Propane

Crops

Identification of Petitioned Substance

Chemical Name:
Propane
Dimethyl methane

CAS Number:
74-98-6

Other Names:
Propane, propyl hydride, bottled gas, liquefied propane gas

Other Codes:
RTECS No. TX2275000

Trade Names:
Propane, n-propane

Characterization of Petitioned Substance

Composition of the Substance:

Propane is an alkane consisting of three carbon and eight hydrogen atoms (molecular formula C_3H_8). The molecular structure of propane, obtained from the Hazardous Substances Data Bank (HSDB, 2007), is shown as Figure 1.

Figure 1. Molecular Structure of Propane

Properties of the Substance:

In its pure form, propane is an odorless gas. Propane may also be compressed into a liquid. It is a constituent of natural gas and of crude petroleum and is isolated from these sources by a “stabilization process” using fractional distillation under pressure. Propane is highly flammable and explosive. Potential symptoms of overexposure are dizziness, confusion, excitation, and asphyxia. Direct contact with liquefied propane may cause frostbite. When exposed to ambient temperatures, liquefied propane will boil and evaporate rapidly (USDA, 2009a). Physical and chemical properties of propane are presented in Table 1.

Specific Uses of the Substance:

Propane is used primarily as a fuel gas and is sometimes mixed with butane and other gases in liquefied petroleum gas (LPG). It is also used as a refrigerant and aerosol propellant (HSDB, 2007). Propane gas is naturally odorless; however, the propane used for fuel purposes is often combined with a malodorant (e.g., methyl mercaptan) that gives it the characteristic musty odor with which it is identified (USDA, 2009a).

Propane is used in devices to control animal pests, primarily burrowing animals such as prairie dogs, gophers, moles, voles, squirrels, rabbits, groundhogs, armadillos, chipmunks, muskrats, shrews, rats, mountain beaver, nutria, ground squirrels, badgers, pocket gophers, marmots, and bog lemmings (CCOF, 2010). Some of these devices are designed to collapse rodent tunnels and suffocate animals. Others (e.g., propane cannon) produce loud noises intended to scare away (but not kill) animal pests (PERC, undated). Propane is also used in agriculture for thermal weed control (i.e., flame weeding) (Diver, 2002).

Table 1. Physical and Chemical Properties of Propane

Physical or Chemical Property	Value[a]
Color	Colorless
Physical state	Gas; may also be found as a compressed liquid
Odor	Naturally odorless; manufacturers/processors add a substance (usually methyl mercaptan) that gives propane the odor of rotten eggs
Molecular weight	44.10 g/mol
Boiling point	-42.1°C (1 atm)
Melting point	-187.6°C
Solubility	Slightly soluble in acetone; soluble in ethanol; very soluble in ethyl ether, benzene, chloroform
Vapor pressure	7150 mm Hg (25°C)
Vapor density	1.56 (0°C); heavier than air
Density (compressed liquid propane)	0.493 g/cm^3 (25°C)
Explosive limits	2.2-9.5% by volume in air

[a]Sources: HSDB, 2007 , USDA, 2009a

Approved Legal Uses of the Substance:

In accordance with 21 CFR 184.1655 and 582.1655, propane is Generally Recognized as Safe (GRAS) when used for its intended purpose in food (as propellant, aerating agent, and gas [used to supply force to expel a product or used to reduce the amount of oxygen in contact with the food in packaging] and when used in accordance with good manufacturing practice.

Propane is not a pesticide registered by EPA under Section 3 of the Federal Insecticide, Fungicide, and Rodenticide Act (FIFRA). However, propane is used in devices that use only physical or mechanical means to control rodents, and such “pest control devices” are subject to some FIFRA requirements (U.S. EPA, 2011a). Examples of rodent control devices that use propane include Meyer Industries’ Rodenator R3 (Meyer Industries, 2010) and products marketed as the Varmitgetter and the Rodent Blaster. Although such devices may be subject to state or local pesticide regulation, these requirements were not identified for this Technical Report. However, in Boulder, Colorado, it is illegal to destroy inhabited prairie dog burrows; thus, propane-based pest control devices cannot be used within the city limits (City of Boulder, 2005). In the United Kingdom, devices like the Rodenator are only legal when used to collapse burrows (not to kill animals), and operators must be sure the burrows are clear of animals before using the device (Meyer Industries, 2010).

