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Final Report: Evaluation of the Potential Toxicity of Dust Palliatives Used in Alaska

U.S. EPA Region 10 Air and Radiation Division Tribal Air Program
and
U.S. EPA Office of Research and Development
Center for Environmental Measurement & Modeling
Watershed & Ecosystem Characterization Division
Multimedia Methods Branch

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Final Report: Evaluation of the Potential Toxicity of Dust Palliatives Used in Alaska

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Table of Contents

Report Figures and Tables

1. Introduction

Eastern Research Groups, Inc. (ERG), a contractor to the U.S. Environmental Protection Agency (EPA), helped EPA evaluate the potential toxicity of dust palliatives used in Alaska. This is a follow-on task to a research effort that ERG assisted the Agency conduct in 2015 (see EPA, 2016 for more information). This current effort in 2019 involved a three-pronged approach, which included (1) performing a targeted literature review to obtain relevant information published since the 2015 literature review effort related to this topic, (2) evaluating literature review findings to identify three palliatives for a computational evaluation, and (3) conducting a computational evaluation to assess the potential toxicity of the three selected palliatives.

1. The main focus of the literature review was to fill toxicity data and information gaps for 17 different palliatives used in Alaska. The targeted literature review involved contacting subject matter experts and palliative manufacturers, as well as researching published literature to find the following information on palliatives: chemical make-up, relevant toxicity values, newer regulations or advisories, and frequency of use in Alaska.
2. EPA conducted a detailed evaluation of information collected during the literature review process to identify 3 of the 17 palliatives to investigate in the next step: the computational evaluation.
3. The computational evaluation of potential palliative toxicity focused on the three palliatives identified by EPA. This part of the project involved a six-step process that aimed to put the limited available palliative toxicity data into perspective for potential human exposures by comparing predicted mammalian toxicity of the palliatives to common household products and established toxicity scales.

This report provides details on activities performed during the targeted literature review, the selection of three palliatives for the toxicity evaluation, and the computational evaluation; summarized findings from each component of the effort; and identified data gaps/research needs. This information is organized into five main sections: “Background,” “Targeted Literature Review,” “Selection of Three Palliatives for the Computational Evaluation of Toxicity,” “Computational Evaluation of Potential Palliative Toxicity,” and “References.”

2. Background

Unpaved road surfaces are commonplace in Alaska, where more than 50 percent of state-owned roads and the majority of local and private roads are unpaved (UAF/AUTC, 2013). Various sources can cause releases of fugitive dust, such as vehicles (e.g., all-terrain vehicles [ATVs]) traveling on unpaved road surfaces (e.g., dirt roads, gravel roads, unpaved runways), and wind blowing across these surfaces and gravel pits (ADEC and EPA, 2018). Much of the fugitive dust in Alaska comprises particulate matter that is less than 10 microns in size (PM_{10}), which can lead to adverse health effects in some exposed individuals (Withycombe and Dulla, 2006). Fugitive dust has other potential negative impacts, such as impairing driver safety by reducing visibility and requiring costly and frequent road and runway maintenance (UAF/AUTC, 2013).

Dust palliatives are products used worldwide to suppress fugitive dust. For several decades in the state of Alaska, tribal, state, urban, and rural city governments have been applying palliatives to control and suppress dust on unpaved road surfaces. Palliative use dates back to the 1960s with the application of salt-based palliatives, such as calcium chloride and magnesium chloride (Connor, 2015). Due to availability, effectiveness, and cost, common palliatives used in Alaska include water, salt-based palliatives, synthetic fluids, and polymers (Milne, 2015).

EPA (2016) documents all of the different types of palliatives used in Alaska as reported by the State of Alaska Department of Transportation & Public Facilities (Alaska DOT&PF), locations in the state where application is generally known to occur, and typical application methods (see Section 4.1 in EPA, 2016 for more information). In 2015, ERG assisted EPA by performing an extensive literature review to investigate dust palliatives used on road surfaces in the state of Alaska, the fate and transport of these palliatives in the environment, the documented effects to human health and the environment, and the applicable regulations associated with palliative use in Alaska. The findings of that report are documented in EPA, 2016. The purpose of this report is to summarize the follow-on effort performed in 2019.

2.1. Overview of Issues

The use of palliatives in the state of Alaska has raised various concerns, including the potential impacts on traditional subsistence resources, possible effects on the environment, and unknown human health risks from exposure.

Several rural communities have expressed concerns about palliatives through Alaska Department of Environmental Conservation (ADEC) Rural Alaska Road Dust Surveys, which have been conducted periodically since 2007. Using findings from these surveys, ADEC concluded that out of 142 participating communities, 90% reported that dust is a problem in their communities. Approximately one-third (about 47) of the communities surveyed reported at least some use of dust suppressants. In addition, over half of the responding communities (>71) were willing to try chemical-based dust palliatives, but they expressed various concerns such as about their potential toxicity, effects on human health, impacts on the environment, and possible effects on subsistence resources (ADEC and EPA, 2018).

Many data gaps and research needs were acknowledged during the last effort (EPA, 2016), such as no documentation about specific impacts to humans or subsistence foods exposed to palliatives. While this previous research did not locate documented information on possible impacts to subsistence resources, subject matter experts referenced anecdotal information from local residents concerned about salt-based palliative components. For instance, residents were concerned about calcium chloride negatively affecting the taste of subsistence berries and fish (Connor, 2015b) and chloride salts without moisture breaking down into dust, becoming airborne, and then landing on berries and fish left outside to dry (Hickman, 2015a).

Based on data gaps identified during the previous effort, EPA initiated this follow-on task in 2019, seeking to determine the potential toxicity of palliatives commonly used in Alaska, which is of great concern to the Alaska Native population.

2.2. Research Goal of Project

This follow-on project, similar to the previous 2015 effort, was created in direct response to questions received from a number of Alaskan tribes and communities about the safety of dust suppressant products. The overarching goal is to evaluate existing knowledge and data gaps on the potential toxicity of palliatives used in Alaska as they relate to possible exposures among the Alaska Native population. Evidence compiled for this project is intended to assist EPA in communicating the relative toxicity of palliatives used in the state, particularly in the context of impacts on subsistence resources and the potential risk to Alaska Natives. To achieve this overarching project goal, the data compilation process focused on addressing the individual objectives stated in Section 2.3

2.3. Project Objectives

The defined objectives of this project include the following:

- Conduct a targeted literature search to obtain relevant documentation published since the completion of the 2015 report and help populate toxicity data/information gaps for the 17 palliatives included in EPA's initial Excel table.
- Use data collected for the targeted literature search to identify three of some of the most common palliatives used in Alaska for the computational evaluation.
- Perform a computational evaluation of the potential toxicity and impacts on human health and the environment associated with the three palliatives selected by EPA.

2.4. Research Questions

The overarching question EPA sought to answer was: What is the relative toxicity of some of the most commonly used palliatives in Alaska? This project seeks to address the following specific questions:

- What is the relative toxicity of palliatives for potentially exposed humans?
- What are the potential health risks from exposure to palliatives?
- Are existing regulations and advisories for all categories of palliatives adequate to protect Alaska Native communities from harmful exposures?
- Are existing regulations and advisories adequate to protect the environment (particularly subsistence resources) and people exposed to these compounds daily?

3. Targeted Literature Review

This section will detail the approach, findings, and data gaps/research needs for the targeted literature review conducted for this project.

3.1. Approach

The primary purpose of the targeted literature review was to obtain information on the chemical make-up, relevant toxicity values (fish, mammal, plant, invertebrate), and frequency of use for the 17 palliatives identified in the previous project (EPA, 2016) and presented in Table 1. In addition, any documentation was sought related to newer regulations or advisories applicable to palliative use and exposure initiated since the 2015 literature search. This initial toxicity information was used to help inform EPA's selection of the three palliatives to focus on in the computational evaluation of toxicity (Section 5).

Table 1. Palliatives Used in Alaska and Included in the 2015 Literature Review: Product Names, Manufacturers, Types, and Chemical Compositions

Product Name	Manufacturer	Type	Chemical Composition / CASRN
Alastac	Apun, LLC	Organic nonpetroleum-based (tall oil)	• Lignosulfonate (CASRN 8062-15-5) (no percentage provided)
AlastaSeal	Apun, LLC	Organic nonpetroleum-based (tall oil)	• Water (34.5-64.5%) • Proprietary pitch/rosin blend (30-60%, CASRN 8016-81-7) • Additives (5.5%)
DirtGlue	GeoCHEM	Polymer	• Water (<52%) • Aqueous acrylate polymer (>45%, non-hazardous) • Additive (<3%, proprietary) • Aqueous ammonia (<1%)
Dowflake	Occidental Chemical Corporation	Salt-based	• Calcium chloride (83-87%, CASRN 10043-52-4) • Water (8-14%) • Potassium chloride (2-3%, CASRN 7447-40-7) • Sodium chloride (1-2%, CASRN 7647-14-5)
Durasoil	Soilworks	Synthetic liquid	• Non-petroleum synthetic alkane fluid • A complex mixture of synthetic linear, branched and cyclic alkanes; "proprietary" component • % composition is a trade secret
Dustaway	Soilworks	Liquid	•No hazardous ingredients at or above 1% •No applicable CASRN(s)
Dust-Off	Cargill	Salt-based	• Water (63-70%) • Magnesium chloride (29-33%, CASRN 7786-30-3) • Magnesium sulfate (1-3.8%, CASRN 7487-88-9) • Proprietary corrosion inhibitor (0.02%)
Earth Armour	Midwest Industrial Supply	Petroleum-based / synthetic liquid	• Severely hydrotreated paraffinic liquids (100% proprietary mixture)
EK-35	Midwest Industrial Supply	Synthetic liquid	• Tall-oil pitch (<60%, CASRN 8016-81-7) • Severely hydrotreated, high viscosity, synthetic isoalkane (>10%, CASRN 72623-86-0) • Alkyl polyamines (<4%, proprietary CASRN)

Table 1. Palliatives Used in Alaska and Included in the 2015 Literature Review: Product Names, Manufacturers, Types, and Chemical Compositions

