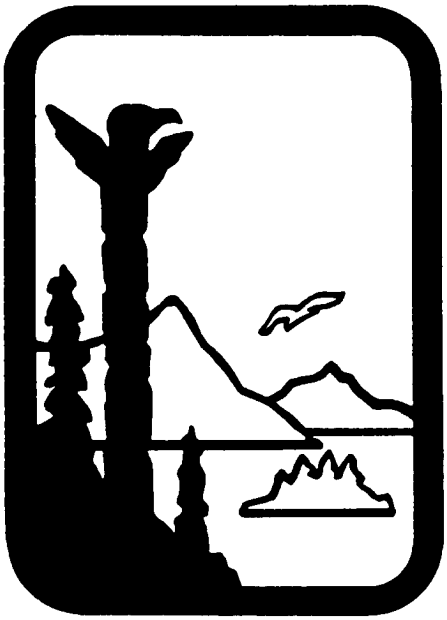
Toxicity & Dust Suppressants



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Purpose: The purpose of this paper is to provide information concerning the toxicity of various dust suppressants (palliatives) currently available for application in Alaska's rural towns and villages where airborne dust is a common health concern. This paper presents information on: 1) how toxicity is measured; 2) where to find information concerning dust suppressants and their toxicity; 3) various types of dust suppressants available; 4) examples of dust suppressant toxicity.

How Toxicity is Measured: Toxicology is the study of the adverse effect of chemicals on living organisms (Klaassen et al., 1996)[1], whereas ecotoxicity is concerned with the effects of a compound or mixture of compounds on multiple organisms within the entire ecosystem (Moriarty, 1988)[2]. Toxicologists subject different organisms (mammals, fish, invertebrates) to chemicals in the laboratory using standard test procedures to determine a chemical's potential adverse effect on humans. The laboratory toxicity test results are then extrapolated to humans. There are two main assumptions that toxicologists use when applying the results of toxicity tests from animals to humans: 1) the effects produced by a compound in the laboratory are applicable to humans; 2) exposure of experimental animals to toxic agents in high doses is a necessary and valid method of discovering possible hazards in humans (Klaassen et al., 1996). The U.S. Environmental Protection Agency (EPA) and others have developed standard laboratory procedures for toxicity testing which can be found at http://www.epa.gov/eerd/methman.htm , http://www.epa.gov/opptsfrs/home/guidelin.htm , and http://ntp-server.niehs.nih.gov/ .

Dose is the quantity of a substance to which the organism, such as a rat, is exposed to in the laboratory. When the substance is introduced to the organism orally (ingested) or through the skin (dermally), the dosage is expressed as milligrams of substance per kilogram of body weight (mg/kg). When the substance is introduced through the air (inhaled) or through the water the dosage is expressed in terms of milligrams per cubic meter of air (mg/m^3) or in parts per million (ppm). Toxicologists plot the dosage versus the measured biological response (e.g. death, percent tumor incidence, reproductive failure) to obtain a dose-response graph or curve.

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(1) "Casarett & Doull's Toxicology, The Basic Science of Poisons", by Curtiss D. Klaassen, 5th Edition, 1996, McGraw-Hill Publishers.

(2) Ecotoxicology, The Study of Pollutants in Ecosystems, by F. Moriarty, 2nd Edition, 1988, Academic Press Publishers.

There are several different types of toxicity tests which measure different biological responses to the chemical being tested. Acute toxicity tests determine the median lethal dose (LD_{50}), which is the single dose of a substance that can be expected to cause death in 50% of the animals tested. The LD_{50} is obtained from the dose-response graph. When the chemical is administered orally or dermally, the median lethal dose, in mg/kg, is referred to as the LD_{50}. When mammals are used as the test subject, the results of the dose-response curve can be directly extrapolated to humans by multiplying the observed LD_{50} (mg/kg) by 70 kilograms, which is the average human bodyweight. When the chemical is administered through the air (inhaled) or through the water, the median lethal dose is referred to as the median lethal concentration (LC_{50}).

