United States Department of Agriculture
Agricultural Marketing Service | National Organic Program
Document Cover Sheet
https://www.ams.usda.gov/rules-regulations/organic/national-list/petitioned

Document Type:

☐ **National List Petition or Petition Update**

A petition is a request to amend the USDA National Organic Program's National List of Allowed and Prohibited Substances (National List).

Any person may submit a petition to have a substance evaluated by the National Organic Standards Board (7 CFR 205.607(a)).

Guidelines for submitting a petition are available in the NOP Handbook as NOP 3011, National List Petition Guidelines.

Petitions are posted for the public on the NOP website for Petitioned Substances.

☒ **Technical Report**

A technical report is developed in response to a petition to amend the National List. Reports are also developed to assist in the review of substances that are already on the National List.

Technical reports are completed by third-party contractors and are available to the public on the NOP website for Petitioned Substances.

Contractor names and dates completed are available in the report.

Sodium Chlorite, for Generation of Chlorine Dioxide Gas

Handling/Processing

Identification of Petitioned Substance

Chemical Names:
Sodium chlorite
Chlorine dioxide

Other Name:
Chlorite (sodium salt)
Chlorous acid, sodium salt
Chlorite sodium
Chlorine dioxide, monohydrate
Chlorine oxide
Chlorine (IV) oxide
Chlorine peroxide
Chloroperoxyl

Trade Names:
Textone (sodium chlorite)
Textile (sodium chlorite)
Alcide LD (sodium chlorite)
Neo Silox D (sodium chlorite)
Caswell No. 755 (sodium chlorite)
Scentrex™ (sodium chlorite)
Alcide (chlorine dioxide)
Aseptrol (chlorine dioxide)
DioxiClear (chlorine dioxide)
MicroClear (chlorine dioxide)
RenNew-D (chlorine dioxide)
Tristel (chlorine dioxide)

CAS Numbers:
7758-19-2 (sodium chlorite)
10049-04-4 (chlorine dioxide)

Other Codes:
EINECS: 231-836-6 (sodium chlorite)
EINECS: 233-162-8 (chlorine dioxide)
RTECS: VZ 4800000 (sodium chlorite)
RTECS: FO 3000000 (chlorine dioxide)
UN: 1496 (sodium chlorite)
UN: 9191 (chlorine dioxide)
UNII: G538EBV4VF: (sodium chlorite)
UNII: 8061YMS4RM (chlorine dioxide)
ICSC: 1045 (sodium chlorite)
ICSC: 0127 (chlorine dioxide)

Summary of Petitioned Use

Chlorine dioxide (CDO) is currently allowed under the National Organic Program (NOP) regulations at 7 CFR §205.605(b) as a nonagricultural synthetic substance that may be used as an ingredient in or on processed products labeled "organic" or "made with organic (specified ingredients or food group(s) for disinfecting and sanitizing food contact surfaces." Sodium chlorite is not currently listed under NOP regulations; however, acidified sodium chlorite is permitted at 7 CFR §205.605(b) for "secondary direct antimicrobial food treatment and indirect food contact surface sanitizing." The primary use of CDO in organic food processing is as a disinfecting and sanitizing agent, with applications ranging from treatment of food contact surfaces and "facilities and equipment" for organic livestock production, to use as an algicide for preharvest treatment of organic crops. The petition before the NOP is to extend the allowed use of chlorine dioxide gas for use as an antimicrobial agent, sanitizer, and/or disinfectant for the direct treatment of fruits and vegetables. The Federal Food and Drug Administration (FDA) currently permits the application of aqueous chlorine dioxide solutions for antimicrobial disinfection of fruits and vegetables.

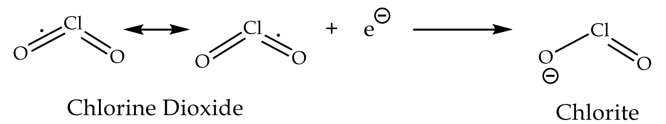
Characterization of Petitioned Substance

Composition of the Substance:

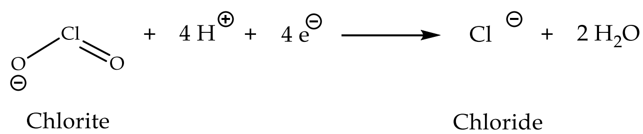
Sodium chlorite is an inorganic salt that exists as a white crystalline solid. It is commercially available as technical grade (80% purity), as well as a premade chlorine dioxide release mixture, where the chlorite salt is impregnated on calcined clay. Sodium chlorite as a solid is slightly hygroscopic (absorbs water).