Action of the Substance:

When used to control rodents in crop production, propane is mixed with compressed oxygen to yield a highly combustible, 2% propane and 98% oxygen mixture. The mixture is then ignited in the underground rodent tunnel and the expansion of gases kills the animals in the burrow via concussion and/or asphyxiation when all the oxygen is consumed (Sullins and Sullivan, 1992). This method also collapses the tunnels. All of the propane is consumed in the reaction (CCOF, 2010).

Commercial devices developed for this method use a long wand attached to two gas hoses leading to oxygen and propane tanks. A valve allows gases to mix and flow through the wand. The gas mixture is ignited by an electrical switch at one end of the wand, which triggers a spark at the other end where the gasses exit. One application method involves one operator driving a vehicle holding the tanks of gases, while another operates the wand (Sullins and Sullivan, 1992).

A propane cannon uses propane to fuel loud blasts at regular intervals using an automatic timer. This device is intended to scare, but not to kill pest animals (PERC, no date).

When used as a thermal weed controller, propane gas burners are directed over weeds. The heat sears the weeds causing the cell sap to expand and disrupt cell walls. The weeds wilt and die usually within a few days (Diver, 2002).

Combinations of the Substance:

Methyl mercaptan is added to propane by manufacturers to create an odor (for detection of leaks and other safety concerns). It may also be used in combination with iso-butane and butane to provide pressure to expel products as a spray or aerosol (LPG) (USDA, 2009a).

Status

Historic Use:

Propane has been used in agriculture for many years, primarily for what is known as "flame" weeding, which uses heat/steam to kill weeds. Flame weeding was a popular thermal weed control technique used from the 1930s until the mid-1960s when selective herbicides were readily available. In the 1980s and 1990s, flame weeding regained popularity, especially among organic farmers (Diver, 2002).

Similar to flame weeders, infrared weeders, which were first created in Europe, contain ceramic or steel plates heated by a propane burner. They destroy unwanted plants in the same way as flame weeders except without the open flame. This method is also more expensive than flame weeding (Diver, 2002).

OFPA, USDA Final Rule:

Propane is not listed as an allowed substance for organic crop production under 7 CFR § 205.601. However, heat methods (fueled with propane) are allowed to control weeds (§ 205.206(c)(5)). Propane is also not listed under § 205.605(b) as an allowed substance in or on processed products labeled as "organic" or "made with organic." Propane is prohibited for use in organic handling due to its potential adverse effect on human health and the environment and because it is a synthetic byproduct of the petrochemical industry (USDA, 2009b; see Evaluation Question 3 for further information on the production of propane).

International:

Propane is not specifically listed on the Canadian Organic Production Systems Permitted Substances List (Canadian General Standards Board, 2011a). The general standards state the following:

> "Pest, disease and weed control shall be centred on organic management practices aimed at enhancing crop health and reducing losses caused by weeds, disease and pests. Organic management practices include cultural practices (e.g. rotations, establishment of a balanced ecosystem, and use of resistant varieties) and mechanical techniques (e.g. sanitation measures, cultivation, traps, mulches and grazing) (Canadian General Standards Board, 2011b)."

This suggests that pest control methods such as traps would be preferred; however, it is possible that the propane-powered pest devices would be compatible as approved "mechanical" techniques.

Canada's Food and Drug Regulations (last modified in April 2011) permit the use of propane as a food additive (where purpose of use is as a pressure dispensing and aerating agent) in unstandardized foods (Canadian Food Inspection Agency, 2011).

Propane is listed by the CODEX Alimentarius Commission as a food additive used as a propellant (i.e., a food additive gas, which expels a food from a container) and is identified with the International Numbering System (INS) #944 (Codex Alimentarius Commission, 1989). Propane is not mentioned in any other CODEX standard.

The European Economic Community (EEC) Council Regulation, EC No. 834/2007 allows for the use of thermal pest control methods, which would likely include methods such as propane flame weeding. No specific references to propane are made in this legislation, thus it is unknown whether propane pest control methods for burrowing animals are allowed in organic agriculture.