Acute toxicity tests measure lethality (death) for a particular animal at a particular dosage, and are usually performed for duration of one to four days (24-96 hours). The lower the LD_{50} or LC_{50} value for a given chemical the greater its toxicity, because it takes a lower dosage to elicit an adverse biological response. For example, a chemical with an oral LD_{50} in rats of 1 mg/kg is more toxic than an LD_{50} of 500 mg/kg, because it only takes 1 milligram of the substance per kilogram of body weight to kill 50% of the organisms as opposed to 500 milligrams per kilogram of body weight to kill the same number of organisms. When evaluating rodent LD_{50}'s, chemicals with an oral LD_{50} less than 50 mg/kg are considered highly toxic, those with an oral LD_{50} of 50-500 mg/kg are considered moderately toxic, and those chemicals with an oral LD_{50} of 500-5,000 mg/kg are considered slightly toxic.

Chronic and sub-chronic toxicity tests measure the ability of a chemical to cause sub-lethal biological effects such as tumor growth, weight loss, organ failure, respiratory and cardiovascular distress, as well as neurological abnormalities. These tests are performed for a period anywhere between 7 days and 2 years. Chronic and sub-chronic toxicity tests also use the dose-response curve to estimate the “no observed adverse effect level” (NOAEL), “lowest observed adverse effect level” (LOAEL) and the “maximum tolerable dose” (MTD). The NOAEL is the highest dose or concentration of a substance to which the test organism is exposed that causes no observable adverse effect. The LOAEL is the lowest dose or concentration of a substance to which the test organism is exposed that causes an adverse effect. The MTD is the dose that suppresses the body weight gain slightly (10%) in a 90-day sub-chronic study (Klaassen et al., 1996). The Effects Concentration (EC) is the toxicant concentration that would cause an adverse effect upon a certain percentage of the test organisms (e.g. EC_{10} or EC_{50}).

Chronic toxicity tests are used to evaluate the ability of a substance to induce adverse biological effects during different life stages and on different parts of the body. Chronic toxicity tests are commonly performed to evaluate the potential of a substance to cause cancer (carcinogen), both benign and malignant (invasive) tumors. Teratology is the study of biological defects induced during development of an organism between conception and birth. A substance which induces an adverse biological effect during gestation is known as a teratogen. Mutagenesis is the ability of chemicals to cause changes in the genetic material (chromosomes) in the nucleus of cells in ways that allow the genetic mutations to be transmitted during cell division. These substances are referred to as mutagens. Germinal mutations can be caused by chemicals that damage chromosomes (DNA) in sperm and ova (eggs). These types of mutations can be transmitted to future generations. Somatic mutations refer to mutations in all other cell types and are not heritable but may result in cell death or transmission of a genetic defect to other cells of the same

tissue type. Mutagens can act on all tissues of the body and can eventually cause cancer or cellular necrosis (death). Mutagenic toxicity tests are used to screen for potential carcinogens because the initiation of chemically induced carcinogenesis is thought to start as a mutagenic event (Klaassen et al., 1996).

Where to Find Toxicity Information: Before using any chemical, such a dust suppressant, it is beneficial to know beforehand- What are its safe handling procedures? What is the chemical's potential for causing adverse biological effects in humans and animals? Is it a potential carcinogen, mutagen or teratogen? What is its LD_{50} or LC_{50} value? What is the chemical's ability to bio-accumulate and persist in the environment? This section provides information on where to find data pertaining to the toxicology of a specific chemical using its Material Safety Data Sheet (MSDS). This section also presents three databases that have been established by EPA and the National Toxicology Program (NTP) for finding information related to the toxicology of a specific chemical or compound.

Material Safety Data Sheets: The U.S. Department of Labor, Occupational Health and Safety Administration's (OSHA) Hazard Communication Standard (1910.1200) requires employees to establish hazard communication programs and to transmit information on the hazards of chemicals to their employees via Material Safety Data Sheets (MSDS). By law, the MSDS is required to provide information for each chemical in use at a particular facility (business, hospital, laboratory, etc.) about its exact chemical ingredients, physical and chemical characteristics, fire and explosive hazards, reactivity data, health hazard data, precautions for safe handling and use. The MSDS also provides toxicological and sometimes ecotoxicity information about each chemical. MSDS information can be obtained from the chemical manufacturer by contacting the manufacturer directly or from their respective Internet website address. Some examples of typical MSDS information for hydroscopic salt dust suppressants can be accessed at the North American Salt Company's website http://www.nasalt.com/msds.htm . MSDS information for other types of dust suppressants are also presented in Table 1.

