

# Calcium Chloride

## Crops

### Identification of Petitioned Substance

1		
2	<b>Chemical Names:</b>	<b>CAS Number:</b>
3	Calcium chloride; Calcium dichloride	10043-52-4 (anhydrous)
4		22691-02-7 (monohydrate)
5	<b>Other Names:</b>	10035-04-8 (dihydrate)
6	CaCl <sub>2</sub> ; CalChlor, Caliac, Dichlorocalcium,	25094-02-4 (tetrahydrate)
7	Huppert's reagent, ice melt, Isocal liquical,	7774-34-7 (hexahydrate)
8	Marley cement accelerator	
9		<b>Other Codes:</b>
10	<b>Trade Names:</b> Briner's Choice, Calcimax, Cor-	CHEBI: 3312
11	Clear, DowFlake, Hi-Cal, Liquical, Jarcal, Tetra	EINECS: 233-140-8
12	80, Unichem CalClor	ICSC: 1184
		InChi: 1S/Ca.2ClH/h;2*1H/q+2;/p-2
		InChi Key:
		UXVMQQNJUSDDNG-UHFFFAOYSA-L
		INS: 509
		RTECS: EV9800000
		UNII: M410D6VV5M

### Summary of Petitioned Use

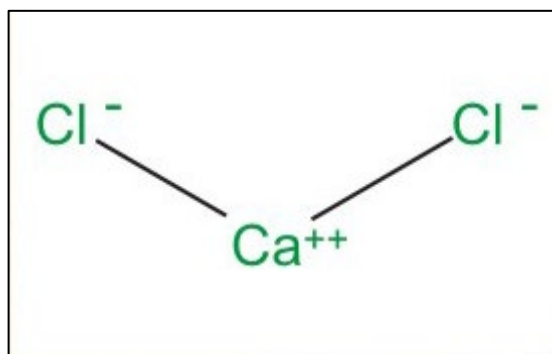
Calcium chloride appears on the National List of nonsynthetic substances prohibited for use in organic crop production. The brine process is natural and prohibited for use except as a foliar spray to treat a physiological disorder associated with calcium uptake [7 CFR 205.602(c)]. This Technical Report was requested by the National Organic Standards Board (NOSB) Crops Committee in support of its sunset review of this listing.

Removal of the substance from the National List would remove the prohibition, render the annotation moot, and effectively allow all uses of nonsynthetic calcium chloride in organic crop production without any limitations. Thus, evaluation of applications of calcium chloride that go beyond the current annotation are included for consideration. Removal of the annotation would prohibit all uses in the crops scope without exception. Reclassification of calcium chloride obtained by the brine process as "synthetic" would also prohibit all uses without exception unless added to the list of allowed synthetics.

### Characterization of Petitioned Substance

#### **Composition of the Substance:**

Calcium chloride is an inorganic salt with the molecular formula CaCl<sub>2</sub>. It can form mono-, di-, tetra-, and hexahydrates (O'Neil, 2013).

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36**Figure 1. Chemical Structure Depiction of Calcium Chloride**

Source: (US NLM, 2020)

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55**Source or Origin of the Substance:**

Commercial calcium chloride is produced by one of three methods: from natural brine deposits that have a high level of calcium chloride, by the Solvay process, and by the hydrochloric acid method. These three difference sources are explained in greater detail under *Evaluation Question #2*.

There are also natural terrestrial deposits in some locations in the world, but these are relatively rare, and the calcium chloride is difficult to recover and refine. Among the ores that contain natural calcium chloride are antarctite (a hexahydrate form discovered in Antarctica), ghiaraite (a volcanic tetrahydrate form), chlorocalcite (a potassium-calcium chloride salt that is also volcanic), sinjarite (a dihydrate form found in Iraq and Turkmenistan), and tachyhydrite (a magnesium-calcium chloride salt) (Hudson Institute of Mineralogy, 2020). Sea water contains approximately 0.15% calcium chloride (Patnaik, 2003).

**Properties of the Substance:****Table 1. Physical and Chemical Properties of Calcium Chloride†**

<b>Property</b>	<b>Characteristic / Value</b>	<b>Source</b>
Molecular Formula	CaCl <sub>2</sub>	(O'Neil, 2013)
Molecular Weight	110.98 g/mol	(O'Neil, 2013)
Percent Composition	Ca: 36.11 percent, Cl: 63.89 percent	(O'Neil, 2013; Patnaik, 2003)
Color	Colorless or white to off-white	(Inchem, 2012; US NLM, 2020)
Physical state at 25°C / 1 Atm.	Cubic crystals, flakes, granules, powder, or fused masses	(O'Neil, 2013; Vrana, 2014)
Melting point	772-782°C	(Inchem, 2012; O'Neil, 2013; US NLM, 2020; Vrana, 2014)
Boiling point	1,670-1,935°C	(Inchem, 2012; Patnaik, 2003; US NLM, 2020)
Solubility in water	0.745 g / mL @ 20°C	(US NLM, 2020)
Solubility in ethanol	0.258 g / mL @ 20°C	(Kiper, 2020)
Heat of solution	-81.85 kJ / mol	(Vrana, 2014)
Density at 25°C	2.2 g / cm <sup>3</sup>	(Inchem, 2012)
Specific gravity at 25°C and 4°C	2.16	(Vrana, 2014)
Electrical conductivity	0.39-4.06 M	(Sun & Newman, 1970)
Viscosity at 787°C	3.34 mPa s	(Kiper, 2020)

†Data are for the anhydrous form.

