Low Sulfur Fuel Oil – Distillate Marine Fuels

Introduction

- To reduce emissions from shipping, the International Maritime Organization (IMO) issued revisions to MARPOL Annex VI, setting a target of January 2020 for the implementation of a new low sulfur fuel policy. This new regulation, known as "IMO 2020," limits the sulfur content of marine fuel to 0.5% for very low sulfur fuel oils (VLSFO) and 0.1% for ultra low sulfur fuel oils (ULSFO).
- Since the implementation of IMO 2020, there has been a trend of identifying Low Sulfur Fuel Oils (LSFOs) primarily by their sulfur content and not using other naming conventions that provide a better description of their viscosity or general fuel type, such as ISO 8217 specifications (see table below). This focus solely on sulfur content causes confusion when fuels with different properties and environmental behavior are called by the same name.
- Like pre-IMO 2020 fuels, LSFOs can be classified as: 1) Distillate Marine fuels, which have API gravity similar to traditional diesel, and 2) Residual Marine fuels, which have API gravity similar to traditional intermediate and heavy fuel oils such as IFO 180 or IFO 380.
- Responders should ask for the Certificate of Analysis (CoA) for LSFO being carried as cargo, or the bunker note for LSFOs being carried as bunker fuel. These documents contain information such as API gravity and viscosity, and sometimes also include the pour point or distillation data. They are good initial sources of information which can be used to classify the LSFO as a distillate or residual fuel and may give an indication of how a fuel will behave in the environment.
- The evidence from the recent literature and samples analyzed in our laboratory suggests that the chemical compositions of Distillate Marine LSFOs are similar to traditional diesel. The amount of sulfur in a distillation fraction increases with boiling range, so diesel-type oils (a lighter fraction) tend to have lower initial concentrations of sulfur. Additionally, in lighter refinery cuts, such as naphtha, distillate, and light vacuum gas oil fractions, sulfur is typically found in smaller, non-aromatic structures such as alkyl sulfides and disulfides. These compounds are relatively easy to remove by hydro-desulfurization.
- This fact sheet covers LSFO Distillate Marine fuel oils, which are similar to traditional marine diesels and marine gas oils. There is a separate fact sheet for LSFO Residual Marine fuel oils. The table below shows the naming convention for distillate marine fuels under the ISO 8217 standard.
- Distillate Marine fuel oils also include Marine Gas Oil (MGO), which is similar to road diesel and often meets the specifications for DMA or DMZ, and Wide Range Gas Oil (WRG), a heavier distillate than MGO.

Property	Unit	Limit	ISO 8217 2017 Standard Distillate Marine Fuel Category			
			DMX[1]	DMA[2]	DMZ[2]	DMB[3]
Kinematic viscosity at 40°C (104°F)	mm^2/s	Max	5.5	6	6	11
		Min	1.4	2	3	2
Density at 15°C (59°F)	g/m^3	Max	-	0.890	0.890	0.900
Flash point	°C	Min	43	60	60	60
Pour point, Summer	°C (°F)	Max	-	0 (32)	0 (32)	6 (43)
Pour point, Winter	°C (°F)	Max	-	-6 (21)	-6 (21)	0 (32)

[1] DMX - special light distillate intended mainly for use in emergency engines.
[2] DMA/DMZ (also termed marine gas oil, MGO) - general purpose marine distillate that must be free from traces of residual fuel.
[3] DMB (marine diesel oil, MDO) - has traces of residual fuel, which can be high in sulfur. The contamination with residual fuel usually occurs in the distribution process, when using the same supply means (e.g., pipelines, supply vessels) used for residual fuel. DMB is produced when fuels such as DMA are brought on board the vessel this manner.

Physical Properties

- Distillate fuel oils are much lighter than water (specific gravity is 0.82-0.88, vs. 1.00 for fresh water and 1.03 for seawater). It is not possible for distillate fuel oils to sink and accumulate on the bottom as free oil.
- Distillate fuel oils tend to have low viscosities, and surface sheens are readily dispersed into the water column when winds exceed 7 knots. However, slicks will be more persistent under low winds and in relatively sheltered waterbodies.