IRIS: EPA's database called the Integrated Risk Information System (IRIS) provides toxicological information on many existing man-made chemicals. IRIS provides toxicity values and brief summaries of the information supporting those values, including the critical effect, the principal and supporting studies, uncertainty factors and key references. Within IRIS, the Toxicological Review provides scientific support and rationale for the hazard and dose-response risk information from human health assessments. Included in the Toxicological Review documents are information on chemical and physical properties, hazard identification, mode-of-action and dose-response, as well as reference doses (RfD), reference concentrations (RfC), cancer slope factors and unit risks, and cancer descriptors that can be utilized in risk assessments. IRIS is user friendly, free of charge and is accessed at http://cfpub.epa.gov/ncea/iris/index.cfm .

ECOTOX: EPA's ecotoxicology database (ECOTOX) is a source for locating single chemical toxicity data for aquatic life, terrestrial plants and wildlife. ECOTOX was created and is maintained by the U.S.EPA, Office of Research and Development (ORD) , and the National Health and Environmental Effects Research Laboratory's (NHEERL's) Mid-Continent Ecology Division (MED). ECOTOX is comprised from three EPA ecological effects databases; AQUIRE, TERRETOX, and PHYTOTOX. The AQUIRE database includes toxic effects data on all aquatic

species including freshwater or saltwater plant and animal species. TERRETOX is the terrestrial animal database. Its primary focus is wildlife species but also includes information on domestic species. PHYTOTOX is a terrestrial plant database that includes lethal and sublethal toxic effects data. EPA's ECOTOX database is free of charge and is accessed at http://cfpub.epa.gov/ecotox/index.html .

National Toxicology Program: The U.S. Department of Health and Human Services' National Toxicology Program (NTP) provides comprehensive reports on carcinogens and toxicity testing. The NTP is an interagency program whose mission is to evaluate agents of public health concern by developing and applying the tools of modern toxicology and molecular biology. NTP provides comprehensive reports on carcinogens which can be accessed at http://ntp-server.niehs.nih.gov/index.cfm?objectid=72016262-BDB7-CEBA-FA60E922B18C2540 .

Types of Dust Suppressants: Dust suppressants include: water (fresh or salt); water absorbing salts such as sodium, magnesium or calcium chloride salts or brines; organic non-petroleum adhesives such as lignosulfonate, animal fats, tall oil and vegetable oil derivatives; organic petroleum products such as asphalt, organic solvents, oils and tars; electrochemical products such as enzymes, ionic solutions and sulfonated oils; synthetic polymers such as polyvinyl acetate and vinyl acrylic emulsions; clay additives such as bentonite and montmorillonite; fibers, mulches, and geotextiles. Re-vegetation can also be used to control dust. The major dust suppressant categories are briefly described in the following section.

In addition to cost, the following factors should be considered when choosing a dust suppressant: its resistance to breakdown due to traffic and weather; its ability to stay on the road and not leach into soil, groundwater or surface water; its potential toxicity to humans during handling; its toxicity to organisms living in the environment (ecotoxicity), and its ability to bio-accumulate or bio-degrade. Some representative LD_{50} and LC_{50} values for various dust suppressants are presented in Table 1. The manufacturer's website, as presented in Table 1, can be consulted for MSDS information for each product.

More information about the various types of dust suppressants available can be found at www.wsdot.wa.gov/TA/T2Center/DustGuide.pdf and at the New Mexico Environment Department, Air Quality Bureau website www.nmenv.state.nm.us/aqb/dust_control2.html . The Alaska Department of Environmental Conservation (ADEC) does not promote or endorse any service provider or product, whether listed or not listed, over any other provider or product.

