Mineral Oil

Livestock

Identification of Petitioned Substance

Chemical Names:
Mineral oil

Other Names:
White mineral oil
Light mineral oil
Heavy mineral oil
Mineral oil, high viscosity
Paraffin oil
Liquid paraffin
Light liquid paraffin
Paraffinum liquidium
Liquid petrolatum
Light liquid petrolatum
Heavy liquid petrolatum
Paraffinum perliquidum
Food-grade mineral oil
Food-grade white oil
P100
P70, P70H
N70, N70H
P15, P15H
N15, N15H

Trade Names:
Drakeol®

CAS Numbers:
64742-47-8
8042-47-5
8012-95-1
8020-83-5
64742-55-8
64742-56-9
64742-65-0
72623-84-8
72623-86-0
72623-87-1
8012-95-1
8042-47-5
92062-35-6

Other Codes:
RTECS No. PY8047000
RTECS No. PY8030000

Summary of Petitioned Use

The U.S. Department of Agriculture (USDA) National Organic Program (NOP) has approved the use of mineral oil as a "synthetic substance allowed for use in organic livestock production for treatment of intestinal compaction, prohibited for use as a dust suppressant" in Title 7 of the Code of Federal Regulations (CFR) Part 205.603. The NOP has also approved the use of mineral oil "for topical use and as a lubricant" in § 205.603.

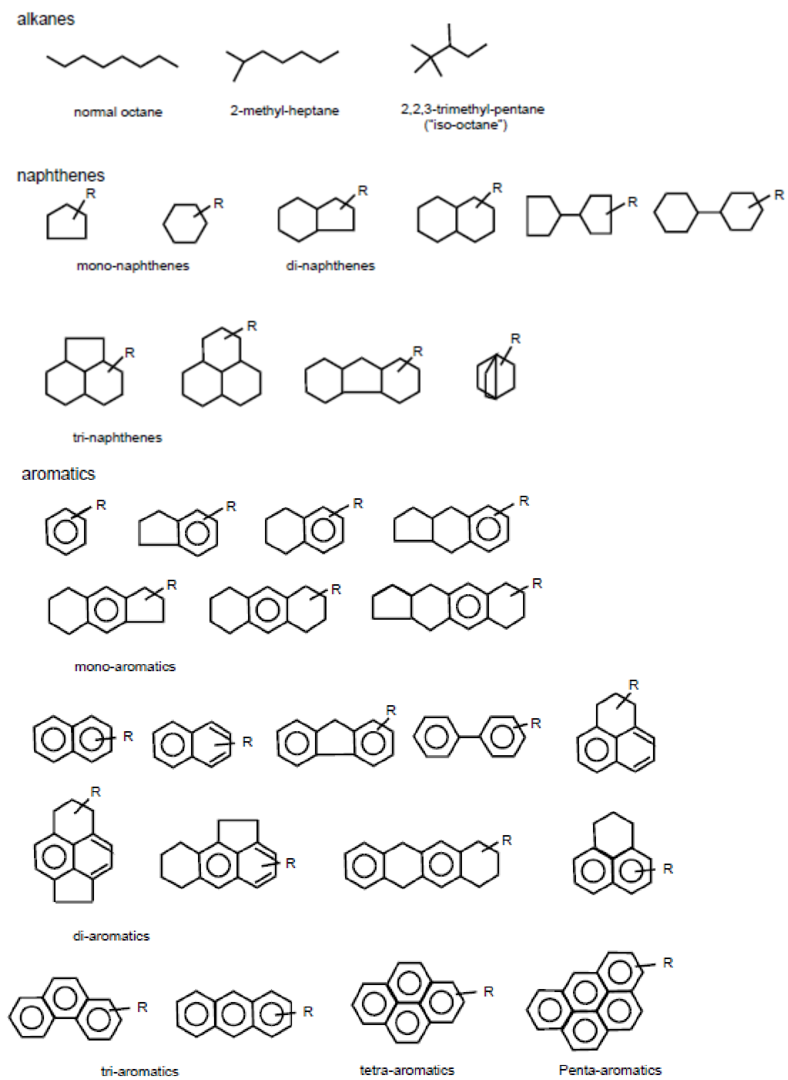
The National Organic Standards Board (NOSB) requested this technical report to update the previous technical reports on mineral oil, with a focus on uses for intestinal compaction in support of the upcoming sunset review for the substance (USDA 2002, USDA 2015). This report will focus on the veterinary applications of mineral oil as a treatment of intestinal compaction within organic livestock production.

Characterization of Petitioned Substance

<u>Composition of the Substance:</u>
Mineral oil is not a single substance but is composed of a mixture of hydrocarbons isolated from crude petroleum oil (EPA 2007, EFSA 2012, IARC 2012). Mineral oil comprises three main types of compounds: saturated paraffins, napthenes, and aromatics (EFSA 2012, IARC 2012). Saturated paraffins (alkanes) are linear and branched hydrocarbons that include only single bonds throughout their chemical structures (EFSA 2012, Timberlake 2016). Saturated napthenes also include only single bonds within their chemical structures but, unlike paraffins, they also include rings (EFSA 2012). Napthenes may include one or multiple rings and may also include alkyl groups (hydrocarbons) extending from these ringed structures (EFSA 2012). Unlike paraffins and napthenes, aromatics are cyclic hydrocarbons that include carbon-carbon double bonds (EFSA 2012, Timberlake

2016). However, aromatic compounds that are present in mineral oils have double bonds that are limited to the aromatic ring portions of the chemical structure (EFSA 2012). Like napthenes, the aromatic compounds found in mineral oil may include multiple aromatic rings and alkyl groups extending from these ringed structures (EFSA 2012). Figure 1 below shows some examples of the three classes of compounds found in mineral oil, with “R” representing one or more alkyl groups (EFSA 2012).

Figure 1. Compound classes within mineral oil



The exact composition of compounds within mineral oil is based on the petroleum source and the refining conditions, as shown by the many CAS numbers that classify mineral oil (EFSA 2012, IARC 2012). Initial crude oils’ compositions are generally classified by their source regions below in Table 1.

Table 1. Compositions of petroleum crude oil by region

Region sourced	Physical appearance	Composition
North Sea	transparent liquid	high concentrations of paraffins and napthenes
Eastern Asia (e.g., China, Indonesia)	solid	high concentrations of paraffins and napthenes
Arabian	dark brown high viscosity liquid	medium concentrations of paraffins and napthenes
Nigerian	dark brown high viscosity liquid	high concentrations of napthenes and aromatics
South American	black solid	high concentrations of napthenes and aromatics

Source: EFSA 2012

While mineral oil formulations vary based on the petroleum crude oil and refining methods used, the mineral oil pertaining to veterinary applications is highly refined and known in the literature as "white mineral oil" (although "mineral oil" is also used interchangeably) (EPA 2009, EFSA 2012, IARC 2012). White mineral oil is used in food and medical applications and undergoes greater refinement to remove aromatic compounds, including polycyclic aromatic hydrocarbons (PAHs) (EPA 2009, EFSA 2012). Since only highly refined mineral oil is used in veterinary applications, the use of mineral oil throughout the remainder of this report refers to highly refined (i.e., white) mineral oil unless otherwise specified. As with less refined products, the exact composition of mineral oil varies, although paraffins are generally a major component and the remaining components are napthenes (IARC 2012).

