APPENDIX I
WATER QUALITY ANALYSIS

PART 1-ELEMENTS IN SEA WATER

Table 1: Elements in Sea Water

Atomic Number	Element	Behavior	Predicted Mean Water Concentration
1	Hydrogen	Biogenic or hydrothermal origin	108 g/kg
2	Helium	Nonnutrient gas	1.9 nmol/kg
3	Lithium	Conservative	178 µg/kg
4	Beryllium	Nutrientlike, but increases with depth	0.2 ng/kg
5	*Boron	Conservative	4.4 mg/kg
6	*Carbon	Nutrient	2200 µmol/kg
7	*Nitrogen	Nonnutrient gas	590 µmol/kg
	Nitrate (species)	Nutrient	30 µmol/kg
8	Oxygen	Biological dependence	857 g/kg
9	Fluorine	Conservative	1.3 mg/kg
10	Neon	Nonnutrient gas	8 nmol/kg
11	*Sodium	Conservative	10.781 g/kg
12	*Magnesium	Conservative	1.28 g/kg
13	Aluminum		1 µg/kg
14	*Silicon	Nutrient	110 µmol/kg
15	*Phosphorus	Nutrient	2 µmol/kg
16	*Sulfur	Conservative	2.712 g/kg
17	*Chlorine	Conservative	19.353 g/kg
18	Argon	Nonnutrient gas	15.6 µmol/kg
19	*Potassium	Conservative	399 mg/kg
20	*Calcium	Correlates with carbonate alkalinity	415 mg/kg
21	Scandium		<1 ng/kg
22	Titanium		< 1 ng/kg
23	Vanadium	Conservative	< 1 µg/kg
24	Chromium	Nutrient-correlated; silicate and phosphate or nitrate	330 ng/kg
25	Manganese	Surface maximum; at depth, correlated with the labile nutrients and negatively correlated with dissolved oxygen	10 ng/kg
26	Iron	Correlated with the nutrients; negatively correlated with dissolved oxygen	40 ng/kg
27	Cobalt	Similar to manganese	2 ng/kg
28	Nickel	Nutrient-correlated; phosphate and silicate	480 ng/kg
29	Copper	Resembles nutrients with sedimentary release; scavenging at intermediate depths	120 ng/kg
30	Zinc	Nutrient-correlated; silicate	390 ng/kg
31	Gallium		10–20 ng/kg
32	Germanium	Nutrient-correlated; silicate	5 ng/kg
33	Arsenic	Nutrient-correlated; phosphate	2 µg/kg
34	Selenium	Nutrient-correlated; silicate and phosphate	170 ng/kg

Table 1: Elements in Sea Water (Continued)

Atomic Number	Element	Behavior	Predicted Mean Water Concentration
35	*Bromine	Conservative	67 mg/kg
36	Krypton	Nonnutrient gas	3.7 nmol/kg
37	Rubidium	Conservative	124 µg/kg
38	Strontium	Nutrient-correlated; phosphate	7.8 mg/kg
39	Yttrium	First approximation; conservative	13 ng/kg
40	Zirconium		< 1 µg/kg
41	Niobium		1 ng/kg
42	Molybdenum	Conservative	11 µg/kg
44	Ruthenium		0.5 ng/kg
45	Rhodium		
46	Palladium		
47	Silver		3 ng/kg
48	Cadmium	Nutrient-correlated; phosphate	70 ng/kg
49	Indium		0.2 ng/kg
50	Tin	Nonconservative; anthropogenic	0.5 ng/kg
51	Antimony	Conservative	0.2 µg/kg
52	Tellurium		
53	Iodine	Nutrient-correlated; nitrate and phosphate	59 µg/kg
54	Xenon	Nonnutrient gas	0.5 nmol/kg
55	Cesium	Conservative	0.3 ng/kg
56	Barium	Nutrient-correlated; silicate, alkalinity	11.7 µg/kg
57–71	Lanthanum and the Lanthanides	Nutrient- or depth-correlated	
72	Hafnium		< 8 ng/kg
73	Tantalum		< 2.5 ng/kg
74	Tungsten		< 1 ng/kg
75	Rhenium		4 ng/kg
76	Osmium		
77	Iridium		
78	Platinum		
79	Gold		11 ng/kg
80	Mercury	Nutrient-correlated; silicate	6 ng/kg
81	Thallium	Conservative	12 ng/kg
82	Lead	Nonconservative; anthropogenic	1 ng/kg
83	Bismuth		10 ng/kg
84	Polonium		
85	(Astatine)		
86	Radon		
87	(Francium)		

Table 1: Elements in Sea Water (Continued)

Atomic Number	Element	Behavior	Predicted Mean Water Concentration
88	Radium		
89	Actinium		
90	Thorium		< 0.7 ng/kg
91	Protactinium		
92	Uranium	Conservative	3.2 µg/kg

Source: Neshyba, S., 1987, p. 188.

