**Determination of Oil Persistence: A Historical Perspective**

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ABSTRACT: Persistence of petroleum-based oils is a very important consideration in assessing the environmental risk of an oil spill, but is a characteristic that is not easily determined for particular types of oil. This paper reviews the significance of oil persistence in the context of U.S. Environmental Protection Agency (EPA) Facility Response Plan (FRP) requirements under the Oil Pollution Prevention regulations. Persistence affects the resources and techniques that are needed to respond to discharges of oils. This paper also explores how the determination of oil persistence has been addressed historically by agencies and organizations that deal with oil spills. For example, the U.S. Coast Guard rules for vessel- and marine transportation facility response plans characterize oil persistence based on distillation temperatures and specific gravities. However, the U.S. Coast Guard recognizes that persistence can vary among different batches of the same oil type and depends on factors such as wave energy, substrate permeability, and weathering. Several other organizations, such as the National Oceanic and Atmospheric Administration (NOAA), provide guidance on general behavior and properties of different groups of oil. The International Maritime Organization (IMO) has established an official list of persistent oils, because its oil spill liability and compensation requirements cover only spills of persistent oils. Comparison and compatibility of oil persistence determination across organizations are summarized.

## Introduction

Persistence is a complex characteristic of oil related to viscosity, adhesiveness, and evaporative character that accounts for an oil's duration in the environment before degrading. The persistence of petroleum-based oils is very important in assessing the environmental risk of an oil discharge and often affects the resources needed for spill recovery and remediation. The U.S. Environmental Protection Agency (EPA) requires the use of oil persistence levels in developing oil discharge response plans. For example, according to EPA Facility Response Plan (FRP) regulatory requirements, the determination of on-water oil recovery capacities, planning distance, and planning volume calculations all require information about an oil's level of persistence. This paper details the EPA definition of oil persistence and its determination and use.

Despite its importance, oil persistence is not defined consistently nor easily categorized. As this paper shows, persistence can be defined and measured in different ways by the many government agencies (primarily EPA

and the U.S. Coast Guard) and other organizations that deal with oil and oil discharges. This paper provides a historical overview and synthesis of the various definitions of oil persistence and determination methods used by agencies and organizations.

**Significance of Oil Persistence Determination for EPA Regulatory Requirements**

The Clean Water Act (CWA), as amended by the Oil Pollution Act of 1990 (OPA 90), authorizes the President to issue regulations establishing procedures, methods, equipment, and other requirements to prevent discharges of oil from vessels and facilities and to contain such discharges. (See 33 U.S.C. 1321(j)(1)(C)). The President has delegated the authority to regulate non-transportation-related onshore facilities to the U.S. Environmental Protection Agency. The President has delegated similar authority over marine transportation-related facilities, deep water ports, and vessels to the U.S. Coast Guard. Because many "complexes," with a combination of transportation-related and non-transportation-related components, fall under the jurisdiction of both agencies, the EPA and U.S. Coast Guard work closely together to provide consistency in their regulations and policy. While OPA 90 makes no distinction between "persistent" and "non-persistent" oils, both EPA and U.S. Coast Guard define these terms in their OPA 90-mandated rulemakings.

The EPA Facility Response Plan rule (40 CFR 112.20 and 112.21) requires facilities meeting certain "substantial harm" criteria to prepare and submit "a plan for responding, to the maximum extent practicable, to a worst case discharge, and to a substantial threat of such a discharge, of oil." As described in the rule, the required response resources can vary according to the characteristics of the oil involved, including persistence. Appendix E, Section 1.2 of the FRP rule states EPA's definition of persistent and non-persistent oils:

*Non-persistent oils or Group 1 oils include:*

(1) A petroleum-based oil that, at the time of shipment, consists of hydrocarbon fractions:
- At least 50 percent of which by volume, distill at a temperature of 340 degrees C (645 degrees F); and
- At least 95 percent of which by volume, distill at a temperature of 370 degrees C (700 degrees F); and

(2) A non-petroleum oil, other than an animal fat or vegetable oil, with a specific gravity less than 0.8.

*Persistent oils include:*

(1) A petroleum-based oil that does not meet the distillation criteria listed above under "Non-persistent oils or Group 1 oils," is further classified based on specific gravity as follows:

- Group 2 - specific gravity less than 0.85;
- Group 3 - specific gravity equal to or greater than 0.85 and less than 0.95;
- Group 4 - specific gravity equal to or greater than 0.95 and less than 1.0; or
- Group 5 - specific gravity equal to or greater than 1.0.

(2) A non-petroleum oil, other than an animal fat or vegetable oil, with a specific gravity of 0.8 or greater. These oils are further classified based on specific gravity as follows:

- Group 2 - specific gravity equal to or greater than 0.8 and less than 0.85;
- Group 3 - specific gravity equal to or greater than 0.85 and less than 0.95;
- Group 4 - specific gravity equal to or greater than 0.95 and less than 1.0; or
- Group 5 - specific gravity equal to or greater than 1.0.

EPA does not characterize animal fats and vegetable oils by persistence group. For vegetable oils and animal fats, "persistence" depends on many environmental factors and does not determine response planning requirements.

As described in more detail later in this report, the EPA's definition of persistence is consistent with that of the U.S. Coast Guard. Both agencies have worked together to achieve and maintain consistent handling of oil persistence characteristics in their respective regulatory process. This is especially important with regard to certain complex facilities, which are subject to both EPA and U.S. Coast Guard oil-related regulations.

