

**RISK ASSESSMENT**  
**DEFENSE ENVIRONMENTAL RESTORATION PROGRAM**  
**PORT HEIDEN, ALASKA**

*Alaska District*  
**U.S. Army Corps of Engineers**

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**I. BACKGROUND**

Work to demolish and clean up an abandoned White Alice military communications site at Port Heiden under the Defense Environmental Restoration Program (DERP) began in 1990 and is still in progress. The DERP project at Port Heiden consists of removing debris and abandoned buildings; cleaning up soils contaminated with petroleum, oil, and lubricants (POL) and asphalt; and restoring the site. An environmental assessment (EA) was written in 1987 for the removal of 333 buildings, several large fuel tanks, about 8,000 55-gallon drums, various scrap metal and debris, 500 cubic yards (yd<sup>3</sup>) of POL-contaminated soil, and soil contaminated with polychlorinated biphenyls. The public review process was completed, and State and Federal permits were issued by the regulatory agencies. The Solid Waste Landfill Permit issued by the Alaska Department of Environmental Conservation (ADEC) stipulated that some soils saturated with POL could be landfilled at the approved on-site locations. The term "saturated" has been defined as 5,000 milligrams total petroleum hydrocarbons (TPH) in one kilogram of soil (5,000 mg/kg or 5,000 ppm).

During the process of restoring the site, the Alaska District determined that additional soil contaminated with POL's should be remediated. The permitted landfills were only large enough for the amount of material initially estimated to require disposal; therefore, not enough space remains for the additional contaminated soils. The ADEC has established interim guidelines which propose cleanup levels of 100 mg/kg. Solid waste landfill permits will not be issued for the disposal of POL-contaminated soils.

An EA was distributed for public review on April 16, 1991, for the remediation of the additional contaminated soil. The quantity is estimated to be between 18,000 and 20,000 yd<sup>3</sup>. This estimate relies upon limited data; the quantity of contaminated soil at the 100 mg/kg level may be significantly higher. The soil would be remediated by burning it in a low-temperature incinerator (700 to 1,500 °F) at the site.

**II. PURPOSE AND NEED FOR RISK EVALUATION**

The cleanup level of 100 mg/kg TPH proposed by the ADEC encompasses the entire State of Alaska, including the most susceptible areas and resources. The purpose of this document is

to describe the hazards present in the contaminated soil at Port Heiden and to present relevant information on physical, chemical, and toxicological properties; likely release of contaminants; fate and transport mechanisms; potential exposure pathways; and potential receptors. A qualitative discussion of potential health and environmental risks and cleanup concentrations concludes the evaluation.

### III. WASTE CHARACTERIZATION

Soil samples were taken from numerous locations throughout the Port Heiden area, including the airport and the White Alice facility. The tests included total petroleum hydrocarbon (TPH), volatile organics, chlorinated hydrocarbons, metals (EP Toxicity), and polychlorinated biphenyls (PCB). The PCB-contaminated soils were removed under a previous contract. The tests indicated that the contamination consists mainly of weathered diesel and asphalts. No volatile organics or chlorinated hydrocarbons were detected. Soil samples were taken at areas where contamination was expected (e.g., under tanks, near barrel dumps, in surface-stained soil) from the surface down to 12 feet below the surface. Concentrations of TPH above 60,000 mg/kg were detected.

Gas chromatograph analyses determined that the contamination is diesel fuel and some asphalts (refer to Appendix). The diesel fuel is probably diesel No. 2, probably blended with some diesel No. 1 to assure it would flow properly in winter. These fuels contain normal and branched-chain alkanes (paraffins), cycloalkanes (naphthenes), aromatics, and mixed aromatic cycloalkanes. Normal alkanes usually predominate, resulting in a clean-burning diesel fuel with a relatively high ignition quality. No. 1 diesel normally contains less than 0.02 percent benzene and very low levels of three- to seven-ring polycyclic aromatic hydrocarbons. No. 2 diesel contains some distillate and may have up to 5 percent three- to seven-ring polycyclic aromatic hydrocarbons.