Environmental Behavior

- When spilled on water, distillate fuel oils quickly spread to a thin film. Even when a diesel is described as a heavy sheen, it is 0.0004 inches thick and contains about 1,000 gallons per square nautical mile of continuous coverage. The volume of oil in areas covered by streamers would be much less. Silver sheen only contains about 75 gallons per square nautical mile.
- When spilled on open water, most of the oil evaporates or naturally disperses within days or less, even in cold water. Thus, there is seldom any recoverable oil on the surface. Figure 1 shows WebGNOME oil weathering model results for both an LSFO diesel and a pre-IMO 2020 diesel at an air temperature of 21°C (70°F) and a wind of 5 knots, and Figure 2 shows WebGNOME model results for the same oils at 21°C (70°F) and 20 knot winds.
- However, if the distillate fuel oil is released on or very close to shore or concentrates on catchment beaches, there can be heavy loading and penetration into the sediments when the groundwater in the beach falls during low tide, even in beaches and flats with a coarse-grained sediment veneer.
- Distillate fuel oil is not as sticky or viscous as black oils. When small spills do strand on the shoreline, the oil tends to penetrate porous sediments quickly, but also tends to be washed off quickly by waves and tidal flushing. Thus, shoreline cleanup may not be needed after small spills.
- Distillate fuel oil that is dispersed in the water column can adhere to fine-grained suspended sediments, which then settle out and are deposited on the bottom of a water body. This process is more likely to occur in streams and rivers with significant suspended sediment loads. It is less likely to occur in open marine settings. This process is not likely to result in measurable sediment contamination for small spills.
- Distillate fuel oil is readily and completely degraded by naturally occurring microbes, under time frames of 1-2 months when there is sufficient oxygen. Nutrient addition may speed this process in soils. Diesel that has penetrated into shoreline sediments where conditions are not favorable for natural removal or degradation may persist for months to years.

Toxicological Properties and Environmental Effects

- Diesel is one of the most acutely toxic oil types. Fish and invertebrates in direct contact with naturally dispersed and entrained diesel in the water column may be killed. However, small spills in open water are so rapidly diluted that fish kills have never been reported. Fish kills have been reported for small spills in confined, shallow water and in streams, where weathering and mixing are reduced. Animals in small streams can be affected for miles downstream of a diesel release. Figure 3 shows CAFE toxicity model results for a variety of salt-water species exposed to diesel for 96 hours.
- Naturally dispersed diesel in shallow, nearshore environment can impact sensitive benthic habitats, such as seagrass beds and coral reefs.
- Where larger amounts of diesel soak into wetland soils, high mortality of animals and plants can be expected.
- Small diesel spills can affect marine birds by direct contact. Mortality is caused by ingestion during preening as well as from hypothermia from matted feathers. Experience with small diesel spills suggests that few birds are directly affected due to the short time the oil is on the water surface. However, small spills could result in serious impacts to birds under the "wrong" conditions, such as a grounding right next to a large nesting colony or transport of sheens into a bird concentration area.

- Shellfish can be tainted from diesel spills in shallow, nearshore areas. These organisms bioaccumulate oil, but will also depurate the oil, usually over a period of several weeks after exposure ends.
- There can be both acute and chronic exposure/effects in shoreline faunal communities, particularly benthic infauna on beaches with persistent oil.