Oil persistence affects the resources needed for oil recovery. In facility response planning, the resources expended to clean up a discharge are determined based on the oil's level of persistence. The following three sections highlight areas where an oil's persistence is used in response planning, as required by 40 CFR 112.20.

*Calculating Planning Distance*

In the EPA FRP rule, Attachment C-III of Appendix C, "Calculation of the Planning Distance" is used to evaluate whether a facility is located where a discharge could cause injury to fish and wildlife and sensitive environments or disrupt operations at a public drinking water intake. To quantify this distance, EPA considers oil transport mechanisms over land, and on still water, tidal-influence areas, and moving navigable waters. The planning distance calculations for moving navigable waters and still waters are based on worst-case discharges of persistent oils (Section 2.5 of Attachment C-III). Persistent oils are of particular concern; however, owners or operators of facilities storing both persistent and non-persistent oils may use a comparable formula for calculating planning distance. The planning distance method for tidal influence navigable water (Section 4.0 of Attachment C-III) is based on worst-case discharges of both persistent and non-persistent oils. For persistent oils discharged into tidal waters, the planning distance is 15 miles from the facility down current during ebb tide and to the point of maximum tidal influence or 15 miles, whichever is less, during flood tide. For non-persistent oils discharged into tidal waters, the planning distance is

5 miles from the facility down current during ebb tide and to the point of maximum tidal influence or 5 miles, whichever is less, during flood tide.

*Determining the required on-water oil recovery capacity*

Section 7.2 of Appendix E of the FRP rule outlines the procedures that must be used in determining the required on-water oil recovery capacity in the event of a discharge. The appropriate persistence group(s) for the types of oil handled, stored, or transported at the facility (as defined above) must be determined. For facilities with oil from different oil groups, each group must be calculated separately. Table 2 of Appendix E (see Exhibit 1) shows the percentages of the total volume to be used for removal capacity planning for petroleum oils, according to oil group. The removal capacity planning information for animal fats and vegetable oils is shown separately in Table 6, Appendix E of the FRP rule. The on-water oil recovery volume is then adjusted according to emulsification factors that correspond with each group, as listed in Appendix E's Table 3 for petroleum oils (see Exhibit 2) (For animal fats and vegetable oils, Table 7 from Appendix E applies). EPA adopted Tables 2 and 3 of Appendix E (Exhibits 1 and 2 shown below) from the U.S. Coast Guard to ensure consistency between the agencies.

**Exhibit 1**
**Oil Removal Capacity Planning Table for Petroleum Oils[1]**

| Spill Location | Rivers and Canals | | | Nearshore/Inland Great Lakes | | |
|---|---|---|---|---|---|---|
| Sustainability of On-water Oil Recovery | 3 Days | | | 4 Days | | |
| Oil Group | Percent Natural Dissipation | Percent Recovered Floating Oil | Percent Oil Onshore | Percent Natural Dissipation | Percent Recovered Floating Oil | Percent Oil Onshore |
| 1. Non-persistent oils | 80 | 10 | 10 | 80 | 20 | 10 |
| 2. Light crudes | 40 | 15 | 45 | 50 | 50 | 30 |
| 3. Medium crudes and fuels | 20 | 15 | 65 | 30 | 50 | 50 |
| 4. Heavy crudes and fuels | 5 | 20 | 75 | 10 | 50 | 70 |
| Group 5 oils are defined in section 1.2.7 of 40 CFR 112 (FRP rule) Appendix E; the response resource considerations are outlined in section 7.6 of the appendix. | | | | | | |

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| 1. Non-petroleum oils are defined in section 1.2.3 of 40 CFR 112 (FRP rule) Appendix E. The response resource considerations for non-petroleum oils other than animal fats and vegetable oils are outlined in section 7.7 of this appendix. |

**Source:** 40 CFR 112 Appendix E, Table 2 and 33 CFR 154, Appendix C, Table 2.

**Exhibit 2**
**Emulsification Factors for Petroleum Oil Groups**

| | |
|---|---|
| **Non-Persistent Oil:** | |
| Group 1 | 1.0 |
| **Persistent Oil**: | |
| Group 2 | 1.8 |
| Group 3 | 2.0 |
| Group 4 | 1.4 |

**Source:** 40 CFR 112 Appendix E, Table 3 and 33 CFR 154 Appendix C, Table 2.

*Calculating Planning Volume for identifying shoreline cleanup oil recovery capacity*

To calculate the shoreline cleanup volume for Groups 1 through Group 4 oils, Section 7.3 of Appendix E to 40 CFR 112 should be used. The shoreline cleanup planning volume, as determined by using Exhibit 1, must be adjusted to reflect an emulsification factor that corresponds with the persistence group of the oil at the facility. Changes in the physical and chemical properties of the oil that result when oil forms an emulsification with water cause evaporation and biodegradation to slow, and may prevent soluble components from dissolving in water. The ease with which an oil emulsifies, and the stability of the emulsion once formed, impact the effectiveness of remedial measures. Therefore, the adjusted shoreline cleanup planning volume is used to identify the resources (oil spill removal organization or other) for appropriate shoreline recovery capability. EPA and U.S. Coast Guard have worked together to determine appropriate emulsification factors.

**Historical Overview of Oil Persistence Determination**

Several other organizations have provided characterizations of oil, including a description of persistence or persistence-like qualities, in order to carry out their various programs and objectives. Determination of oil persistence

and specific definitions of persistence are not consistent across organizations. The following sections describe many of these approaches for addressing oil persistence.

