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Environmental Evaluation of Dust Stabilizer Products

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Final report

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Abstract: Personnel of the U.S. Army Engineer Research and Development Center (ERDC), Vicksburg, MS, and Navy Environmental Health Center (NEHC), Portsmouth, VA, evaluated the environmental fate and effects of six commercially available dust stabilizer products. As part of the evaluation, a relative risk comparison was made of the six materials to other materials that have been used historically to control dusts (i.e., diesel, crude oil, fuel oil). Data for this evaluation were obtained primarily through literature review, communication with the manufacturers of the products, and through some limited analytical chemistry. Data gaps and uncertainties were also identified and described. Conclusions were derived from the results of the evaluation, with each stabilizer group presented separately along with general conclusions applicable to all stabilizers studied.

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Preface

This report was prepared as part of the Pavements Research Program, AT22 Work Package 238, for the Assistant Secretary of the Army for Acquisition, Logistics, and Technology, to describe a risk-based assessment of the human health and environmental impacts of six commercially available dust stabilizers.

Users of information from this report include the U.S. military's engineer units charged with expedient road and airfield construction, the U.S. Army Maneuver Support Battle Lab, U.S. Army Engineer School, U.S. Army Force Projection Battle Lab Support Element, U.S. Army Deployment Modernization Office, U.S. Army Force Projection Center of Excellence, U.S. Army Force Projection Program Manager, U.S. Transportation Command, U.S. Army Corps of Engineers, Airfield Commanders, U.S. Army Aeronautical Services Agency, U.S. Air Force Civil Engineer Support Agency, U.S. Air Force Air Mobility Command, and agencies assigned operations planning responsibilities.

This report was prepared by personnel from the U.S. Army Engineer Research and Development Center (ERDC), Environmental Laboratory (EL), Vicksburg, MS, and U.S. Navy Environmental Health Center (NEHC), Portsmouth, VA. The findings and recommendations presented in this report are based upon tests and analyses conducted at ERDC. The research team consisted of Dr. Jeffery Steevens, Dr. Burton Suedel, Dr. Sandra Brasfield, Alan Kennedy, Leslie Yoo, Alfreda Gibson, William Blackburn, and Richard A. Price, Environmental Risk Assessment Branch, EL; Christina Kennedy, Environmental Processes Branch, EL; and Dr. J. Thomas Pierce, NEHC. This report was prepared under the supervision of Dr. Robert P. Jones, Acting Chief, Environmental Risk Assessment Branch, EL; Dr. Richard E. Price, Chief, Environmental Processes and Engineering Division; and Dr. Beth Fleming, Director, EL.

COL Richard B. Jenkins was Commander and Executive Director of ERDC. Dr. James R. Houston was Director.

- Their hydrophobicity indicates that they are likely to sorb to soils and sediments and be relatively stable in these environments and therefore unlikely to be transported in water.
- Hydrocarbon-based stabilizers may cause some limited toxicity in sediments as a result of ingestion of sediment particles with sorbed product.
- Data gaps for these stabilizers include degradation information, terrestrial toxicity, and potential for polymer to result in inhalation exposures.

Polysaccharide Dust Stabilizers

- The main ingredients of Surtac® are sugar, starch, and soap and are thus expected to pose little or no environmental hazards.
- No data exist regarding the environmental fate and transport as well as human health and ecotoxicological properties.

General

- The exposure assessment indicated that applicators and the war fighter can potentially come into contact with dust stabilizers. Persons in these groups can most likely contact stabilizers via direct contact with the material or through incidental ingestion of soil, dermal contact, and inhalation of airborne particles.
- Ecological receptors most likely to contact stabilizers are those that are immobile or have limited mobility such as plants and soil invertebrates, respectively. In arid environments, species such as lizards could contact stabilizer-treated soils. In addition, organisms that burrow may be exposed through inhalation of volatile compounds or particles derived from the dust stabilizers. Stabilizers that are water soluble can be mobilized via surface runoff and reach nearby water bodies where aquatic and benthic receptors can contact these materials. Stabilizers that are insoluble may be transported in runoff water through the transport of product sorbed to soil and sediment particles.
- A comparison between petroleum stabilizers and the nontraditional stabilizers clearly showed the stabilizer products in the current evaluation are much less toxic to aquatic organisms than the petroleum products used historically by the DoD. The acute aquatic LC₅₀ values for unleaded gasoline, diesel fuel, lube oil, Kuwait crude and Prudhoe Bay crude generally ranged from 1 to 300 mg/L, which are considered to be slightly to moderately toxic. Conversely, the five commercially

1 Introduction

Dust stabilizers (also called dust suppressants or palliatives) are chemicals or other materials used to control airborne dust from land surfaces. They work by changing the physical and chemical properties of the soil surface. Dust stabilizers are used to meet air quality standards, control nuisance dust, and reduce erosion of soils. Specific applications include mining, construction, agriculture, and military activities (Sanders and Addo 1993; U.S. Environmental Protection Agency (USEPA) 2004). Dust control during military activities is a critical need due to increased training and operations in arid environments.

A wide variety of soil stabilizer chemicals and other materials have been used for dust abatement (Gebhart et al. 1996; Price et al. 1991; USEPA 2004). Materials used for dust abatement include fresh and saltwater, salts and brines (e.g., calcium chloride and magnesium chloride), petroleum-based organics (e.g., asphalt emulsions, crude oil, and diesel fuel), non-petroleum-based organics (e.g., vegetable oils, molasses, and ligninsulfonate), mulch and fiber mixtures (e.g., lignin products), clay additives (e.g., bentonite and montmorillonite), electrochemical products (e.g., ammonium chloride and enzymes), and synthetic polymers (e.g., polyvinyl acetate and vinyl acrylic) (Sanders and Addo 1993; Bolander and Yamada 1999; USEPA 2004).