IFOAM (2010) states that, "Physical methods for pest, disease and weed management are permitted, including the application of heat." This would indicate that methods such as flame weeding are allowed; however, it is unclear if this includes the use of propane to control burrowing animals.

According to the Japanese Agricultural Standard for organic plants, physical methods (e.g., using light, heat, and sound), biological methods (e.g., using plants that naturally repel pests), and a short list of naturally-derived chemical substances are the only techniques allowed to control pest species in organic agriculture. Propane is not an allowed substance on this list. Although it is used as part of a physical method to destroy burrows via explosion, the primary intention of the device is to suffocate the animal. Therefore, it is unlikely that it would be allowed for burrowing pest management in organic agriculture in Japan (JMAFF, 2005). However, flame weeding would be permitted as a thermal plant control method.

Evaluation Questions for Substances to be used in Organic Crop or Livestock Production

Evaluation Question #1: What category in OFPA does this substance fall 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?

The substance does not fall under any of the categories listed in 1(A); however devices which use propane could be considered a production aid. Propane is listed as an inert nonfood chemical and is allowed for use in nonfood pesticide products for conventional production (U.S. EPA, 2011b). However, propane is not included in the August 2004 listing of minimal risk inert ingredients (historically referred to as "4A" and "4B") (U.S. EPA, 2010). Propane is listed as a "List 3" substance on the August 2004 EPA List of Inerts.

Evaluation Question #2: 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)).

Propane is a byproduct of natural gas processing and petroleum refining. Most of the U.S. supply of liquid propane is produced in the United States. Methane and other hydrocarbons, including propane, are obtained by separation from natural gas using a combination of increased pressure and decreased temperature. Propane is also a byproduct of crude petroleum refining, which uses chemical processes to break down and modify the structure of petroleum compounds (MEA, 2006).

Evaluation Question #3: Is the substance synthetic? 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)).

Propane is obtained by physical means of separation from natural gas (pressure and temperature); when it is obtained in this way, it is not chemically changed and is considered nonsynthetic (MEA, 2006). However, propane is also a synthetic byproduct of the petroleum refining industry; propane isolated from these processes would be considered synthetic (MEA, 2006).

Evaluation Question #4: Describe the persistence or concentration of the petitioned substance and/or its by-products in the environment (7 U.S.C. § 6518 (m) (2)).

According to the HSDB (2007), propane has moderate mobility in soil, but it is readily broken down by soil microorganisms within 24 hours. Most propane exists as a gas in the environment and will move from soil or water to the air due to its high vapor pressure. In the air, propane gas is broken down by hydroxyl radicals and has a half life of 14 days. Bioconcentration of propane in aquatic organisms is low (HSDB, 2007). The material safety data sheet (MSDS) from Amerigas (2002) indicates that "no adverse ecological effects are expected" from propane. Another MSDS (Inergy Services, 2006) states that, "releases are expected to cause only localized non-persistent environmental damage," which is supported by the rapid degradation of propane in soil and the relatively rapid breakdown of propane gas in the air.

There are a number of known and potential contaminants in commercial liquefied propane gas products. These include the plasticizers methyl linoleate, dioctyl adipate, and butyl benzyl phthalate. Some of these contaminants can be removed from the final product using methods such as activated carbon filtration (Sambrano and Meyer, 2006; PERC, 2006). These plasticizers are not particularly persistent in the environment. Butyl benzyl phthalate, for example, adsorbs to soil and does not usually leach into groundwater. It is biodegraded in soil by 74-79% in about 10-50 days and in water in about 6 days in (HSDB, 2010). According to the EPA, "dioctyl adipate presents a small hazard to the freshwater aquatic environment" (U.S. EPA, undated). The MSDS for methyl linoleate indicates that this product is air and light sensitive and will produce carbon oxides in the event of a fire. The chemical, physical, and toxicological properties have not been thoroughly investigated, so it is unclear if this chemical is an ecological toxicant (Sigma Aldrich, 2011).

Evaluation Question #5: 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)).