***U.S. Coast Guard***

The U.S. Coast Guard and EPA share responsibilities in implementing Section 311 of the Clean Water Act (CWA), and the Oil Pollution Act of 1990 (OPA 90). Executive Order 11735 gives the U.S. Coast Guard the authority to establish procedures, methods, and other requirements to prevent and contain discharges of oil from vessels and marine transportation-related onshore and offshore facilities. The U.S. Coast Guard's *Oil or Hazardous Material Pollution Prevention Regulations for Vessels*, 33 C.F.R. 155 establishes requirements for oil spill response plans for certain vessels. Vessel owners or operators must determine the persistence of the oils they carry, as certain response plan calculations depend on the level of persistence of an oil. The U.S. Coast Guard regulations also define oil groups according to their persistence:

*Non-persistent or Group 1 Oil* is defined as "a petroleum-based oil that, at the time of shipment, consists of hydrocarbon fractions:

- At least 50% of which, by volume, distill at a temperature of 340°C (645°F); *and* at least 95% of which, by volume, distill at a temperature of 370°C (700°F)."

*Persistent Oil* is defined as "a petroleum-based oil that does not meet the distillation criteria for non-persistent oils." Unlike non-persistent oils, persistent oils are then further classified based on specific gravity, as follows**:**

- Group 2 - Specific gravity less than 0.85 crude [API° >35.0][1]
- •Group 3 - Specific gravity between 0.85 and less than .95 [API° ≤35.0 and >17.5]
- Group 4 - Specific gravity between 0.95 to and including 1.0 [API° ≤17.5 and >10.0]
- Group 5 - Specific gravity greater than 1.0 [API° ≤10.0]

These definitions are consistent with the EPA's definitions, as described above. The U.S. Coast Guard stipulates that distillation characteristics are determined using the American Standards and Testing of Materials (ASTM) Method D 86/78, "or any subsequent revision thereof" and that ASTM Standard D 1298, entitled "Standard Practice for Density, Relative Density (Specific Gravity), or API Gravity of Crude Petroleum and Liquid Petroleum Projects by Hydrometer Method" be used to determine specific gravity for the purposes of all U.S. Coast Guard rules that refer to this classification of oil types.

[1]Note that API gravity (API°) can be converted to specific gravity using the following formula:

specific gravity (at 15.5°C) = 141.5/(API°+131.5)

Despite the existence of a definition of "persistent oils" and "non-persistent oils" with respect to U.S. Coast Guard regulations, as described above, there is not an official list of "persistent oils" or "non-persistent oils." According to the U.S. Coast Guard's Office of Response[2], the major reasons for the lack of a list of persistent and non-persistent oils are two-fold:

- Different batches of a particular oil type may have different characteristics, including those related to persistence in the environment;
- Any particular oil type may have different characteristics of persistence at different times in a spill (due to changes related to weathering) and in different environmental conditions (e.g., differences in water salinity, air and water temperature).

Thus, U.S. Coast Guard emphasizes that it is important not to confine parameters of oil persistence to specific lists of oils because there can be very different behavior of the oils in actual spill situations. The labeling of oils by "types" with related characteristics of persistence in the environment is often too general to apply to all batches of oils.

As shown in the four examples below, non-persistent and persistent oils are often treated differently in response planning requirements. The uses of oil persistence in response planning for U.S. Coast Guard and EPA are very similar. Since there is no list of persistent and non-persistent oils, but only a definition of the different oil groups, it is up to the owner/operator to determine what type of oils the vessel or facility is handling, based on the criteria of distillation fractions and specific gravity, at the time of shipment. Presumably, if the facility or vessel owners/operators had difficulty classifying the different oil types that they handle or ship, they should contact the EPA Oil Program Center for additional guidance.

*Calculations to appropriately reduce impact on fish and wildlife and sensitive environments* Marine transportation-related facilities (those that could reasonably be expected to cause significant and substantial harm to the environment by discharging oil into navigable waters) are required by the U.S. Coast Guard's February 1996 Final Rule *Response Plans for Marine Transportation-Related Facilities* (33 CFR 154) to develop response plans containing a section on fish and wildlife and sensitive environments. This section must, for worst case discharges, "[l]ist all fish and wildlife and sensitive environments identified in the Area Contingency Plan (ACP) which are

[2]Personal communication between Robert Pond, U.S. Coast Guard Office of Response and Dagmar Schmidt Etkin, August 2003.

potentially impacted by a discharge of persistent oils, non-persistent oils, or non-petroleum oils" and describe the response actions that the facility will take to protect these areas. (33 CFR 154.1035(b)(4)(ii)(A)-(B)). This section must identify the appropriate equipment and required personnel to protect the fish, wildlife and sensitive environments which fall within distances calculated according to the persistence of the oil contained by the facility. Distances are to be calculated as follows:

- For persistent oils and non-petroleum oils discharged into non-tidal waters, the distance from the facility reached in 48 hours at maximum current
- For persistent and non-petroleum oils discharged into tidal waters, 15 miles from the facility down current during ebb tide and to the point of maximum total influence or 15 miles, whichever is less, during flood tide.
- For non-persistent oils discharged into non-tidal waters, the distance from the facility reached in 24 hours at maximum current
- For non-persistent oils discharged into tidal waters, 5 miles from the facility down current during ebb tide and to the point of maximum tidal influence or five miles, whichever is less, during flood tide. (33 CFR 154.1035(b)(4)(iii)(A-B)

*Calculating worst case discharge planning volumes*

Appendix C of the *Response Plans for Marine Transportation-Related Facilities* rule (33 CFR 154), "Guidelines for Determining and Evaluating Required Response Resources for Facility Response Plans" requires a determination of the worst case discharge volume of oil in the facility. In determining both on-water recovery and shoreline cleanup capacity, facilities which handle, store, or transport oil from different petroleum groups (non-persistent Group 1 or persistent Groups 2, 3 or 4) must calculate each Group separately. Consistent with EPA's FRP requirements, the oil's persistence group is used with a table in the appendix (reproduced as Exhibit 3 below; note its similarity to EPA's FRP rule Appendix E Table 2, shown as Exhibit 1 above) to determine the percentage of the total volume to be used for removal capacity planning. The on-water oil recovery volume must then be adjusted using the appropriate emulsification factor (dependent on level of oil persistence) found in another table in the appendix, which is identical to the EPA FRP rule's Appendix E Table 3 (see Exhibit 2 above).