Asphalt is a mixture of bitumen and mineral matter, usually sand. Bitumen is a viscous substance that can be liquid, semisolid, or solid. It is soluble in carbon disulfide and consists essentially of hydrocarbons and their derivatives. Bitumen is obtained from the distillation of suitable crude oils by treatment of the residues (occasionally the heaviest fraction).

### IV. FATE AND TRANSPORT OF CONTAMINANTS

Research efforts were conducted by Fleischer et al. (1986) to determine the environmental fate of petroleum products. The study centered on 13 compounds because of their use in petroleum

products, their tendency to be released to the subsurface environment, and their potential toxicity. These compounds are listed in table 1.

The environmental fates of the organic compounds were examined by conducting computer simulations using an unsaturated zone environmental fate model. The results of the model are presented in table 2. Based on these results, the evaluated organic compounds can be divided into four groups: (1) those that preferentially adsorb onto soil particles; (2) those that volatilize rapidly; (3) those that pose an immediate threat to ground water supplies; and 4) those for which no one migration pathway dominates. Table 3 lists the percentage of each compound that takes each pathway, according to the computer model results.

The compounds in the diesel fuel that volatilize in air have probably already done so, as it has been at least 20 years since the diesel was spilled. The fractions of concern are mainly those from the multiple pathways group, such as ethylbenzene; phenol, which may dissolve in ground water; and to a lesser extent, those that primarily cling to soil particles.

**Environmental Factors Influencing Transport**

The environmental conditions that influence the mobility of contaminants are discussed in the following paragraphs. The contaminants appear to be located within the unsaturated soil layer (the layer above ground water). The natural transport mechanism for the contaminants in the project area will be infiltration of ground water or surface water from the soil.

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TABLE 1.--Common constituents of petroleum products

Gasoline and fuel oils	Heavy oils and waste oils
Benzene	Benzo(a)Anthracene
Ethylbenzene	Benzo(a)Pyrene
(n) Heptane	Naphthalene
Pentane	Phenanthrene
(n) Hexane	
1-Pentene	
(o) Xylene	
Toluene	
Phenol	

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TABLE 2.--Relative environmental partitioning of petroleum constituents based on results of a computer model (SESOIL)

Petroleum compound	Adsorption onto soil particles (%)	Volatilization (%)	Soluble Portion in ground water and soil moisture (%)
Benzene	3	62	35
Ethylbenzene	21	59	20
(n)Heptane	0.1	99.8	0.1
(n)Hexane	0.1	99.8	0.1
(n)Pentane	0.1	99.8	0.1
Benzo(a)Anthracene	100	0	0
Benzo(a)Pyrene	100	0	0
Naphthalene	61	8	31
Phenanthrene	88	2	10
1-Pentene	0.1	99.8	0.1
Phenol	9	0.01	91
Toluene	3	77	20
(o)Xylene	15	54	31

TABLE 3.--Petroleum compounds grouped by migration pathway

Adsorb to soil particles	Volatilize in air	Dissolve in ground water	Multiple pathways
Benzo(a)Pyrene	(n)Hexane	Phenol	Benzene
Phenanthrene	(n)Heptane		Ethylbenzene
Benzo(a)Anthracene	(n)Pentane		Naphthalene
	1-Pentene		Toluene
			(o)Xylene

Port Heiden has a moderate polar maritime climate, characterized by high winds, mild temperatures, cloud cover, and frequent precipitation. Temperatures average between 34 and 54 °F in summer and from 13 to 31 °F in winter, with extremes of 11 and 74 °F. The area receives an average of 43 inches of precipitation each year, including 98 inches of snow.