Product Name	Manufacturer	Type	Chemical Composition / CASRN
EnviroKleen	Midwest Industrial Supply	Synthetic liquid	• Polyolefin (<60%, CASRN 9003-27-4) • Severely hydrotreated, high viscosity, synthetic isoalkane (>10%, CASRN 72623-86-0)
Freedom Binder 400	Freedom Industries	Organic nonpetroleum-based (tall oil)	• Water (30-60%) • Tall-oil pitch (30-60%, CASRN 8016-81-7) • Surfactant blend (1-10%, proprietary CASRN)
Liquidow	Occidental Chemical Corporation	Salt-based	• Water (53-72%) • Calcium chloride (28-42%, CASRN 10043-52-4) • Potassium chloride (<3%, CASRN 7447-40-7) • Sodium chloride (<2%, CASRN 7647-14-5)
LSP-400	3M	Polymer	• Water (44-54%) • Olefin acrylate polymer (33-39%, proprietary CASRN) • Ammonium alkyl sulfate (2-6%, proprietary CASRN) • Ethyl lactate (1-5%, proprietary CASRN) • Alkyl ester (1-5%, proprietary CASRN) • Sodium alkyl ether sulfate (1-2%, proprietary CASRN)
Permazyme (11X)	Pacific Enzymes	Enzyme	• Proprietary blend of enzymes
Soil Sement	Midwest Industrial Supply	Polymer	• Water (50-95%) • Acrylic and vinyl acetate polymer (5-50%, non-hazardous)
Soiltac	Soilworks	Polymer	• Copolymer of vinyl acetate, ethylene and vinyl ester with mineral fillers and protective colloid liquid product • Synthetic vinyl copolymer dispersion (55%, non-hazardous) • Water (45%)
Top Seal	Soils Control International	Enzyme	• Copolymers, vinyl acrylic, water, and proprietary formulations • Vinyl acetate (<0.1%, CASRN 108-05-4)

Data collection involved the following overall steps:

1. Searching for and compiling relevant publicly available resources (e.g., published literature) documented between 2015 and 2019 that pertain to the palliatives of interest.
2. Reviewing summaries for data sources obtained during the previous effort to identify supplemental content for the palliatives of interest in this task.
3. Contacting subject matter experts and palliative manufacturers to seek palliative-specific information not located via publicly available sources.

The following subsections describe specific information-gathering activities, which mirrored the overall process followed in 2015 for continuity. Figure 1 highlights each step in the process.

3.1.1. *Primary Documentation Search*

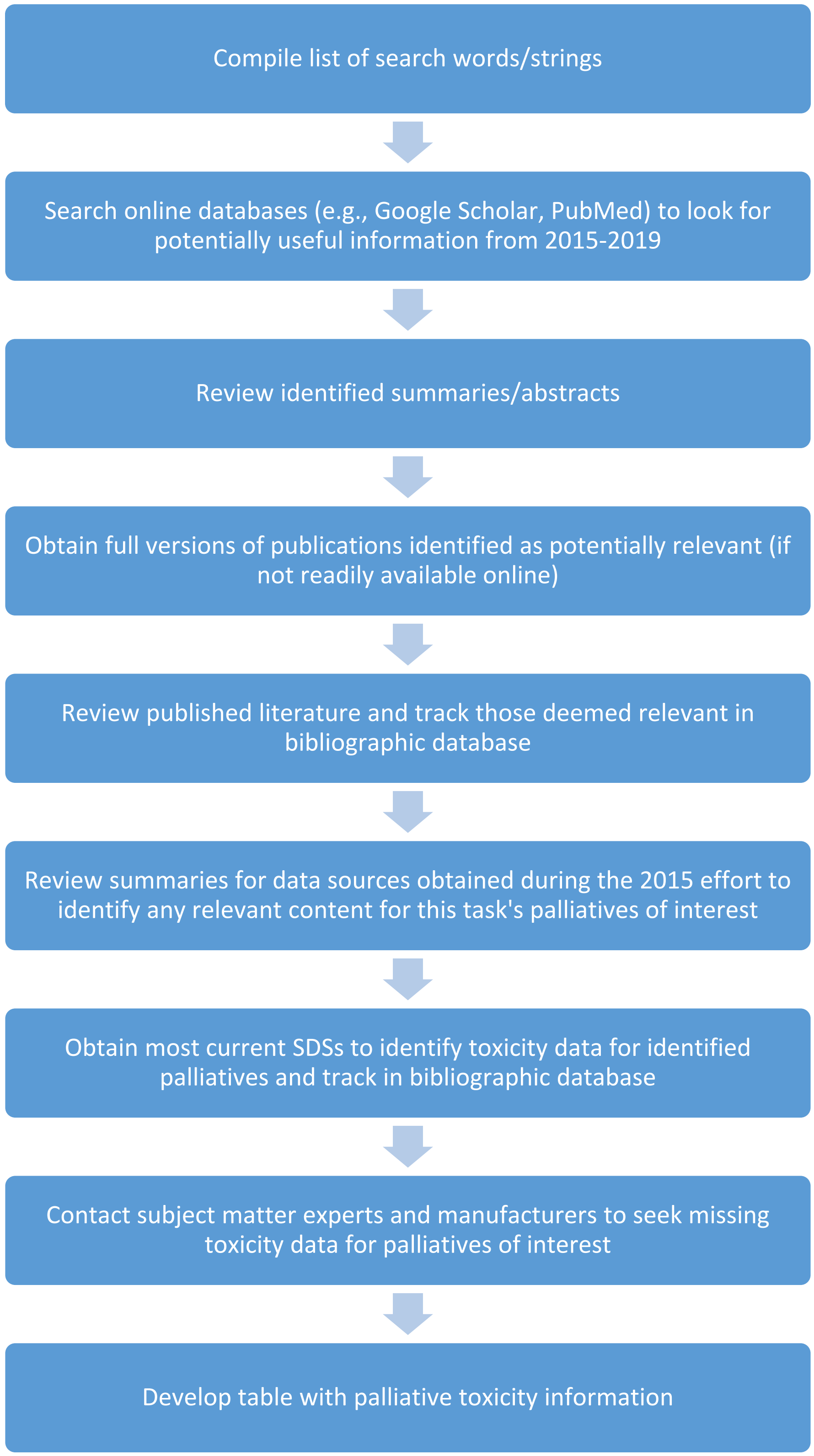
ERG gathered palliative-specific information from various online sources. This process involved searching publicly available databases and websites using a similar assemblage of relevant keywords and search strings developed during the previous effort, but with some refinements based on the targeted nature of this particular follow-on literature search (e.g., documentation published from 2015-present, searching on specific palliatives already known to be used in Alaska). The following search tools were used:

- Google Scholar (https://scholar.google.com/).
- Scientific search engines including the U.S. National Library of Medicine's PubMed (https://www.ncbi.nlm.nih.gov/pubmed), Hazardous Substances Data Bank (HSDB; http://toxnet.nlm.nih.gov/cgi-bin/sis/htmlgen?HSDB) and PubChem (https://pubchem.ncbi.nlm.nih.gov/).,
- State reference sources: Alaska Department of Environmental Conservation (http://dec.alaska.gov/), University of Alaska Fairbanks/Alaska University Transportation Center (http://autc.uaf.edu/publications/), and Alaska Department of Transportation and Public Facilities (http://www.dot.state.ak.us/).
- Google (https://www.google.com).
- Websites for manufacturers of palliatives included in Table 1.

For this effort, the strategy for identifying relevant keywords and keyword search strings focused on the specific palliatives of interest and the desired types of information to collect. The process for each of these is summarized below.

- *General search terms* comprised some combination of the words listed below.
  - Where: Alaska.
  - What: dust palliative, dust suppressant, dust control, dust abatement.
  - Details: fate and transport, toxicity, environmental effect, environmental impact, human health, subsistence, regulation.

Figure 1. Process to Collect and Document Information on Palliatives Used in Alaska



- *Palliative general search terms* consisted of some assemblage of the words listed below.
    - What: dust palliative, dust suppressant.
    - Details: fate and transport, toxicity, environmental effect, environmental impact, human health.
- *Palliative-specific searches* to identify the most current safety data sheets (SDSs) for each product consisted of performing searches on Google and palliative manufacturing websites, using a combination of the words listed below.
    - What: palliative name.
    - Details: manufacturer, safety data sheet, SDS.
- *Palliative-specific searches* for those palliatives from Table 1 with no publicly available information consisted of some assemblage of the words listed below.
    - What: Alastac, AlastaSeal, Dust-Off, Freedom Binder 400, LSP-400.
    - Details: fate and transport, toxicity, environmental effect, exposure, health.
- Additional targeted efforts were conducted. These included searching:
    - Individual terms on Alaska state websites: dust palliative, dust suppressant, dust control, dust abatement, dust suppression, and road dust management.
    - PubChem and TOXNET for each of the 17 palliative names as well as non-proprietary chemical names/CASRNs for palliatives with no available data.
    - Summaries developed for the publications reviewed during the extensive 2015 literature review effort. Any relevant palliative-specific toxicity data was sought for palliatives included in Table 1.

When searching for reference literature, the process involved reviewing abstracts, identifying references most likely to contain relevant information, and obtaining full-text references when possible. Throughout the literature search process, ERG compiled relevant information about each reference in an Excel-based bibliographic database (e.g., author, date, title, URL [if applicable], full citation, and summary notes for the reference).

While some reference materials were available online in their entirety, others were limited to abstracts or brief summaries. To complete the primary literature search, ERG established a tiered approach for reviewing and compiling relevant information, which applied to all documents reviewed under this task order. The process included searching online databases for references potentially relevant to palliatives and project objectives (Step 1), targeting documents that could be useful based on a review of abstracts and other information (Step 2), obtaining and reviewing full references for those deemed relevant (Step 3), summarizing the information contained (Step 4), and flagging whether the references contained information on chemical make-up of palliatives, relative toxicity values, newer regulations or advisories applicable to palliative use and exposure, and any mention of frequency of specific palliative use in Alaska. Toxicity information gleaned from the published literature and the palliative manufacturing SDSs was compiled into a table. Each step of the documentation search process is summarized in Table 2.