Appendix B of the U.S. Coast Guard's *Oil or Hazardous Material Pollution Prevention Regulations for Vessels* regulation (33 CFR 155) ("Determining and Evaluating Required Response Resources for Vessel Response Plans") lists similar requirements and tables used to calculate the worst case discharge planning volumes for vessels (33 CFR 155, Appendix B, Section 7).

**Exhibit 3**
**Oil Removal Capacity Planning Table**

| Spill Location | Rivers and Canals | | | Nearshore/Inland/Great Lakes | | | Offshore | | |
|---|---|---|---|---|---|---|---|---|---|
| **Sustainability of On-Water Oil Recovery** | 3 Days | | | 4 Days | | | 6 Days | | |
| **Oil Group** | % Natural Dissipation | % Recovered Floating Oil | % Oil on Shore | % Natural Dissipation | % Recovered Floating Oil | % Oil on Shore | % Natural Dissipation | % Recovered Floating Oil | % Oil on Shore |
| **Non-persistent Oils(Group I)** | 80 | 10 | 10 | 80 | 20 | 10 | 95 | 5 | – |
| **Light Crudes (Group II)** | 40 | 15 | 45 | 50 | 50 | 30 | 75 | 25 | 5 |
| **Medium Crudes/Fuels (Group III)** | 20 | 15 | 65 | 30 | 50 | 50 | 60 | 40 | 20 |
| **Heavy Crudes/Fuels (Group IV)** | 5 | 20 | 75 | 10 | 50 | 70 | 50 | 40 | 30 |

**Source:** 33 CFR 154, Appendix C, Table 2.

*Response plan development and evaluation criteria*

The *Response Plans for Marine Transportation-Related Facilities* rule (33 CFR 154) lays out separate sets of criteria for facilities that handle, store, or transport Group I through Group IV petroleum oils than for facilities that handle, store, or transport Group V petroleum oils (33 CFR 154.1045 and 154.1047). Among the differences in requirements for these two types of facilities is the response time. For facilities with Group I through Group IV oils (non-persistent oils or persistent oils with a specific gravity less than or equal to 1), response resources must be positioned so that they can arrive at the scene of discharge: within 6 hours of the discovery of a discharge, in higher volume port areas and the Great Lakes; or within 12 hours of the discovery of a discharge in all other locations (33 CFR 154.1045(d)(3)(ii - iii). For facilities handling, storing, or transporting Group V petroleum oils (persistent oils with a specific gravity greater than 1), response resources must be capable of being at the spill site within 24 hours of the discovery of a discharge (33 CFR 154.1047(d).

The U.S. Coast Guard rule on vessel response plans (33 CFR 155) requires vessel owners or operators to identify in the response plan, and ensure availability of, sufficient boom for oil containment and collection. The minimum quantity of boom required for shoreline protection varies depending on oil persistency. Minimum requirements are listed in a table in Appendix B of 33 CFR 155 (reproduced here as Exhibit 4).

**Exhibit 4**
**Shoreline Protection Requirements**

| Location | Boom | Availability hours | |
|---|---|---|---|
| | Ensured by contract or other approved means (ft.) | Higher volume port areas | Other areas |
| **Persistent Oils** | | | |
| Open Ocean | - | - | - |
| Offshore | 15,000 | 24 | 48 |
| Nearshore/Inland/Great Lakes | 30,000 | 12 | 24 |
| Rivers & Canals | 25,000 | 12 | 24 |
| **Non-Persistent Oils** | | | |
| Open Ocean | - | - | - |
| Offshore | - | - | - |
| Nearshore/Inland/Great Lakes | 10,000 | 12 | 24 |
| Rivers & Canals | 15,000 | 12 | 24 |

**Source:** 33 CFR 155, Appendix B, Table 2.

*Credits for on-water recovery capability*

Although this provision is currently being examined through rulemaking actions, both the January 1996 Final Rule on Vessel Response Plans (33 CFR 155) and the February 1996 Final Rule on Response Plans for Marine Transportation-Related Facilities (33 CFR 154) presently allow for facilities or vessels operating in areas with year-round pre-approval for dispersant use and which handle, store or transport Group II or III persistent petroleum oils, to request a credit for up to 25 percent of the on-water oil recovery capability worst case discharge, as necessary to meet the requirements of applicable rule subparts (33 CFR 155.1050(j) and 33 CFR 154.1045(i)).

***National Oceanic and Atmospheric Administration***

The National Oceanic and Atmospheric Administration (NOAA) Office of Restoration provides the U.S. Coast Guard and the Regional Response Teams with scientific information related to oil behavior, including oil persistence, as it relates to oil spill response and restoration of the environment. This office does not maintain a specific list of persistent and non-persistent oils. However, in its 1992 training manual, *An Introduction to Coastal Habitats and Biological Resources for Spill Response*[3], and in other NOAA publications, NOAA Office of Restoration defines four types of oil for which a general assessment of the behavior and fate of the oil can be made. These types, determined based on all properties of spilled oil, are described in Exhibit 5.