Soils around Port Heiden are primarily of volcanic origin and very rich in nutrients. Soil depths range from shallow at higher

elevations to deep and organic in lower, wet areas. Upland soils are composed of volcanic ash interspersed with rocks, rubble, or cinders, and are typically silty or sandy, wet, and susceptible to wind erosion on exposed sites. The soils deepen with decreasing elevation and are characterized as ash types having a loamy texture and high organic content. Rich peat-type soils composed of sedge peat and sphagnum, with lenses of volcanic ash, are found on poorly drained sites along rivers and valley bottoms and in depressions on morainal hills. Some mineral soils contain gel-like clays that become fluid with sudden stress and may harden after disturbance.

Contaminants detected within the unsaturated zone above ground water were not detected in ground water or surface water samples. Exploratory digging near the White Alice site indicates that the depth of contamination is 12 feet. This is one of the largest contaminated areas located on ground that provides relief from the surrounding area. The test pit indicated a layer of clay between the lower limit of the contaminated soil and ground water, which is about 35 feet below the ground surface.

Mobility of the POL contaminates by percolation to the ground water will depend on the solubility and organic carbon partition coefficients of the compounds (with consideration of the adsorption effects to surrounding materials); the volume and rate of percolating water from precipitation; and the rate of percolation through underlying materials.

In general, water is the primary solvent in soil. However, bulk hydrocarbons released during spills, leaks, and ruptures of tanks and pipes may enter the soil as the primary solvent in localized situations. When a spill occurs, the bulk hydrocarbon will migrate downward in unsaturated zone soil due to gravity and capillary forces. As a mass of bulk hydrocarbon migrates beyond a unit mass of unsaturated soil, a small amount of the total hydrocarbon mass will remain attached to the soil particles. This is referred to as "residual saturation." If the migrating mass of bulk hydrocarbon is small relative to the soil surface area, the mass of bulk hydrocarbon eventually will be exhausted as it is converted to residual saturation. When the conversion is complete, downward migration ceases.

Percolating water, in unsaturated zone soil containing residual saturation, can initiate the downward migration of hydrocarbon. This is expected to continue until the hydrocarbon is fixed and/or adsorbed by soil particles, encounters an impermeable bed, or reaches ground water. Fixation reactions will remove an element from migrating water and immobilize it, either within the structure of a mineral or at the mineral surface. Adsorption is an accumulation of an element at the surface of soil particles, with a decrease in the concentration of the dissolved element in water.

If an organic chemical (in this instance, the weathered diesel) is extensively adsorbed by soil particles, it will not leach through the soil profile. If it remains at the soil surface, environmental and human health effects may arise due to the increased concentration of chemical in the zone of plant growth, possibly contaminating a food supply. If the chemical is weakly adsorbed, it may leach through the soil profile and reach ground water and surface waters. Recent research has shown that a number of organic chemicals (PAH, toluene, etc) bind onto dissolved organic macromolecules such as humic acid, fulvic acid, or organic matter. In most soil-water systems, these macromolecules are not mobile, and they tend to be extensively adsorbed onto soil surfaces. The high organic content of the soils in the Port Heiden area has tended to bind POL organic chemicals, as indicated by the rather shallow migration at the test pit. The adsorption also affects other transport and transformation reactions, such as volatilization, photolysis, hydrolysis, and biodegradation.

Volatilization of the lighter components of the diesel spilled or leaked on the soil at Port Heiden began with the initial spill. The relatively nonporous surface soil (high organic, fine volcanic ash) allowed the lighter carbon chains ( $C_{10}$  and lighter) with lower vapor pressures to enter the atmosphere. The volatilization was also aided by the almost constant winds on the Alaska Peninsula. Table 2 shows the percentages of the given chemical compounds of the diesel that have been volatilized.

The concentrations of chemicals can be degraded further through organic chemical reactions in soil. In general, five organic chemical reactions are known to occur in soil systems: hydrolysis, substitution, elimination, oxidation, and reduction.