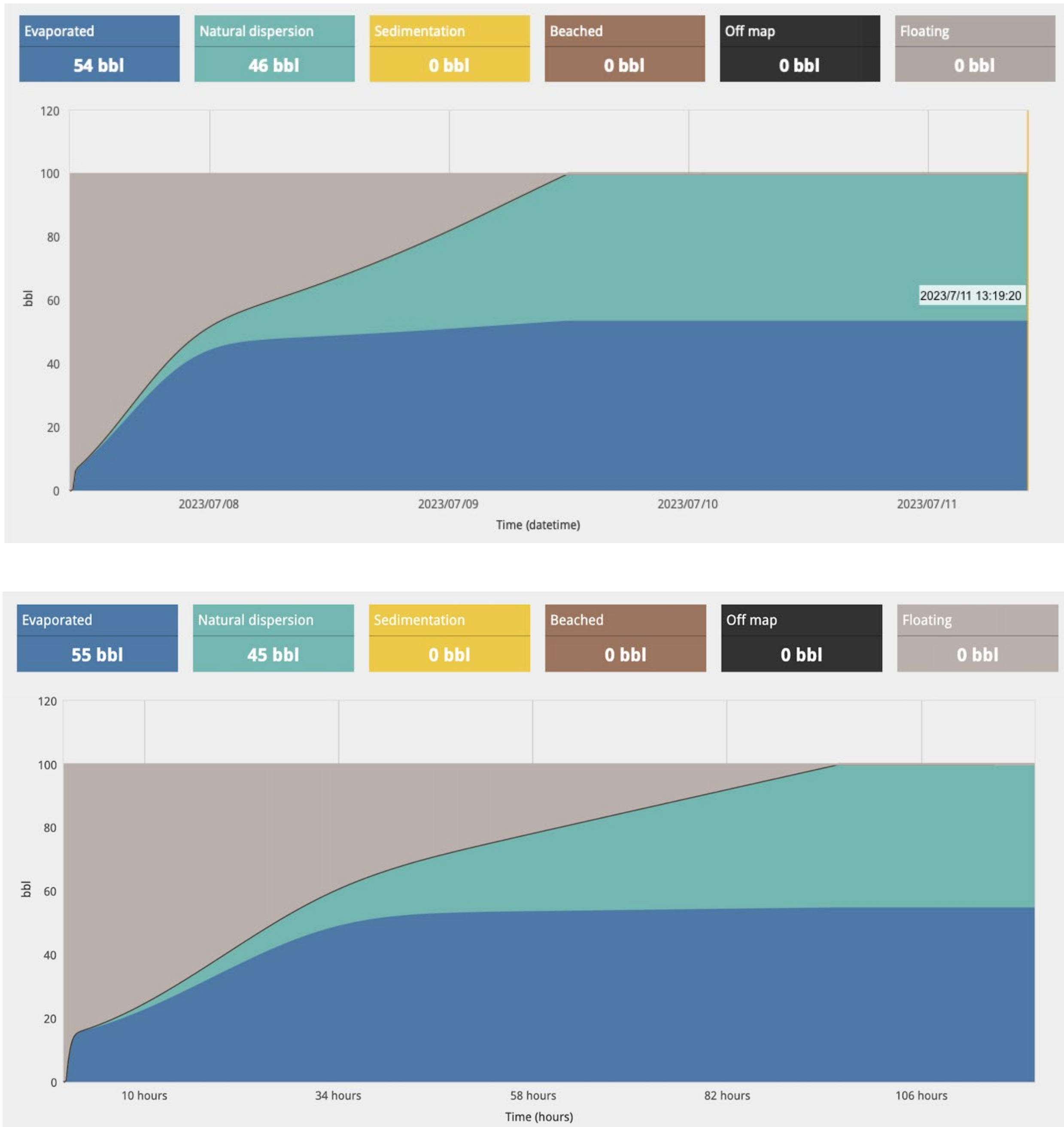
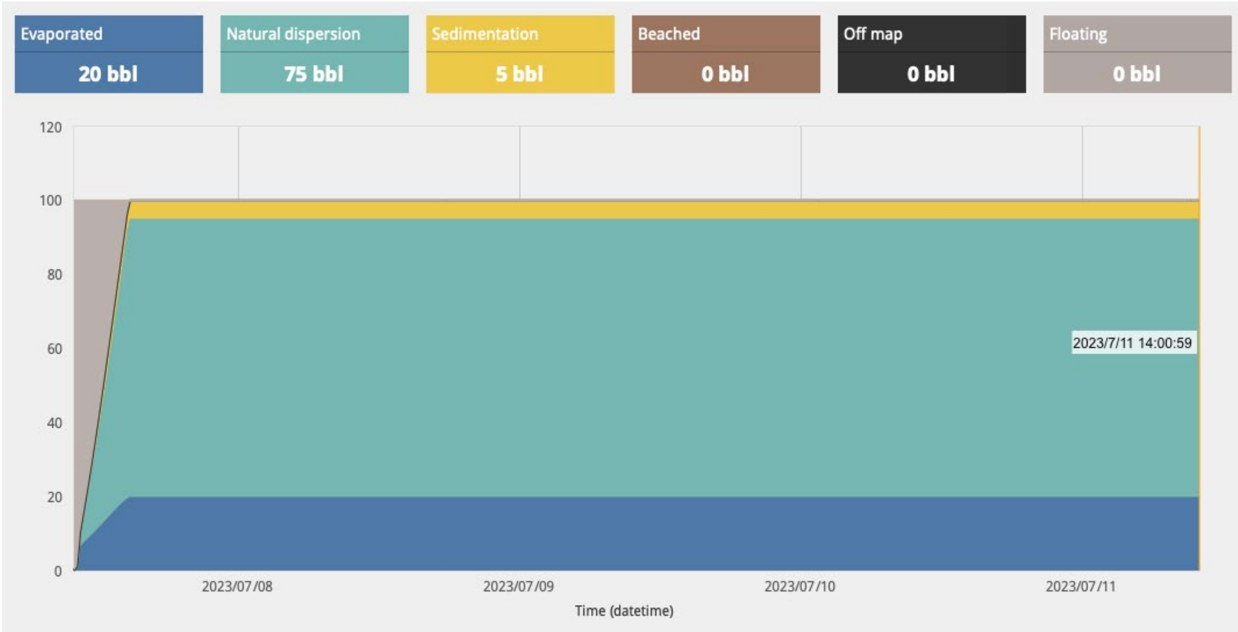