Table 2. Steps for Primary Documentation Search Using Online Data Sources

Step	Task
1	Search online data sources (e.g., Google Scholar, PubMed) using keywords and keyword search strings.
2	Review abstracts and summary information for each reference.
	Flag sources of information relevant for project-specific needs.
3	If accessible, obtain and review the full reference, and cite and summarize it in the bibliographic database.
4	Search online data sources to obtain the most current SDS for each palliative.
5	Populate the bibliographic database with SDS reference information.

3.1.2. *Consultation with Palliative Manufacturers and a Subject Matter Expert*

As part of the literature search effort, ERG reached out to manufacturers and a subject matter expert to seek toxicity data for the palliatives with no publicly available toxicity information. No palliative-specific toxicity information was obtained for 5 of the 17 palliatives (Alastac, AlastaSeal, Dust-Off, Freedom Binder 400, and LSP-400) during this process.

3.2. Findings

This section synthesizes the findings of the targeted literature review effort. ERG conducted more than 150 search queries to obtain relevant information published since the 2015 effort. Using our institutional knowledge and subject matter experience, ERG evaluated the results of these queries in online websites, and identified literature considered relevant in the bibliographic database. Using the targeted search terms and short time frame window (2015-2019), ERG cataloged nine new resources relevant to the topics of interest, with eight marked as relevant to the project scope and requiring a full review. Articles deemed relevant were those that provided information directly related to the project objectives, goals, and research questions (e.g., dealt with palliative toxicity, included details on palliative chemical make-up, specifically referenced the palliatives of interest). ERG deemed articles irrelevant if they fell outside of this scope (e.g., referred to palliative performance, summarized information on dust effects). In searching the literature review summary results from the past effort, ERG identified 16 articles relevant to the current project goals, and these were evaluated for relevant toxicity data. Updated SDSs were located for 6 of the 17 palliatives, with the previously obtained SDSs for the remaining palliatives still the most applicable.

As stated, the goal of this targeted search was to identity information in newer references related to toxicity, chemical make-up of palliatives, newer regulations or advisories applicable to palliative use and exposure, and any mention of frequency of specific palliative use in Alaska. Results are presented in the following subsections by these topics.

3.2.1. *Palliative Toxicity*

Of utmost concern to EPA for this project was identifying toxicity values (human and environmental) to support the ability to conduct a computational evaluation of potential toxicity (discussed in Section 5), and thereby enabling the Agency to address the stated concerns of Alaska Natives about the potential harm from exposures to palliatives used in the state. Table 3 summarizes whether toxicity data were found for each of the 17 palliatives, narrowed down by toxicity data for fish, mammals, plants, invertebrates, and other aquatic species.

Table 3. Available Toxicity Data for the Subject Palliatives

Product Name	Available Toxicity Data					References
	Fish	Mammals	Plants	Invertebrates	Other Aquatic Species	
Alastac*	***Yes***	***Yes***	No	No	No	Apun, LLC, 2009
AlastaSeal	No	No	No	No	No	Apun, LLC, 2010
DirtGlue	***Yes***	No	No	***Yes***	No	GeoCHEM, Inc., 2010
Dowflake	***Yes***	***Yes***	***Yes***	***Yes***	No	Occidental Chemical Corporation, 2016a
Durasoil	***Yes***	No	***Yes***	***Yes***	***Yes***	Soilworks, 2019
Dustaway	No	***Yes***	No	No	No	Author unknown, 2017
Dust-Off	No	No	No	No	No	Cargill Salt, 2002
Earth Armour	No	***Yes***	No	No	No	Midwest Industrial Supply, Inc., 2010
EK-35	***Yes***	No	No	***Yes***	No	Midwest Industrial Supply, Inc., 2015a; Midwest Industrial Supply, Inc., 2017
EnviroKleen	***Yes***	***Yes***	No	***Yes***	No	Midwest Industrial Supply, Inc., 2015b; Steevens et al., 2007; TSL, Tri-State Laboratories, 2002
Freedom Binder 400	No	No	No	No	No	Freedom Industries, 2009
Liquidow	***Yes***	***Yes***	***Yes***	***Yes***	No	Occidental Chemical Corporation, 2016b
LSP-400	No	No	No	No	No	3M, 2010
Permazyme (11X)	No	No	No	***Yes***	No	Hobe Associates, 2015
Soil Sement	***Yes***	No	No	***Yes***	No	Midwest Industrial Supply, Inc., 2015c, 2015d
Soiltac	***Yes***	No	***Yes***	***Yes***	***Yes***	Soilworks, 2018a, 2018b
Top Seal	***Yes***	***Yes***	No	***Yes***	***Yes***	Rocky Mountain Remediation Services, LLC, 1996; Soils Control International, Inc., 2006

*Data identified for Alastac were presented on the product's SDS to show the toxicity of various lignosulfonates (the chemical composition of this palliative), but are not necessarily specific to this exact palliative formulation.

Cells populated with a "Yes" are those species for which toxicity data were located for a particular palliative. As noted and shown in the table, aquatic toxicity testing data were available for more of the palliatives than mammalian toxicity data. No toxicity data were found for AlastaSeal, Dust-Off, Freedom Binder, and LSP-400. ERG provided the full compilation of specific toxicity data to EPA as a separate deliverable titled "Bibliographic Database and Toxicity Table."

3.2.2. *Chemical Make-up of Palliatives*

This targeted literature search identified a few publications that mention chemical constituents in particular palliatives (e.g., sodium chloride, calcium chloride), but did not provide chemical make-up information specific to the 17 palliatives included in EPA's investigation. The chemical compositions of the 17 dust palliative products and ingredient CASRNs, when available (i.e., are not proprietary ingredients), were identified from their SDSs (see Table 1).

3.2.3. *Newer Regulations or Advisories Applicable to Palliative Use and Exposure*

One document obtained during the targeted literature search (Jones, 2017) mentions the topic of regulations or advisories related to palliatives. This report evaluated available guidelines in the United States related to selecting, identifying, and applying various dust palliatives. Jones (2017) reported that the U.S. does not have any official specifications related to chemical-based palliatives but identifies that palliative suppliers must adhere to the Federal Highway Administration requirements for chemical treatments on unpaved roads. These requirements are referred to as "Standard Specifications for the Construction of Roads and Bridges on Federal Highway Projects" (FHWA, 2014). Jones (2017) also states that chemical-based products used on unpaved roads cannot exhibit "the characteristic of toxicity", per U.S. EPA's Resource Conservation Recovery Act (RCRA).

3.2.4. *Frequency of Specific Palliative Use in Alaska*

ERG's targeted literature search identified no additional publications that documented frequency of specific palliative use in Alaska beyond what was documented in EPA's 2015 effort (see EPA, 2016 for more information). EPA did locate one report that summarized a pilot project involving the use of EnviroKleen and Durasoil on sections of road in the Native Village of Ruby. The purpose of this pilot project was to measure PM_{10} concentrations in ambient air before and after palliative application (ADEC, 2017).

3.3. Data Gaps/Research Needs

This literature search effort yielded some details related to the targeted topics of interest, but information gaps and research needs remain. The bullets below highlight remaining gaps on the specific topics explored.

- No toxicity data were found for four of the palliatives: AlastaSeal, Dust-Off, Freedom Binder, and LSP-400.
- Limited mammalian toxicity data are available for the subject palliatives.
- The chemical compositions of the dust palliative products and ingredient CASRNs were not available in all cases due to some having proprietary formulations.
- No data were found on direct human health effects associated with exposure to palliatives applied in the environment.
- The possible effects of palliatives on subsistence food sources are not well understood or documented in the published literature.
- No federal, state, or other regulations were identified that pertain to palliative use specifically in Alaska. While there are some rules that can generally apply to the use of palliatives, no new data were identified during this follow-on search related to guidelines or advisories in place that apply to palliative use and exposure.
- The frequency of specific palliative use in Alaska is not well documented in the published literature.

4. Selection of Three Palliatives for the Computational Evaluation of Toxicity

The process for selecting the three palliatives for the computational evaluation involved an examination of the literature search findings and consultations with subject matter experts (see Section 4.1.4). The approach used, and the ultimate palliative selection, are summarized in the sections that follow.

4.1. Approach

To pinpoint the most appropriate three palliatives for inclusion, ERG examined the targeted literature search findings by considering the focused topics summarized in Sections 4.1.1 through 4.1.3 and reaching out to subject matter experts (see Section 4.1.4).

4.1.1. *Products with the Least Available Toxicity Data*

ERG identified the palliative products that had the least toxicity information available from the literature review. The following five products had the least toxicity information available:

- AlastaSeal: The manufacturer of this product, Apun, LLC, indicated it has not sold the product since 2013 or 2014, and had no palliative toxicity data to provide.
- Alastac: Apun, LLC, the manufacturer of this product, has not sold it since 2013 or 2014. Apun, LLC had no palliative-specific-toxicity data to provide. However, toxicity data were located in the palliative's SDS related to palliatives with similar chemical make-up (i.e., lignosulfonate products), but data specific to this exact palliative were not available.
- Dust-Off: Contacts made to the manufacturer, Cargill, yielded no available toxicity information.
- Freedom Binder 400: Freedom Industries, the manufacturer of this discontinued palliative, went out of business in 2014.
- LSP-400: The manufacturer of this palliative, 3M, reported that there is no toxicity data available for this product, as it was not fully commercialized in the U.S.

4.1.2. *Products with the Most Available Toxicity Data*

ERG identified the palliative products that had the most toxicity information available from the literature review. About the same amount of information was found for the following eight palliatives:

- Dowflake
- Durasoil
- EK-35
- EnviroKleen
- Liquidow
- Soil Sement
- Soiltac
- Top Seal

4.1.3. *Frequency of Palliative Use in Alaska*

To further inform the selection of three palliatives for the computational evaluation, EPA sought to hone in on the frequency of use in Alaska for the 17 palliatives known to be used in the state. As noted in Section 3.2.4, ERG found no additional information during the 2019 targeted literature search regarding frequency of use of palliatives in Alaska, but EPA did locate one report that documented the pilot testing of Durasoil and EnviroKleen in a single village (ADEC, 2017). As such, ERG considered information documented in the previous report (EPA, 2016) and ADEC, 2017, which is summarized below.

