life stages are the most vulnerable to oil impact. For example, the eggs and larvae of many fish species float on the surface and the thin walls can absorb hydrocarbons into the egg or larvae and cause an impact. Many animals recognize their young by smell, and if the juveniles are coated with oil, they will be rejected and die. Similarly, it has been found that even a small amount of oil on a nesting bird can be transferred to the egg and cause mutations. Many water plants depend on breathing of air through the exposed leaves.

Figure 7. Beach oiled with crude oil

If these are covered with even sheen, the plant will be unable to photosynthesize and thus die.

The long-term impact of an oil spill on the ecosystem is the destruction of habitat rather than the death of an individual plant or animal (an exception is rare or endangered species). Transient sheen will not likely cause any permanent habitat loss, whereas the chronic release of sheen from an oiled shoreline or in the case of a marina with chronic small spills could cause a change in the habitat and hence have an environmental impact. Most ecosystems are very resilient, and quickly recruit species from adjacent non-contaminated areas. During this recruitment process, the biodiversity of the ecosystem could be reduced.

The sheen from most oil spills will weather in a few days and be dissipated due to the effects of evaporation and wave action. Thus for the spill situation, the issue of sheen is generally transitory.

The main threat of sheen is to eggs, larvae and juveniles and thus will be greatest during the spring breeding season and for a time thereafter.

8. RULE OF THUMB

It is a rule of thumb that 90% of the oil is in 10% of the area, that is the thick oil. And conversely 10% of the oil is in 90% of the area, that is the sheen.

9. DEFINITIONS

API Gravity—is an expanded density scale to describe crude oils and is measured in degrees (º) API Gravity = (141.5/S.G.) - 131.5

Dispersant--a surface-active agent that reduces the surface tension between oil and water

Dispersion--the process by which oil is incorporated into water as small droplets. Sometimes called entrainment

Entrainment--trapping of a bubble of one liquid in another non-miscible liquid

Interference pattern—caused by the reflection from the top and bottom of the film. If the film thickness is equal to a wavelength of light, that colour will be more strongly reflected

Micron--one millionth of a metre

Miscible--the degree to which two liquids will mix and form a single solution

Nadir--to look at something from a vertical position that is directly down.

Sheen—thin oil film observed when oil is spilled on water

Surface tension—forces between two non-miscible liquids which prohibits their motion

Viscosity--the resistance of a fluid to flow

Weather--used when describing oil spills as those processes, which cause a change in the properties of the oil with time. Weathering processes include evaporation, dispersion and dissolution

10. GENERAL READING

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