Figure 1. *WebGNOME model output for a 100 bbl diesel spill; wind of 5 knots and water temperature of 21°C (70°F) for a LSFO diesel (top) and pre-IMO 2020 diesel (bottom). Note that the fate is very similar for both types of diesel, with little initial natural dispersion at low wind speeds. WebGNOME:* [*https://gnome.orr.noaa.gov*](https://gnome.orr.noaa.gov)



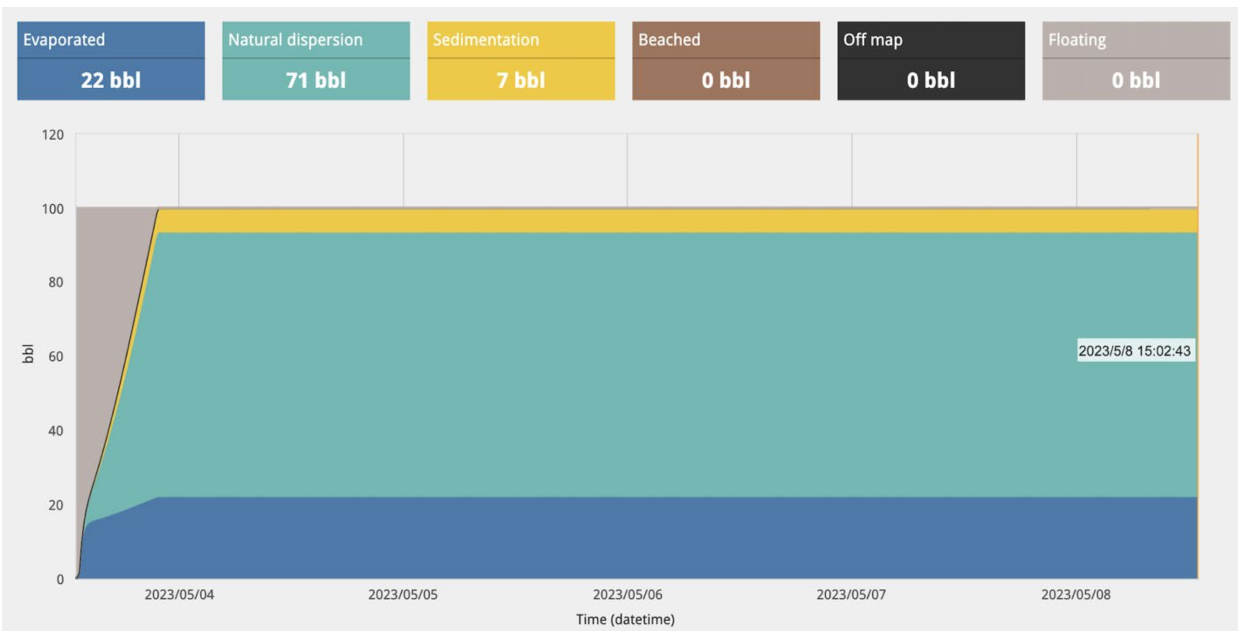


Figure 2. *WebGNOME model output for a 100 bbl diesel spill; wind of 20 knots and water temperature of 21°C (70°F) for a LSFO diesel (top) and pre-IMO 