- Soil Sement®, Soiltac, Permazyme, and TopSeal® have had a very limited number of applications in the state, with testing sometimes representing the only application.

- Calcium chloride has been the main type of product used on roads managed by Alaska DOT&PF; Alaska DOT&PF records show that calcium chloride was applied to more than 800 miles of roads and highways each year from 2005 to 2010.
- The following palliatives were applied to village roads at least once during the 2005 to 2010 time period: EnviroKleen®, Earth Armour™, Soil-Sement®, LSP-400, Alastac, and AlastaSeal.
- The following palliatives were applied to other non-village roads (i.e., roads not specified as village roads in the source document) at least once during the 2005 to 2010 timeframe: EK35®, EnviroKleen®, Durasoil®, Soiltac, Top Seal®, Dustaway, and the now discontinued Freedom Binder 400.
- EnviroKleen and Durasoil were both used on roads in the Native Village of Ruby in 2014.
- Other products have been used in Alaska since 2010, such as the application of EK35® and Durasoil® at airports, but documentation of these uses is not readily available to the public.

These research findings indicate that salt-based products, specifically calcium chloride, are the main type of product used on unpaved roads managed by the Alaska DOT&PF. Toxicity information on contaminants in salt-based palliatives (calcium chloride, magnesium chloride, and sodium chloride) were identified in published reports obtained during the literature search. Of the salt-based palliatives in Table 1, toxicity information is available for Dowflake and Liquidow (main salt-based component: calcium chloride). No data were found specific to Dust-Off (main salt-based component: magnesium chloride).

4.1.4. *Input from Subject Matter Experts*

To further aid in the selection process, EPA contacted two subject matter experts in palliative use in Alaska: Billy Connor and David Barnes with the University of Alaska Fairbanks – Alaska University Transportation Center. EPA shared the information collected during the targeted literature search and proposed three synthetic palliatives to possibly include in the computational evaluation: Durasoil (manufactured by Soilworks), and EK-35 and EnviroKleen (manufactured by Midwest Industrial Supply). The experts:

- Confirmed that these three synthetic palliatives are commonly used in Alaska.
- Indicated there is a lot of data already available on calcium chloride, magnesium chloride, and sodium chloride from a number of documented sources, but less data available on synthetic products such as those proposed.
- Agreed that it would be beneficial to focus the computational evaluation of toxicity on Durasoil, EK-35, and EnviroKleen.

4.2. Findings

Based on this detailed evaluation, EPA ultimately selected three synthetic liquid palliatives to focus on in the computational evaluation of potential toxicity: Durasoil (manufactured by Soilworks), and EK-35 and EnviroKleen (manufactured by Midwest Industrial Supply). EPA selected these palliatives based on the following considerations:

- The previous research effort (EPA, 2016) found that synthetic fluids are some of the most appealing types of palliatives for use in the state because of their product availability, cost, and effectiveness (Barnes and Connor, 2014). In addition, non-salt-based chemical palliatives have gained popularity for several reasons, such as their effectiveness at reducing dust and their relative price efficiency (Milne, 2015).
- They are some of the most commonly used palliatives in the State of Alaska.
- They have available laboratory toxicity testing data.
- Their use and toxicity are not as well documented as commonly used salt-based palliatives.
- The effectiveness of Durasoil and EnviroKleen was previously studied as part of an ADEC dust monitoring study in the Native Village of Ruby and additional information on these products will build a more complete knowledge base.
- Subject matter experts concurred they were appropriate for inclusion.

4.3. Data Gaps

Available information indicates which palliatives were applied to village roads at least once, but the number of times and locations that each type of palliative was used on village roads is still unknown. Using institutional knowledge and input from subject matter experts, EPA was able to identify some of the most commonly used palliatives in Alaska to include in the computational evaluation

5. Computational Evaluation of Potential Palliative Toxicity

This section summarizes the approach, findings for each step of the process, and data gaps/research needs for the computational evaluation of potential palliative toxicity conducted for this project.

5.1. Approach

Evaluating the potential for human toxicity of these palliatives is limited by the lack of information on specific chemical composition. Each palliative is a chemical mixture composed of a proprietary blend of organic compounds. For example:

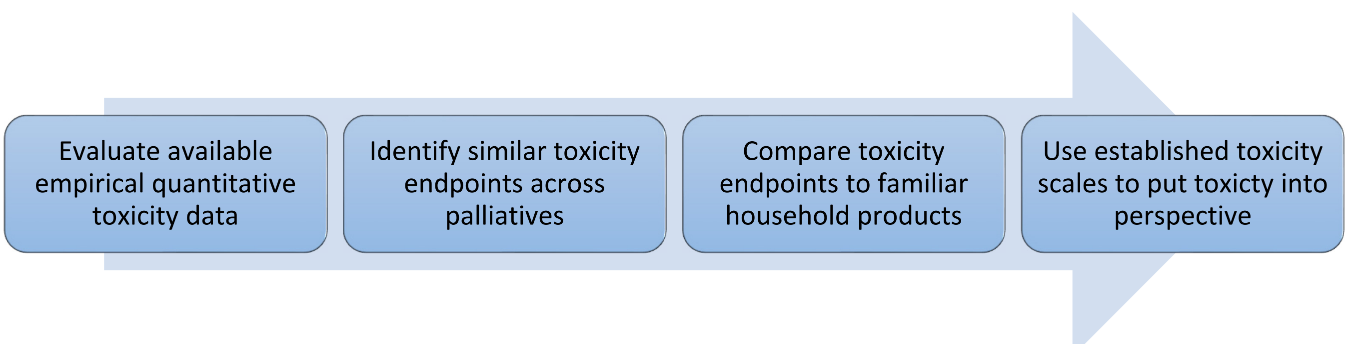
- EnviroKleen is composed of a mixture of <60% polyolefin (CASRN 9003-27-4) and >10% of hydrotreated, high viscosity, synthetic isoalkane (CASRN 72623-86-0).
- EK-35 is a mixture of <60% tall-oil pitch (CASRN 8016-81-7), >10% severely hydrotreated, high viscosity, synthetic isoalkane (CASRN 72623-86-0), and <4% of proprietary alkyl polyamines.
- Durasoil is a proprietary blend of non-petroleum synthetic alkanes. No information is available on the specific constituent compounds.

The toxicity information that is available for these palliatives is based on testing conducted on the whole product, which helped us understand the potential toxicity of each product as it is intended to be used and applied.

Because we do not know the specific chemical constituents and their properties, ERG was unable to use traditional computational toxicological methods such as quantitative structure activity relationship (QSAR) models for this effort, as they rely on input of a specific chemical structure of a compound. However, ERG was able to employ methods that are similar to QSAR-type approaches, which allow us to draw inferences from a wider range of toxicity data. Using this approach, ERG evaluated the relative toxicity of the three subject palliatives while also presenting results in units (doses) that are familiar to a general population.

Figure 2 shows the main objectives at a high level for the computational evaluation of potential toxicity for the three subject palliatives.

Figure 2. Main Objectives for the Computational Evaluation of Potential Toxicity



For the first main objective, ERG collected toxicity data for Durasoil, EK-35, and EnviroKleen using online resources and personal communication with the manufacturers (Midwest Industrial Supply and Soilworks). Additional scientific approaches were used to convert the available aquatic toxicity values (available as fish *LC50s*[1]) for Durasoil, EK-35, and EnviroKleen to mammal toxicity values (oral rat *LD50s*[2]), making them relatable to human exposures.

[1] LC50 = concentration that causes death in 50% of tested organisms within a certain time period
[2] LD50 = dose expected to cause death in 50% of tested organisms within a certain time period

ERG prepared the following step-by-step process to meet the other three main objectives:

1. Compare the ecological toxicity for endpoints consistent across all three palliatives (50% lethal concentrations [LC50s])
2. Compare the ecological toxicity endpoints (LC50s) to familiar household products using LC50s
3. Extrapolate ecological toxicity endpoints (LC50s) to mammalian toxicity endpoints (50% lethal doses [LD50s])
4. Compare the mammalian toxicity endpoints to familiar household products using LD50s
5. Extrapolate mammalian toxicity endpoints (LD50s) to human equivalent doses (HEDs)
6. Present the toxicity of palliatives using established toxicity scales

5.2. Findings

This section provides the findings for each step conducted during the computational evaluation.

5.2.1. *Step 1: Compare Ecological Toxicity Using Available Data*

ERG compiled all available toxicity data for Durasoil, EK-35, and EnviroKleen that were obtained via online resources and personal communication with manufacturers.[3] Based on a review of available information, ERG identified that ecological toxicity tests have been conducted under acute and chronic exposure conditions for all three palliatives as whole products. Table 4 provides all the test results of these studies for two fish species (rainbow trout and fathead minnow), three invertebrates (mysid shrimp, two types of water flea, and earthworms), and bacterium.

Based on the palliative-specific toxicity data shown in Table 4, the most sensitive endpoints varied across palliatives:

- For Durasoil the most sensitive endpoint (the lowest toxicity value) was for 7-day IC25 of growth in mysid shrimp observed at concentrations of >1,000 mg/L. The IC25 is a point estimate of the toxic concentration that would cause a 25% reduction in a non-lethal biological measurement. For this toxicity assessment, 1,000 mg/L was the maximum concentration tested, and so an estimated value of >1,000 mg/L was applied as the IC25. For fish, the most sensitive endpoint was a 96-hour LC50 of >2,000 mg/L for survival of rainbow trout and a 7-day IC25 for growth of >2,000 mg/L for fathead minnow. This does not necessarily mean Durasoil is not potentially toxic, just that the concentration that would elicit changes in growth/reproduction and survival in the tested aquatic species are greater than 1,000 mg/L and 2,000 mg/L, respectively.
- For EK-35, the most sensitive endpoint was for a 7-day lowest observed effect concentration (LOEC) for growth/reproduction in rainbow trout of >10 mg/L. The LOEC for survival was measured as 20 mg/L. The 7-day no observed effect concentration (NOEC) for both growth/reproduction and for survival was estimated to be 10 mg/L. Therefore, together the evidence suggests detrimental effects for growth/reproduction and survival start occurring in rainbow trout exposed to between 10 and 20 mg/L of EK-35.
- For EnviroKleen, LOECs and LC50s were estimated to be ≥1,000 mg/L across species, exposure scenarios, and health endpoints. The corresponding NOECs were all estimated to be 1,000 mg/L. Taken together, this means that no toxicity endpoint was observed at the maximum concentration used across these toxicity assessments. This does not necessarily mean EnviroKleen is not potentially toxic, just that the concentration that would elicit changes in growth/reproduction and survival in the tested aquatic species are greater than 1,000 mg/L.