Depending on type, dust stabilizers work in one of three ways, all of which basically transform smaller dust particles into bigger particles (Bolander and Yamada 1999; Lohnes and Coree 2002; Tingle et al. 2004; USEPA 2004). Salts, brines, and clay additives attract moisture to soil particles. Water, petroleum-based products, and some synthetic organic materials form a crust or protective surface on the soil. Many of the synthetic polymer products and non-petroleum products act as a binding agent to agglomerate or aggregate soil particles. Electrochemical materials expel water from soil voids, thus increasing soil compaction.

Dust stabilizers are typically diluted in water at the site and applied to the soil surface by spraying suppressant directly to the surface via a spray hose, gun, or bar at the rear of a truck (USEPA 2004). The type of application used depends on the acreage needing coverage. Stabilizer benefits

are maximized when sufficient soil penetration is achieved, usually on the order of 10-20 mm thickness (Bolander and Yamada 1999).

Most of the research concerning dust stabilizers has focused on the effectiveness with which these stabilizers bind and sequester soil particles (Sanders and Addo 1993; Epps and Ehsan 2002; Tingle et al. 2004; USEPA 2004). Little is known regarding the fate and potential human and environmental effects associated with application and use of these products for dust control. The majority of the environmental studies published to date have focused on salts and brines, ligninsulfonates, and petroleum-based products (Roald 1977; Zhordania et al. 1982; Ettinger 1987; Heffner 1997; Kimball 1997; Lohnes and Coree 2002; USEPA 2004).

Non-petroleum based organics, especially ligninsulfonate and salts such as calcium chloride, are the most widely used dust stabilizers in the United States (Lohnes and Coree 2002; Washington Department of Ecology 2003). In Washington state, ligninsulfonate products were used in 41 percent of dust abatement road projects, followed by water (33 percent), magnesium chloride (8 percent), emulsified asphalt (8 percent), petroleum products and calcium chloride (both at 4 percent), and other products at 2 percent (Washington Department of Ecology 2003). However, human health, environmental, and other concerns over the use of many of these materials preclude their use for military activities, especially in arid environments. For example, salts and brines have corrosive properties (Bolander and Yamada 1999; Addo et al. 2004) thus posing a maintenance problem and precluding their use around military vehicles. Salts are also toxic to some species of trees and other vegetation (Bolander and Yamada 1999) and work best in areas where the relative humidity is above 30-40 percent (Hefner 1997), precluding their use in arid environments. Ligninsulfonate is highly water soluble, causing erosion and leaching of the lignin during exposure to moisture, thus resulting in strength degradation (Palmer et al. 1995, as reported in Tingle et al. 2004). This susceptibility to moisture precludes its use in many military applications. The scarcity of water in arid areas of the world precludes its use in these environments. Thus, there is a need for materials that are readily available in large quantities that can be transported to remote regions of the world to suppress dust during military activities. These materials must also not be hazardous to human health or the environment. For these reasons, alternatives to the more commonly used salts, ligninsulfonates, and petroleum products (e.g., crude oil) such as synthetic polymers and polysaccharides are receiving increased interest by the Department of

Human toxicity

The bioavailability of the cured vinyl acetate and acrylic polymers is expected to be below levels that can cause toxicity. The cured product is expected to have limited biological significance. However, there is some potential for effects associated with exposure to the unpolymerized formulation prior to application.

One of the constituents of the vinyl acetate polymer is vinyl acetate. A significant amount of data is available regarding the toxicity of vinyl acetate. As a substrate for polymerization, vinyl acetate is a concern due to its metabolism (e.g., more toxic products are actually produced through its biological transformation). The 2-carbon ethenyl group (like vinyl chloride) is metabolized by carboxyesterase to yield acetate and acetaldehyde. Acetaldehyde is suggested to be an initiator or possibly a promoter of nasal tumors (Hazardous Substance DataBank (HSDB) 2006). Thus, exposures occurring during its formulation or administration are a potential issue. There is evidence in rodents that vinyl acetate is a carcinogen, resulting in its classification as a 2B carcinogen. It is thought that the mechanism of toxicity is through direct DNA damage. Non-carcinogenic effects are rather limited. Chronic exposures suggest no effects at exposure levels below 5 to 10 ppm in air. At higher exposure levels (7 to 142 ppm), effects include CNS perturbation, emphysema, early onset mortality, and changes in hepatic enzymes. Chronic exposure (100 weeks) to drinking water resulted in increased liver neoplasms and uterine adenocarcinomas. Several limits have been established for vinyl acetate (HSDB 2006). The American Council of Government Industrial Hygienists (ACGIH) has established two threshold limit values: a time-weighted average (TWA) of 10 ppm in air for exposure during an 8-hr work day and short-term exposure limit (STEL) of 15 ppm which represents the highest allowable level during a short-term exposure. The Occupational Safety and Health Administration (OSHA) has established Permissible Exposure Limits (PEL) of 10 ppm (TWA) and 20 ppm (STEL) for a 15-min exposure. The National Institute for Occupational Safety and Health (NIOSH) established a single standard of 4 ppm for a 15-min exposure.