While there is no mention of "persistence" per se, NOAA's oil-type groupings indicate that oil will remain in the environment, i.e., "persist" to varying degrees in oil types 2, 3, and 4. Oil type 1 is said to evaporate within one to two days, i.e., not persist in the environment.

**Exhibit 5**
**NOAA-Defined Oil Types**

**Type 1: Very Light Oils (Jet Fuels, Gasoline)**

- Highly volatile (should evaporate within 1-2 days).
- High concentrations of toxic (soluble) compounds.
- Localized, severe impacts to water column and intertidal resources.
- Duration of impact is a function of the resource recovery rate.
- No dispersion necessary.
- No cleanup necessary.

**Type 2: Light Oils (Diesel, No. 2 Fuel Oil, Light Crudes)**

[3]Hazardous Materials Respons Assessment Division, National Oceanic and Atmospheric Administration. 1992. *An Introduction to Coastal Habitats and Bioligical Resources for Oil Spill Response.* Report No. HMRAD92-4. http://response.restoration.noaa.gov/oilaids/monterey/monterey.html

| |
|---|
| • Moderately volatile; will leave residue (up to one-third of spill amount) after a few days.<br>• Moderate concentrations of toxic (soluble) compounds.<br>• Will "oil" intertidal resources with long-term contamination potential.<br>• Has potential for subtidal impacts (dissolution, mixing, sorption onto suspended sediments).<br>• Cleanup can be very effective. |
| **Type 3: Medium Oils (Most Crude Oils)** |
| • About one-third will evaporate within 24 hours.<br>• Maximum water-soluble fraction 10-100 ppm.<br>• Oil contamination of intertidal areas can be severe and long-term.<br>• Oil impacts to waterfowl and fur-bearing mammals can be severe.<br>• Chemical dispersion is an option within 1-2 days.<br>• Cleanup most effective if conducted quickly. |
| **Type 4: Heavy Oils (Heavy Crude Oils, No. 6 Fuel Oil, Bunker C)** |
| • Heavy oils with little or no evaporation or dissolution.<br>• Water-soluble fraction is less than 10 ppm.<br>• Heavy contamination of intertidal areas likely.<br>• Severe impacts to waterfowl and fur-bearing mammals (coating and ingestion).<br>• Long-term contamination of sediments possible.<br>• Weathers very slowly.<br>• Chemical dispersion seldom effective.<br>• Shoreline cleanup difficult under all conditions |

***National Research Council for the National Academy of Sciences***

The National Research Council for the National Academy of Sciences 2003 study, *Oil in the Sea III: Inputs, Fates, and Effects*[4], includes persistence as one of the characteristics that affects oil's behavior in the environment. In this study, oils were not placed into categories such as "persistent" or "non-persistent," but rather classified as to how long they generally persist in the environment. As shown in Exhibit 6 (reproduced from the *Oil in the Sea III* study) gasoline and light distillates, including diesel, persist for "days." Crude oils persistent for "months." Heavy distillates, including heavy fuel oil persist for "years."

***Washington State Department of Ecology***

Chapter 173-183 of the state of Washington Administrative Code, *Preassessment Screening and Oil Spill Compensation Schedule Regulations*, establishes procedures to assess resource damage resulting from oil spills. It applies a compensation schedule that is based on a relative ranking of the severity of effects caused by spilled oil. The

[4]National Research Council for the National Academy of Sciences. *Oil in the Sea III: Inputs, Fates, and Effects.* The National Academies Press, Washington DC. 2003.

ranking is based on the known chemical, physical, and mechanical properties of six classes of oil, as well as other factors that may affect the severity and persistence of the spill on the environment. The relative ranking scores are found in Table 1 of the Code, and repeated here in Exhibit 7.

**Exhibit 6**
**Processes that Move Petroleum Hydrocarbons Away from Point of Origin**

| | Weathering | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| **Input Type** | **Petroleum Persistence** | **Evaporation** | **Emulsification** | **Dissolution** | **Oxidation** | **Horizontal Transport or Movement** | **Vertical Transport or Movement** | **Sedimentation** | **Shoreline Stranding** | **Tarballs** |
| Seeps | years | H | M | M | M | H | M | M | H | H |
| Gasoline | days | H | NR | M | L | L | L | NR | NR | NR |
| Light Distillates | days | M | L/L | H | L | M | H | L | L | NR |
| Crudes | months | M | M | M | M | M | M | M | H | M |
| Heavy Distillates | years | L | M | L | L | H | L | H | H | H |
| Produced Water | days | M | NR | M | M | L | L | L | L | NR |
| Vessel Operational | months | M | L | M | L | M | L | L | L | M |
| 2-Stroke Engines (gasoline & light distillates) | days | H | NR | M | L | L | L | L/NR | NR | NR |
| Atmospheric | days | H | NR | M | M | H | NR | L | NR | NR |
| Land Based | U | M | L | L | L | M | M | M | NR | U |

Note: H = high; L= low; M = moderate, NR = not relevant; U = unknown
**Source:** National Research Council for the National Academy of Sciences. 2003. *Oil in the Sea III*, Table 4-7 (page 113). The table was developed by consensus of the committee on Oil in the Sea, and is based on many assumptions. It is intended to provide only a general idea of the relative importance of the fates processes.