Propane is nonirritating to the eyes, nose, and throat. Dermal contact with liquefied propane can cause burns and frostbite. A study that examined short-term human inhalation exposure to low-moderate levels of propane gas (i.e., 250 to 1,000 ppm) did not show symptoms in exposed individuals. However, humans exposed to higher levels of propane (e.g., 100,000 ppm) experienced symptoms of central nervous system depression including vertigo and disorientation. There is a risk of asphyxiation from exposure to propane gas in confined spaces that are not well ventilated. Asphyxiation is one of the intended actions of propane when used to control burrowing rodents (HSDB, 2007).

The complete combustion of propane results in the formation of carbon dioxide (CO_2) and water vapor, while incomplete combustion can produce carbon monoxide (CO). CO_2 and CO exposures can be harmful, especially in areas that are not well ventilated. High levels of CO_2 in the environment displace oxygen, which can cause hypoxia (oxygen deprivation) or anoxia (complete loss of oxygen) in an exposed person, which can cause coma or death. Moderate levels may cause headaches, dizziness, restlessness, a tingling or pins and needles feeling, difficulty breathing, sweating, tiredness, increased heart rate, and elevated blood pressure (WI DHFS, 2005). CO interferes with the ability of the red blood cells to carry oxygen in the blood. Exposure to moderate levels of CO can cause headache, fatigue, dizziness, and nausea. Exposure to high concentrations of CO can cause coma or death within minutes (CCOSH, 2006). Propane-oxygen devices must emit enough gas to displace oxygen and kill rodents; however, there are no indications that humans operating the device would be at risk of asphyxiation or other effects from high CO/CO_2 exposure because the reactions take place underground and the gases likely dissipate into outdoor air (Sullins and Sullivan, 1992).

<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)).

Propane is released into the environment from manufacturing and disposal of petroleum and natural gas products. However, as discussed in response to Evaluation Question #4, propane is not persistent in soil as it is readily broken down by soil microorganisms within 24 hours. Propane gas also has a relatively rapid breakdown in the air with a half life of 14 days. In aquatic organisms, propane is expected to have a low bioconcentration potential (HSDB, 2007).

Misuse, incorrect storage, or accidents (e.g., during transportation) involving propane may result in fire or explosions due to its flammability and its reactivity with oxygen.

<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)).

Propane is highly reactive with oxygen at high pressure (causing a combustion reaction). It can also react vigorously with oxidizing materials such as bromine, chlorine, or fluorine. An explosive reaction occurs when propane is combined with chlorine dioxide (HSDB, 2007). No interactions between propane and other common substances used in agriculture were identified.

<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)).

The petitioned method of collapsing burrows using propane may injure or kill nontarget species occupying or living nearby the treated burrows. It may also cause fires if the nearby vegetation is dry (Sullins and Sullivan, 1992).

The force produced by the propane/oxygen reaction may disturb the soil and soil organisms due to the concussive forces and/or loud noises generated. However, the likelihood and extent of these disturbances is unclear. If a fire is produced from the propane explosion, soil structure may be altered and soil organic matter may be lost or consumed. Reduced soil porosity and increased soil pH due to alterations in soil chemistry may also be expected. These effects can indirectly affect water retention of the soil and increase erosion. Depending upon the severity, duration, and other characteristics of the fire, soil damage can be slight to more severe; in most cases, the effects of fire are minor and short-lived (BCMAFF, 2004). Because propane is readily degraded by soil bacteria, soil disturbance related to propane itself would not be expected.

<u>Evaluation Question #9:</u> Discuss and summarize findings on whether 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 discussed in Evaluation Question #4, propane has moderate mobility in soil and is readily degraded by soil microorganisms within 24 hours. Most propane exists as a gas in the air, where it is broken down by hydroxyl radicals and has a half life of about 14 days (HSDB, 2007). Propane is considered relatively nontoxic when released into the environment. However, the method that uses propane to explode rodent burrows may kill nontarget species within or in close proximity to the burrows. As discussed in Evaluation Question #8, the concussive forces and potential fires caused by propane explosions may damage surrounding plant life and disturb soil structure and soil communities.

<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)).