In addition to the abiotic reactions, many organic chemicals can be degraded by biotic reactions. Biotic reactions are those that involve biota; in soil systems, these include plants, animals, insects, and microorganisms. Although plants, animals, and insects can degrade many organic chemicals, they do not play a significant role in degrading organic chemicals in soil. Microorganisms play a major role in degrading organic chemicals in soil. The biodegradation of an organic chemical is the modification or decomposition of the chemical by soil microorganisms, ultimately producing microbial cells, carbon dioxide, and water. It is most important to recognize that microorganisms possess numerous enzymes within their cells which are responsible for the biodegradation of organic chemicals.

The biodegradation rate of an organic chemical generally depends on the following:

- a. The presence of soil organisms capable of degrading the chemical.

- b. The number of organisms present in the soil system.
- c. Soil temperature. As the temperature increases, the microbiological activity increases.
- d. Adequate moisture in the soil to support microorganisms' metabolic processes.
- e. The presence of the essential elements.
- f. The concentration of the organic chemical.

## V. EXPOSURE PATHWAYS

### Land Use

The Port Heiden area, as outlined in the Bristol Bay Regional Management Plan (1985), is to be managed primarily for fish and wildlife habitat and harvest, recreation, and future oil and gas exploration and development. The project area, which includes the White Alice site and the village of Meshik, was selected for conveyance to the Meshik Village Council and the Bristol Bay Native Corporation.

Current land use in the area is determined by the limited local road system and the location of usable structures. The road system provides transportation routes for hunting and fishing, berry picking, and other subsistence and recreational activities. The airport is important to the Meshik village economy, as it is the only transportation link outside the community.

The population of Meshik is currently fewer than 100 permanent residents, of which the majority are Alaska Native (Eskimo). The village, located about 5 miles south of the airport and 6 miles from the White Alice facility, is connected to the local road system.

Some hunting by hunters other than Meshik village residents occurs at the project site. A portion of the Alaska Peninsula caribou herd passes through the Port Heiden area during the spring and fall migrations. These animals could come in contact with the contaminated areas. Other mammalian species with the potential for contact with the contaminated areas include brown bear, fox, wolves, weasels, microtines, and arctic ground squirrels.

### Potential Exposure Pathways and Receptors

Wildlife could become exposed by ingesting contaminated soil while grazing, ingesting contaminated forage, drinking rain water and meltwater in temporary pools, and to some extent, inhaling



the contaminants. No contamination was found in any of the waterway systems, including lakes, streams, and ground water. The exposure route to aquatic resources is minimal, as is the potential for exposure by predators (including humans) from the water. The potential exposure pathways for the Port Heiden area are presented in table 4.

Soil exposure and inhalation are probably not significant exposure pathways. Inhalation of the compounds would mainly occur from windblown soil particles to which the chemical compounds are attached. The moist, heavy air in the region and the dense vegetative growth reduce the amount of airborne particulate matter, thus decreasing the potential for exposure. Soil exposure is also at a minimum. The surface area of the contaminated soil is extremely small compared to the surrounding area. Skin contact by humans is probably rare; there would be no reason for anyone to touch the contaminated soil. The contaminated areas are far removed from the village; children would not play on the chemical compounds. Soil ingestion by wildlife is feasible and is considered as a potential exposure mode.

Hunting and subsistence use of the land are the likely paths for human exposure, while hunting and grazing are the likely paths for wildlife exposure.

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TABLE 4.--Potential exposure pathways for contaminants from the Port Heiden site

Pathway	Intermediate receptor	Exposure mode	Receptor
Hunting	Game species	Ingestion	Humans, predators
Berry picking		Ingestion	Humans, wildlife
Soil exposure		Ingestion, dermal	Humans, wildlife
Air		Inhalation	Humans, wildlife

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## VI. CARCINOGENIC RISK AND TOXICITY ASSESSMENT

### General.

Since diesel fuel is composed of a complex mixture of hydrocarbons, there are few methods for the environmental analysis of "diesel fuel" as an entity, but many methods for the analysis of its component hydrocarbons. As stated previously, preliminary analysis of the soils at Port Heiden indicated that the contamination was weathered diesel and some asphalt. Subsequent sampling was done for TPH to determine the 5,000  $\mu\text{g}/\text{kg}$  concentrations for landfill. Additional testing for the chemical components of the contaminated soil was not necessary at that time.