<u>Source or Origin of the Substance:</u>

Mineral oil is named according to the mineral sources (fossil fuels) from which it derives and is isolated as a product from crude oil. Mineral oil is isolated from crude oil through a variety of refining processes, including atmospheric and vacuum distillation, dewaxing, acid treatment (oleation), and hydro-treatment (EPA 2009, EFSA 2012, IARC 2012). These processes remove heavy metals, oxygen, nitrogen, sulfur organic compounds, aromatic compounds, and other impurities (EFSA 2009, EFSA 2012). Evaluation Question 2 of this report discusses these processes in more detail.

<u>Properties of the Substance:</u>

The properties of mineral oil vary based on its composition, which is determined by the petroleum source and refining methods used (described previously in the "Composition of the Substance" section). General properties of mineral oil—including less refined mineral oils—are displayed below in Table 2.

Table 2. Properties of mineral oil

Property	Mineral oil
CAS Nos.	64742-47-8, 8042-47-5, 8012-95-1, 8020-83-5, 64742-55-8, 64742-56-9, 64742-65-0, 72623-84-8, 72623-86-0, 72623-87-1, 8012-95-1, 8042-47-5
Physical appearance	clear/pale yellow liquid
Odor	odorless, odor of lanolin
Molecular weight	28.2–843.6 g/mol
Number of carbon atoms	C9–C60
Melting point	< 0 °C
Boiling point	150–894 °C
Flash point	168.33 °C
Specific gravity	0.79–0.94 at 15.6 °C
Vapor pressure	<0.1 kPa at 20 °C, <1mmHg at 20 °C
Solubility	insoluble in water, soluble in ethanol and hydrocarbons

Sources: PC 2017a, PC 2017b, SL 2005, EPA 2007, EPA 2009, EFSA 2009, EFSA 2012, Geritrex 2014, APS 2015

Specific Uses of the Substance:

Mineral oil is used in many applications across a variety of industries, including metal work and fabrication, lubricants, pesticides, cosmetics, food processing, and pharmaceuticals (EFSA 2012, IARC 2012). The highly refined mineral oils that are the focus of this report are used as a laxative for both humans and animals (EFSA 2012, MP 2019).

In livestock production, mineral oil is used to treat colic, constipation, ruminal bloat, and impaction or compaction within the digestive tract (White and Dabareiner 1997, Lopes et al. 1999, Costello 2005, El-shafaey 2007, Athar et al. 2011). Mineral oil is used to treat large colon impactions, which are the leading cause of colic (Lopes et al. 1999, Blikslager 2005). When used for large colon impactions, mineral oil is administered in doses from 0.5–1.0 gallon (Blikslager 2005). Laxatives, including mineral oil, can be used in early stage colic treatments in ruminants to remove digestive tract blockages that cause colic. The use of mineral oil or other laxatives are often combined with intravenous saline infusions and analgesics (ACVS, White and Dabareiner 1997).

Mineral oil can also be used as a preventative measure against colic in horses, and it may be added to the abomasum cavity of ruminants to treat rare abomasal impactions (White and Dabareiner 1997, Blikslager 2005, Shafaey 2007, Athar et al. 2011). Mineral oil is used as a lubricant for esophageal tubes to relieve pressure from trapped gas in cases of ruminal bloat (Costello 2005). Mineral oil is also used to treat ileal impactions in horses as an alternative to surgery (Hanson et al. 1996), and it is administered in equine ileal impactions when the combination of IV fluids and analgesics fails to promote a gastral reflex (Hanson et al. 1996). While mineral oil is generally administered orally, it may also be administered rectally or directly through surgical access points during some procedures (El-shafaey 2007, Athar et al. 2011).

Approved Legal Uses of the Substance:

The USDA NOP lists mineral oil as a "synthetic substance allowed for use in organic livestock production, for treatment of intestinal compaction, prohibited for use as a dust suppressant" and "for topical use and as a lubricant" in 7 CFR 205.603.

The United States Food and Drug Administration (FDA) allows mineral oil to be used as a component in animal feeds, provided that it "not exceed 3.0 percent in mineral supplements, nor shall exceed 0.06 percent of the total ration when present in feed or feed concentrates," as stipulated in 21 CFR 573.680. Mineral oil may be used as an animal feed ingredient:

- "to reduce dustiness of feeds or mineral supplements."
- "to serve as a lubricant in the preparation of pellets, cubes, or blocks and to improve resistance to moisture of such pellets, cubes, or blocks."
- "to prevent segregation of trace minerals in mineralized salt."
- "to serve as a diluent carrier in the manufacture of feed grade biuret in accordance with good manufacturing practice."
- "for the removal of water from substances intended as ingredients in animal feed."

The FDA also allows the use of mineral oil in animal drugs, including the following:

- as a component of bambermycins accounting for up to 1.00% (21 CFR 668.95)
- as a component of fenbendazole accounting for up to 1.00% (21 CFR 558.258)
- as a component of lasalocid accounting for up to 1.05% (21 CFR 558.311)

The FDA, as stipulated in 21 CFR 369.20, requires mineral oil laxatives to bear the following warning: "*Caution*—Take only at bedtime. Avoid prolonged use. Do not administer to infants or young children, in pregnancy, or to bedridden or aged patients unless directed by a physician." The FDA allows the use of mineral oil in several over-the-counter medicines for human use, including the following:

- as a skin protectant active ingredient (21 CFR 347.10) (when used in skin protection formulations, the warning "for external use only" must be applied to the label, unless "oral use of the product is also provided," as stipulated in 21 CFR 347.50)
- in either mineral oil or light mineral oil forms in ophthalmic emollients, with the limitation of "up to 50 percent in combination with one or more other emollient agents" (21 CFR 349.14)

- as a protective active ingredient in anorectal drugs (21 CFR 346.14)

The FDA has designated white mineral oil as a substance that "may be safely used in food" in 21 CFR 172.878. The FDA lists many food applications for white mineral oil in § 172.878, including as a "release agent, binder, or lubricant" in many food applications, as a "defoamer," and as a dust control agent in food processing. The FDA allows mineral oil to be used as an ingredient in food-grade biuret with a 0.5% maximum in 21 CFR 573.220.