As a substrate for polymerization, acrylate is of concern due to dermatologic conditions, more specifically, common contact allergy. Structurally and toxicologically, vinyl acetate and acrylate share a two-carbon functionality. Like vinyl acetate, once reacted, the potential for human exposure or effects from acrylate-incorporating polymers is of limited significance. Acrylate polymers are considered relatively benign and

Human toxicity

Very little human toxicity is expected with Surtac[®]. Polysaccharides, including the engineering substrates termed sugar, starch, and soap, are natural products of limited inhalation toxicity interest. Soaps might be capable of causing dermatitis, although of only minimal significance. Inhalation reference exposure concentrations should be kept below 1,000 ppm (Pierce 2006).

Toxicity to ecological receptors

No ecotoxicological data were found for Surtac[®].

Conclusions

No data were identified regarding the environmental fate and transport, as well as human health, and ecotoxicological properties of the polysaccharide dust stabilizers. However, the main ingredients of Surtac[®] are sugar, starch, and soap and are thus expected to pose little or no environmental hazards.

3 Exposure Assessment

Exposure assessment is the process of measuring or estimating the intensity, frequency, and duration of human or wildlife exposure to an agent in the environment. This section discusses how soil stabilizers are distributed in the environment and estimates potential contact between the hypothetical receptor populations and stabilizers. The frequency and duration of the hypothetical contact have been assumed to occur routinely, although such contacts have not been observed or documented for the activities being evaluated (e.g., applicators and war fighters).

There are two basic steps in the exposure assessment for the hypothetical activities being evaluated. First, the exposure setting was characterized and receptor populations identified. Second, exposure pathways were identified and graphically presented in a conceptual model (CM). This second step also included qualitatively characterizing chemical sources, mechanisms of release, and exposure routes at theoretical exposure points. Conditions expected to be present and activity patterns of humans and wildlife indicate the presence of completed exposure pathways for contact with soil stabilizers (USEPA 2004).

Identification and evaluation of receptor populations and exposure pathways

For this evaluation, hypothetically exposed populations and associated exposure scenarios were developed and evaluated. These exposure scenarios were based on some of the types of activities that occur when stabilizers are applied to soils by applicators and subsequently through contact with these soils by war fighters during routine activities. Contact with the stabilizers could occur for applicators during preparation and application as well as war fighters inadvertently contacting soils treated with stabilizers. Wildlife receptors such as birds, mammals, invertebrates, plants, and aquatic organisms could also contact stabilizers applied to soils. Exposure assessment for stabilizers is shown separately below for humans and wildlife.

Potential releases to and transport in the environment

Release and transport of stabilizers to soils may result in contamination of secondary sources including surface water, ground water, air, and

sediment. The potential migration pathways by which stabilizer components can move from source areas to receptor populations were considered in the development of the CM.

The following potential migration or retention mechanisms for stabilizers in the environment were considered during the development of the CM. Surface water runoff may transport stabilizers into surface water bodies. Chemicals released from surface water through volatilization may be dispersed in the air and then transported by vapor migration. Chemicals released to surface water may include free phase chemicals that may enter sediments. Chemicals in surface water may be released to sediment (through deposition and sorption), biota (through uptake), surface water (through runoff), and air (through volatilization). Chemicals in air may be transported to sediment and surface water through wet or dry deposition. Chemicals in sediment may be released to surface water (through desorption/sorption) and biota (through uptake).

The fate of stabilizers in the environment also depends on chemical-specific characteristics, such as water solubility, potential for degradation and bioaccumulation, chemical molecular weight, application rates and methods, and environmental conditions such as wind speed, rainfall, and soil grain size (USEPA 2004). The potential for stabilizers to migrate in the environment were considered as the exposure pathways were evaluated and indicated in the CM.

Potential exposure pathways for humans

Identification of potentially contaminated media and identification of potential exposure pathways were made based upon our understanding of the uses of soil stabilizers and where these products may be applied. Exposure points indicated in the CM (Figure 1) were selected based on accessibility of treated soils and hypothetical activity patterns for applicators and war fighters. These exposure scenarios were assumed to contribute the majority of total exposure due to hypothetical activities.

Complete exposure pathways for applicators and/or war fighters as indicated in the CM for qualitative evaluation are as follows:

- ingestion of material directly or indirectly through ingestion of soil, sediment, surface water and groundwater
- inhalation of stabilizers in air
- dermal and eye contact directly with material during application or indirectly through contact with soil, surface water, sediments, and groundwater.

As shown in Figure 1, potentially complete exposure pathways are noted with an open circle. Potential exposure pathways applicable to stabilizers were represented in the CM.

Figure 1 shows potentially complete pathways for applicators and war fighters. These activities represent direct exposure to materials during application or indirect contact with environmental media, since human receptors are not likely to purposefully ingest stabilizers. Direct contact with materials will occur with applicators mixing and applying material to soil. Contact with soil will occur for applicators that may accidentally slip, trip, or fall into soil where stabilizers are being applied or have been recently applied. In addition, war fighters may come in direct contact with material through potential drift or contact with soil after application. Soil contacted dermally could adhere to uncovered hands, arms, face, or other parts of the body where chemicals can absorb through the skin. Inhalation of stabilizers could occur when persons inhale airborne stabilizer particles. Inhalation of stabilizers could occur due to wind carrying liquid stabilizers as mists during application or when soils are physically disturbed and particles are otherwise released into the air.

Contact with sediments, surface water, or groundwater is limited to persons that may accidentally slip, trip, or fall into a body of water containing stabilizers. This can occur if a person washes stabilizer application equipment in a water body. Although this is not likely to occur routinely, the potential for this activity has been included here. If someone were to contact a surface water body, he might be exposed to stabilizers in surface water through incidental ingestion and dermal contact with surface water. This person could also be exposed to stabilizers through incidental ingestion and dermal contact with sediment. Sediments contacted dermally could adhere to the person's feet, hands, and lower legs where chemicals

can absorb through the skin into the body. The sediment referred to in the CMs is located beneath the surface water.