Chlorine dioxide can be synthetically generated in several ways, most of which use a sodium chlorite precursor, which is activated through oxidation to the neutral radical species.

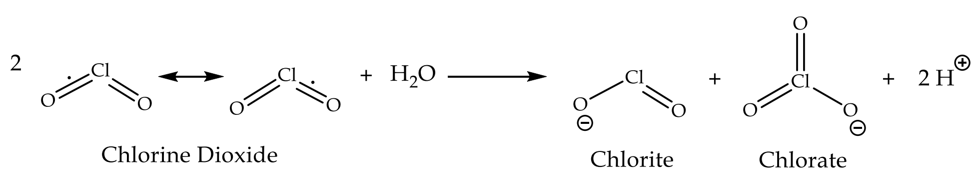
Chlorine dioxide gas is highly reactive, and can be explosive in concentrations greater than 10% (v/v) (ICPS, 2002; WHO, 1998). Chlorine dioxide gas undergoes decomposition by reduction to form chlorite ions (Equation 1). The resulting chlorite remains reactive, and can undergo further reduction to chloride, which is the predominant end-product of chlorine dioxide decomposition (Equation 2). In the absence of a reducing agent (i.e., when CDO is unable to act as an oxidant), it forms decomposition products of chlorite and chlorate ions (Equation 3). With these decomposition reactions in mind, chlorite, chlorate, and chloride are all potential by-products for the use of chlorine dioxide gas (JECFA, 2008).



Equation 1



Equation 2



Equation 3

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

Several industrial synthetic procedures are used in the production of sodium chlorite, which include the following: the treatment of chlorine dioxide with sodium hydroxide and a reducing agent (e.g., sodium sulfite), the treatment of chlorine dioxide with sodium peroxide (Na_2O_2), or an alkaline solution of hydrogen peroxide (H_2O_2).

Due to the reactivity of chlorine dioxide (CDO) gas, and its explosive nature when concentrated, CDO is generated on-site prior to required usage. There are several methods for the generation of CDO gas from sodium chlorite, all of which involve the oxidation of the chlorite ion to the neutral radical species. This oxidation process can be completed by treatment with H^+ from an acid, or electrochemically by the electrolysis of a sodium chlorite solution, and by treatment with chlorine gas (Cl_2).

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

The properties of calcium carbonate are summarized in Table 1.

Table 1. Properties of Sodium Chlorite and Chlorine Dioxide

Property	Sodium Chlorite	Chlorine Dioxide
CAS registry number	7758-19-2	10049-04-4
Molecular formula	$NaClO_2$	ClO_2
Molecular weight	90.45 g/mol	67.46 g/mol
Color	White crystalline solid (80% technical grade, slightly hygroscopic)	Greenish yellow to orange gas
Density/Specific gravity	Crystal: 2.468 g/cm^3	1.765 g/cm^3 at -56 °C

	1.642 at 0 °C	1.62 g/cm^3 at -11 °C
Melting point	180 – 200 °C, decomposes at melting point	-59 °C
Boiling point	No data	11 °C
Water solubility	39 g/L at 30 °C	3.0 g/L at 25 °C and 34 mmHg

Sources: Budavari, 1989; FSANZ, 2003; PubChem 24870; PubChem 23668197
Specific Gravity = Ratio of the density of a substance compared to the density of a reference substance (e.g., water).

Specific Uses of the Substance:

Chlorine dioxide (CDO) is well known for its antimicrobial effects through oxidative inactivation (Stubblefield et al., 2014; Lee et al., 2015; Park et al., 2017). When used as a fumigation agent, there are no residual traces of the CDO disinfectant, or disinfection by-products (DBP) of chlorite and chlorate, as identified in equations 1 and 3 (JECFA, 2008). The efficacy of CDO gas against a wide range of microorganisms has been demonstrated in several studies across a variety of fruits and vegetables (Gomez-Lopez et al., 2009; Goodburn et al., 2013; Park et al. 2015; Lee et al., 2015). These studies also relate the increased efficacy of CDO in gas form, compared to its use in aqueous solution, which is primarily due to the increased penetration of the gas treatments, as well as the ability to effectively treat irregular surfaces (Subblefield et al., 2014; Lee et al. 2015; Park et al., 2017).