The FDA allows the use of mineral oil and white mineral oil in several components of food and drug packaging, including in 21 CFR 175.105, § 175.210, § 176.200, CFR 176.210, § 173.340, § 177.1310, and § 177.1620, § 177.2260, § 177.2600, § 177.2800, § 176.170, § 175.230, § 175.300, § 173.340, § 177.1200, and § 178.3740. The FDA allows the use of mineral oil in several applications as an "indirect food additive, adjuvant, production aid, and sanitizer," including in § 178.3570, § 178.3620, § 178.3910, and § 178.3910.

The FDA permits the use of technical white mineral oil "wherever mineral oil is permitted for use as a component of nonfood articles complying with 21 CFR Parts 175.105, 176.200, 176.210, 177.2260, 177.2600, 177.2800, 178.3570 and 178.3910" in 21 CFR 178.3570.

The United States Environmental Protection Agency (EPA) lists mineral oil and white mineral oil as an "inert ingredient[s] permitted in minimum risk pesticide products" for "pesticides of a character not requiring FIFRA regulation" in 40 CFR 152.25.

The United States Animal and Plant Health Inspection Service allows the use of mineral oil as a lubricant "that is applied to the limbs of a horse sorely for protective and lubricating purposes while the horse is being shown or exhibited at a horse show, horse exhibition, horse sale or horse auction" in 9 CFR 11.1.

Action of the Substance:

The organic livestock applications of mineral oil are due to its laxative properties. The laxative nature of mineral oil is due to its low absorption and bioavailability, causing it to remain within the digestive tract until excretion, usually in feces (EPA 2009, EFSA 2009, EFSA 2012). Since mineral oil is poorly absorbed and metabolized, it lines the walls of the digestive tract and acts as a lubricant, which is its primary mode of action (Flomenbaum et al. 2002, Blikslager 2005, EPA 2009, Athar et al. 2011, HMHW 2014). The lubricating nature of mineral oil is used to treat blockages within the digestive tract, ranging from fecal matter, to undigested roughage and feeds, to foreign objects (Blikslager 2005, El-shafaey 2007, Athar et al. 2011). The poor water solubility of mineral oil also acts as a barrier for water movement, which prevents the loss of water from fecal matter, preventing stools from hardening. Mineral oil has been reported to further soften fecal matter in the colon prior to excretion (El-shafaey 2007).

Combinations of the Substance:

When mineral oil is used as a laxative for the treatment of constipation and digestive blockages, it is generally administered alone and in its pure form (>99%); however, some reports indicate that it has been given as a water emulsion (El-shafaey, 2007, Athar et al. 2011).

When used to treat colic and ileal impactions in horses and ruminants, mineral oil is typically administered in combination with analgesics (e.g., flunixin meglumine) and intravenous (IV) delivery of saline or other fluids (ACVS, Hanson et al. 1996, Lopes et al. 1999). Mineral oil is co-applied with IV fluids and analgesics because of the complimentary nature of the three treatments (White and Dabareiner 1997, Bilkslager 2005). IV fluid treatments provide hydration to digestive blockages, which are often dry matter. Hydration of the blockage promotes structural change and allows it to change shape and exit the digestive tract (White and Dabareiner 1997, Lopes et al. 1999, Athar et al. 2011). Analgesics are used primarily to relieve the pain that accompanies impactions and colic. The pain associated with these conditions is related to intestinal spasms and contractions around the blockage, which can cause intermittent pain (White and Dabareiner 1997, Bilkslager 2005).

Status

Historic Use:

Mineral oil has been recognized for its laxative effects in both human and animal treatments. Mineral oil is a common treatment for a variety of livestock digestive blockages and impactions as well as colic (Lopes et al. 1999, Costello 2005, El-shafaey 2007, Athar et al. 2011). Mineral oil is allowed in organic livestock production to treat intestinal compaction and for use as a topical lubricant in 7 CFR 205.603. Mineral oil has also been used in conventional agricultural production as an animal feed additive and as a dust suppressant (EFSA 2009, EFSA 2012).

Organic Foods Production Act, USDA Final Rule:

Mineral oil is not listed in the Organic Foods Production Act of 1990. The USDA NOP lists mineral oil as a "synthetic substance allowed for use in organic livestock production, for treatment of intestinal compaction, prohibited for use as a dust suppressant" and "for topical use and as a lubricant" in 7 CFR 205.603.

International:

Canada - Canadian General Standards Board Permitted Substances List

Mineral oil is listed in the Canadian General Standards Board Permitted Substances List in Table 5.3 as a "Health care product and production aid" and is permitted "for external use."

CODEX Alimentarius Commission, Guidelines for the Production, Processing, Labelling and Marketing of Organically Produced Foods (GL 32-1999)

Mineral oil is listed in Table 2 of the CODEX as a "substance for plant, pest and disease control" under the subcategory "traps." Paraffin oil is also listed in Table 2 of the CODEX in the subcategory "mineral."

European Economic Community (EEC) Council Regulation, EC No. 834/2007 and 889/2008

Mineral oil is listed in EC No. 889/2008 as an insecticide and fungicide that is limited for use "only in fruit trees, vines, olive trees and tropical crops (e.g., bananas)." Paraffin oil is also listed in EC No. 889/2008 as an insecticide and aracnacide.

Japan Agricultural Standard (JAS) for Organic Production

Mineral oil is not listed in the JAS.

International Federation of Organic Agriculture Movements (IFOAM)

Mineral oil is listed in the IFOAM in Appendix 3 as a "crop protectant and growth regulator."

Evaluation Questions for Substances to Be Used in Organic Crop or Livestock Production

Evaluation Question #1: Indicate which category in OFPA that the substance falls under: (A) Does the substance contain an active ingredient in any of the following categories: copper and sulfur compounds, toxins derived from bacteria; pheromones, soaps, horticultural oils, fish emulsions, treated seed, vitamins and minerals; livestock parasiticides and medicines and production aids including netting, tree wraps and seals, insect traps, sticky barriers, row covers, and equipment cleansers? (B) Is the substance a synthetic inert ingredient that is not classified by the EPA as inerts of toxicological concern (i.e., EPA List 4 inerts) (7 U.S.C. § 6517(c)(1)(B)(ii))? Is the synthetic substance an inert ingredient which is not on EPA List 4, but is exempt from a requirement of a tolerance, per 40 CFR part 180?

A) Mineral oil is a medicine that is used in organic livestock production, primarily for its laxative properties. When mineral oil is used for veterinary purposes, it is highly refined to remove crude oil contaminants and potentially hazardous aromatic compounds (EPA 2009, EFSA 2009, EFSA 2012).

Additionally, mineral oil is used in conventional agriculture as a parasiticide for mite control, primarily in poultry production.

B) Mineral oil in the form of "white mineral oil (petrolatum) 8042-47-5" is on the EPA List 4 inerts.