**Exhibit 7**
**Washington Department of Ecology Oil Spill Damage Compensation Schedule**
**Relative Ranking Scores for Classified Oils[1]**

| Oil Class | Acute Toxicity | Mechanical Injury | Persistence |
|---|---|---|---|
| **Prudhoe Bay Crude Oil** | 0.9 | 3.6 | 5 |

| | | | |
|---|---|---|---|
| **Bunker C** | 2.3 | 5 | 5 |
| **No. 2 Fuel Oil** | 2.3 | 3.2 | 2 |
| **Gasoline** | 5 | 1 | 1 |
| **Kerosene** | 1.4 | 2.4 | 1 |
| **Kerosene-type Jet Fuel** | 1.4 | 2.4 | 1 |

[1]Ranks are based on scale of 0 to 5, where 0 represents the least harmful effect and 5 represents the most harmful effect .
**Source:** Washington Department of Ecology (2003)

For oils not listed in Exhibit 7, the rule provides formulae for determination of acute toxicity and mechanical injury. To determine persistence, the rule states, "A persistence relative ranking score is determined from empirical data describing the length of time the spilled oil is known to, or is likely to, persist in a variety of habitat types. Scoring is assigned on a 1 to 5 scale as follows:

| Score | Anticipated Persistence |
|---|---|
| **5** | 5 – 10 years or more |
| **4** | 2 – 5 years |
| **3** | 1 – 2 years |
| **2** | 1 month – 1 year |
| **1** | days – weeks |

These rankings are entered into a formula with which state officials determine the natural resource damages for a particular spill in order to impose fines and penalties on the responsible party.

***Environment Canada***

The Emergencies Science Division (ESD) of Environment Canada, Ottawa, Ontario, states that "oil is almost never classified as persistent and non-persistent" with regard to oil properties.[5] In his book, *The Basics of Oil Spill*

[5] Personal communication between Dr. Merv Fingas, Chief of the Emergencies Science Division of Environment Canada and Dagmar Schmidt Etkin, August 2003.

*Cleanup*[6], Fingas discusses how recovery of the environment after spills is dependent both on the properties of the oil type and the nature of the substrate or habitat into which the oil is spilled, as well as the degree of cleanup. It avoids classifying specific oils by "persistence" but presents properties of typical oils as shown in Exhibit 8.

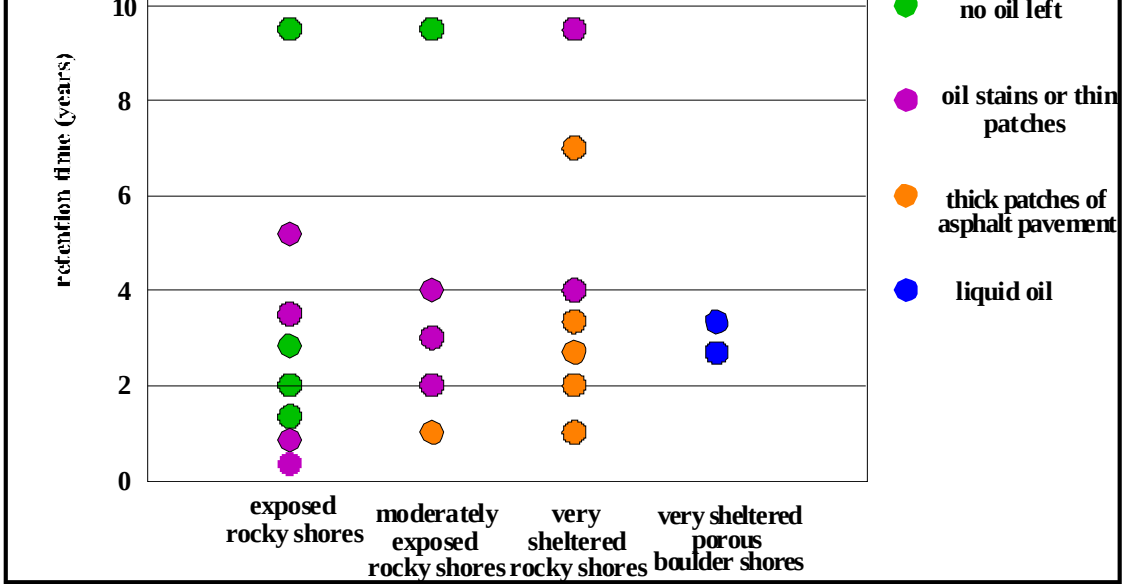
**Exhibit 8**
**Typical Oil Properties**

| Property | Units | Oil Types | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | | **Gasoline** | **Diesel** | **Light Crude** | **Heavy Crude** | **Intermediate Fuel Oil** | **Bunker C** | **Crude Oil Emulsion** |
| **Viscosity** | mPas at 15ºC | 0.5 | 2 | 5 to 50 | 50 to 50,000 | 1,000 to 15,000 | 10,000 to 50,000 | 20,000 to 100,000 |
| **Density** | g/mL at 15ºC | 0.72 | 0.84 | 0.78 to 0.88 | 0.88 to 1.00 | 0.94 to 0.99 | 0.96 to 1.04 | 0.95 to 1.0 |
| **Flash Point** | ºC | -35 | 45 | -30 to 30 | -30 to 60 | 80 to 100 | >100 | >80 |
| **Solubility in Water** | ppm | 200 | 40 | 10 to 50 | 5 to 30 | 10 to 30 | 1 to 5 | – |
| **Pour Point** | ºC | NR | -35 to -1 | -40 to 30 | -40 to 30 | -10 to 10 | 5 to 20 | >50 |
| **API Gravity** | | 65 | 35 | 30 to 50 | 10 to 30 | 10 to 20 | 5 to 15 | 10 to 15 |
| **Interfacial Tension** | mN/m at 15ºC | 27 | 27 | 10 to 30 | 15 to 30 | 25 to 30 | 25 to 35 | NR |
| **Distillation Fractions** (% distilled at:) | 100ºC | 70% | 1% | 2 to 15% | 1 to 10% | – | – | NR |
| | 200ºC | 100% | 30% | 15 to 40% | 2 to 25% | 2 to 5% | 2 to 5% | NR |
| | 300ºC | - | 85% | 30 to 60% | 15 to 45% | 15 to 25% | 5 to 15% | NR |
| | 400ºC | - | 100% | 45 to 85% | 25 to 75% | 30 to 40% | 15 to 25% | NR |
| | residual | - | - | 15 to 55% | 25 to 75% | 60 to 70% | 75 to 85% | NR |

NR = not relevant
**Source:** Fingas (2001).