The current allowed usage for chlorine dioxide in organic food processing is as a disinfection and sanitizing agent for food contact surfaces, facilities, and equipment for crop and livestock production, as well as for the processing of "organic" or "made with organic" ingredients and food groups (7 CFR §205.601(a), 205.603(a), and 205.605(b)). However, CDO is an active disinfectant produced by the acidification of sodium chlorite, which is permitted at 7 CFR §205.605(b) as "secondary direct antimicrobial food treatment and indirect food contact surface," with the exception that acidification must be completed with citric acid. This petition is to extend the use of CDO in gaseous form for the antimicrobial treatment of products labeled "organic" or "made with organic (specified ingredients or food group(s))."

CDO is permitted by the FDA as an antimicrobial treatment for a range of food products, including fruits and vegetables and poultry processing (21 CFR §173.300). CDO is also used as bleaching agent in both flour and whole wheat flour (21 CFR §137.105(a) and 137.200(a)). CDO is also widely used in the sanitation and treatment of water systems, and is allowed by the FDA as a disinfectant in bottled water (21 CFR §165.110(b)).

Beyond treatment of food and agricultural products, CDO is also widely used in the paper industry for the bleaching of cellulose and paper pulp (EPA, 2000; Gomez-Lopez et al., 2009), and for the treatment of medical and hazardous waste (40 CFR §268.42(a)).

Approved Legal Uses of the Substance:

The FDA has approved the usage of sodium chlorite at 21 CFR §186.1750(b) as "a slimicide in the manufacture of paper and paperboard that contact food," at levels of 125 – 250 ppm. Sodium chlorite is also approved for use as an adhesive with no limitations (21 CFR §175.105(c)), the bleaching of "food starch-modified," with levels "not to exceed 0.5 percent." (21 CFR 172.892(b)).

Sodium chlorite is a major component of acidified sodium chlorite (ASC). ASC is permitted by the FDA at 21 CFR §178.1010(b) for antimicrobial "use on food processing equipment and utensils," and "dairy processing equipment." ASC is also permitted by the FDA for antimicrobial use with generally recognized as safe (GRAS) acids for the antimicrobial treatment of poultry, and as a component of ASC, which is used to treat fruits and vegetables, poultry, red meat, seafood, and raw agricultural products (21 CFR §173.325).

The FDA has also permitted chlorite as an allowed residual disinfectant in bottled water, with a maximum concentration of 1.0 mg/L (21 CFR §165.110(b)).

The USDA NOP has approved the usage of ASC at 7 CFR §205.605(b) as a synthetic for "secondary direct antimicrobial food treatment and indirect food contact surface sanitizing. Acidified with citric acid only," for "processed products labeled as "organic" or "made with organic (specified ingredients or food group(s))."

Chlorine dioxide is permitted for the safe use in food "as an antimicrobial agent in water used in poultry processing," and to "wash fruits and vegetables that are not raw agricultural commodities in an amount not to exceed 3 ppm residual chlorine dioxide," with the exception that "treatment of fruits and vegetables with chlorine dioxide shall be followed by a potable water rinse or by blanching, cooking, or canning" (21 CFR 173.300(b)). CDO is permitted by the FDA for the "bleaching and artificial aging" of flour and whole wheat flour, "in a quantity not more than sufficient" (21 CFR §137.105(a) and 137.200(a)). CDO has also been approved at 21 CFR §178.1010(b) for use as a component of aqueous solutions, with a minimum concentration of 100 ppm, and a maximum concentration of 200 ppm, for use "on food-processing equipment and utensils, and on other food-contact articles." The FDA has also permitted CDO as an allowed residual disinfectant in bottled water, with a maximum concentration of 0.8 mg/L (21 CFR §165.110(b)).

The current allowed usage for chlorine dioxide in organic food processing is as a disinfection and sanitizing agent for food contact surfaces, facilities, and equipment for crop and livestock production, and for the processing of "organic" or "made with organic" ingredients and food groups (7 CFR §205.601(a), 205.603(a), and 205.605(b)).