The chemical compositions of diesel No. 1, kerosene, and fuel oil No.1 are essentially equivalent. Diesel No. 2 is approximately equivalent to fuel oil No. 2. Data on carcinogenic and toxic effects for the like compounds will be discussed. Ingestion is the major exposure pathway discussed in this section. The rationale for this is discussed in the previous section, Exposure Pathways.

### Diesel Fuels

Toxic Effects - Animals. The oral  $\text{LD}_{50}$  (lethal dose which kills 50 percent of the animals tested) for rats using kerosene (JP-5) was  $>60$  milliliters/kilogram of body weight of animal (ml/kg bw). The  $\text{LD}_{50}$  for another brand of kerosene was 28 ml/kg bw in rabbits and 20 ml/kg bw in guinea pigs, while 28 ml/kg bw killed 4 of 15 rats.

The oral  $\text{LD}_{50}$  of diesel fuel (unspecified) in rats was 7.5 grams/kg bw. The oral  $\text{LD}_{50}$ 's of No. 2 home heating oil in three tests with rats were 12.0, 15.7, and 17.5 grams/kg bw.

Groups of male and female mice were administered 250-2,000 mg/kg bw marine diesel fuel in acetone or 4,000 mg/kg bw diesel fuel by dermal application on 5 days per week for 13 weeks; no treatment-related deaths occurred. An increased severity of mild chronic active dermatitis at the site of application was observed in the high-dose group.

Toxic Effects - Humans. There have been no tests performed on humans, and little information exists on human ingestion of diesel fuels. A young woman who claimed to have ingested a large amount of diesel fuel (1.5 liters) in a suicide attempt developed toxic lung disease over the next few days, with fever, dry cough, and basal opacities on chest X-ray. The condition resolved over the following 4 months.

From absorption of the chemical through the skin, a man who cleaned his hands and arms with diesel fuel over several weeks developed renal failure after about 3 months.

Carcinogenicity Evaluation. There is inadequate evidence that diesel fuel or fuel oils cause cancer in humans. There is limited evidence that marine diesel fuel and No. 2 fuel oil cause cancer in experimental animals. Marine diesel fuel is possibly carcinogenic to humans. Distilled fuels (kerosene, diesel Nos. 1 and 2, and fuel oil Nos. 1 and 2) are not classifiable as to their carcinogenicity to humans. These evaluations were established by the International Agency for Research on Cancer of the World Health Organization.

#### Heavy or Residual Fuel Oils

Although these oils differ from asphalt, they are both manufactured from distillation residues from refinery processing. Residual fuel oils are complex mixtures of relatively high-molecular-weight compounds. Residual fuels tend to exhibit greater concentrations of condensed aromatics than do the lighter fuels.

Toxic Effects. Little toxicological study has been done using residual fuel oils. One study indicated there were no adverse effects in sheep fed about 100 grams of bunker fuel per day for up to 10 days.

Carcinogenicity Evaluation. There is sufficient evidence that residual fuel oils cause cancer in experimental animals. Residual fuel oils are possibly carcinogenic to humans.

### VII. HUMAN HEALTH RISKS FOR PETROLEUM HYDROCARBON CHEMICAL COMPOUNDS

In most cases, the information in this section is drawn from the Public Health Statement in the Agency for Toxic Substances and Disease registry's (ATSDR) toxicological profile for the chemical. The lowest exposure concentrations that may be associated with adverse effects, or minimum risk levels (MRL's), are included in the summaries. MRL's as used in ATSDR toxicological profiles are estimates of exposure levels posing minimum risk to humans. Exposure to concentrations below the MRL are not expected to result in adverse non-carcinogenic health effects. MRL's include adjustments to reflect human variability and, where appropriate, the uncertainty of extrapolating from laboratory animal data to humans. The MRL can be used as a benchmark to which the levels humans may encounter in this environment can be compared.