Fingas (2001) states that the properties of viscosity, adhesion, penetration, and degradation are all related to persistence and the speed of "recovery" of the environment after a spill. In EPA's planning for remediation after an oil spill, characteristics of the environment need to be considered as well as the oil's persistence determination. Fingas states that a product like gasoline, which is highly biodegradable even under minimally aerobic conditions and is considered a "non-persistent oil" according to EPA and U.S. Coast Guard definitions, has the capacity to penetrate substrates deeply. According to Fingas, gasoline under this condition can take nearly as long to degrade or break down as bunker fuel, which is generally considered a "persistent oil." Degree of penetration into the substrate is dependent

[6]Fingas, M. 2001. The Basics of Oil Spill Cleanup. Lewis Publishers, Washington, DC. 233 pp.




on substrate permeability or porosity. Penetration can be affected by adhesive properties and viscosity, which varies with ambient temperature.

***International Petroleum Industry Environmental Conservation Association***

The International Petroleum Industry Environmental Conservation Association (IPIECA) also emphasize the importance of the substrate, rather than the oil type, in spill recovery. In its 1995 report, *Biological Impacts of Oil Pollution: Rocky Shores* they refer to varying "residence time" of oils not by oil type, but by the type of shoreline impacted. Typical "residence times" of oil on a variety of rocky shores with no cleanup are shown in Exhibit 9.

**Exhibit 9**
**Typical Oil Resoidence Times on a Variety of Rocky Shores with No Cleanup**

**Source:** IPIECA, 1995.

***American Petroleum Institute***

In its 1995 report, *A Critical Review of Toxicity Values and an Evaluation of the Persistence of Petroleum Products for Use in Natural Resource Damage Assessments*, the American Petroleum Institute (API) reviewed persistence of crude oil and various petroleum products to assess the relative persistence of oil products in the aquatic environment, and to rank oil products based upon their persistence in the aquatic environment. The results of API's analysis with regard to persistence of various broad categories of petroleum products are shown in Exhibits 10 and 11.

**Exhibit 10**
**Persistent Fraction of Petroleum Products in Aquatic Environments**

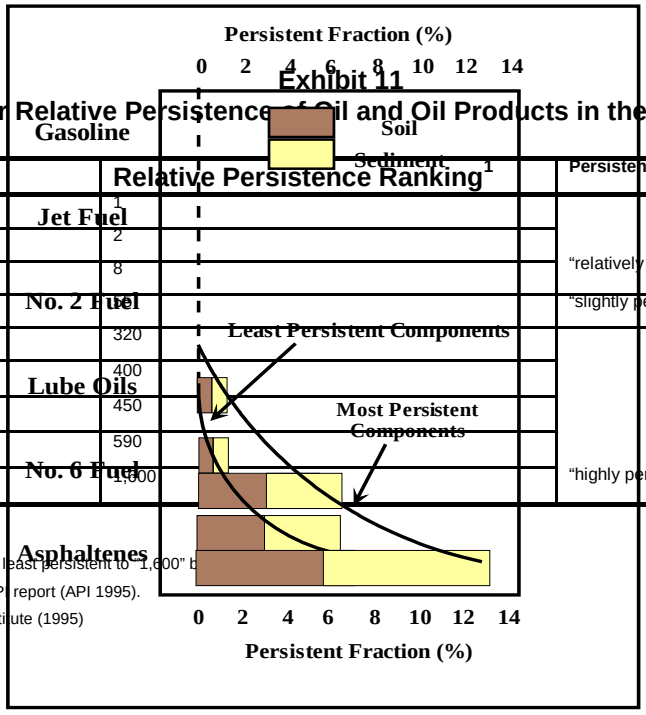
NOTE: Fractions are expressed as percent of original material remaining in water, sediment, and soil. For each pair, the top bar represents the most persistent components and the bottom bar the least persistent components.
**Source:** American Petroleum Institute 1995

**Exhibit 11**

**Numerical Scale for Relative Persistence of Oil and Oil Products in the Aquatic Environment**

| Oil/Oil Product | Relative Persistence Ranking[1] | Persistence Classification[2] |
|---|---|---|
| Gasoline | 1 | |
| Jet Fuel | 2 | |
| No. 2 Fuel Oil | 8 | "relatively non-persistent" |
| Lube Oils | 160 | "slightly persistent" |
| Light Crude Oil | 320 | |
| No. 6 Fuel Oil | 400 | |
| Medium Crude Oil | 450 | |
| Heavy Crude Oil | 590 | |
| Residual Asphaltenes | 1,600 | "highly persistent" |

NOTES:
1. Relative ranking with "1" being least persistent to "1,600" b
2. Based on text description in API report (API 1995).
**Source:** American Petroleum Institute (1995)




***International Maritime Organization***

From an international perspective, the definitions of oils accepted by the International Maritime Organization (IMO), an agency of the United Nations, are the most universally applied in international shipping, in international conventions, and in the national regulations of most nations.