The EPA permits the use of CDO at 40 CFR §180.940(b) and (c) as an ingredient in "an antimicrobial pesticide formulation [that] may be applied to: Dairy processing equipment, and food-processing equipment and utensils," when the "end-use concentration is not to exceed 200 ppm."

The EPA also permits the use of CDO as a disinfecting and sanitizing agent for water systems. The EPA includes CDO as a component of "total chlorine," which is required for public water systems that do not use filtration (40 CFR §141.72(a)). Under these EPA regulations there is a maximum disinfectant level goal of 0.8 mg/L of chlorine dioxide (40 CFR §141.54 and 141.65). The EPA allows the use of CDO as an agent for the "chemical or electrolytic oxidation" of medical and hazardous wastes (40 CFR §268.42(a)).

The EPA allows the use of CDO as a bleaching agent in the paper pulping process (40 CFR §430.01).

Action of the Substance:

Chlorine dioxide gas, as generated from sodium chlorite, acts as an antimicrobial agent whose mode of action is not entirely understood. The most accepted explanations of the activity of CDO are in relation to the disruption of protein synthesis, and the loss of permeability controls of cellular walls and membranes (EFSA, 2008; Gomesz-Lopez et al., 2009; Park et al., 2015; Meireles at al., 2016). These disruptions to cellular processes are due to the oxidation strength of CDO, which upon reaction is primarily reduced to chlorite (Equation 1). The resulting disinfection by-product chlorite remains reactive, and when in contact with electron-rich species (i.e., organic matter), is further reduced to chloride ions (Equation 2). CDO is effective for the inactivation of bacteria, viruses, and protozoa over a wide pH range (Neal et al., 2012; Yang et al., 2013; Stubblefield et al., 2014; Park et al., 2015).

Several studies have indicated that gaseous CDO treatments are as, or more, effective than aqueous treatments. The increase in efficacy of gaseous CDO has been attributed to increased penetration ability, which is especially important for the treatment of biofilms, and improved contact with irregular surfaces (Stubblefield et al., 2014; Park et al., 2015; Park et al., 2017). CDO has also been documented as having a synergistic effect with high relative humidity, which is likely due to the stability and high solubility of the gas in aqueous solution (Park et al., 2015; Park et al., 2017; Visvalingam et al., 2017).

Combinations of the Substance:

Sodium chlorite, for use in the generation of chlorine dioxide gas, is available in several combinations. Sodium chlorite is available as a white crystalline solid (80%, technical grade). Technical grade sodium chlorite may be used in combination with citric acid to form acidified sodium chlorite, which is identified on the National List. Treatment of solid sodium chlorite with an acid also results in the generation of the petitioned substance, chlorine dioxide gas. Alternatively, solid sodium chlorite may be oxidized with chlorine (Cl_2) gas, resulting in the generation of chlorine dioxide gas.

Sodium chlorite is also marketed in the form of sachets, in which the sodium salt is impregnated in a zeolite, such as calcined clay. Sodium chlorite impregnated zeolites can then be treated with solid or liquid acids to generate CDO gas. If a liquid acid is used, an unspecified buffer is also present to control the formation and release of the chlorine dioxide gas (NOSB, 2016).

Status

Historic Use:

Aqueous chlorine dioxide has historically been used in organic agricultural production as a disinfectant and sanitizer for facilities, equipment, and utensils due to its antimicrobial properties. Within organic agricultural production, chlorine dioxide has also been a component of the antimicrobial solutions derived from acidified sodium chlorite (ASC). ASC has been used as an antimicrobial treatment of fruits and vegetables when acidified with citric acid, and followed by treatment of the product to remove residual disinfectant and by-products. (7 CFR §205.605(b)).

Within non-organic agricultural production, CDO is also used for the antimicrobial treatment of poultry, and as a component of ASC, is used for treatment of fruits and vegetables, poultry, red meat, seafood, and raw agricultural products (21 CFR §173.325).

Organic Foods Production Act, USDA Final Rule:

Neither sodium chlorite nor chlorine dioxide are listed in the Organic Foods Production Act of 1990.

Sodium chlorite is listed in the USDA organic regulations at 7 CFR §205.605(b) as an allowed synthetic under "Acidified sodium chlorite," and is approved as a "secondary direct antimicrobial food treatment and indirect food contact surface sanitizing. Acidified with citric acid only."