Humans exposed to propane at inhaled concentrations of 250–1,000 ppm (up to 8 hours/day for 2 weeks) exhibited no notable physiological effects. However, at concentrations of 100,000 ppm, subjects suffered central nervous system depression expressed by distinct vertigo in under 15 minutes. If liquid propane comes in contact with the skin, it can cause burns and frostbite. Case studies of high propane exposure (both accidental and deliberate) reported other central nervous system effects such as disorientation and death from cardiac effects (HSDB, 2007).

The use of propane/oxygen explosion devices also poses a physical safety risk to the operator. Improper use and/or inadequate safety gear could result in injury from explosion, flying debris, or fire (Meyer Industries, 2010).

Evaluation Question #11: 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)).

One potential alternative would be injection of carbon dioxide gas (CO_2) into burrows. Because CO_2 is heavier than air, it sinks to the bottom of the burrow, displacing oxygen, and suffocating the animals inside. It is unclear, however, if CO_2 would remain at a high enough concentration long enough once injected into the ground to cause death to the target animals (Sullins and Sullivan, 1992). Unlike the propane/oxygen method, this approach does not require explosions, which may be associated with fire and operator safety issues. Commercial systems are available that use an internal combustion engine used to generate CO, but no commercial CO_2 systems have been identified. Traditionally, most CO_2 was sequestered from natural reservoirs in rock formations. It can also be captured from natural gas combustion and new technologies are being developed to capture it from fertilizer, ethanol, and hydrogen plants (DOE, undated). It is unclear if CO_2 from natural reservoirs is available as a commercial source or whether it could be differentiated from a synthetic source.

A synthetic substance that can be used in rodent control is Vitamin D_3, which is listed on the National List for use in crop production as a rodenticide (§ 205.601(g)). Vitamin D_3, also known as cholecalciferol, is the active ingredient in commercially available rodenticide baits. Another substance allowed as a rodenticide under § 205.601(g) is sulfur dioxide. This substance may be used in smoke bombs for underground rodent control only. However, this substance is expected to be removed from the National List after its sunset date of October 21, 2012.

No other chemical alternatives to the petitioned substance were identified. Physical control methods are described in Evaluation Question #12.

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

There are a number of alternative practices to control burrowing rodent populations. For example, ground squirrels and other rodents can be controlled to some degree via trapping (e.g., with humane traps). Trapping is labor intensive but highly effective, especially for a small population of animals (Government of Alberta, 2006). One study (Meerburg et al., 2006) found that live traps, consisting of a wooden bait box filled with nonpoisonous peeled oat, were equally as effective as rodenticides in controlling rodents on 10 farms. The use of natural attrition (i.e., predators such as coyotes and foxes) can also help control burrowing animal populations. Supporting predator habitat, such as building nesting platforms for hawks and other aerial nesters, will encourage the natural predator populations. It is unlikely that natural attrition could control a pest population alone as the overall effect on ground squirrel damage via this method has been described as "not significant." However, it may be effective in combination with other pest management strategies (Government of Alberta, 2006). Because the aforementioned methods are physical, mechanical, and biological, they are allowed by the National Organic Program (NOP) to control pests.

Shooting rodents can also help control populations; however, this is generally considered ineffective for burrowing animals because they seldom come above ground (Andelt and Case, 2006). Flooding burrows can also be helpful for either drowning the animals or forcing them out of their burrows into traps or snares. However, an operator must be careful to avoid flooding near underground structures or building foundations to avoid damage (Cleary and Craven, 2005)

Physical, mechanical, and biological methods are often more successful when combined with an ecologically-based rodent management (EBRM) system. EBRM relies on knowledge of the population biology, social behavior, taxonomy, and community ecology of rodents in establishing appropriate pest management methods. EBRM principles have proven successful in a number of studies in several countries including Vietnam (Singleton et al., 2004; Brown et al., 2000). Tested EBRM systems include most or all of the following: trap-barrier systems, physical destruction of burrows, synchronized planting and harvesting of crops, clean up of weeds and other refuse, and embankment size reduction to discourage burrowing. When these strategies were employed together, EBRM was just as effective as traditional rodent management (e.g., rodenticides), and these strategies often cost less than traditional methods (Singleton et al., 2004; Brown et al., 2000).

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