[3] Data are based on the most current manufacturers' safety data sheets (SDSs), with more specifics on those toxicity values gleaned from the additional references cited, when available. For Durasoil, based on laboratory data collected over time (and provided to ERG by the manufacturer), testing results reported as IC25s and IC50s were assumed to be based on toxicity growth tests.

Table 4. Toxicity of Durasoil, EK-35, and EnviroKleen

Species	Toxicity Measure	Durasoil[a]	EK-35[b,c,d]	EnviroKleen[d,e,f]
Fish				
Rainbow Trout (*Oncorhynchus mykiss*)	96-hour LC50 (survival)	>2,000 mg/L	30 mg/L	>1,000 mg/L
	96-hour NOEC (survival)	-	-	1,000 mg/L
	96-hour LOEC (survival)	-	-	>1,000 mg/L
	7-day LC50 (survival)	-	23 mg/L	>1,000 mg/L
	7-day NOEC (survival)	-	10 mg/L	1,000 mg/L
	7-day LOEC (survival)	-	20 mg/L	>1,000 mg/L
	7-day LC50 (growth/reproduction)	-	> 10 mg/L	>1,000 mg/L
	7-day NOEC (growth/reproduction)	-	10 mg/L	1,000 mg/L
	7-day LOEC (growth/reproduction)	-	> 10 mg/L	>1,000 mg/L
Fathead Minnow (*Pimephales promelas*)	96-hour LC50 (survival)	-	271 mg/L	>1,000 mg/L
	96-hour NOEC (survival)	-	125 mg/L	1,000 mg/L
	96-hour LOEC (survival)	-	250 mg/L	>1,000 mg/L
	7-day LC50 (survival)	>28,000 mg/L	97.3 mg/L	>1,000 mg/L
	7-day NOEC (survival)	-	31.3 mg/L	1,000 mg/L
	7-day LOEC (survival)	-	62.5 mg/L	>1,000 mg/L
	7-day LC50 (growth/reproduction)	-	114 mg/L	>1,000 mg/L
	7-day NOEC (growth/reproduction)	-	31.3 mg/L	1,000 mg/L
	7-day LOEC (growth/reproduction)	-	62.5 mg/L	>1,000 mg/L
	7-day IC25 (growth)	>2,000 mg/L	-	-
	7-day IC50 (growth)	>39,000 mg/L	-	-
Invertebrates				
Mysid Shrimp (*Americamysis bahia*)	96-hr LC50 (survival)	-	111 mg/L	>1,000 mg/L
	96-hr NOEC (survival)	-	63 mg/L	1,000 mg/L
	96-hr LOEC (survival)	-	130 mg/L	>1,000 mg/L
	7-day LC50 (survival)	>2,000 mg/L	58.6 mg/L	>1,000 mg/L
	7-day NOEC (survival)	-	25 mg/L	1,000 mg/L
	7-day LOEC (survival)	-	50 mg/L	>1,000 mg/L
	7-day LC50 (growth/reproduction)	-	>50 mg/L	>1,000 mg/L
	7-day NOEC (growth/reproduction)	-	50 mg/L	1,000 mg/L
	7-day LOEC (growth/reproduction)	-	>50 mg/L	>1,000 mg/L
	7-day IC25 (growth)	>1,000 mg/L	-	-
Water Flea (*Daphnia magna*)	48-hour LC50 (survival)	18,000 mg/L	-	-
Water Flea (*Ceriodaphnia dubia*)	48-hr LC50 (survival)	-	>1,000 mg/L	>1,000 mg/L
	48-hr NOEC (survival)	-	1,000 mg/L	1,000 mg/L
	48-hr LOEC (survival)	-	>1,000 mg/L	>1,000 mg/L
	7-day LC50 (survival)	-	>1,000 mg/L	>1,000 mg/L
	7-day NOEC (survival)	-	500 mg/L	1,000 mg/L
	7-day LOEC (survival)	-	1,000 mg/L	>1,000 mg/L

Table 4. Toxicity of Durasoil, EK-35, and EnviroKleen

Species	Toxicity Measure	Durasoil[a]	EK-35[b,c,d]	EnviroKleen[d,e,f]
Water Flea (*Ceriodaphnia dubia*) [continued]	7-day LC50 (growth/reproduction)	-	375 mg/L	>1,000 mg/L
	7-day NOEC (growth/reproduction)	-	250 mg/L	1,000 mg/L
	7-day LOEC (growth/reproduction)	-	500 mg/L	>1,000 mg/L
Earthworm (*Eisenia andrei*)	14-day LC50 (survival)	>670,000 mg/L	-	-
Other				
Bacterium (*Aliivibrio fischeri*)	15-minute IC50 (growth)	>500,000 mg/L	-	-

Notes:
"-" indicates no data are available
IC25 = Point estimate of toxic concentration that would cause a 25% reduction in non-lethal biological measurement
IC50 = Point estimate of toxic concentration that would cause a 50% reduction in non-lethal biological measurement
LC50 = Lethal Concentration, 50%
LOEC = Lowest Observable Effects Concentration
mg/L = milligrams per liter
NOEC = No Observable Effects Concentration
References:
[a] Soilworks. 2019. Durasoil safety data sheet. Revised April 2, 2019. https://www.soilworks.com/media/115319/sds1501001-durasoil-safety-data-sheet-en-.pdf.
[b] Midwest Industrial Supply, Inc. 2015. EK35 Series safety data sheet. Revised May 21, 2015. http://midwestind.com/wp-content/uploads/MW_EK35_Series_SDS.pdf.
[c] Midwest Industrial Supply, Inc. 2017. Environmental data for EK35 synthetic organic dust control. http://midwestind.com/wp-content/uploads/MW_EK35-Environmental-Data.pdf.
[d] ABC Laboratories, Inc. 2003. Study title: 7-day survival and growth tests of dust suppression products EK-35 and EnviroKleen to the rainbow trout, *oncorhynchus mykiss*, determined under static removal conditions. Provided by Cheryl Detloff, Midwest Chemist.
[e] Midwest Industrial Supply, Inc. 2015. EnviroKleen safety data sheet. Revised May 22, 2015. http://midwestind.com/wp-content/uploads/MW_EnviroKleen_SDS.pdf.
[f] ABC Laboratories. 2002. EnviroKleen environmental data, acute and chronic aquatic toxicity. Provided by Cheryl Detloff, Midwest Chemist.

ERG evaluated all the available toxicity data and identified toxicity endpoints that were consistently measured across the three palliatives for the same given species and duration of exposure (shown in Table 5). These endpoints include the 96-hour LC50 for rainbow trout, 7-day LC50 for the fathead minnow, and 7-day LC50 for the mysid shrimp. An examination of the toxicity data for these specific endpoints indicates that EK-35 is more toxic than Durasoil and EnviroKleen because it consistently has the lowest toxicity value. Of the three common toxicity endpoints, the most sensitive is the 96-hour LC50 for rainbow trout, which indicates that 50% of trout died when exposed to EK-35 at a concentration of 30 mg/L for 96 hours. For EnviroKleen and Durasoil, the 96-hour LC50s for survival were not observed at the maximum concentrations tested and were therefore estimated to be >2,000 mg/L and >1,000 mg/L, respectively. This rainbow trout acute toxicity endpoint, as well as the other two chronic toxicity endpoints (7-day LC50 for fathead minnow and 7-day LC50 for mysid shrimp), suggest that EK-35 has the potential to be more toxic than both Durasoil and EnviroKleen.

Table 5. Common Toxicity Measures for Durasoil, EK-35, and EnviroKleen

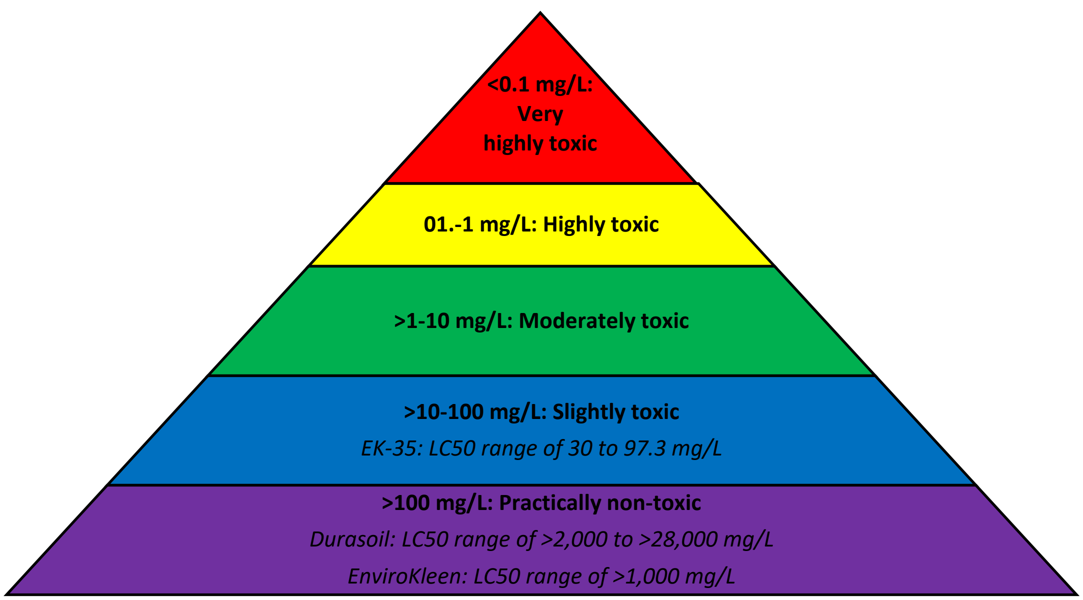
Toxicity Endpoint	Durasoil[a]	EK-35[b]	EnviroKleen[c]
96-hour LC50 (survival) for rainbow trout (*Oncorhynchus mykiss*)	>2,000 mg/L	30 mg/L	>1,000 mg/L
7-day LC50 (survival) for fathead minnow (*Pimephales promelas*)	>28,000 mg/L	97.3 mg/L	>1,000 mg/L
7-day LC50 (survival) for mysid shrimp (*Americamysis bahia*)	>2,000 mg/L	58.6 mg/L	>1,000 mg/L

References:
[a] Soilworks. 2019. Durasoil safety data sheet. Revised April 2, 2019. https://www.soilworks.com/media/115319/sds1501001-durasoil-safety-data-sheet-en-.pdf.
[b] Midwest Industrial Supply, Inc. 2015. EK35 Series safety data sheet. Revised May 21, 2015. http://midwestind.com/wp-content/uploads/MW_EK35_Series_SDS.pdf.
[c] Midwest Industrial Supply, Inc. 2015. EnviroKleen safety data sheet. Revised May 22, 2015. http://midwestind.com/wp-content/uploads/MW_EnviroKleen_Series_SDS.pdf.