Chlorine dioxide is listed in the USDA organic regulations at 7 CFR §205.601(a) as an allowed synthetic substance for organic crop production, with the exception that "residual chlorine levels in the water in direct crop contact or as water from cleaning irrigation systems applied to soil must not exceed the maximum residual disinfectant limit under the Safe Drinking Water Act." CDO also appears in 7 CFR §205.603(a) as an allowed substance for the "disinfecting and sanitizing facilities and equipment," used in organic livestock production. CDO is also listed in USDA organic regulations at 7 CFR §205.605(b) as an allowed synthetic material for "disinfecting and sanitizing food contact surfaces."

International

Canadian General Standards Board Permitted Substances List

Sodium chlorite is not listed in CAN/CGSB-32.311-2015.

Chlorine dioxide is listed in CAN/CGSB-32.311-2015, Table 7.3 "Food-grade cleaners, disinfectants and sanitizers permitted without a mandatory removal event," with the exception that CDO levels do not exceed maximum levels for safe drinking water, Table 7.4. "Cleaners, disinfectants, and sanitizers permitted on organic product contact surfaces for which a removal event is mandatory," with permission for use "up to maximum label rates."

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

Neither sodium chlorite nor chlorine dioxide are listed in the GL 32-1999 CODEX.

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

Neither sodium chlorite nor chlorine dioxide are listed in EC No. 834/2007 and 889/2008.

Japan Agricultural Standard (JAS) for Organic Production

Neither sodium chlorite nor chlorine dioxide are listed in the JAS for Organic Production.

International Federation of Organic Agriculture Movements (IFOAM)

Sodium chlorite is not listed in the IFOAM Norms.

Chlorine dioxide is listed in the IFOAM Norms in Appendix 4, Table 2, "Indicative List of Equipment Cleansers and Equipment Disinfectants," with a limitation of "an intervening event or action must occur to eliminate risks of contamination."

Evaluation Questions for Substances to be used in Organic Handling

Evaluation Question #1: 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)).

Sodium chlorite is manufactured from the chemical or electrochemical reduction of sodium chlorate—in the presence of hydrochloric acid (HCl)—resulting in the formation of chlorine dioxide. The synthesized chloride dioxide is then reacted with hydrogen peroxide (H_2O_2) and aqueous sodium hydroxide (NaOH) (21 CFR §186.1750(a)), producing an aqueous solution of 30 – 50% sodium chlorite. The solution can then be dried to yield solid sodium chlorite, or further diluted to obtain aqueous solutions of a desired concentration (JECFA, 2007).

Chlorine dioxide can be manufactured in a variety of ways, most of which are derived from the treatment of a sodium chlorite precursor with an activator (i.e., oxidant). As stated in the above description of the manufacture of sodium chlorite, chlorine dioxide may also be formed by the chemical or electrochemical reduction of chlorate ions (ClO_3^-) in the presence of hydrochloric acid (HCl) (JECFA, 2007).

Due to the reactive nature of CDO, and its propensity for explosion when concentrated, it is generated on-site at the point-of-use, and is typically generated by the activation of sodium chlorite (Gomez-Lopez et al., 2009; Lee et al., 2015). CDO may be generated by the treatment of sodium chlorite with chlorine gas (Cl_2), which is the most common industrial means for the formation the petitioned substance (JECFA, 2008; EFSA, 2008; Lee et al., 2015; Clordisys, 2016; Meireles et al., 2016). CDO may also be generated by the treatment of sodium chlorite with H^+. This acid may by hydrochloric, or any other acid, and may be introduced in both solid and solution forms (Lee et al., 2015; Meireles et al., 2016; EFSA, 2016, NOSB, 2016; Visvalingam, 2017). Furthermore, the H^+ may be produced electrochemically by the electrolysis of an aqueous sodium chlorite solution (Yu et al., 2014; EFSA, 2016).

Evaluation Question #2: 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)). Discuss whether the petitioned substance is derived from an agricultural source.

Sodium chlorite and the subsequently generated chlorine dioxide gas are synthetic materials made by chemical processes, and are not created by naturally occurring biological processes. Neither sodium chlorite nor chlorine dioxide are derived from agricultural sources. The manufacture of both sodium chlorite and chlorine dioxide are described above in **Evaluation Question #1**.

The ability to produce the desired CDO gas from sodium chlorite with any acid allows for the selection of one of several GRAS acid sources (e.g., citric acid).