Water: Water is usually the most readily available dust suppressant. Both fresh and salt water can be used to suppress dust. Repeated applications are required when using water as a dust suppressant due to evaporation. If salt water is used, there is a potential for chloride to accumulate which is potentially toxic to freshwater fish, plants and trees. There are several companies which manufacture watering equipment specifically for watering roads to control dust. The following websites can be consulted for available equipment and price quotes:

- http://www.ciequip.com/index.html ;
- http://www.wyliesprayers.com/resource/manuals/ ;
- http://www.waterboytransporter.com/.

The "Water Dog" watering system, manufactured by C & I Equipment Company, Incorporated (Tucson, Arizona, www.ciequip.com/index.html), is presented here for example. This watering system is manufactured with different tank sizes (e.g. 325, 500, 1,000 and 2,000 gallon tanks). The "Water Dog" watering system can be purchased with a gasoline high pressure pump, electric valve to control rear spray from a towing vehicle, hose package, side spray attachment and trailer. The total costs for the "Water Dog" 500 gallon, 750 gallon and 1,000 gallon watering system with trailer and accessories are $10,155, $11,682, and $13,318 US dollars, respectively (which includes delivery to Anchorage, Alaska). A picture of the "Water Dog" 1,000 gallon watering system in Figure 1.

Figure 1. "Water Dog" 1,000 Gallon Rear Spray
(courtesy C & I Equipment, Inc.)

The rear spray feature is standard equipment on the 1,000 gallon trailer and allows you to spray an area approximately 30' wide while you are towing the trailer.

Water Absorbing Salts & Brines: Calcium, magnesium and sodium chloride dry salts or brines control dust by absorbing moisture from the air causing the dust particles to bind together. These products are some of the mostly widely used dust suppressants. Calcium and magnesium chloride suppressants work at a lower relative humidity than sodium chloride salts and are more effective under dryer conditions. There would not be any expected human health concerns when handling these products, however, as with salt water there are potential impacts to freshwater fish and plants due to the accumulation, potential leaching and runoff of chloride. The experimental LD_{50} and LC_{50} values for various salt-based dust suppressant products range from the slightly toxic to practically non-toxic range (>500 ppm). Some representative LD_{50} and LC_{50} values for salt based dust suppressants are presented in Table 1. The manufacturer's website, as presented in Table 1, can also be consulted for MSDS information for each product.

Organic Non-Petroleum Products: Organic non-petroleum products include lingninsulfonate, tall (pine) oil, vegetable oil derivatives and molasses. Ligninsulfonate is derived from wood that has been treated with sulfuric acid to produce paper fiber and waste liquor which contains the lignin. Ligninsulfonate is water soluble so its effectiveness is limited in rainy climates. Tall (pine) oil is also a by-product of the paper industry and is recovered during the sulfate Kraft paper process. Tall oil contains rosin, oleic acid and linoleic acid and is also water soluble, so it will breakdown after being exposed to rainwater. As with any type of oil, if large quantities are spilled into an adjacent waterway these types of dust suppressants can cause harm to birds and mammals by coating their feathers or fur thus reducing their ability to keep warm. These types of dust suppressants also carry a high biological oxygen demand and can deplete the oxygen supply of an adjacent water body if leaching or spillage occurs potentially resulting in fish kills. As presented in Table 1, LD_{50} and LC_{50} values for some common organic non-petroleum dust palliatives range from slightly toxic to non-toxic.

Organic Petroleum Products: Organic petroleum based dust suppressants include liquid asphalt, modified asphalt emulsions, mineral oils and petroleum resins. These types of products are effective for controlling dust but may be the most toxic and are potentially carcinogenic. Asphalt and petroleum based oils contain semi-volatile polyaromatic hydrocarbons (PAHs) and volatile organic compounds (VOCs), some of which are known human carcinogens. During application, the asphalt emulsion is commonly heated to allow for smooth application. The heated asphalt emulsion releases vapors which contain PAHs and VOCs that can be inhaled or absorbed through the skin of the people applying the product. The LD_{50} and LC_{50} values for some common petroleum-based dust palliatives range from moderately toxic (50-500 mg/kg) to slightly toxic (>500 mg/kg).