There is no clear way to distinguish between the toxicity of Durasoil and EnviroKleen given these data, as LC50s were not observed for both palliatives at the maximum concentrations tested. However, the toxicity tests for Durasoil used a maximum concentration that was greater than the toxicity tests for EnviroKleen, providing evidence to suggest that Durasoil likely has the lower toxicity of the two.

To provide added perspective, Figure 3 compares the toxicity values presented in Table 5 to EPA's ecotoxicity scale for aquatic organisms (EPA, 2017). Based on this toxicity scale for the three common toxicity measures across the subject palliatives, the aquatic toxicity results presented for Durasoil and EnviroKleen for 96-hour LC50s for rainbow trout, 7-day LC50s for fathead minnow, and 7-day LC50s for mysid shrimp all are at least a factor of 10 greater than 100, indicating they are practically non-toxic to aquatic organisms. The LC50s for EK-35 for these three endpoints ranged from 30 mg/L to 97.3 mg/L, falling within EPA's slightly toxic range for aquatic toxicity. These toxicity levels mean that Durasoil, EK-35, and EnviroKleen are unlikely to adversely affect the survival of fish in the environment where they would most likely be present at much lower concentrations.

Figure 3. Comparison of Palliative Ecotoxicity to EPA's Ecotoxicity Scale for Aquatic Organisms



5.2.2. *Step 2: Compare Ecological Toxicity of Palliatives (LC50s) to Familiar Household Products*

ERG collected information from manufacturers' SDSs on the ecological toxicity of an array of common household products. The 96-hour LC50s for rainbow trout survival for the three palliatives were then compared to common household products to help put the relative toxicity information into context for a broader audience. Of note, while data for the palliatives were based on whole products, the household data were based on the primary active ingredient of each product. ERG conducted a sweep to locate available toxicity data for a plethora of commonly used household products. Aquatic toxicity data were identified to enable comparisons between products and one endpoint across all three palliatives: 96-hour LC50s for rainbow trout survival. The products included air freshener & deodorizer, bar soap, hand & body lotion, hand sanitizer, no-rinse body wash, and salt. The LC50s for these products are displayed in Table 6.

Table 6. LC50 Rainbow Trout Toxicity of Household Items

Common Household Product	Active Ingredient (percent in product, if known)	96-hour LC50 Rainbow Trout *(Oncorhynchus mykiss)* (mg/L)
Air Freshener & Deodorizer	Acetone, 60-80%	4,740-6,330
Bar Soap	Glycerin, 1-10%	50
Hand & Body Lotion	Glycerol, proprietary percentage	67,500
Hand Sanitizer	Ethanol, 50-75%	42
No-rinse Body Wash	Propylene glycol, proprietary percentage	40,613
Salt	Sodium chloride, 98.5-99.5%	2,800

*Information was obtained from product SDSs.
LC50s presented in the SDSs in the unit of mL/L were converted to mg/L.

Based on this endpoint comparison, EK-35 has a lower LC50 (30 mg/L) and is therefore more toxic than all of the household products listed in Table 6. The evaluative data show that Durasoil and EnviroKleen are less toxic than hand sanitizer and bar soap. However, a judgement cannot be made on the relative toxicity of Durasoil and EnviroKleen compared to the remaining household products because LC50s were not observed at the maximum concentrations tested in these palliative aquatic toxicity assessments (2,000 mg/L and 1,000 mg/L, respectively).

5.2.3. *Step 3: Extrapolate Ecological Toxicity Data (LC50s) to Mammalian Toxicity (LD50s)*

The available toxicity data for each palliative (shown in Table 4) are primarily from studies conducted with fish or invertebrates. No mammalian toxicity data, such as 50% lethal doses (LD50s), were available for the palliatives as whole products. However, methods have been developed to relate LC50s in non-mammalian species to LD50s in mammals (Delistraty et al., 1998; Hodson, 1985; Janardan et al., 1984; Kaiser and Esterby, 1991; Zolotarev et al., 2017). These methods involve developing regression models from a large collection of paired observations of LC50s, for example in fish, and LD50s in rats from toxicity studies on a wide range of chemicals. Table 7 presents a summary of regression models published in the scientific literature that were developed to relate LC50s in rainbow trout to rat LD50s.

Table 7. Regressions for Fish LC50s and Rat LD50s

Reference	Test Chemicals	N[a]	Y Variable[b]	X Variable[b]	Slope	Intercept	r[c]
Janardan et al. 1984	Priority Pollutants	24	Rat LD50 (mmol/kg)	Fathead Minnow LC50 (µmol/L)	0.35	-0.161	0.63
Janardan et al. 1984	Priority pollutants and pesticides combined	64	Male Rat LD50 (mmol/kg)	Fathead Minnow LC50 (µmol/L)	0.33	-0.34	0.58
Janardan et al. 1984	Priority pollutants and pesticides combined	64	Female Rat LD50 (mmol/kg)	Fathead Minnow LC50 (µmol/L)	0.36	-0.259	0.67
Janardan et al. 1984	Chlorinated pesticides	12	Male Rat LD50 (mmol/kg)	Fathead Minnow LC50 (µmol/L)	0.59	0.192	0.999
Janardan et al. 1984	Chlorinated pesticides	12	Female Rat LD50 (mmol/kg)	Fathead Minnow LC50 (µmol/L)	0.28	0.38	0.999
Hodson 1985	Phenols, benzenes, anilines, solvents, misc.	15	Rat LD50 (mmol/kg)	Trout LC50 (mmol/L)	0.7086	1.6553	0.62
Kaiser and Esterby 1991	Variety of chemical lasses	91	Rat LD50 (mmol/kg)	Fathead Minnow LC50 (mmol/L)	0.36	-1.16	0.583
Delistraty et al. 1998	Pesticides and non-pesticides	213	Trout LC50 (mmol/L)	Rat LD50 (mmol/kg)	0.722	-2.16	0.512

[a] The number of chemicals used in developing the regression model
[b] LD50s and LC50s were logged for regression analyses
[c] Correlation coefficient
mmol/kg = millimoles per kilogram
µmol/L = micromoles per liter

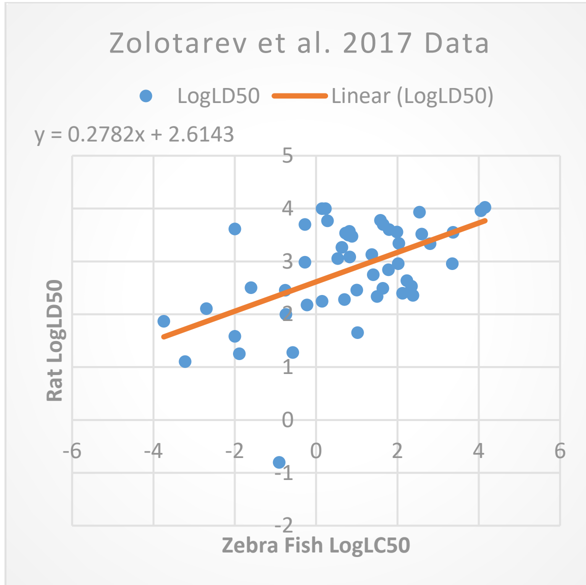
The regression models in Table 7 were based on data from individual chemicals with known properties, and the models are often improved by including these properties as covariates. For example, a compound's octanol-water partition coefficient (lgP or logKow) has been established as an important covariate in predicting a mammalian LD50 from a fish LC50. This is because the partition coefficient is a measure of hydrophobicity, and very hydrophobic compounds tend to accumulate in fish to a much greater degree than in mammals.

An additional limitation of the regression models presented in Table 7 is that they were fit to data in molar units. Because toxicological effects occur at the molecular level, molar units are most appropriate when comparing toxicities of different compounds. However, without knowing the constituent composition of each palliative, ERG did not know the molecular weight of each compound within each palliative, which meant we are unable to use the regression equations from Table 7 directly. Instead, we used a similar approach and developed a regression model based on the units of the available toxicity data, mg/L (as opposed to molar units).