Petroleum Hydrocarbon Toxicology

The petroleum hydrocarbon constituents can be divided into five major groups: aromatics (including benzene, ethylbenzene, toluene, and xylene); polycyclic aromatic hydrocarbons (PAH's); alkanes; alkenes; and cycloalkanes.

Benzene

Benzene has a long history of industrial use, most notably as a solvent and as a starting material for the synthesis of other chemicals.

Benzene is readily absorbed by inhalation and ingestion but is relatively poorly absorbed through the skin. Since benzene is quite volatile, inhalation is the most likely route of exposure.

Benzene is toxic to the blood-forming organs and the immune system. Excessive exposure (inhalation of concentrations of 10 to 100 ppm) can result in anemia, a weakened immune system, and headaches. Occupational exposure to benzene may also be associated with spontaneous abortions and miscarriages (supported by limited animal data) and certain developmental abnormalities such as low birth weight, delayed bone formation, and bone marrow toxicity. Benzene is regarded as a human carcinogen based on numerous studies documenting excess leukemia mortality among occupationally exposed workers.

Ethylbenzene

Ethylbenzene is an organic chemical which occurs naturally in coal tars and petroleum. It is also found in manmade products such as paints, inks, and insecticides. Gasoline contains approximately 2 percent ethylbenzene by weight. Ethylbenzene is readily absorbed into the body following inhalation, or eating or drinking contaminated food or water. Ethylbenzene as a liquid can be absorbed by the skin, but vapors are not as readily absorbed. Humans exposed to levels of ethylbenzene as low as 460 ppm in the air for short periods have complained of eye and throat irritation.

The MRL of 0.29 ppm of ethylbenzene in air was derived from long-term exposure studies in animals. At concentrations higher than the MRL, effects observed included birth defects in rats and biochemical changes in the brains of rabbits. Exposure of mice to concentrations greater than 1,200 ppm resulted in death.

Toluene

Toluene is used as a solvent in the production of a variety of products and as a constituent in the formulation of automotive and aviation fuels. Toluene can affect the body if it is

inhaled, contacts the eyes or skin, or is swallowed. It may also enter the body through the skin. Toluene may cause irritation of the eyes, respiratory tract, and skin; fatigue; weakness; confusion; headache; dizziness; and drowsiness. These symptoms have been reported in association with occupational exposure to airborne concentrations of toluene ranging from 50 ppm (189 milligrams per cubic meter [ $\text{mg}/\text{m}^3$ ]) to 1,500 ppm (5,660  $\text{mg}/\text{m}^3$ ). These symptoms generally increase in severity with increases in toluene concentration.

The MRL for short-term exposure to toluene in air is 1.0 ppm. The MRL for long-term exposure to toluene in air is 0.3 ppm (1.1  $\text{mg}/\text{m}^3$ ). The MRL for oral exposure to toluene is 460 for short-term and 84 ppm for long-term exposure.

### Xylene

Xylenes are natural components of coal tar and petroleum. Most xylenes used commercially are manmade. There are three isomers of xylene (ortho-, meta-, and para-xylene) which can occur as a mixture and are referred to here as xylenes. Xylenes are used in solvent mixtures and cleaning agents and as an ingredient in airplane fuel and gasoline. Exposure to xylene may occur by breathing xylene fumes or eating or drinking xylene-contaminated food or water. Xylene is rapidly absorbed following inhalation or ingestion. Short-term exposure of humans to high levels of xylene (100-299 ppm) causes irritation of the skin, eyes, nose, and throat; increased reaction time to a visual stimulus; impaired memory; stomach discomfort; and possible changes in the liver and kidneys. Long-term exposure of laboratory animals to xylene in air (12,800 ppm) resulted in changes in the cardiovascular system, changes in liver weights, and hearing loss.

No studies were located regarding the long-term effects of inhalation or ingestion of xylene by humans. Xylene may be fatal if large enough concentrations are inhaled or ingested. Ingestion of 5,000 ppm of xylene in food by laboratory rats resulted in impaired visual function. Decreased body weight and increased numbers of defects in unborn rats were observed at higher concentrations. MRL's have not been derived for the oral or inhalation exposure routes.