War fighters have the potential to contact treated soils, sediments, surface water, or groundwater as part of training and mission activities (i.e., crawling on ground, contact with equipment, or passing through water). War fighters may accidentally slip, trip, or fall into soils containing cured stabilizers or into nearby water or sediment containing stabilizers transported from treated areas. If someone were to contact such stabilizers, he might be exposed to stabilizers through incidental ingestion, inhalation, and dermal contact. Soil, water, and sediment contacted dermally could adhere to exposed parts of the body where chemicals can absorb through the skin. Inhalation of cured or degraded stabilizers could occur when war fighters inhale airborne stabilizer particles. Inhalation of stabilizers could occur due to wind carrying stabilizers attached to airborne particles or when soils are physically disturbed (e.g., at a helipad) and particles are otherwise released into the air.

Potential exposure pathways for wildlife

Exposure pathways were considered complete only when stabilizers could migrate from a source and subsequently contact and be accumulated by an ecological receptor via one or more exposure routes (e.g., ingestion).

Ecological exposure pathways considered include:

- source(s) of stabilizers and their mechanism(s) of release to the environment
- transport medium (or media) and mechanism(s) of transfer from one medium to another
- point (or area) of potential receptor contact with stabilizers.

The potential exposure pathways incorporated each of these elements and are represented in the CM (Figure 1). The sources of stabilizers considered in this assessment are current and historical applications and accidental releases. Potential release mechanisms include surface water runoff, infiltration and migration, volatilization, erosion, and suspended sediment transport. Through these release mechanisms, stabilizers originating from past and/or current applications could potentially be a source of exposure for ecological receptors.

Stabilizers in secondary source materials may be released via several mechanisms, including incorporation into the food-web. Stabilizers released to surface water and/or sediment can be contacted or ingested by aquatic and terrestrial receptors. Terrestrial receptors may directly contact or ingest surface water. Surface runoff could transport surface soil-containing stabilizers to surface water and sediment, potentially exposing aquatic receptors. Through food-web interactions, aquatic receptors can be ingested, in turn, by higher trophic level receptors.

Complete dermal exposure pathways for ecological receptors to media such as sediments are difficult to document; for many receptors (e.g., mammals grooming fur), ingestion of stabilizers will likely occur before actual dermal contact occurs.

Wildlife pathways analysis

Exposure pathways are routes by which a constituent migrates from a source to a receptor. Pathways that are potentially complete for stabilizers are listed and discussed below:

- *Surface water*: Direct contact (dermal and respiratory) and ingestion of surface water are potentially complete pathways to aquatic and terrestrial receptors, respectively.
- *Sediment*: Sediment contact and ingestion potentially occur only for benthic receptors (e.g., aquatic benthos and bottom feeding fish) because sediment will be substantially washed off items consumed by terrestrial receptors feeding on organisms inhabiting surface waters.
- *Soil*: Ingestion of soil by biota and direct uptake of stabilizers by vegetation are potentially complete exposure pathways. Soils will be substantially washed off items consumed by terrestrial and avian receptors feeding on organisms inhabiting surface waters.
- *Ground water*: Ground water pathways are not complete for ecological receptors as they are not directly contacted until it reaches the surface either as a seep or becomes surface water.
- *Air*: Air exposure pathways are not well characterized for ecological receptors and, therefore, were not considered complete.
- *Biota*: Direct ingestion of biota (including fish and crustaceans) by higher trophic level ecological receptors is a potentially complete exposure pathway.

These exposure pathways served as one component of the CM. The diagram depicting exposure pathways for ecological receptors are presented in Figure 1.

Potential receptors

For this evaluation, hypothetically exposed human and wildlife populations were evaluated. Routine contact with the stabilizers could occur for applicators and war fighters inadvertently contacting soils treated with stabilizers. Wildlife receptors such as birds, mammals, invertebrates, plants, and aquatic organisms could also directly or indirectly contact stabilizers applied to soils.

Human receptors

Receptor populations and potential exposure pathways have been identified with respect to proximity to contaminated media, theoretical activity patterns, and the presence of sensitive subgroups. As discussed above, these receptor populations are largely limited to applicators that apply the stabilizers to soils, persons who may wash stabilizer equipment in a water body, and the war fighter that contacts soil during training and operational activities. As a standard part of quantitative risk evaluation, regulatory guidance requires that subpopulations that may be more sensitive to chemical exposures be evaluated. The subpopulations evaluated typically include infants and children, elderly persons, pregnant and nursing women, and people with chronic illnesses. These groups are included in the regulatory guidance because they may be at higher risk due to unique behavior patterns or physical conditions. For example, children may be more likely than adults to contact soil, sediment, and surface water due to play activities. Although consideration has been given to these subpopulation categories in this evaluation, the mostly restricted access to soils treated on military lands targeted for stabilizer application makes routine contact for such individuals highly unlikely. If such individuals were to contact these soils, it would be as a trespasser. However, the trespasser exposures would be expected to be much less than the war fighter and applicator.