<u>Evaluation Question #2:</u> Describe the most prevalent processes used to manufacture or formulate the petitioned substance. Further, describe any chemical change that may occur during manufacture or formulation of the petitioned substance when this substance is extracted from naturally occurring plant, animal, or mineral sources (7 U.S.C. § 6502 (21)).

Mineral oil is a substance that is produced by refining petroleum crude oil (EPA 2007, EFSA 2012, IARC 2012). The final composition of mineral oil is determined by the source of the crude oil as well as the specific refining conditions used (EFSA 2012, IARC 2012). Prior to the refining process, the petroleum crude oil is desalted and fractionated to various boiling points (EFSA 2009, EFSA 2012, Wright 2012). In the desalting process, crude oil is washed with water to remove salts, minerals, and heavy metals that may be present in the crude oil (EFSA 2009, Wright 2012). The salts (ionic compounds) are more soluble in water than in the hydrophobic hydrocarbon crude oil mixture, enabling their migration from the crude oil into the water washes (EFSA 2009, Timberlake 2016).

After the desalting process, the crude oil is fractionated by heating from 350–380 °C, at or around atmospheric pressure, to allow for separation of groups of compounds based on their boiling points (EFSA 2009, EFSA 2012, IARC 2012, Wright 2012). The desalting process removes water soluble salts, predominantly sodium chloride (NaCl) and magnesium chloride ($MgCl_2$). Salt removal prevents corrosion of refining equipment and improves crude oil purity (Abdul-Wahab et al. 2006). The fractionating process uses a large fractional distillation column to allow for many evaporation and condensation cycles, known as theoretical plates, which enhances the separation process (Timberlake 2016). The fractionating process effectively separates crude oil into hydrocarbons with similar sizes, as the size of the carbon chain directly influences the boiling point of each substance (Wright 2012, Timberlake 2016). Mineral oil is produced from relatively heavy distillates, typically varying between 9 and 40 carbons (EPA 2009, EFSA 2012). Once the distillate has been isolated from the crude, it undergoes the deasphalting process (Wright 2012). In this process, propane is used as an extraction solvent to remove any tar from the distilled fraction (Wright 2012). In some refining processes, tars are removed from vacuum distillation processes, rather than through deasphalting (EFSA 2009, EFSA 2012).

Once the base of compounds that make up mineral oil are separated from the crude oil by the desalting and fractionating processes, they are refined to produce the final product. The general refining process is discussed below, although specific refining processes and conditions vary between producers and mineral oil formulations (EFSA 2012).

Mineral oil was traditionally refined through solvent extractions followed by the oleation process (EFSA 2012, Wright 2012). In the solvent extraction process, the fractionated distillate is extracted with various solvents, including phenol, furfural, or sulfur dioxide, to remove aromatic compounds (Wright 2012). Following the removal of these compounds, the remaining substance is primarily composed of paraffin and napthene compounds (Wright 2012). While the solvent extraction removes most of the aromatic compounds, as much as 20% may remain in the mineral oil at this stage (EFSA 2012, Wright 2012).

In traditional refining, solvent extraction is followed by oleation, or acid refining. Oleation is the treatment of the extracted substances with fuming sulfuric acid (EFSA 2009, IARC 2012, Wright 2012). The concentrated acid treatment is used as a means of hydrogenation, converting compounds with carbon–carbon double bonds into saturated hydrocarbons (EFSA 2009). The oleation process is not often used for the production of modern mineral oil due to the large quantities of acid sludge byproducts formed in the process (EFSA 2009, Wright 2012). These byproducts pose an environmental hazard and must be properly treated for disposal (Wright 2012).

In modern mineral oil production, the refining process often includes a second distillation process to remove any impurities that may have been carried by the distillate from neighboring fractions. Unlike the initial fractionating process, additional distillations are typically performed under vacuum to reduce the temperatures required in the process (IARC 2012).

Modern refining of mineral oil may still include the use of a solvent extraction step for the removal of aromatic compounds (EFSA 2012, Wright 2012). However, in these modern mineral oil production, solvent extraction is followed by further refining to eliminate aromatic compounds to trace levels (EFSA 2012, IARC 2012, Wright 2012). These additional refining steps may include dewaxing, which removes more viscous compounds and waxes, as well as the majority of remaining aromatic substances (EFSA 2012, Wright 2012).

Most refining processes replaced the oleation process with hydrocracking in the 1960s (EFSA 2009, IARC 2012). In the hydrocracking process, the mineral oil is subjected to high temperatures (300–420 °C) under high pressures of hydrogen gas (3000 psi) in the presence of a metallic or zeolite catalyst (EFSA 2009, EFSA 2012, Wright 2012). The extreme conditions of hydrocracking processes hydrogenate unsaturated compounds, and convert aromatic compounds and napthenes to saturated hydrocarbon chains (EFSA 2009, EFSA 2012, Wright 2012). After the completion of hydrocracking processes, aromatic compounds have been reduced to trace levels, and paraffins have become the primary component of the mineral oil (EFSA 2009, EFSA 2012, Wright 2012).

The final step in most mineral oil refinement is hydrotreating. This process is similar to hydrocracking, although under less extreme conditions. In hydrotreating processes, the mineral oil is subjected to hydrogen gas and metallic catalysts to ensure complete saturation (EFSA 2009, EFSA 2012, IARC 2012, Wright 2012). This process is important due to the extreme conditions associated with hydrocracking. The high pressures and temperatures of hydrocracking break apart the ring structures of aromatic compounds and napthenes, and carbon – carbon double bonds may be formed in the process (Wright 2012). Hydrotreating ensures that any points of unsaturation introduced during the refining process are hydrogenated to give complete chemical saturation (Wright 2012).

<u>Evaluation Question #3:</u> **Discuss whether the petitioned substance is formulated or manufactured by a chemical process, or created by naturally occurring biological processes (7 U.S.C. § 6502 (21)).**

As described in Evaluation Question 2, mineral oil is a synthetic substance that is manufactured by refining crude oil. Some of the compounds in mineral oil exist in crude oil, while others are produced in the refining process. The refining process isolates a mixture of hydrocarbons in crude oil based on their physical properties (e.g., vapor pressure, boiling point, solubility) (EFSA 2009, EFSA 2012, IARC 2012). During the isolation process, organic compounds that include oxygen, nitrogen, sulfur, and other impurities are removed through various purifications processes or reactions (EFSA 2009, EFSA 2012). During the refining process, the isolated hydrocarbons undergo a hydrogenation process to replace any existing multiple bonds with additional carbon – hydrogen single bonds to produce the completely saturated compounds that make up mineral oil (EFSA 2009, EFSA 2012).