2020 diesel (bottom). Note that the fate is very similar for both types of diesel, with high natural dispersion at high wind* speeds. *WebGNOME: https://gnome.orr.noaa.gov*

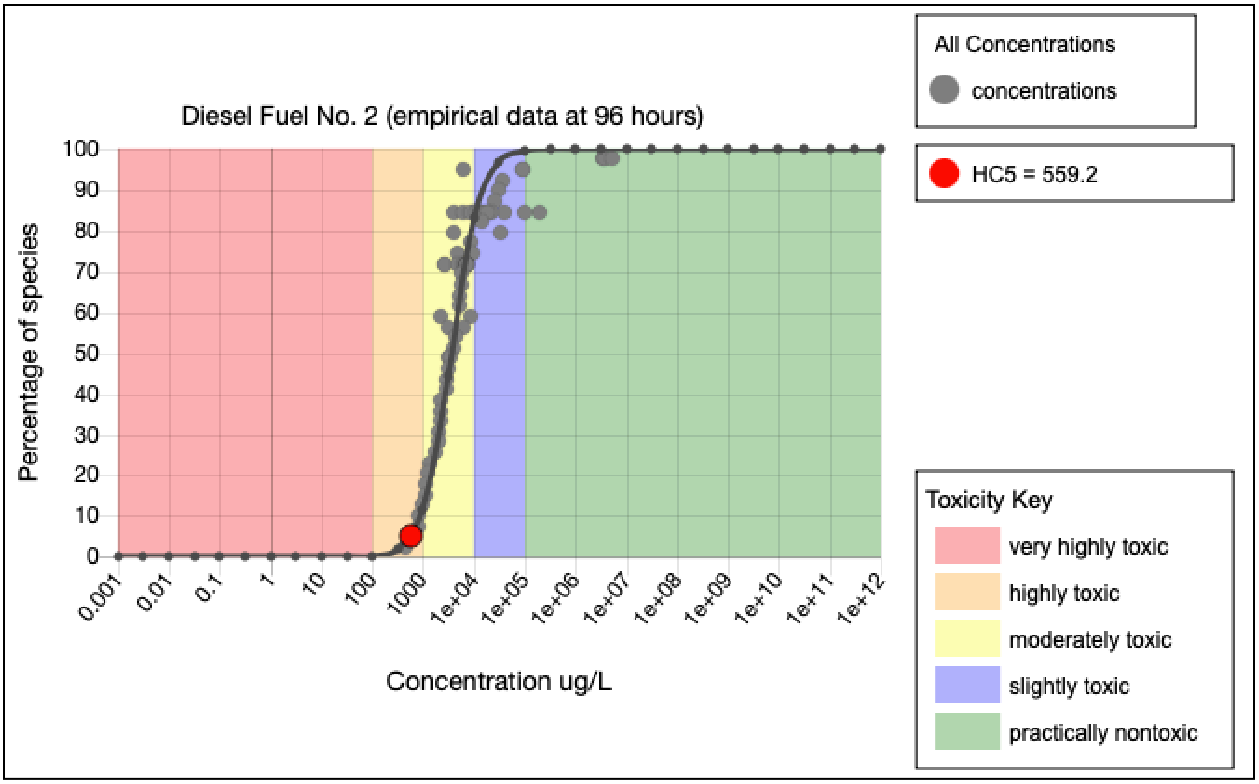


Figure 3. *CAFE (Chemical Aquatic Fate and Effects) toxicity model results for a wide range of salt-water species for exposures at 96 hours, indicating that diesel can be slightly to highly toxic to aquatic organisms. CAFE:* *https://response.restoration.noaa.gov/cafe*

Useful References

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