Evaluation Question #3: If the substance is a synthetic substance, provide a list of nonsynthetic or natural source(s) of the petitioned substance (7 CFR § 205.600 (b) (1)).

There is no published literature that indicates the presence of a natural or non-synthetic source of the petitioned substance. Due to the instability of the generated CDO species, it is not long-lived. Likewise, its precursor and major initial decomposition product (chlorite) is also reactive, and is further reduced to chloride (Cl^-), as seen in Equation 2.

Evaluation Question #4: Specify whether the petitioned substance is categorized as generally recognized as safe (GRAS) when used according to FDA's good manufacturing practices (7 CFR § 205.600 (b)(5)). If not categorized as GRAS, describe the regulatory status.

Sodium chlorite has been designated by the FDA as generally recognized as safe (GRAS) at 21 CFR §184.1750(b), and is allowed as an "ingredient used at levels from 125 to 250 parts per million as a slimicide in the manufacture of paper and paperboard that contact food."

Chlorine dioxide is not listed in the FDA as GRAS. However, the generation of CDO from sodium chlorite in calcined or sulfated kaolin clay, or from the combination of particles of sodium polyphosphate, magnesium sulfate, sodium silicate, and sodium chlorite incorporated into low density polyethylene, do appear in the FRA GRAS inventory (GRN 000161; GRN 000062).

Evaluation Question #5: Describe whether the primary technical function or purpose of the petitioned substance is a preservative. If so, provide a detailed description of its mechanism as a preservative (7 CFR § 205.600 (b)(4)).

The primary request for the petitioned substance is for the allowed use of chlorine dioxide gas in organic food processing as a disinfecting/sanitizing antimicrobial agent for direct food contact with agricultural products such as fruits and vegetables.

While this request does not indicate the primary use of CDO as a preservative, there have been literature reports that indicate treatment of fruits and vegetables with CDO gives preservative qualities by increasing the shelf-life of products. This action is likely due to the inactivation of microorganisms that facilitate food spoilage (Gomez-Lopez et al., 2009; NOSB, 2016; EFSA, 2016).

Evaluation Question #6: Describe whether the petitioned substance will be used primarily to recreate or improve flavors, colors, textures, or nutritive values lost in processing (except when required by law) and how the substance recreates or improves any of these food/feed characteristics (7 CFR § 205.600 (b)(4)).

There is no published literature that indicates that the use of either sodium chlorite or chlorine dioxide treatments act to recreate or improve flavors colors, texture, or nutritive values in products. However, chlorine dioxide is allowed by the FDA as a "bleaching and artificial aging" agent for both flour and whole wheat flour at 21 CFR §137.105(a) and 137.200(a).

Evaluation Question #7: Describe any effect or potential effect on the nutritional quality of the food or feed when the petitioned substance is used (7 CFR § 205.600 (b)(3)).

There are no direct reports in the literature that link CDO applications to degradation of the nutritional quality of the treated products. While the reactivity of CDO with phenolic species has the potential to impact the content of phytochemicals in treated products, there have been no studies that document phytochemical degradation (Gomez-Lopez et al., 2009). A study has shown CDO to be unreactive towards amino acids (EFSA, 2005), and in general, the literature supports that CDO is unreactive toward the nutritional content of treated products (Gomez-Lopez et al., 2009; EFSA, 2005; NOSB, 2016).

<u>Evaluation Question #8:</u> List any reported residues of heavy metals or other contaminants in excess of FDA tolerances that are present or have been reported in the petitioned substance (7 CFR § 205.600 (b)(5)).

Since the source of sodium chlorite for CDO generation can vary, there is the potential for heavy metal contamination within the sodium chlorite precursor. The solid is manufactured to an 80% purity as 'technical grade,' and in general, no purification steps are documented. While the remaining 20% is likely to be other sodium salts (i.e., sodium chloride, sodium carbonate, etc.), the lack of purification steps does not rule out the presence of heavy metal contaminants (e.g., lead), although lead would be limited by manufacture specifications to 5 mg/kg (JECFA, 2007a). However, there have been no reports of the presence of heavy metals or other contaminants in the petitioned substance.

Despite the potential for trace heavy metal contaminants, the generation and application of chlorine dioxide as a gas results in trace impurities remaining in the sachet, or gas generator—meaning that they will not contact the food surface. This is in direct comparison with the use of aqueous solutions of CDO, such as ASC, which may result in a transfer of trace impurities to food surfaces (Clordisys, 2016).