Ecological receptors

Specific ecological receptor groups were selected based on the evaluation of assessment endpoints and exposure pathways previously described. The

receptor selections were limited to those receptors that are most likely to contact soils treated with stabilizers in the field. These receptors include birds (e.g., passerines such as robin and granivorous birds such as quail), mammals (e.g., rodents), reptiles and amphibians (a.k.a. herptiles; e.g., lizards), soil invertebrates (e.g., earthworms), plants (herbaceous vegetation such as grasses and shrubs), and aquatic organisms such as fish and benthic invertebrates. Receptors most likely to contact stabilizers are those species that are not mobile (sessile) or have limited mobility such as plants and soil invertebrates (e.g., pill bugs and earthworms) that may be contacted by stabilizer applications. Because stabilizers are commonly used in arid environments, species such as lizards are also likely to contact stabilizer-treated soils that have cured. Stabilizers that are water-soluble have a greater potential to reach water bodies where they can contact fish and other aquatic and benthic receptors. Persons washing applicator equipment in water bodies also facilitate contact between stabilizers and aquatic receptors.

Conceptual model (CM)

A CM is a graphical representation used to identify: (1) all potential or suspected sources of contamination; (2) release and potential migration mechanisms; and (3) potential exposure pathways, including receptors, which lead to an exposure point (Figure 1). It was assumed that future land use would not change. Therefore, future exposure populations and pathways were assumed to be the same as those evaluated under current conditions.

The symbols used in the CM are as follows:

- *Open Circle* represents potentially complete exposure pathways that are likely to contribute significantly to exposure.
- *Not Applicable* represents exposure pathways that are not applicable for a particular receptor.

In general, an exposure pathway describes the course a chemical takes from the source to the exposed individual. An exposure pathways analysis links the source, location, and type of environmental release with population location and activity patterns to determine the significant pathways of exposure. An exposure pathway is considered complete only if all four of the following elements are present: (1) a source and mechanism of chemical release to the environment; (2) an environmental retention or

transport medium (e.g., sediment, surface water) for the released chemical; (3) a point of potential contact with the contaminated medium (exposure point); and (4) an exposure route (e.g., ingestion, inhalation, dermal contact) at the contact point.

In summary, this exposure assessment indicated that a select group of human and ecological receptors can plausibly contact dust stabilizers. Potential human receptors are applicators, persons who may wash applicator equipment in a water body, and the war fighter. Persons in these groups can most likely contact stabilizers directly or via incidental ingestion of soil, dermal contact, and inhalation of airborne particles. Ecological receptors most likely to contact stabilizers are those that are immobile such as plants and soil invertebrates. In arid environments, species such as lizards could be exposed through direct contact of stabilizer-treated soils or through inhalation of volatile compounds or particulates derived from the stabilizer products. Water soluble stabilizers can be mobilized via surface runoff and reach nearby water bodies where aquatic and benthic receptors can contact these materials.

4 Comparative Risk

Dust control during military activities is a growing concern due to increased training and operational activities in arid and other environments around the world. As part of these activities, wheeled and tracked equipment and aircraft may suspend arid soils and impact the ability for the military to successfully conduct operations (Rushing et al. 2005). Dust stabilizers are used by DoD to meet air quality standards, reduce erosion and maintenance costs on unpaved road surfaces, and reduce fugitive dust during military training and maneuvering activities. The DoD has historically used readily available petroleum-based organics such as asphalt emulsions, crude oil, gasoline, and diesel fuel for dust abatement (USAEC 2006). Such petroleum-based products work by forming a crust or protective surface on the soil (Bolander and Yamada 1999; Lohnes and Coree 2002; Tingle et al. 2004; USEPA 2004).

The primary advantage for using petroleum-based products is that they are readily available during maneuvers and training exercises as these products are also used to fuel military vehicles and are already in place. However, petroleum-based products (i.e., diesel, crude oil, fuel oil) are no longer advised for use because the fate and adverse effects on humans and the environment are relatively well known and documented (Eisler 1985). Such products contain hydrocarbons (some of which are known carcinogens) to which humans and wildlife can be exposed (McMillen et al. 2001). When applied to soils, hydrocarbons in petroleum-based stabilizers can be ingested or cling to the skin or dermis of animals. Volatile components, mists from application, and suspended soil particles can be inhaled. Hydrocarbons can be transported to subsoil and groundwater via leaching or dissolution. If groundwater reaches the surface, it can be ingested or its emissions inhaled.

Human health

There are three main human exposure routes for dust stabilizers: dermal, inhalation, and ingestion. These exposure routes have been highlighted in Chapter 3 in the conceptual model and described for applicators, persons washing application equipment, and the war fighter, all via incidental exposure. For the purposes of this analysis, the polysaccharide stabilizer Surtac[®] is of limited concern for exposures through ingestion, inhalation,

Service (USFWS 1984). This scale rates chemicals based on readily available toxicity information for aquatic organisms. The USFWS scale uses an LC₅₀ value as the basis for comparison, which is the concentration of a chemical or substance that would be lethal to 50 percent of a population of the test organisms (e.g., fish, benthic invertebrate) within 48 to 96 hours. Each substance is rated into one of seven categories. The least toxic category is termed “relatively harmless” and includes substances for which the LC₅₀ value is >1,000 mg/L; the most toxic category is termed “super toxic” and includes substance for which the LC₅₀ value is <0.01 mg/L. This rating scale was used to determine the relative aquatic toxicity of petroleum-based stabilizer products and the six stabilizers that are the subject of this report.

Valid comparisons of various soil stabilizers using the USFWS rating scale must include toxicity data that are comparable with respect to the scale’s endpoint (48 to 96 hr LC₅₀ values) and include freshwater species that may be impacted by stabilizer runoff. For these reasons, the comparisons were made using acute (24 to 96 hr) LC₅₀ values for freshwater fish, primarily fathead minnows (*Pimephales promelas*) and salmonids such as rainbow trout (*Oncorhynchus mykiss*). Toxicity data for the subject stabilizers were obtained from manufacturer’s data and are also presented in Appendices A through F. No aquatic toxicity data for Surtac® were found. Freshwater toxicity data for unleaded gasoline, diesel fuel, lube oil, and two types of crude oil (Kuwait and Prudhoe Bay crude) were obtained from the published literature (Frankenfeld et al. 1975; Moles et al. 1979; Poirier et al. 1986; Lockhart et al. 1987; Rice 1973; Vandermeulen and Hrudey 1987).