<u>Evaluation Question #4:</u> **Describe the persistence or concentration of the petitioned substance and/or its byproducts in the environment (7 U.S.C. § 6518 (m) (2)).**

At the time of this report, the author did not find environmental studies on highly refined mineral oil. The EPA has reported that mineral oil has a short environmental lifetime of 2–3 days in aquatic environments (EPA 2007). The low vapor pressure and water solubility of mineral oil makes it unlikely to migrate within the environment (EPA 2007). The low solubility and volatility of mineral oil makes it most likely to be found in the soil or other terrestrial environments, where it is broken down through metabolic processes (EFSA 2012). Mineral oil has a longer environmental lifetime in soil, where it undergoes slow biodegradation (EPA 2007, EFSA 2012). The environmental persistence of mineral oil metabolites are not quantifiable due to the variety of possible compounds and their ubiquitous nature within the environment, but are not thought to bioaccumulate (EFSA 2012).

Sodium and magnesium chlorides are the predominant solutes in desalting effluents (Abdul-Wahab et al. 2006). Both sodium and magnesium chloride salts are prevalent in nature and can be found in mineral formations and seawater (Atkins et al. 2008). Given the ubiquitous presence of these salts in nature, their environmental concentrations from desalting crude oil are not readily quantifiable.

Aromatic molecules are cyclic hydrocarbons that are thermodynamically stable due to their delocalized pi-electrons, which dramatically reduce their reactivity (Baird and Cann 2008, Timberlake 2016). The identity of aromatics in crude oil is variable based on the region of origin (discussed above in the "Composition of the Substance" section) (EFSA 2012, IARC 2012, Serio and Levine 2015). Aromatic compounds are likely to undergo oxidation in the environment, converting to more polar aromatic derivatives including quinones and phenolic compounds. Aromatic compounds and their oxidized derivatives can be further degraded into small hydrocarbon metabolites by microorganisms (Serio and Levine 2015). Aromatic molecules pose a hazard to aquatic environments due to their long environmental lifetimes. The stability of aromatic molecules in aquatic environments may result in their bioaccumulation in fish and other marine animals (Baird and Cann 2008).

As discussed in Evaluation Question 2, most modern refining processes have replaced oleation due to environmental concerns related to acidic byproducts. Oleation processes use fuming sulfuric acid to hydrogenate unsaturated hydrocarbons. Sulfuric acid is a strong acid that can lower the pH of water and terrestrial systems if not properly neutralized (Atkins et al. 2008, Baird and Cann 2008). Because of the highly reactive nature of sulfuric acid, it is readily converted to more stable hydrogen sulfate (HSO_4^-) and sulfate ions (SO_4^{2-}). Hydrogen sulfate and sulfate ions are found in many biological molecules and are prevalent in the environment (Baird and Cann 2008).

<u>Evaluation Question #5:</u> Describe the toxicity and mode of action of the substance and of its breakdown products and any contaminants. Describe the persistence and areas of concentration in the environment of the substance and its breakdown products (7 U.S.C. § 6518 (m) (2)).

As described above in Evaluation Question 4, mineral oil undergoes slow biodegradation in terrestrial and soil environments, although the substance has a short aquatic lifetime of two to three days (EPA 2007). Mineral oil is generally non-toxic in the environment (EPA 2007, EFSA 2012). The EPA has stated that mineral oil is not hazardous to mammals, birds, honey bees, and aquatic life, with a few exceptions (EPA 2007). Mineral oil metabolites have also been designated as non-toxic and form a variety of compounds that are biologically ubiquitous (EPA 2007, EFSA 2012).

Mineral oil is non-toxic to mammals and birds, except in cases where it is applied directly to bird eggs (EPA 2007). In these cases, mineral oil may have a hazardous effect by preventing airflow through the eggshell (EPA 2007). Mineral oil is non-toxic to fish, shrimp, and other marine invertebrae (EPA 2007). One study reported that fish can survive a 50/50 mixture of mineral oil and water (EFSA 2012). However, mineral oil may be hazardous to oysters, as it may disrupt their ability to metabolize nutrients (EPA 2007). Mineral oil may also be hazardous to water fleas (*Daphina magna)*, which may be suffocated when coated in mineral oil; coating is the mode of action of pesticides and parasiticides against mites and mosquitos (EPA 2007, EFSA 2012).

There have been previous reports of mineral oil phytotoxicity; however, these reports predate industry changes to mineral oil refining (EPA 2007). Some PAHs and other aromatic compounds have been reported to have phytotoxic properties, but these are generally removed in modern mineral oil formulations through additional refining steps (EPA 2007, EFSA 2009, EFSA 2012, IARC 2012). In an EPA evaluation of mineral oil for pesticide use, the agency stated that it "does not have concerns for phytotoxicity." They cited the heavy application of mineral oil in pesticides without adverse effects since the general changes in manufacturing have resulted in aromatic compounds being removed or decreased to trace amounts (EPA 2007, EFSA 2012).

Since mineral oil is poorly absorbed in mammals, it is likely to be excreted in the manure of treated livestock (EPA 2009). As described in Evaluation Question 4, mineral oil is unlikely to migrate from the manure into other environments (EPA 2007). The highly refined mineral oil used in veterinary applications does not contain aromatic compounds and would not be expected to contribute to environmental contamination (EPA 2007, EPA 2009, EFSA 2012).

<u>Evaluation Question #6:</u> Describe any environmental contamination that could result from the petitioned substance's manufacture, use, misuse, or disposal (7 U.S.C. § 6518 (m) (3)).

As described in Evaluation Questions 4 and 5, mineral oil and its metabolites may have relatively long environmental lifetimes but are generally non-toxic. The EPA has approved mineral oil for direct application to both terrestrial and aquatic systems as a pesticide (EPA 2007, EFSA 2012). The EPA has classified mineral oil as having low acute toxicity to plants and animals within the environment and stated that it is unlikely to migrate from its initial place of application (EPA 2007). The highly refined mineral oil used in veterinary applications is even less likely to be a source of environmental contamination because in this application, potentially harmful aromatic compounds are completely removed (EPA 2007, EPA 2009, EFSA 2012).

Environmental contamination may occur during extraction and transportation of the crude oil through accidental releases (e.g., oil spills, contamination from fracking) (EIA 2020). As discussed in Evaluation Question 2, the refining process may involve harsh chemicals (e.g., fuming sulfuric acid), the byproducts of which must be carefully handled to prevent environmental contamination (EPA 2009, EFSA 2009, IARC 2012, Wright 2012). Aromatic compounds that are removed from crude oil during refining processes pose water pollution risks and may bioaccumulate in fish and other marine animals. Accumulation of aromatic compounds has been reported to produce liver lesions and tumors in some fish (Baird and Cann 2008). The refining process is the third largest producer of greenhouse gases and other atmospheric pollutants, including carbon dioxide (CO_2), methane (CH_4), and reactive nitrogen oxides (e.g., nitric oxide [NO], nitrous oxide [N_2O]) (EPA 2013).