There is little information readily available regarding liquid asphalt and asphalt emulsion LD_{50} and LC_{50} toxicity values. However, there are Threshold Limit Values (TLVs) provided for asphalt products as shown in Table 1. TLVs are not standards but are guidelines designed for use by industrial hygienists in making decisions regarding safe levels of inhalation exposure to various chemical substances and physical agents found in the workplace. TLVs are permissible airborne limits (mg/m^3) of hazardous chemicals and represent conditions under which it is believed that nearly all workers may be repeatedly exposed day after day without adverse effect. The TLV Time Weighted Average (TLV-TWA) allows a time-weighted average concentration for a normal 8-hour working day and a 40-hour working week, to which nearly all workers may be repeatedly exposed without adverse effect.

As with any chemical, the MSDS should be read before use to avoid personal injury during application. Once asphalt is stabilized it should not pose a risk to humans or wildlife. Liquid petroleum-based oils are not recommended for application near drinking water (groundwater or surface water) supplies due to potential contamination from leaching or stormwater runoff. Liquid petroleum-based oils should be used with extreme caution and kept away from waterways and wildlife areas.

Synthetic Polymer Emulsions: Synthetic polymer emulsions include polyvinyl acetate and vinyl acrylic derivatives which bind or adhere to the dust particles. These types of dust suppressants increase the tensile strength (cohesiveness or bearing strength) of clay roads and only need to be applied once every few years. However, synthetic polymers tend to breakdown under moist and freezing conditions. As shown in Table 1, the LD_{50} and LC_{50} values for some common synthetic polymer based dust palliatives range from moderately toxic (50-500 mg/kg) to slightly toxic (>500 mg/kg). Again, as with any chemical, the MSDS should be read before use to avoid personal injury during application.

Electrochemical Derivatives: These types of dust suppressants include enzymes, acids, ammonium chloride, sulphonated oils and specialty products. These types of products generally work best with clay soils and act by reducing the water content of the soil thus increasing compaction. Some products are water soluble while others are highly acidic oxidizers and can react violently with metals. Minimal information is available concerning their ecotoxicity. The MSDS should be read before use to obtain toxicity information and to avoid personal injury during application.

Clay Additives: Clay additives include natural clay materials such as bentonite and montmorillonite. These types of dust suppressants work best under dry conditions and act by agglomerating the fine dust particles and increasing the tensile strength of the soil. Wet conditions reduce their effectiveness. No toxic impact would be expected from using or applying these natural materials.

Table 1. Dust Palliatives- Toxicity Comparison Table

Suppressant Category	Product Name[1]	Environmental Toxicity[2]	Organism(s)	References[3
WATER	Fresh or Salt Water	No Toxicity	All	Not applicable
Hydroscopic Suppressants				
Calcium Chloride	DOWFLAKE (85% Calcium Chloride)	LC_{50} = 759-3,005 mg/l	Daphnia magna (water flea)	www.dow.com/calcium/product/index.htm
		LC_{50} = 8,350-10,650 mg/l	Lepomis macrochirus (bluegill)	www.peterschemical.com/
	LIQUIDOW (28%-42% Calcium Chloride)	LC_{50} = 759-3,005 mg/l	Daphnia magna (water flea)	
		LC_{50} = 8,350-10,650 mg/l	Lepomis macrochirus (bluegill)	
Magnesium Chloride (aqueous solution)	DUSTGARD	Oral LD_{50}= 8100 mg/kg; 7600 mg/kg	Rat Mouse	www.peterschemical.com/
Blend of Calcium & Magnesium Chloride	DUST FYGHTER (38% Calcium Chloride & 34% Magnesium Chloride)	Oral LD_{50} = 900-2100 mg/kg.	Rat	www.midwestind.com/dustfyghter.htm
Organic Non-Petroleum Adhesives				
Ligninsulfonates	DUSTAC	LC_{50} = 4,250 ppm	juvenile Rainbow trout	http://www.bellmarine.com/toxicology_data.htm
	Calcium Lignosulfonate	LD_{50} > 5000 mg/kg	Rat	http://ptcl.chem.ox.ac.uk/MSDS/CA/calcium_lignosulfonate.html
Tall Oil Emulsion	Road Oyl	LD_{50} > 5000 mg/kg	Rat	http://www.midwestind.com/roadoyl.htm
	ENTAC	Non-Toxic	-----	http://www.entacemulsions.com/msds.htm
Synthetic Polymer Emulsion				
Vinyl Acrylic	Soil Sement	Acute Survival LC_{50} = 320 ppm Chronic Survival LC_{50} = 510 ppm Chronic Growth & Reproduction LC_{50} = 540 ppm	Rainbow trout Rainbow trout Rainbow trout	http://www.midwestind.com/soilsement.htm
	Earthbound L	Oral LD_{50} >2000 mg/kg.	Rat	http://www.earthchem.com/material-safety-data-sheets.htm
	Enviroseal Liquid Dust Control	Oral LD_{50} >5000 mg/kg Dermal LD_{50}>5000mg/kg	Rat Rabbit	http://www.enviroseal.com/ldc.htm