Comparisons of various petroleum stabilizers with recently developed stabilizers indicated distinct toxicity differences between the groups (Figure 2). The toxicity data for unleaded gasoline, diesel fuel, lube oil, Kuwait crude, and Prudhoe Bay crude generally ranged from 1 to 300 mg/L, which fall into the slightly to moderately toxic categories. Conversely, the five stabilizers for which data were available indicated LC₅₀ values ranging from a low of 500 mg/L up to 10,000 mg/L, indicating that these products were in the practically nontoxic to relatively harmless categories.

5 Uncertainty and Data Gaps

This section identifies sources of uncertainty and data gaps associated with the analysis of existing information outlined in previous sections of this report. Specific sources of uncertainty and data gaps are discussed below.

Missing information (data gaps)

Information gaps where sources, mechanisms of exposure, and exposure pathways are not identified or important aspects of the ecology are not known can affect risk estimates. Information concerning the toxicity of the six products studied leaves a substantial data gap. Nearly all toxicity data are unpublished and only available from the manufacturers. Toxicity data are lacking for complete animal kingdoms for some stabilizers. While the relative toxicity of five of the six subject stabilizers were in the practically nontoxic to relatively harmless range, it is unclear whether the lack of aquatic toxicity based on manufacturers' data holds true for other species. Confirmatory studies are needed to determine the toxicity with more certainty and to determine the toxicity of these products to other species that can reasonably contact these products in the field. Environmental fate data for many of the stabilizers are also unknown. Data gaps specifically identified in this report are:

- information on chemical composition
- environmental fate (i.e., degradation and partitioning) and transport information for all products
- inhalation exposure data for all polymer emulsions
- toxicity of all stabilizers to emergent and established plants
- toxicity of all stabilizers to soil invertebrates
- toxicity of all stabilizers to terrestrial vertebrates (i.e., reptiles)
- toxicity of all stabilizers to aquatic organisms, especially species other than fish
- toxicity of cured acrylic polymer for terrestrial and aquatic species
- toxicity of Soiltac[®], Durasoil[®], and Surtac[®] to mammals.

Errors in the conceptual model

If relationships between sources and receptors are missing or incorrectly identified, risks could be under- or overestimated. Proper CM

development can help reduce this uncertainty. In this report, the development of a comprehensive CM that identified all known potential pathways and receptor groups reduced the overall uncertainty of missing pathways and receptors. However, due to the various applications for these materials and activities associated with training and mission-related activities, it is difficult to determine intact exposure pathways for the war fighter. A concern that remains is the fate of these stabilizers in the environment after application. These characteristics are best determined from knowledge of the active and inactive components of these complex mixtures, which is difficult to determine due to the proprietary nature of the products.

Use of representative species

Representative species such as lizards and soil invertebrates were selected to signify the different species groups that could potentially contact dust stabilizers in arid regions. These species were of specific interest following discussions with personnel involved in efficacy testing and use of materials. As a result of the broad geographical locations for the use of these products, species not identified in the CM could also potentially contact stabilizers. However, the potential exposure and effects of stabilizers is not likely to be uniform across species. Therefore, hazards to species not identified in this report could be higher or lower than those estimated for species evaluated in this report.

- Their hydrophobicity indicates that they are likely to sorb to soils and sediments and be relatively stable in these environments and therefore unlikely to be transported in water.
- Hydrocarbon-based stabilizers may cause some limited toxicity in sediments as a result of ingestion of sediment particles with sorbed product.
- Data gaps for these stabilizers include degradation information, terrestrial toxicity, and potential for polymer to result in inhalation exposures.

Polysaccharide dust stabilizers

- The main ingredients of Surtac[®] are sugar, starch, and soap and are thus expected to pose little or no environmental hazards.
- No data exist regarding the environmental fate and transport as well as human health and ecotoxicological properties.

General

- The exposure assessment indicated that applicators and the war fighter can potentially come into contact with dust stabilizers. Persons in these groups can most likely contact stabilizers via direct contact with the material or through incidental ingestion of soil, dermal contact, and inhalation of airborne particles.
- Ecological receptors most likely to contact stabilizers are those that are immobile or have limited mobility such as plants and soil invertebrates, respectively. In arid environments, species such as lizards could contact stabilizer-treated soils. In addition, organisms that burrow may be exposed through inhalation of volatile compounds or particles derived from the dust stabilizers. Stabilizers that are water-soluble can be mobilized via surface runoff and reach nearby water bodies where aquatic and benthic receptors can contact these materials. Stabilizers that are insoluble may be transported in runoff water through the transport of product sorbed to soil and sediment particles.
- A comparison between petroleum stabilizers and the nontraditional stabilizers clearly showed the stabilizer products in the current evaluation are much less toxic to aquatic organisms than the petroleum products used historically by the DoD. The acute aquatic LC₅₀ values for unleaded gasoline, diesel fuel, lube oil, Kuwait crude, and Prudhoe Bay crude generally ranged from 1 to 300 mg/L, which are considered to be slightly to moderately toxic. Conversely, the five commercially available

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Appendix A: Soiltac®

Product information and identification

- Manufacturer: Soilworks®, LLC, 681 N. Monterey Street, Gilbert, AZ 85233-8318
- Telephone number: 800-545-5420
- Emergency telephone number: 800-545-5420
- Online information: <http://www.soilworks.com/>

Composition

Soiltac® is composed of vinyl acetate copolymer (50–65 percent), water (50–35 percent), and vinyl acetate monomer (<0.5 percent) (Soilworks 2006b).