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

When used as petitioned, neither sodium chlorite nor chlorine dioxide are expected to have a negative impact on the environment or biodiversity. Due to the reactive nature of gaseous CDO, it is not expected to persist or bioaccumulate in the environment (NOSB, 2016). As seen in Equations 1 and 3, CDO rapidly decomposes to chlorite (ClO_2^-) and chlorate (ClO_3^-), with the final endpoint being chloride (Cl^-) (GRN 000161; JECFA, 2007a; Lee et al., 2015; Clordisys, 2016; Park et al., 2017). Chloride is prevalent in nature and physiology, and therefore, will not provide an adverse impact at anticipated concentrations (WHO, 2000).

Due to the high reactivity of both CDO gas and its chlorite by-product, residual CDO, chlorite, and chlorate concentrations are below those observed for approved aqueous treatments using CDO or ASC in solution, and residual concentrations are often below the analytical limit of detection (LOD) (GRN 000161; Gomez-Lopez et al., 2009; Stubblefield et al., 2014). Due to the lack of appreciable residues of chlorine dioxide, chlorate, or chlorite post CDO gas treatment, there is no need for the potable water rinse that is currently requited for aqueous treatments, such as with ASC. The ability to eliminate the requirement for the post-treatment rinse allows for a reduction in waste water effluent, further protecting environmental concerns (NOSB, 2016; Clordisys, 2016).

Years of CDO use for water treatment have had no reported adverse environmental effects, and the proposed methods in this petition would use lower concentrations than present in water treatment applications (Gomez-Lopez et al., 2009). CDO has also been documented as facilitating oxidation, rather than chlorination processes. Importantly, this results in the absence of trihalomethanes (THMs), which are documented environmental hazards and carcinogens.

Despite the anticipation of low levels of persisting CDO and subsequently formed chlorite, both substances have been documented as being dangerous to aquatic environments (FDA, 2006). However, environmental studies show that the LC_{50}s for a range of aquatic species are higher than the anticipated concentrations for the petitioned substances, which, combined with the reported facile degradation of CDO and sodium chlorite, indicate that concentrations of the substances in the environment will be insignificant compared to background environmental concentrations.

<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)).

Chlorine dioxide is a known respiratory irritant, and irritant of the eyes and mucus membranes; however, due to lack of study, required concentrations for irritation are not well defined (WHO, 2000; IPCS, 2002; NOSB, 2016). The Occupational Safety and Health Administration (OSHA) has designated CDO as an air contaminant, and has established a short-term exposure limit of 0.3 ppm during any 15-minute period of a 10-hour workday, or a permissible exposure limit of 0.1 ppm for a time-weighted average over an 8-hour workday (29 CFR §1910.1000). However, as stated above in **<u>Evaluation Question #9</u>**, CDO is highly reactive, and is expected to rapidly decompose, making CDO exposure possible only for isolated on-site incidents.

Due to the rapid decomposition of CDO, it is unlikely to result in the formation of any human health effects. As seen in Equations 1 and 3, CDO rapidly decomposes to chlorite (ClO_2^-) and chlorate (ClO_3^-), with the final endpoint being chloride (Cl^-) (GRN 000161; JECFA, 2007a; Lee et al., 2015; EFSA, 2016; Clordisys, 2016; Park et al., 2017). Chloride is prevalent in nature and physiology, and therefore, will not provide an adverse impact at anticipated concentrations.

Both chlorite and chlorate are readily absorbed in the body; however, due to the physiological prevalence of chloride in the body, there are no reliable analytical methods to track their metabolism (EPA, 2000; WHO, 2000). Current studies suggest that following ingestion both oxychloro anions are reduced to chloride, which is excreted in urine (EPA, 2000). Furthermore, the estimated intake values anticipated of chlorite and chlorate are well below the no-observed-adverse-effect-level (NOAEL) of 30 mg/kg as identified by the WHO (WHO, 2000).

Neither chlorate, chlorite, nor CDO have been characterized as carcinogens (EPA, 2000; IPCS, 2002; Gomez-Lopez et al., 2009). CDO has also been documented as facilitating oxidation, rather than chlorination processes. Importantly, this results in the absence of trihalomethanes (THMs), which are documented environmental hazards and carcinogens.