Table 1. Dust Palliatives- Toxicity Comparison Table (continued)

Suppressant Category	Product Name[(1)]	Environmental Toxicity[(2)]	Organism(s)	Reference
Organic Petroleum Products				
Modified Asphalt Emulsions	COHEREX (60% petroleum resins + 40% wetting agent)	LD_{50} = 95 ppm	Fish	http://www.rejuvtec.com/COHEREX%20Dust%20Retardant
	ROAD PRO NT ~30% Asphalt	No specific toxicity data Contains Asphalt	Possible Human Carcinogen	http://www.midwestind.com/roadpront.htm
	PennzSuppress-D	Chronic LC_{50} =130 mg/L Acute LC_{50}= 510mg/L. Chronic LC_{50} = 194 mg/L Acute LC_{50} = 913 mg/L.	Fathead minnow Rainbow trout	http://www.pennzsuppress.com/html/msi.htm
Dust Oil/Dust Fluids	ENVIROKLEEN (high viscosity synthetic iso-alkane)	LC_{50} >500,000 ppm	Rainbow trout & Mysidopsis bahai	http://www.midwestind.com/
	DUOPRIME OIL 350 (white mineral oil)	Oral LD_{50} Acute: >5000 mg/kg.	Rat	http://www.lyondell.com/Lyondell
		Dermal LD_{50}: Acute: >2000 mg/kg.	Rabbit	
Asphalt Cutback	MC-70 (liquid asphalt)	TLV-TWA =5 mg/m^3 (no ecotoxicity data)	Humans	http://albina.com/Asphalt/msds.htm
Asphalt Emulsion	CSS-1 (>57% asphalt)	TLV-TWA=5 mg/m^3 (no ecotoxicity data)	Humans	http://albina.com/Asphalt/msds.htm
Electro-Chemicals				
Enzymes	Perma-Zyme 11x	No Data	??	http://www.remtech-eng.com/PermaZTx.html
Ionic	Road Bnd EN-1	Corrosive-may react violently with metals.	none	http://www.roadbond-en1.com/aboutRoadbonden.htm
Sulfonated Oil	CBR Plus	No Data	??	http://www.cbrplus.com/product.asp

Notes: (1) Disclaimer: This list has been drawn from sources generally available to the public and is intended solely to assist in identifying potential service and product providers. The Alaska Department of Environmental Conservation/Air Quality Division disclaims any warranty, expressed or implied, regarding the services or products of the listed providers. Furthermore, the Alaska Department of Environmental Conservation/Air Quality Division does not promote or endorse any service provider or product, whether listed or not listed, over any other provider or product. **(2)** Toxicity factors based on LC_{50} or LD_{50} = lethal concentration or lethal dose of product expressed in parts per million (ppm) that will produce 50% mortality rate in the test group in 96 hours (4 days). Typically, LC_{50} or LD_{50} values less than 100 ppm are considered toxic; $\leq$ 1,000 ppm considered practically nontoxic; and > 10,000 is considered non-toxic.