ERG developed two regression models that predict mammalian toxicity (LD50s) using the available LC50 fish toxicity data from Table 5 for the three subject dust palliatives. The two regression models were based on data sets from two studies that included paired fish LC50s and rat LD50s. The steps for developing these models were as follows:

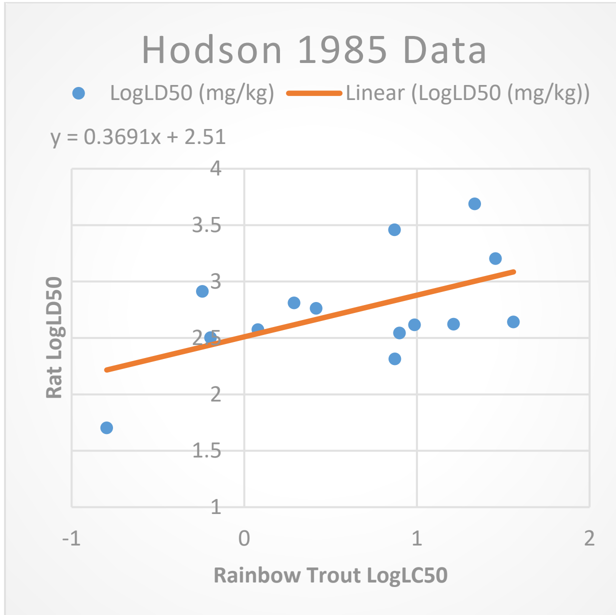
- Zolotarev et al. (2017) present paired zebra fish LC50s and rat LD50s for 50 compounds in units of mg/L and mg/kg, respectively. These data were log transformed and ERG ran a regression on the data in Excel using Excel's Data Analysis Toolpak. The regression model was significant ($p = 0.000096$), though the model has limited explanatory power (correlation coefficient, $r = 0.52$). Results are shown in Figure 4. The regression equation from this model fit is: LogLD50 = 0.278*LogLC50 + 2.614.

Figure 4. Regression Based on Data from Zolotarev et al. (2017)



- Hodson (1985) presents paired rainbow trout LC50s and rat LD50s for 14 compounds in units of mmol/L and mmol/kg. ERG looked up molar densities for each of these chemicals and used these values to convert from molar units into mg/L and mg/kg. These data were log transformed and a regression was run on the data in Excel using Excel's Data Analysis Toolpak. The regression model was significant ($p = 0.045$), though the model has limited explanatory power ($r = 0.54$). Results are shown in Figure 5. The regression equation from this model fit is: LogLD50 = 0.369*LogLC50 + 2.51.

Figure 5. Regression Based on Data from Hodson (1985)



The fact that these two models were significant demonstrates that there is an association between fish LC50s and rat LD50s. This allowed ERG to extrapolate from the limited toxicity data available for each palliative. Keeping in mind that the correlation from these models was not large, we could still form a first order approximation. Therefore, the regression equations from each model were used to extrapolate LD50s for the two fish endpoints (96-hour survival LC50s for rainbow trout and 7-day survival LC50s for fathead minnow) from Table 8. Of note, the shrimp toxicity values were not used to predict LD50s because the two data sets used in developing the regression models were based on fish toxicity data.

Table 8 shows the predicted rat LD50s that result from applying these models to the toxicity data for the three palliatives.

Table 8. Predicted Rat LD50s in mg/kg for the Three Palliatives

Model	Toxicity Endpoint	Durasoil[a]	EK-35[b]	EnviroKleen[c]
Model based on Zolotarev et al. 2017 data	Rat LD50 (extrapolated from 96-hour LC50 for rainbow trout)	>3,409	1,060	>2,811
	Rat LD50 (extrapolated from 7-day LC50 for fathead minnow)	>7,104	1,470	>2,811
Model based on Hodson 1985 data	Rat LD50 (extrapolated from 96-hour LC50 for rainbow trout)	>5,351	1,136	>4,143
	Rat LD50 (extrapolated from 7-day LC50 for fathead minnow)	>14,173	1,753	>4,143

The two models produced surprisingly similar results. This can be seen when comparing the regression equations above, or by looking at the range of predicted LD50 values for EnviroKleen, which had the same LC50 inputs for both rainbow trout and fathead minnow of >1,000 mg/kg. The two models produced predicted LD50s that ranged from >2,811 to >4,143 mg/kg, a factor difference of approximately 1.5. Still, the predicted mammalian toxicity values in Table 8 vary depending on which regression model and LC50 input were used. The variation seen in predicted LD50s is greatest for Durasoil, primarily because the input values for this palliative had the greatest range (from >2,000 mg/kg for the 96-hour LC50 for rainbow trout to >28,000 mg/kg for the 7-day LC50 for fathead minnow). The predicted LD50 values for EK-35 had the smallest range from 1,060 mg/kg to 1,753 mg/kg.

Because the Hodson model was developed from rainbow trout toxicity data, an argument can be made that this is the more appropriate model to use when extrapolating from a rainbow trout LC50. The Zolotarev et al. (2017) model was based on zebra fish data but was developed from a much larger number of chemicals and conducted more recently. Neither model used fathead minnow data, however.

While no mammalian toxicity data were available for the palliatives as whole products, for the EnviroKleen palliative only, ERG was able to obtain LD50 toxicity on its two chemical constituents. Those data are presented here to offer additional perspective. LD50s were available for two different raw materials that make up EnviroKleen: polyolefin and a synthetic isoalkane. The synthetic fluid had a rat oral LD50 >5,000 mg/kg, and polyolefin (polyisobutylene) had a rat oral LD50 >5,000 mg/kg. Thus, while the available LD50s are not representative of mammalian toxicity on the full palliative composition, these two materials make up 100% of EnviroKleen at proprietary proportions and therefore are good indicators of the potential toxicity of the palliative. The LD50 values here are consistent with the predicted values presented in Table 8.

5.2.4. *Step 4: Compare Mammalian Toxicity Data (LD50s) to Common Household Products*

In the previous Step 2, ERG compared 96-hour LC50s in rainbow trout between the three subject palliatives and a variety of common household products. In Step 4, ERG compared the predicted oral rat LD50s for the three palliatives to oral rat LD50s for the same products as in Step 2, as well as a few additional common household products for which only LD50s were available (see Table 9). While Step 2 involved comparing LC50s for the palliatives to common household products, this LD50 comparison was performed because an LD50 dose is an easier to understand toxicity metric for humans than an LC50, which is an aquatic toxicity concentration. The findings of this comparison are presented below:

- EK-35: Aspirin (1,500 mg/kg) and bug spray (1,747 mg/kg) fall within the predicted LD50 range for EK-35 (1,060 mg/kg to 1,753 mg/kg), but EK-35 is more toxic than the other household products except for laundry detergent.
- Durasoil: Components of air freshener & deodorizer, baby foaming shampoo & wash, bar soap, hand and body lotion, and hand sanitizer all fall within the lower bounds of Durasoil's predicted toxicity range (>3,409 mg/kg to >14,173 mg/kg). Aspirin (1,500 mg/kg), bug spray (1,747 mg/kg), and laundry detergent (333 mg/kg) are more toxic than Durasoil.
- EnviroKleen: LD50s for aspirin, bug spray, and laundry detergent fall below the lower bounds of EnviroKleen's predicted toxicity range (>2,811 mg/kg to >4,143 mg/kg), meaning EnviroKleen's predicted toxicity is lower than these products.

It is worth noting that Durasoil and EnviroKleen are more difficult to assess because the extrapolated LD50s are based on their LC50s, for which ERG only knew that their toxicity was above a certain tested maximum concentration. However, as summarized above, we can more confidently speak to the household product LD50s that fall within the predicted LD50 ranges for the palliatives and to those below those ranges.

Table 9. Oral Rat LD50 Toxicity of Household Items

Common Household Product	Active Ingredient	Oral LD50 Rat (mg/kg)
Air Freshener & Deodorizer	Acetone, 60-80%	5,800
Antiperspirant/Deodorant Spray	Propylene glycol, 3-7%	20,000
Aspirin	Acetylsalicylic acid, 100%	1,500
Baby Foaming Shampoo & Wash	Mixture of ingredients	>5,000
Bar Soap	Glycerin, 1-10%	12,600
Bug Spray (mixture of ingredients)	Mixture of ingredients	1,747
Hand & Body Lotion	Glycerol, proprietary percentage	12,600
Hand Sanitizer	Ethanol, 50-75%	7,060
Liquid Laundry Detergent	Caustic potash, 45%	333
No-rinse Body Wash	Propylene glycol, proprietary percentage	20,000
Salt	Sodium chloride, 98.5-99.5%	>3,000

5.2.5. *Step 5: Extrapolate Mammalian Toxicity (LD50s) to HEDs*

The toxicity of each substance can further be interpreted by converting the extrapolated mammalian doses (LD50s) into human equivalent doses (HEDs) based on allometric equations, which relate body weight and surface area between species. This method is commonly used in risk assessments, for example in deriving oral reference doses, and allows for an easier to understand metric of toxicity in terms of human exposure (EPA, 2010).

The EPA-recommended equation for calculating an HED is: Laboratory animal exposure (mg/kg) x DAF = HED (mg/kg), where DAF is the Dosimetric Adjustment Factor, a factor that relates the body weight of the test animal to that of the human. For rats, the recommended DAF is 0.24. To account for interspecies variability, an uncertainty factor of 3 is also applied. Table 10 shows the calculated HEDs derived from the predicted LD50s.

Table 10. Human Equivalent Doses in mg/kg

Model	Toxicity Endpoint	Durasoil	EK-35	EnviroKleen
Model based on Zolotarev et al. 2017 data	Rat LD50 (extrapolated from 96-hour LC50 for rainbow trout)	>273	85	>225
	Rat LD50 (extrapolated from 7-day LC50 for fathead minnow)	>568	118	>225
Model based on Hodson 1985 data	Rat LD50 (extrapolated from 96-hour LC50 for rainbow trout)	>428	91	>331
	Rat LD50 (extrapolated from 7-day LC50 for fathead minnow)	>1,134	140	>331

5.2.6. *Step 6: Present the Toxicity of Palliatives Using Established Toxicity Scales*

To better understand the toxicity of the predicted LD50s for humans, ERG compared the estimated range of predicted palliative LD50s (Durasoil: >3,409 to >14,173 mg/kg, EK-35: 1,060 to 1,753 mg/kg, and EnviroKleen: >2,811 to >4,143 mg/kg) to the established Hodge and Sterner (1943) toxicity scale (see

Figure 6 and Table 11). This scale rates toxicity from extremely toxic to relatively harmless using a total of four levels in between (for a total of six). Based on that scale, EK-35 is classified as slightly toxic, corresponding to a probable lethal dose in humans of ingesting approximately a pint. While precise estimates of LD50 for Durasoil and EnviroKleen are not available, at their most toxic estimate (the lowest predicted LD50), EnviroKleen would also be classified as slightly toxic, whereas Durasoil would be either classified as slightly toxic or practically non-toxic depending on which model estimate was used. A practically non-toxic classification would correspond to a probable lethal dose in humans of ingesting a quart. The actual toxicity of Durasoil and EnviroKleen, however, is not truly known and predictions are limited by the available toxicity data.