<u>Evaluation Question #7:</u> Describe any known chemical interactions between the petitioned substance and other substances used in organic crop or livestock production or handling. Describe any environmental or human health effects from these chemical interactions (7 U.S.C. § 6518 (m) (1)).

There have been some reports that the administration of mineral oil to humans may prevent the proper absorption of nutrients such as vitamins and minerals (Weinstein 2001, Gal-Ezer and Shaoul 2006, EPA 2009, HMHW 2014). However, these reports have been controversial, and possible interactions between mineral oil and nutrients are disputed in the literature (Gal-Ezer and Shaoul 2006, EPA 2009). Despite the disputed nature of these claims, it is recommended that mineral oil laxatives for humans be administered between meals or before bedtime to prevent potential interference with nutrient absorption (Baker et al. 1999, Weinstein 2001, Gal-Ezer and Shaoul 2006). Based on the current literature, it is possible that mineral oil may interfere with nutrient absorption in livestock that are undergoing active mineral oil treatment.

<u>Evaluation Question #8:</u> Describe any effects of the petitioned substance on biological or chemical interactions in the agro-ecosystem, including physiological effects on soil organisms (including the salt index and solubility of the soil), crops, and livestock (7 U.S.C. § 6518 (m) (5)).

As described in Evaluation Questions 4 and 7, mineral oil is unlikely to have meaningful interactions with the agro-ecosystem. Mineral oil is unlikely to migrate from the manure of treated animals (EPA 2007, EFSA 2012). The chemical saturation of the compounds that make up mineral oil are generally unreactive and are unlikely to promote chemical and biological processes other than their metabolism (Timberlake 2016). Mineral oil is generally non-toxic to both plants and animals and is unlikely to have effects on crops (EPA 2007). As detailed in Evaluation Question 7, mineral oil my interfere with absorption of nutrients by the treated livestock, although this requires further research for verification (Weinstein 2001, Gal-Ezer and Shaoul 2006, EPA 2009). Mineral oil has a laxative effect in mammals, although this effect is therapeutic and is the purpose of its administration to livestock.

<u>Evaluation Question #9:</u> Discuss and summarize findings on whether the use of the petitioned substance may be harmful to the environment (7 U.S.C. § 6517 (c) (1) (A) (i) and 7 U.S.C. § 6517 (c) (2) (A) (i)).

As described in Evaluation Questions 4–8, mineral oil may be relatively long-lived, but it has a low acute toxicity in the environment. The highly refined form of mineral oil used for veterinary applications has no aromatic compounds and has limited use in relatively small quantities (EPA 2007, EPA 2009, EFSA 2009, EFSA 2012). Given the level of mineral oil purity, its uses, and its non-toxic nature, it seems unlikely to be the source of environmental contamination when used for veterinary applications (EFSA 2012).

<u>Evaluation Question #10:</u> Describe and summarize any reported effects upon human health from use of the petitioned substance (7 U.S.C. § 6517 (c) (1) (A) (i), 7 U.S.C. § 6517 (c) (2) (A) (i)) and 7 U.S.C. § 6518 (m) (4)).

Mineral oil is generally not absorbed by humans, although absorbed mineral oil is metabolized to fatty acids and components of lipid compounds or acidic compounds that are excreted in urine (Gal-Ezer and Shaoul 2006, EPA 2009, EFSA 2009, EFSA 2012). Mineral oil has laxative effects in humans, although this effect is often therapeutic and the purpose of the mineral oil product (HMHW 2014). Mineral oil used in laxative formulations is generally made up of larger and less bioavailable compounds, which prevents absorption and improves the laxative effect (EFSA 2012).

As described in Evaluation Question 7, mineral oil has been reported to interfere with the absorption of nutrients. While the veracity of these interactions is debated in the literature, mineral oil laxatives are recommended to be taken between meals or before bedtime (Baker et al. 1999, Weinstein 2001, Gal-Ezer and Shaoul 2006, EPA 2009).

Aspiration of mineral oil droplets is a rare but serious and potentially fatal risk (Weinstein 2001). Aspiration may occur when the airway is not clear or when mineral oil mists are encountered and have been reported to cause lipoid pneumonitis and pneumonia (Weinstein 2001, Gal-Ezer and Shaoul 2006, HMHW 2014, MP 2019).

The highly refined mineral oil discussed in this technical report has shown no signs of mutagenicity, carcinogenicity, or the potential to cause other adverse effects (IARC 1987). Highly refined mineral oil has been designated as a group 3 substance, which are "not classifiable as to their carcinogenicity to humans" by the International Agency for Research on Cancer (IARC) (IARC 1987).

Highly refined mineral oils are included in a range of food and pharmaceutical products with long-term doses of up to 100 mL/day without causing adverse effects in humans (EFSA 2012). A case of long-term human overdose with no adverse effect has been reported at 400 mL daily over the course of 5 months (Gal-Ezer and Shaoul 2006). This daily dosage dramatically exceeded the recommended daily dose by 100–400X without the patient showing adverse effects or disruption to nutrient absorption (Gal-Ezer and Shaoul 2006).

Crude and less refined mineral oils have been designated as group 1 substances and designated as "carcinogenic to humans" by the IARC, likely due to the PAHs that remain within mineral oils with limited refinement (IARC 1987, IARC 2012). Most cancer cases linked to mineral oil with limited refining are skin and scrotal cancer (IARC 1987, IARC 2012). These cancer cases are predominantly linked to industrial lubricant applications where the mineral oil is aerosolized (IARC 2012). However, these cases often include the inhalation of other potentially carcinogenic substances, making the role of mineral oil lubricants difficult to conclude (IARC 2012).

<u>Evaluation Question #11:</u> Describe all natural (non-synthetic) substances or products which may be used in place of a petitioned substance (7 U.S.C. § 6517 (c) (1) (A) (ii)). Provide a list of allowed substances that may be used in place of the petitioned substance (7 U.S.C. § 6518 (m) (6)).

There are a variety of natural substances that may provide laxative and digestive lubricating effects. The most similar substances to mineral oil have similar chemical compositions but are derived from natural, plant-based sources. These include vegetable oil, olive oil, and other agricultural oils, which, like mineral oil, act to line the digestive tract to provide lubrication for blockages (Berry 2018). However, these substances differ in structure from mineral oil as they are not necessarily chemically saturated (Timberlake 2016). The points of chemical unsaturation found in the presence of carbon–carbon double bonds in the structure make these compounds more reactive and more easily metabolized (Timberlake 2016). The more rapid metabolism of these compounds will likely shorten their environmental lifetimes and further reduce the potential for bioaccumulation from the already-low levels in mineral oil. However, the metabolic activity of these alternative oils are also likely to make them less effective as a digestive lubricant due to their higher bioavailability.