Fluoride (0.2 mg/L), acetone (110 mg/L), and vinyl acetate (230 mg/L) were detected in an undiluted sample. Several metals were detected including aluminum (1.2 mg/L), arsenic (0.6 mg/L), barium (0.4 mg/L), boron (0.48 mg/L), chromium (0.6 mg/L), copper (0.9 mg/L), iron (0.9 mg/L), manganese (1.2 mg/L), and zinc (1.8 mg/L). As reported, it was unclear if these were qualified data or represent method detection limits. However, it can be assumed these are detected compounds. No other metals were detected above 0.02 mg/L. No volatile organics, organochlorine pesticides, polychlorinated biphenyls, chlorinated herbicides, carbamate pesticides, organophosphate pesticides, phenol, or cyanide were detected (Soilworks 2006c).

Acetic acid butyl ester (390 ppm), propanoic acid butyl ester (510 ppm), and vinyl acetate (375 ppm) were presented in the specified amounts. Chemical analysis was conducted by ERDC (2006) using purge-and-trap GC/MS.

Physical and chemical information

- Mixture
- Color: white, transparent when cured
- Odor: mild
- pH: 4.0-6.0
- Vapor pressure: 18.65 mmHg at 21 °C

- Boiling point: > 100 °C
- Solubility in water: completely soluble
- Physical state: mobile liquid
- Specific gravity: 1.04 – 1.10 (Soilworks 2006b).

Environmental fate and transport

- Incompatibility: mineral acids and alkalis
- Stability: stable at ambient temperatures, coagulation may occur following freezing, thawing, or boiling
- Hazardous polymerization: will not occur (Soilworks 2006b).

No other information is available.

Human health and toxicological data

No known health hazards are reported on MSDS (Soilworks 2006b).

Ecotoxicological data

Aquatic

Fathead minnow (*Pimephales promelas*) had LC₅₀ values of 1,208 mg/L of undiluted product in a 96-hr acute toxicity test. Rainbow trout (*Oncorhynchus mykiss*) had LC₅₀ values of >1,000 mg/L of undiluted product in a 96-hr acute toxicity test. Water fleas, *Daphnia magna* and *Ceriodaphnia dubia*, had LC₅₀ values of 608 and 154 mg/L, respectively, in 48-hr acute toxicity tests. Green algae (*Raphidocelus subcapitata*) had LC₅₀ values of >1,000 mg/L of undiluted product in a 96-hr acute toxicity test (Soilworks 2006c).

Terrestrial

No plant or terrestrial data are available.

Application and usage recommendations

Application

Recommendations for application include pre-wetting the site with water at a rate of 100 ft²/gal. Various rates are recommended for helipads, runways, roadways, and general dust control (Table 1). Material should be diluted with water ranging from 1:4 to 1:35 (product:water). The

manufacturer recommends applying the diluted product using spray nozzles in multiple coats and allowing the material to dry for 24 hours prior to area use.

Personal protection

- Eye protection: chemical safety glasses
- Hand protection: rubber or plastic gloves – the breakthrough time of the gloves must be greater than the intended use period
- Protective clothing: no specific recommendations
- Ventilation: maintain air concentrations in workspaces in accord with exposure standards on ingredients (Soilworks 2006b).

Application and usage recommendations

Application rates

Various rates are recommended for helipads, runways, roadways, and general dust control (Table 1). Material should be diluted with water ranging from 1:4 to 1:12 (product:water). The manufacturer recommends applying the diluted product using spray nozzles and allowing the material to dry for 12 to 24 hours prior to area use.

Personal protection

- **Respiratory protection:** A respiratory protection program meeting OSHA and American National Standards Institute (ANSI) standards must be followed. If airborne concentrations are up to 10 times the exposure limit, a half-mask air purifying respirator equipped with ammonia/methylamine cartridges and N95 filters should be used. Local exhaust ventilation with a minimum capture velocity of 100 ft/min at the point of vapor evolution should also be used.
- **Eye protection:** Safety glasses with side shields must be used. Eye protection worn must be compatible with respiratory protection system.
- **Hand protection:** Gloves other than chemically resistant materials may not provide adequate protection (neoprene).

Appendix E: Durasoil®

Product information and identification

- Manufacturer: Soilworks®, LLC, 681 N. Monterey Street, Gilbert, AZ 85233-8318
- Telephone number: 800-545-5420
- Emergency telephone number: 800-545-5420
- Online information: www.soilworks.com

Composition

Durasoil® is composed of severely hydrotreated, branched alkanes and alkylated saturated ring compounds (Soilworks 2004a).

Chemical analysis by ERDC (2006) using gas chromatography with flame ionization detection revealed a carbon range from C22 thru C30.

No pesticides were detected from a range of 0.01 mg/L to 10 mg/L (detection limit). No metals were detected from a range of 0.5 µg/L to 0.5 mg/L. No volatiles detected from a range of 1 to 75 mg/L. Total extractable organics were not detected due to elevated reporting limits (1,000 mg/L) (Soilworks 2006a).