Table 11. Toxicity Classes of Predicted Palliative LD50s, Using the Hodge and Sterner Scale

Toxicity Rating	Commonly Used Term	Oral Rat LD50 Scale Range in mg/kg	Predicted LD50s in mg/kg (from Table 8)			Probable Lethal Dose in Humans
			Durasoil*	EK-35	EnviroKleen*	
1	Extremely Toxic	1 or less				1 grain (a taste, a drop)
2	Highly Toxic	1-50				4 mL (1 tsp)
3	Moderately Toxic	50-500				30 mL (1 fl. oz.)
4	Slightly Toxic	500-5,000	>3,409 to >14,173	1,060 to 1,753	>2,811 to >4,143	600 mL (1 pint)
5	Practically Non-toxic	5,000-15,000				1 liter (or 1 quart)
6	Relatively Harmless	15,000 or more				1 liter (or 1 quart)

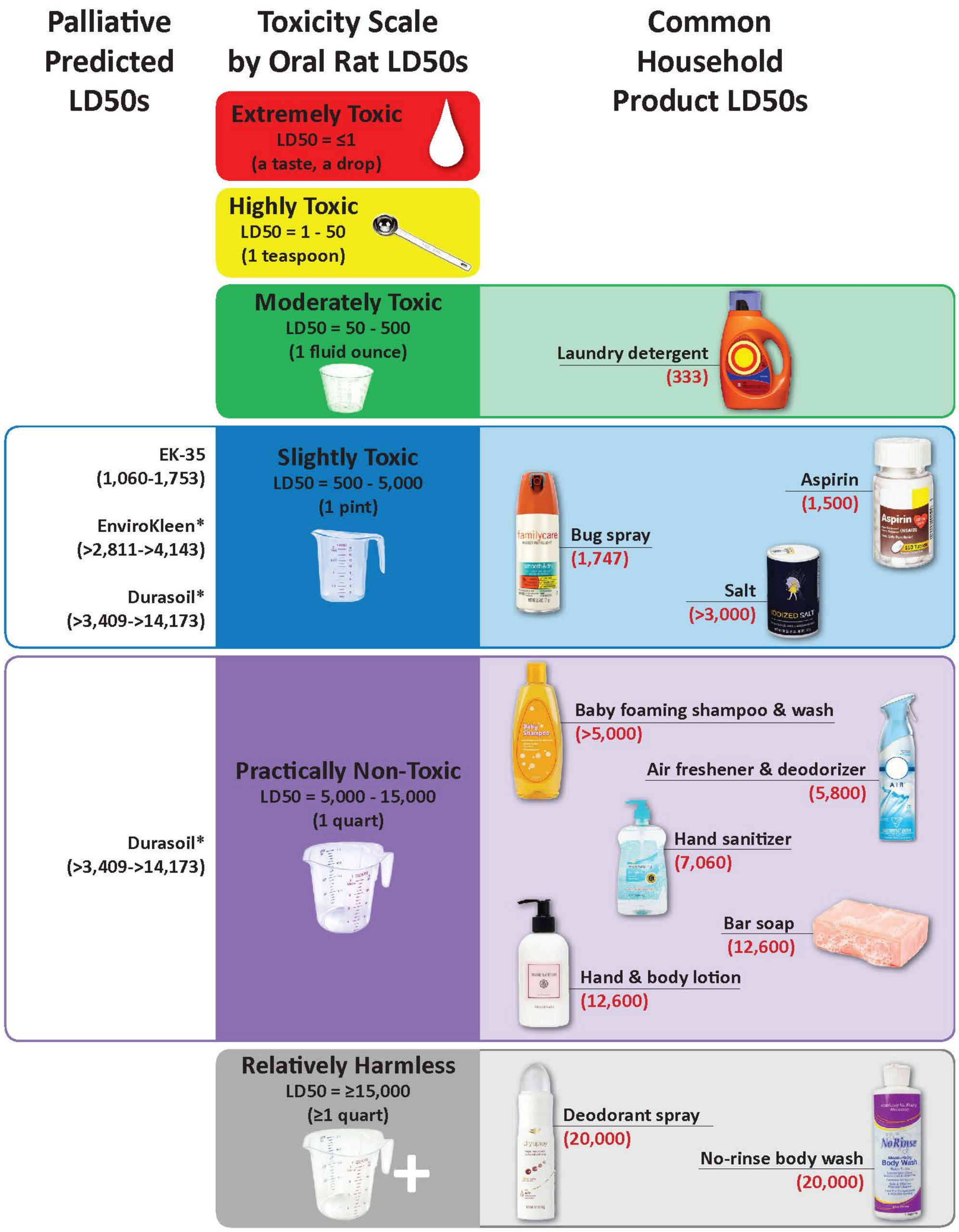
*Toxicity values for Durasoil and EnviroKleen represent lower bounds and could be larger (less toxic) than the values reported here.

The Hodge and Sterner scale is referenced in various sources, such as https://www.ccohs.ca/oshanswers/chemicals/ld50.html.

5.2.7. *Computational Evaluation Conclusions*

The approach described herein allowed ERG to put the limited available aquatic toxicity data for three subject palliatives into perspective in terms of relative toxicity and human exposure. Based on our extrapolations, these three palliatives fall into the "slightly toxic" to "practically non-toxic" categories for human exposure using an established toxicity scale. Using this established toxicity scale, it is estimated that there is a 50% chance of death for humans who consumed 1 pint (slightly toxic) to 1 quart (practically non-toxic) of pure palliative product. In the environment, they are greatly diluted. It is unlikely that subsistence foods near roads would be a conduit for ingesting this much of the palliative product. For example, the LC50s for fish would not be of concern to Alaska Native people because even if palliatives were to runoff into nearby water bodies, they would be greatly diluted.

Figure 6. Hodge and Sterner Toxicity Scale: LD50s (in mg/kg) for Palliatives and Household Products



All numerical values are LD50s in units of milligrams per kilogram (mg/kg).
*Toxicity values for Durasoil and EnviroKleen represent lower bounds and could be larger (less toxic) than the values reported here. The extrapolated LD50s are based on their LC50s, for which it is only known that their toxicity is above a certain tested maximum concentration, which is why ">" symbols are applied to the ranges. Durasoil falls into two categories, based on its wide range of predicted LD50s.

The Hodge and Sterner scale is referenced in various sources, such as https://www.ccohs.ca/oshanswers/chemicals/ld50.html.

Overall, EK-35 was found to be the most toxic of the three palliatives. Because LC50s were not observed at the maximum concentrations tested for Durasoil and EnviroKleen, ERG cannot definitively say which of the two palliatives is more toxic. However, based on the maximum concentrations tested during toxicity assessments, there is evidence to suggest that Durasoil likely has a lower toxicity than EnviroKleen. To give an idea of how comparatively toxic the palliatives are, the established Hodge and Sterner Toxicity Scale was used to compare the predicted palliative LD50s to LD50s for household products.(Figure 6). Specifically,

- This comparison to household products revealed that EK-35 was more toxic than the active ingredients of most household products evaluated. The most toxic estimate for EK-35 fell in the same toxicity range as aspirin and bug spray, but was more toxic than other household products examined (e.g., bar soap) except for laundry detergent.
- Durasoil was in the same toxicity range of products like baby foaming shampoo and wash, bar soap, and hand sanitizer, and was less toxic than aspirin, bug spray, and laundry detergent.
- EnviroKleen's predicted toxicity was lower than aspirin, bug spray, and laundry detergent, and within the same toxicity range as salt.

This comparative analysis between the estimated toxicity of these three palliatives and common household products shows that Durasoil and EnviroKleen in their pure, undiluted form are not more toxic than many commonly used household items.

5.3. Data Gaps/Research Needs

As with all scientific approaches of this nature, there are some limitations that need to be acknowledged with the computational evaluation of potential toxicity. The identified limitations include the following:

- The specific chemical composition of each dust palliative is proprietary, which prevented the ability to conduct chemical-specific analyses.
- Computational approaches such as QSAR rely on understanding the chemical structure of a compound to better understand its behavior given structurally-similar compounds. Though these data were unavailable, ERG was able to employ computational methods to evaluate relative toxicity.
- Mammalian toxicity data were not available for the three subject dust palliatives as whole products.
- Based on available data, specific adverse human or ecotoxic effects associated with these palliatives are unknown.
- There are inherent uncertainties in any type of extrapolation approach, such as that used here to extrapolate LC50 aquatic concentrations to LD50 mammalian doses. For example, a model is only as good as the test dataset. That is, extrapolating information for chemicals that are very different than the compounds used to develop the model would not be appropriate. However, the two different models used in the approach above led to similar results, which provides evidence for their predictions.
- Toxicity endpoints for two of the palliatives (Durasoil and EnviroKleen) were reported as being greater than the maximum concentration tested, so the exact toxicity levels were unknown. Not knowing the actual concentrations for the LC50s limited our ability to conclusively compare these palliatives to many of the household products.
- The regression models were originally developed using data from individual chemicals with known properties. These models are improved by including chemical-specific properties as covariates. For this effort, chemical-specific information to include in the model was not available.
- The regression models reported in the literature were fit to data in molar units. ERG compensated for this limitation by using a similar approach and developing a regression model based on the units of our toxicity data, mg/L (as opposed to molar units).
- Toxicity data presented in the SDSs for household products were often based on the main ingredients, not the whole product as for the palliative toxicity data.
- When comparing LC50s, aquatic data for household products were only located in SDSs for one of the three common endpoints for acute toxicity: 96-hour LC50 in rainbow trout.

To address some of these limitations, additional toxicity data for these palliatives is desired. Specifically, studies should evaluate the toxicity of these palliatives to mammals at endpoints beyond lethality. This additional data would provide for a more direct evaluation of the potential toxicity of these three palliatives to humans. Moreover, having the actual levels at which certain endpoints occur for Durasoil and EnviroKleen would allow for calculating actual estimates of toxicity, rather than needing to use the available upper bound data based on the maximum concentrations tested.

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