The European Food Safety Authority (EFSA) has recently reviewed the possible effect of antimicrobial treatments for the emergence of antimicrobial resistance, and have reported that there are no documented cases of antimicrobial resistance from CDO treatments (EFSA, 2008).

Due to the low persistence of CDO, chlorite, and chlorate residues following product treatments with gaseous CDO, risks to human health due to implementation of antimicrobial CDO treatments are minimal (GRN 000161; Gomez-Lopez et al., 2009; Stubblefield et al., 2014; Park et al., 2017).

<u>Evaluation Question #11:</u> Describe any alternative practices that would make the use of the petitioned substance unnecessary (7 U.S.C. § 6518 (m) (6)).

Non-chemical treatments for inactivation of microorganisms are prevalent in the literature. These methods include irradiation with UV or pulsed light, as well as ionizing radiation, which has been regarded as among the most effective inactivation treatments (Ramos et al., 2013; Meireles et al., 2016).

Given the importance of fruits and vegetables to a balanced nutritional diet, the safeguarding of these products for consumption is paramount. With the possibility of contamination at several points along the supply chain—from growth/production, to processing and distribution—effective disinfection techniques are important to maintain the safety of agricultural products from foodborne pathogens, which is even more important given that these products may be consumed raw. Based on this information, in concert with studies that show water washes alone do no significantly reduce the prevalence of foodborne pathogens, alternatives to microorganism safeguards are not recommended (Neal et al., 2012; Goodburn et al., 2013; Ramos et al., 2013; Park et al., 2015; Meireles et al., 2016).

Evaluation Question #12: 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)).

Acids (Alginic, Citric, and Lactic)

Weak organic acids (e.g., alginic, citric, and lactic acids) are permitted under USDA NOP regulations at 7 CFR §205.605(a). Many organic acids also have widespread consumer approvals and GRAS status with the FDA and European Commission (EC) (Meireles et al., 2016). They have documented antimicrobial ability due to environmental pH reduction, which result in disturbances to membrane permeability, anion accumulation, and reduction of intracellular pH resulting interference to nutrient transport and macromolecular synthesis (Parish et al., 2003; WHO, 1998; Inatsu et al., 2005; and Miller et al., 2009).

However, the use of acids as disinfecting and sanitizing agents may result in changes to the organoleptic properties of the products, including flavor and other sensations (Meireles et al., 2016). The use of organic acids also may provoke corrosion in processing equipment, and has a high associated cost of use. The application of organic acids, such as citric acid, also requires a dramatic increase in concentration of the disinfectant ($5 \times 10^3 - 1 \times 10^4$ ppm for citric acid compared to < 200 ppm for CDO) (Meireles et al., 2016).

Enzymes

Enzyme's mode of action is the direct attack on the developmental processes of biofilms, and in the process catalyze the formation of antimicrobial agents, making them an effective means of biofilm inactivation and removal (Simones et al., 2010, Thallinger et al., 2013; Meireles et al., 2016).

However, the heterogeneous nature of enzyme treatments, coupled with the long treatment times required, limit their effectiveness as a standalone treatment option (Augustin et al., 2004; Lequette et al., 2010; Meireles et al., 2016).

Microorganisms

Microorganisms can be used as a means of eliminating foodborne pathogens, primarily by introduction of beneficial microorganisms, which compete for resources with pathogenic microorganisms (Ramos et al., 2013). Among the most prevalent microorganisms used for the prevention of pathogenic organisms is lactic acid bacteria (LAB). LAB not only competes for resources, but also produces antibacterial chemicals, such as organic acids and bacteriocins—most predominantly nisin (Rogers, 2008). While the application of microorganisms offers a promising alternative to chemical treatments, their uses are organism specific, and further research is required before their applications as disinfecting and sanitizing treatments are industrially viable (Ramos et al., 2013; Ling et al., 2015; Meireles et al., 2016).

Evaluation Information #13: Provide a list of organic agricultural products that could be alternatives for the petitioned substance (7 CFR § 205.600 (b) (1)).

There are no direct reports in the literature that offer the use of an organic agricultural product (7 CFR §205.600(b)) as a viable alternative to the disinfection and sanitizing qualities of CDO gas generated from activation of sodium chlorite.

Report Authorship

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

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

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