### Polynuclear Aromatic Hydrocarbons (PAH's)

Polynuclear aromatic hydrocarbons (PAH's) are absorbed by inhalation and ingestion, and to a small degree through the skin. They are usually transported in the environment in association with particulates. In air, they are constituents of smoke from incomplete combustion (including automobile exhaust) and may be absorbed to dust particles. In water, they also tend to adhere to particulates, since they are quite insoluble.

Based on the available information, PAH's do not appear acutely toxic; however, some are regarded as human and animal carcinogens which can cause cancerous lesions at the point of body contact: in the lungs if inhaled, in the gastrointestinal tract if ingested, and on the skin in the event of chronic skin exposure. There is limited evidence suggesting that PAH's may exhibit reproductive and developmental toxicity as well.

There is relatively little information on the aquatic toxicity of PAH's. The compounds appear to be toxic to marine life at concentrations as low as 300 micrograms/liter. They are carcinogenic to fish as well as to animals and man. An increased incidence of tumors has been observed in some species of fish exposed to sediments containing elevated concentrations of PAH's. Bio-concentration appears to be significant only for PAH's having four or more rings.

#### Aliphatic Petroleum Hydrocarbons (Alkanes: C-8 to C-13)

Aliphatic petroleum hydrocarbons (PHC's) is a term used to refer to a mixture of long-chain hydrocarbon compounds derived from petroleum which are often components of petroleum products. In general, aliphatic PHC's with five or more carbons produce narcosis and central nervous system disturbances and can irritate the lungs at high airborne concentrations. The straight-chain aliphatic PHC's appear to be more toxic than their branched-chain isomers. The most toxic aliphatic is n-hexane?

Ingestion of n-hexane may cause nausea, vertigo, bronchial and general intestinal irritation, and central nervous system effects. Unconsciousness can result from central nervous system depression. After exposure to 800 ppm for 15 minutes, n-hexane has been shown to irritate the eyes and mucous membranes, and skin contact can cause irritation and dryness. Chronic exposure to n-hexane vapors may result in damage to the peripheral nervous system and symptoms such as numbness in the fingers and toes. If exposure continues, paralysis characterized by impaired walking and grasping may result. Concentrations of n-hexane associated with nerve damage have not been firmly documented.

### VIII. RISK COMPARISON

This section normally compares the risk of everyday activities and cancer rates for the general population with the risk potential from the contamination at the project site. Unless the project area is very contaminated, the risk of a motor vehicle accident or the risk of cancer from smoking is considerably higher. Since there are no statistics on risks for total petroleum hydrocarbons, not to mention weathered diesel fuel, and since no data exist on concentrations of chemical components of

the hydrocarbons in the project area, no risk numbers will be compared.

## IX. CONCLUSIONS AND RECOMMENDATIONS

### Introduction

Preliminary chemical sampling of the soil at the Port Heiden DERP site indicated that approximately 20,000 yd<sup>3</sup> of TPH-contaminated soil remains on the site. This quantity is based on field surveys, limited test data, and some assumptions. The soil samples were taken from areas likely to have high concentrations of contamination: under and around fuel tanks, near barrel dumps, in surface-stained soils, etc. Surface and ground water samples taken at the immediate vicinity as well as downhill from the contaminated soils indicated that the migration of the contamination has been minimal. The fuel spills occurred at least 20 years ago, yet samples at depth indicate that vertical migration has also been minor. The ground water table is about 20 feet below the ground surface. It appears very unlikely that any contaminants would reach ground water, even if no further action were taken to remediate the TPH-contaminated soils. This is probably due to several factors: (1) the relatively small amount of fuel which was spilled or leaked; (2) a relatively high organic carbon content in the soil from vegetation and volcanic ash; and (3) a distinct subsurface clay layer observed in sampling.