* These eight elements are called conservative; they exist in uniform relative concentrations throughout all oceans.

= These are the commonly labeled plant *nutrient* elements.

Abbreviations used in this table:

g	grams
kg	kilograms
mg	milligrams
ng	nanograms
nmol	nanomols
µg	micrograms
µmol	micromols

PART 2-TRANSFORMATION OF PETROLEUM PRODUCT INTRODUCED TO THE MARINE ENVIRONMENT

Petroleum introduced to the marine environment goes through a variety of physical, chemical, and biological transformations during its transport by advective and spreading processes. Advection and spreading begin immediately after introduction of petroleum to the ocean and cause a rapid increase in the exposure area to subsequent "weathering" processes. Advection is due to the influence of overlying winds and/or underlying currents. Spreading results from a dynamic equilibrium between the forces of gravity, inertia, friction, viscosity, and surface tension. The weathering process includes evaporation, dissolution, vertical dispersion, emulsification, and sedimentation. Also, photochemical oxidation of some of the components of petroleum can be induced by sunlight. (National Academy Press, 1985, p. 270)

In addition to the physical and chemical processes identified above, biological processes also act on the different fractions of the original petroleum in various ways. Biological processes include degradation by microorganisms to carbon dioxide or organic components in intermediate oxidation stages, uptake by larger organisms and subsequent metabolism, storage, or discharge. (National Academy Press, 1985, p. 270)

- Evaporation—Evaporation may be responsible for the loss of from one-to two-thirds of an oil spill mass in a period of a few hours or a day, depending on the area of the slick, the oil composition, wind speed, and other factors.
- Dissolution—Dissolution is the act or process of dissolving one substance in another. Dissolved hydrocarbon concentrations in water are particularly important because of their potentiality for exerting a toxic effect on biological systems. This process is less important from the viewpoint of mass lost by the spill, for dissolution of even a few percent of a spill is unlikely. (National Academy Press, 1985, p. 277)
- Adsorption—This is the process by which one substance is attracted to and adheres to the surface of another substance without actually penetrating its internal structure. The various forms of oil in seawater can be sorbed onto settling particles and delivered to the bottom sediments (National Academy Press, p. 284).
- Biodegradation—This is the degradation of substances resulting from their use as food energy sources by certain microorganisms. Biodegradation of petroleum is seen by most workers as one of the principal mechanisms for removal of petroleum from the marine environment. Microorganisms (bacteria, yeasts, fungi) are important in the degradation of petroleum in surface films, slicks, the water column, and sediments. Zooplankton are known to aid in the sedimentation of oil droplets and oil associated with particulate matter through

their ingestion. (National Academy Press, 1985, p. 284). Benthic invertebrates such as polychaetes also have a significant role in the degradation of sediment-bound oil (Gardner, et al, 1979).

- Dispersion—Dispersion is the process of the distribution of spilled oil into the upper layers of the water column by natural wave action or application of chemical dispersants. The movement of oil into the water column determines the lifetime of a slick. The primary mechanism is believed to be propulsion by surface turbulence of oil into the water column as a "show" of oil droplets (National Academy Press, 1985, p. 289).
- Emulsification—Emulsification is the process whereby one liquid is dispersed into another liquid in the form of small droplets. Emulsification or mousse formation is dependent on the chemical composition of petroleum products, photochemical and microbial oxidation, and temperature.
- Photo Oxidation—The sunlight-promoted chemical reaction of oxygen in the air and petroleum products is one example of photo oxidation. About 25 percent of the average oil spill evaporated and, in the gaseous state, is almost certainly all oxidized photochemically by OH radical and other [gas] species in hours or days to CO, CO_2, oxygenated organics (Heicklen, 1976). These processes prevent oil's reentry into the sea as petroleum.

REFERENCES USED IN THIS APPENDIX

Gardner, et al, 1979. *Degradation of Selected Polycyclic Aromatic Hydrocarbons in Coastal Sediments: Importance of Microbes and Polychaete Worms,* Water Air Soil Pollution. 11:339-347, in National Academy Press, 1985. *Oil in the Sea, Inputs, Fates, and Effects,* Washington, D.C.: National Academy Press.

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