The1969 Convention on Civil Liberty for Oil Pollution Damage (CLC), as amended in 1971 and 1992, covers liability for damage caused by oil pollution from tankers. The 1971 International Oil Pollution Compensation Fund Convention (IOPC), as amended in 1984, establishes a fund to compensate parties suffering economic, though not environmental or natural resource damage, from tanker spills. Both conventions cover only "persistent oil." IMO believed that it was "unnecessary" to cover non-persistent oils, since they tend to evaporate quickly, disappear by natural forces, and do not cause widespread pollution. In addition, the IMO took into account that 80% of the oil transported by tankers is crude oil, which is defined as a persistent oil.

In these two conventions, the general definition of "persistent oil" is consistent with the definition applied by the EPA and U.S. Coast Guard:

> All oils which are not within the category of "non-persistent oil" as defined shall be regarded as "persistent oil." "Non-persistent oil" is oil which, at the time of shipment, consists predominantly of non-residual fractions and of which more than 50 per cent by volume of the hydrocarbon fractions distills at a temperature of 340° C (645° F) and at least 95 per cent by volume of the hydrocarbon fractions distills at 370° C (700° F) when tested by the American Society for Testing and Materials Method D 86/78 or any subsequent revision thereof.

"Persistent oil" is further defined by the IMO as: crude oil, fuel oil, heavy diesel oil, and lubricating oil carried as cargo or bunkers of a ship. According to IMO, "non-persistent oil" includes: gasoline, light diesel oil, and kerosene.

According to IOPC Fund officials, this definition of persistent oil "remains probably the most precise method of drawing an accurate dividing line between persistent and non-persistent oil, which could satisfy both the lawyers and technical experts and which would be simple to ascertain as a matter of fact." Since there are legal proceedings that are often involved in disputes regarding oil spill claims brought by CLC- and IOPC Fund-signatory nations, it is important to have very clear guidelines with respect to oil types covered by the conventions. To that end, the IOPC Fund has developed a list of persistent oils that it applies in determining whether specific spill incidents fall under its jurisdiction in terms of damage claims.

Historically, this CLC/IOPC Fund list of persistent oils did not always exist. At the time of the drafting of the original 1969 Civil Liability Convention (later replaced with the 1992 version), the legislators recognized the danger of listing specific oils as those that were persistent. According to IOPC Fund's *Non-Technical Guide to the Nature And Definition of Persistent Oil*, the main reasons for not creating a list were:

- Different nomenclature for the same hydrocarbon oils in different parts of the world would lead to confusion and inequitable treatment;
- Intermediate products and process stocks change their name and make-up quite frequently and new stocks appear at regular intervals;
- Crude oils are sold singly or in mixtures and are frequently named from the fields or regions from which produced; this also causes confusion; and
- Any oils not specifically listed would be excluded from coverage by the Conventions and would require an amendment of the Conventions and its ratification before any such oil could be included.

The vast majority of nations are signatories to these IMO conventions. [The US is the notable exception.] Signatory nations must enact national legislation implementing the stipulations in the conventions in order to officially "ratify" these conventions. As part of the ratification of the CLC and IOPC Fund Convention, these nations have adopted IMO's official definition of "persistent oil" and "non-persistent" oil.

The International Tanker Owners Pollution Federation (ITOPF), an organization that represents tanker owners and works in concert with the IOPC Fund, also recognizes the definitions of "persistent oil" and "non-persistent oil" as adopted by the IOPC Fund. ITOPF's position is that this definition "ensures consistency in the application of the term and overcomes the variety of terminologies that may be used on a local or regional basis," as noted in a position paper on the organization's website (www.itopf.com) (Anderson, 2001). Anderson also states that this consistency is very important in the US, even though "the concept of persistence/non-persistence has no direct relevance in the law [OPA 90]." In the context of the insurance perspective of oil persistence, she states that "given the significant potential liability associated with loading or discharging persistent oil cargoes in the waters of the US, it has been necessary to apply a weighting on such voyages." Insurers have adopted the IOPC Fund definition of persistence/non-persistence as a method for including an additional premium (or weighting) on persistent oil cargoes based on its greater potential financial risk in the event of an oil spill.

Yet, ITOPF also recognizes that there are difficulties in some applications of the definition of "non-persistent oil" to distinguish persistent oils covered by CLC and IOPC Fund. In her paper, Anderson (2001) points out that the definition "cannot be applied to non-mineral oils despite the persistence of some of these oils," because they cannot tolerate the distillation process required to determine persistence as per the definition.

**Summary: Comparison and Compatibility of Oil Persistence Determination Across Organizations**

The three major organizations associated with oil discharges discussed here, the EPA, U.S. Coast Guard, and IMO, have consistent definitions for "persistent" and "non-persistent oils," based on distillation temperatures. EPA and U.S. Coast Guard both further classify persistent oils into groups based on specific gravity.

However, as EPA, U.S. Coast Guard, and IMO have stated, there are limitations to defining persistence so strictly as to labeling types of oils by their persistence level: different stocks of a particular type of oil may have different persistence characteristics, and these might change according to environmental conditions; and any types of oil inadvertently left off of a list may be unintentionally excluded from regulation. EPA and U.S. Coast Guard regulations emphasize the importance of taking oil persistence characteristics into consideration in planning appropriate response to discharge. They also recognize, as other organizations involved with oil spill recovery attest, that environmental conditions must be considered as well.