Physical and chemical information

- Color: clear
- Odor: odorless
- pH: N/A not an aqueous solution
- Vapor pressure: < 1 mmHg
- Boiling point: > 260 °C
- Solubility in water: insoluble
- Physical state: viscous liquid
- Specific gravity: 0.845-865
- Pour point: -5 °C
- Flashpoint: > 149 °C (Soilworks 2004a).

Environmental fate and transport

- Stability: stable
- Incompatibility: may react with strong organic oxidizing agents
- Hazardous decomposition: carbon monoxide, carbon dioxide, and other oxides that may be generated as products of combustion
- Hazardous polymerization: will not occur (Soilworks 2004a).

No other information is available.

Human health and toxicological data

No toxicological data are available (Soilworks 2006a).

Ecotoxicological data

Aquatic toxicity

No effects on survival were observed in 4-day old rainbow trout (*Oncorhynchus mykiss*), juvenile fathead minnow (*Pimephales promela*), and 1- to 5-day old mysid shrimp (*Americamysis bahia*) exposed to up to 10,000 mg/L Durasoil® in a 96-hr toxicity test (BES 2005a).

No effects on survival were observed in (unknown age) fathead minnow (*Pimephales promela*) exposed up to 750 mg/L Durasoil® in a 96-hr toxicity test (BES 2005b).

Significant mortality in the water flea (*Daphnia magna*) was observed at concentrations as low as 1 mg/L in a 96-hr toxicity bioassay (BES 2005c).

Chronic toxicity (survival and growth) was not observed in a 7-day toxicity test using larval fathead minnow (*Pimephales promela*) at concentrations up to 10,000 mg/L. Chronic toxicity (algal growth) was not observed in a 96-hr toxicity test using green algae (*Selenastrum capricornutum*) at concentrations up to 10,000 mg/L. Significant toxicity (survival and reproduction) of *Daphnia magna* was observed. The LC₅₀ value was 9.18 mg/L (no variance reported). The IC₅₀ value for reproduction was 9.07 mg/L (no variance reported) (BES 2005d).

Sediment toxicity was assessed using a 10-day *Hyalella azteca* amphipod bioassay. Briefly, Durasoil® was applied to soil at different rates (1 gal/50 ft², 1 gal/35 ft², and 1 gal/20 ft²), the soil wetted, and toxicity test

conducted. This is a conservative estimate because it is assumed that the coated soil is washed into the water body. Using this approach, significant mortality in amphipods was observed at 1 gal/35 ft² and 1 gal/20 ft² (BES 2005e).

Terrestrial toxicity

No effect on the earthworm (*Eisenia fetida*) was observed following 14-day exposures to Durasoil[®] at 1 gal/50 ft², 1 gal/35 ft², and 1 gal/20 ft² treatments (BES 2005f).

Application and usage recommendations

Application rates

Various rates are recommended for helipads, runways, roadways, and general dust control (Table 1). Material should not be diluted.

Personal protection

- **Eye protection:** Eye protection is not required under conditions of normal use. If material is handled such that it could be splashed into eyes, wear splash-proof safety goggles.
- **Hand protection:** No skin protection is required for single, short duration exposures. For prolonged or repeated exposures, use impervious synthetic rubber (boots, gloves, aprons, etc.) over parts of the body subject to exposure (Nitrile recommended).
- **Protective clothing:** Launder soiled clothes.
- **Ventilation:** This is not required under normal conditions in a well-ventilated workspace. An organic vapor respirator NIOSH approved for organic vapors is recommended under emergency conditions (Soilworks 2004a).

Appendix F: Surtac®

Product information and identification

- Manufacturer: Soilworks®, LLC, 681 N. Monterey Street, Gilbert, AZ 85233-8318
- Telephone number: 800-545-5420
- Emergency telephone number: 800-545-5420
- Online information: www.soilworks.com

Composition

Surtac® is composed of a mixture of polyols and partially hydrogenated heterocyclics, water (32-35 percent), and other proprietary ingredients (Soilworks 2004b).

Chemical analysis by ERDC (2006) using gas chromatography mass spectrometry revealed no quantifiable peaks.

Physical and chemical information

- Color: pale yellow
- Odor: sweet
- pH: 5.5-7.0
- Vapor pressure: no data
- Boiling point: 105 °C
- Melting point: 170 °C
- Solubility in water: soluble
- Physical state: viscous liquid emulsion
- Specific gravity: 1.37 (Soilworks 2004b).

Environmental fate and transport

- Stability: stable
- Incompatibility: may react with strong organic oxidizing agents
- Hazardous decomposition: carbon monoxide, carbon dioxide, and other oxides that may be generated as products of combustion
- Hazardous polymerization: will not occur (Soilworks 2004_).

No other information is available.

Human health and toxicological data

Dermal

Prolonged or repeated exposure and contact with skin may cause irritation.

Carcinogenicity

None of the components present in this material at concentrations equal to or greater than 0.1 percent are listed by IARC, National Toxicology Program, OSHA, or ACGIH as a carcinogen.

Ingestion

Ingestion may destabilize people with diabetes (Soilworks 2004b).

Ecotoxicological data

No ecotoxicological data are available.

Application and usage recommendations

Application rates

Limited information is available for application rates and methods. However, application rates (Table 1) were provided by the manufacturer for application to helipads for dust control.

Personal protection

- Eye protection: Eye protection is not required under normal use.
- Hand protection: No skin protection is required for single, short duration exposures. For prolonged or repeated exposures, use impervious synthetic rubber (boots, gloves, aprons, etc.) over parts of the body subject to exposure (Nitrile recommended).
- Protective clothing: Launder soiled clothes.
- Ventilation: This is not required under normal conditions in a well-ventilated workspace (Soilworks 200b4).