Castor oil is a natural alternative to mineral oil for laxative applications. Castor oil is produced as a vegetable oil pressed from castor beans. Unlike the oils described above, the laxative effects of castor oil are based on the production of a metabolite, ricinoleic acid (Williams 2012). Ricinoleic acid acts as an intestinal stimulant, which promotes gastric reflexes (Williams 2012). Like mineral oil, castor oil may reduce the absorption of nutrients, including vitamins A, D, E, and K (CC 2021).

The USDA NOP has also approved the use of flunixin as "synthetic substances allowed for use in organic livestock production" in 7 CFR 205.603. Flunixin meglumine is a non-steroidal analgesic with noted anti-inflammatory and antipyretic activity (USDA 2007). Flunixin is administered for treatment of equine colic as a pain reliever and to prevent gastric rupture (USDA 2007). While flunixin meglumine is a possible alternative to mineral oil for treatment of colic in horses, it is often used in combination with mineral oil, as the substances have different effects (Hanson et al. 1996, Lopes et al. 1999). Additionally, flunixin meglumine does not offer an alternative to mineral oil for laxative applications in the treatment of constipation, ruminant bloat, and some digestive blockages.

The USDA NOP has also approved the use of magnesium sulfate as a "synthetic substances allowed for use in organic livestock production" in 7 CFR 205.603. Magnesium sulfate is an alternative to mineral oil for laxative applications in livestock and is typically mixed with water and administered orally (Blikslager 2005, USDA 2011). Magnesium sulfate is a more potent laxative than mineral oil and works through a different mode of action (Blikslager 2005). Rather than acting as a digestive lubricant, magnesium sulfate softens fecal matter by increasing water absorption within the fecal blockage (Blikslager 2005). Magnesium sulfate is also associated with electrolyte imbalances, including hypermagnesemia, and requires more careful dosing than mineral oil (Blikslager 2005).

Evaluation Question #12: Describe any alternative practices that would make the use of the petitioned substance unnecessary (7 U.S.C. § 6518 (m) (6)).

Compaction of the digestive tract may occur for many reasons but has been reported to be closely linked to quality of animal feeds. Literature reports cite ingestion of feeds or roughage that are high in undigestable materials (e.g., lignin, sand) as potential reasons for impaction or compaction (Hanson et al. 1996, Athar et al. 2011). The source of the undigestable material may be the vegetation/pasture of the animal or contamination due to improper storage or harvesting of animal feeds (Hanson et al. 1996, Lopes et al. 1999). Given the link between the presence of undigestable materials and digestive compaction and impaction, one alternative practice is to ensure that feeds have low quantities of indigestible material and are free from potential contaminants.

In some cases, compaction is not related to animal feeds, or feed alternatives may not be readily available. In these cases, there are relatively few alternative practices, as administration of mineral oil is a standard treatment for colic, compaction, and impaction (Lopes et al. 1999, Athar et al. 2011). A study by Lopes found that endermal fluid treatments of either water or saline solutions had similar success to traditional mineral oil and was more effective in cases of fecal hydration (Lopes et al. 1999). Endermal fluid treatments for colic consisted of warm tap water (35 °C), with doses that varied between 85–350 mL/kg (Dabareiner and White 1995, Lopes et al. 1999). IV treatments with water and saline solutions have also been reported as potential treatments for colic and digestive impactions (Lopes et al. 1999, Blikslager 2005). Endermal and IV fluid treatments may provide an alternative to mineral oil for other livestock as well.

The most common alternative to mineral oil is the manual surgical removal of blockages (e.g., fecal matter, undigested food) (Hanson et al. 1996, Athar et al. 2011). Surgery is also the veterinary approach following unsuccessful mineral oil treatment, as colic, impaction, and compaction may be fatal (Lopes et al. 1999, Athar et al. 2011). However, in some surgical alternatives, mineral oil is added to the digestive component after the manual removal of the blockage to remove any remaining material in other digestive cavities (Athar et al. 2011).

A large needle may be used as an alternative to mineral oil lubricants in cases of ruminal bloat (Costello 2005). Like with other surgical treatments, needle puncture to alleviate gas build-up is also used when the mineral oil treatments are unsuccessful, as severe ruminal bloat may be fatal (Costello 2005).

Report Authorship

The following individuals were involved in research, data collection, writing, editing, and/or final approval of this report:

- Philip Shivokevich, Visiting Assistant Professor of Chemistry, University of Massachusetts Amherst
- Samantha Olsen, Technical Editor, Savan Group
- Catherine Canary, Technical Editor, Savan Group

All individuals are in compliance with Federal Acquisition Regulations (FAR) Subpart 3.11—Preventing Personal Conflicts of Interest for Contractor Employees Performing Acquisition Functions.

References

Abdul-Wahab S, Elkamel A, Madhuranthakam CR, Al-Otaibi MB. 2006. Building inferential estimators for modeling product quality in a crude oil desalting and dehydration process. Chemical Engineering and Processing: Process Intensification. 45(7): 568-577.

[ACVS] American College of Veterinary Surgeons. Colic in adult cattle. [accessed 2021 Feb 20]. https://www.acvs.org/large-animal/colic-in-adult-cattle

Athar H, Mohindroo J, Singh K, Singh T, Singh O. 2011. Diagnosis and surgical management of abomasal impaction in bovines. The Indian Veterinary Journal. 88: 36-38.

Atkins P, Overton T, Rourke J, Weller M, Armstrong F. 2008. Inorganic chemistry. 4th ed. New York (NY): Oxford University Press.

[APS] AquaPheonix Scientific. 2015. Mineral oil, light SDS. [accessed 2021 Jan 6]. https://beta-static.fishersci.com/content/dam/fishersci/en_US/documents/programs/education/regulatory-documents/sds/chemicals/chemicals-m/S25439.pdf

Baird C, Cann M. 2008. Environmental Chemistry. 4th ed. New York (NY): W. H. Freeman and Company.

Baker SS, Liptak GS, Colletti RB, Croffie JM, Di Lorenzo C, Ector W, Nurko S. 1999. Constipation in infants and children: evaluation and treatment. Journal of Pediatric Gastroenterology and Nutrition. 29(5): 612-626.

Berry J. 2018. Can olive oil be used to treat constipation? Medical News Today. [accessed 2021 Jan 12]. https://www.medicalnewstoday.com/articles/313416

Blikslager AT. 2005. Principles of treatment for impaction – laxatives, fluid therapy and analgesia. American Association of Equine Practioners. Quebec.

[CC] Cleveland Clinic. 2021. Castor oil oral solution. [accessed 2021 Jan 12]. https://my.clevelandclinic.org/health/drugs/18391-castor-oil-oral-solution

Costello R. 2005. Bloat in young calves and other pre-ruminant livestock. Merrick's Inc. [accessed 2021 Jan 12]. https://www.vetassociateshazelgreen.com/storage/app/media/CalfBloat.pdf

Dabareiner RM, White NA. 1995. Large colon impaction in horses: 147 cases (1985-1991). Journal of the American Veterinary Medical Association. 206: 679-685.