The degradation of the fuel began with its release. The lighter components have volatilized. Both biotic and abiotic reactions continue the degradation. Adsorption by soil particles and binding to dissolved organic macromolecules have limited much of the chemical compounds' migration.

### Risk to Wildlife

The contaminated soil is relatively shallow. The depth of saturation probably averages between 1 and 2 feet. The contaminated surface area covers about 20,000 to 40,000 square yards, or 4 to 8 acres. Migratory mammal species such as caribou would be little affected by contaminated soils. The project area is in their migratory route, which they pass through in a few days. Concentrations of 100 grams of bunker fuel for 10 consecutive days showed no adverse effects on sheep. Although sheep and caribou may have different tolerances, a caribou would have to eat 16 kilograms of soil of the highest concentration of TPH found at the site per day for 10 days to equal a concentration of bunker fuel which had no effect on the sheep.

Smaller mammals with a modest home range may be adversely affected by the higher concentrations of contaminated soil. Oral

LD<sub>50</sub>'s for rats using heating oil were 12.0, 15.7 and 17.5 grams/kg bw. These concentrations are not physically obtainable for the animals at the project site, since the weathered diesel has lost much of its potency. A small mammal weighing 1 kilogram would have to eat at least 2 kilograms of the most contaminated soil to equal 12.0 grams/kg bw of No. 2 fuel oil. However, adverse effects could occur. LD<sub>50</sub>'s kill half the animals tested within a short period (96 hours). Concentrations much lower could cause chronic effects leading to death. These small mammals are prey for all the predatory mammals and the larger predatory birds of the area. The maximum no-effect concentration for these small mammals is not known. Greatly decreasing the TPH concentration in the soils, as is being proposed, would definitely insure no acute effects to small mammals and would substantially decrease the probability of chronic effects.

#### Risk to Humans

The effects of the contaminated soils on the human population are negligible at this time. The contaminated areas are far removed from any population centers; the site gets occasional visitors for subsistence or recreational purposes. Children would be the most susceptible group to hazardous or contaminated soils. If they were allowed to play in the contaminated soils, adverse effects could occur. It is reasonable to believe that supervised children would not be allowed to play continuously on the TPH-contaminated soils. Since the contaminated areas are more than 3 miles from the village, children would not be expected to wander there inadvertently. Physical (skin) contact with the contaminated soils is highly unlikely for any age group. Studies have shown that dermal contact with diesel fuel can have adverse effects, but these effects occurred with prolonged contact with the contaminant.

Ingestion of food containing diesel fuel from the contaminated soil could occur with the taking of game or berries which have been exposed to the contaminants. The higher the concentration in the soil, the higher the probability of ingesting contaminants. Caribou is the major game species hunted in the project area. Since the caribou only migrate through the area, they probably do not accumulate high enough concentrations of the contaminants to be a significant human health hazard. Resident animals, such as hares and ptarmigan, would be considered a higher risk if eaten.

#### Recommendations

Based on the foregoing conclusions, the Alaska District makes the following recommendations:

1. Soils with TPH concentrations in excess of 5,000 mg/kg should be remediated by incineration, preferably at high



temperature. High temperature units have distinct advantages for destruction of long chain (C-30+) hydrocarbons. The 5,000 mg/kg was the concentration in the original cleanup level. The risk evaluation substantiates this level as not being excessively harmful to human health and the environment.

2. Soils with TPH concentrations in excess of 100 mg/kg should be remediated by incineration in those areas nearest the village. These areas are delineated in the plans located in the appendix. The 100 mg/kg is a cleanup level proposed by the Alaska Department of Environmental Conservation. This level would virtually eliminate any risk to human health.

3. The soils should be replaced, fertilized, and seeded with grasses after remediation. This would act as a cap over the remaining contaminated soils. Capping the remaining soils is similar to landfilling. With the major source of contamination removed, the clay layer between the contamination and ground water, and a vegetated cap, the remaining TPH soil becomes unavailable. This would allow natural processes to degrade the contamination.

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