El-shafaey EAA. 2007. Diagnosis and management of abomasal disorders in cattle. Master of Veterinary Medical Sciences Thesis. [accessed 2021 Jan 2]. https://www.researchgate.net/publication/324520138_Diagnosis_and_Management_of_Abomasal_Disorders_in_Cattle

[EIA] United States Energy Information Administration. 2020. Oil and petroleum products explained. [accessed 2021 Jan 11]. https://www.eia.gov/energyexplained/oil-and-petroleum-products/oil-and-the-environment.php

[EPA] United States Environmental Protection Agency. 2007. Revised Eligibility Decision (RED) for aliphatic solvents. US EPA Office of Pesticide Programs.

[EPA] United States Environmental Protection Agency. 2009. Provisional peer-reviewed toxicity values for white mineral oil (CASRN 8012-95-1 and 8020-83-5). Superfund Health Risk Technical Support Center, National Center for Environmental Assessment.

[EPA] United States Environmental Protection Agency. 2013. Petroleum refineries sector. [accessed 2021 Jan 11]. https://www.epa.gov/sites/production/files/2016-11/documents/refineries_2013_112516.pdf

[EFSA] European Food Safety Authority. 2009. Scientific opinion on the use of high viscosity white mineral oils as a food additive. EFSA panel on Food Additives and Nutrient Sources added to Food (ANS). EFSA Journal. 7(11): 1387.

[EFSA] European Food Safety Authority. 2012. Scientific opinion on mineral oil hydrocarbons in food. EFSA panel on Contaminants in the Food Chain (CONTAM). EFSA Journal. 10(6): 2704.

Flomenbaum NE, Goldfrank LR, Hoffman RS, Howland MA, Lewin NA, Nelson LS. 2002. Goldfrank's toxicologic emergencies. 10th ed. New York (NY): McGraw-Hill.

Gal-Ezer S, Shaoul R. 2006. The safety of mineral oil in the treatment of constipation – a lesson from prolonged overdose. Clinical Pediatrics. 45(9): 856-858.

Geritrex. 2014. Mineral oil light & heavy SDS. [accessed 2021 Jan 2]. https://imgcdn.mckesson.com/CumulusWeb/Click_and_learn/SDS_9GERIT_MINERAL_OIL_16OZ.pdf

Hanson RR, Schumacher J, Hamburg J, Dunkerley SC. 1996. Medical treatment of horses with ileal impactions: 10 cases (1990-1994). Journal of the American Veterinary Medical Association. 208(6): 898-900.

[HMHW] Harvard Men's Health Watch. 2014. Don't bomb the bowel with laxatives. Harvard Health Publishing, Harvard medical School. [accessed 2021 Jan 10]. https://www.health.harvard.edu/newsletters/harvard_mens_health_watch/2014/may

[IARC] International Agency for Research on Cancer. 1987. Mineral oils: untreated and mildy treated (group 1) highly refined oils (group 3), in overall evaluations of carcinogenicity: an updating of IARC Monographs volumes 1 to 42. IARC Working Group on the Evaluation of Carcinogenic Risks to Humans.

[IARC] International Agency for Research on Cancer. 2012. Mineral oils, untreated or mildly treated, in IARC monographs on the evaluation of carcinogenic risks to humans, No. 100F. IARC Working Group on the Evaluation of Carcinogenic Risks to Humans.

Lopes MAF, Moura GS, Filho JD. 1999. Treatment of large colon impaction with enteral fluid therapy. American Association of Equine Practitioners Proceedings. 45: 99-102.

[MP] MedlinePlus. 2019. Mineral oil overdose, in Animated Dissection of Anatomy for Medicine (A.D.A.M.) Medical Encyclopedia. [accessed 2021 Jan 2]. https://medlineplus.gov/ency/article/002684.htm

[PC] PubChem Database. 2017a. Mineral oil, CID=347911096. National Center for Biotechnology Information. [modified 2020 Feb 7, accessed 2021 Jan 2]. https://pubchem.ncbi.nlm.nih.gov/substance/347911096

[PC] PubChem Database. 2017b. Light mineral oil, CID=347911206. National Center for Biotechnology Information. [modified 2020 Feb 7, accessed 2021 Jan 2]. https://pubchem.ncbi.nlm.nih.gov/substance/347911206

[SL] Sciencelab.com, Inc. 2005. Mineral oil MSDS. [accessed 2021 Jan 2]. http://dept.harpercollege.edu/chemistry/msds1/Mineral%20oil%20ScienceLab.pdf

Serio N, Levine M. 2015. Efficient extraction and detection of aromatic toxicants from crude oil and tar balls using multiple cyclodextrin derivatives. Marine Pollution Bulletin. 95(1): 242-247.

Silberberg MS. 2003. Chemistry: the molecular nature of matter and change. 3rd ed. New York (NY): McGraw-Hill Higher Education.

Timberlake KC. 2016. General, organic, and biological chemistry: structures of life. 5th Ed. United States: Pearson Education Inc.

[USDA] United States Department of Agriculture. 2002. Mineral oil technical evaluation report. [accessed 2021 Jan 5]. https://www.ams.usda.gov/sites/default/files/media/Min%20oil%20Technical%20Advisory%20Panel%20Report.pdf

[USDA] United States Department of Agriculture. 2007. Flunixin technical evaluation report. [accessed 2021 Jan 10]. https://www.ams.usda.gov/sites/default/files/media/Flunixin%20TR.pdf

[USDA] United States Department of Agriculture. 2011. Magnesium sulfate technical evaluation report. [accessed 2021 Jan 9]. https://www.ams.usda.gov/sites/default/files/media/MGSu%20Technical%20Evaluation%20Report%20Livestock.pdf

[USDA] United States Department of Agriculture. 2015. Mineral oil technical evaluation report. [accessed 2021 Jan 5]. https://www.ams.usda.gov/sites/default/files/media/Min%20oil%20Technical%20Evaluation%20Report%20%282015%29.pdf

Weinstein M. 2001. First do no harm: the dangers of mineral oil. Pediatrics & Child Health. 6(3): 129-131.

White NA II, Dabareiner RM. 1997. Treatment of impaction colics. Veterinary Clinics of North America: Equine Practice. 13(2): 243-259.

Williams SCP. 2012. Just a spoonful of castor oil. American Association for the Advancement of Science, ScienceMag. [accessed 2021 Jan 7]. https://www.sciencemag.org/news/2012/05/just-spoonful-castor-oil

Wright J. 2012. The fundamentals of mineral oil base refining. Machinery Lubrication. [accessed 2021 Jan 11]. https://www.machinerylubrication.com/Read/28960/mineral-oil-refining