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58 Minor impurities, particularly sodium chloride, will cause the physical properties to vary. Calcium  
59 chloride is freely soluble in water, with liberation of much heat (O'Neil, 2013). Additional ecological  
60 toxicity information is provided in Table 3 under *Evaluation Question #9*.

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62 **Specific Uses of the Substance:**

63 In the United States, the main use of calcium chloride is on roads for de-icing and dust control (Kemp &  
64 Keegan, 2012). De-icing accounts for about 30 percent of the calcium chloride used in the United States, and  
65 dust control and road stabilization account for another 25 percent (Vrana, 2014). The anhydrous form is  
66 hygroscopic, and is used as a drying, dehydrating, or desiccating agent (O'Neil, 2013).

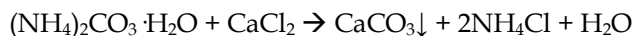
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68 The only permitted use of calcium chloride in organic crop production is as a source of soluble, available  
69 calcium that is applied to foliage to correct calcium deficiencies (Swezey et al., 2000). Apples (*Malus*  
70 *domestica*) are the primary crop on which it is used, for the purpose of preventing the physiological  
71 disorder known as bitter pit. Pears (*Pyrus* spp.) deficient in calcium also respond favorably to calcium  
72 chloride treatments (Prasad et al., 2015). Calcium chloride is sometimes used to prevent or treat the  
73 physiological disorder known as blossom end rot in tomatoes (*Lycopersicon esculentum*), pepper (*Capsicum*  
74 *annuum*), eggplant (*Solanum melongena*), and watermelon (*Citrullus lanatus*) (Taylor & Locascio, 2004).  
75 However, excess chlorine is correlated with increased incidences of blossom end rot and black spotting on  
76 fruit (Geilfus, 2018). Various subtropical and tropical fruit – such as lychee (*Litchi chinensis*) and papaya  
77 (*Carica papaya*) – may also be treated. Other diseases linked to calcium deficiencies are tip burn in lettuce  
78 (*Lactuca sativa*) and black heart in celery (*Apium graveolens*) (De Freitas et al., 2016; Simon, 1978). Calcium  
79 chloride solution completely suppressed tip burn induced in lettuce grown in growth chambers (Misaghi &  
80 Grogan, 1978). A University of Hawaii extension publication recommended spraying calcium chloride as  
81 one effective treatment for black heart control in celery (Nakagawa, 1957).

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83 Other agricultural uses include the stabilization of ammonia nitrogen. Natural sources of ammonia, such as  
84 manure, can retain nitrogen more effectively if combined with calcium chloride when applied to soil (Heck,  
85 1931; Witter & Kirchmann, 1989). The calcium precipitates as calcium carbonate in manure and the  
86 ammonia forms ammonium chloride (Witter & Kirchmann, 1989):

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89 Synthetic ammonia-based fertilizers, including ammonium thiosulfate and urea, can also be combined with  
90 calcium chloride to reduce volatilization and increase the amount of plant-available nitrogen (Sloan &  
91 Anderson, 1995). The reactions depend on the nitrogen source being conserved, soil type, temperature,  
92 moisture, and soil biological activity.

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94 Chlorine is an essential element for plant growth taken up by plants in the chloride form (Brady, 1984;  
95 Broyer et al., 1954; Tisdale & Nelson, 1966). Crops observed to have symptoms of chlorine deficiencies  
96 include barley (*Hordeum vulgare*), beets (*Beta vulgaris*), carrots (*Daucus carota*), clover, corn (*Zea mays*), cotton  
97 (*Gossypium hirsutum*), kiwifruit (*Actinida deliciosa*), lettuce (*Lactuca sativa*), oil palms (*Elaeis* spp.), spinach  
98 (*Spinacia oleacea*), and wheat (*Triticum aestivum*) (Broyer et al., 1954; Geilfus, 2018; Ozanne, 1958; Tisdale &  
99 Nelson, 1966). Chlorine deficiencies are rare and occur only in heavily leached soils without any chlorine  
100 inputs (Marschner, 2011). More common are toxic excesses of chlorine in soils, which reduces yields and  
101 degrades soil quality (Geilfus, 2018).

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103 Seed priming is a technique where seeds are treated with water or a solution that initiates germination and  
104 reduces plant stress. Halopriming involves soaking seeds in an aerated saline solution to prepare them for  
105 planting in saline soils. Calcium chloride is one of the salts commonly used for halopriming (Sher et al.,  
106 2019; Singh et al., 2015). Wheat, millet, and sorghum were all documented to have improved performance  
107 under saline conditions when the seed was primed with a calcium chloride solution prior to planting (Sher  
108 et al., 2019).

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110 Calcium chloride is a food and feed additive. In food, it is used as a humectant and curing agent (Klaassen,  
111 2001). It is also used to coagulate cheese and extract alginates from seaweed (Saltmarsh, 2000). Calcium  
112

113 chloride is used as an alternative to sodium chloride as a salt in low-sodium foods. In brewing, calcium  
114 chloride is used to reduce the hardness of water (Saltmarsh, 2000). As a feed additive, it is used as an  
115 available source of nutrient calcium and chloride, as an electrolyte and as a sequestrant [21 CFR 582.6193].  
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#### 117 **Approved Legal Uses of the Substance:**

118 Calcium chloride and its hydrated forms appear in the Association of American Plant Food Control  
119 Officials (AAPFCO) Official Publication as a recognized calcium source with the chemical formula of  $\text{CaCl}_2$   
120 (AAPFCO, 2020). It is also Generally Recognized As Safe (GRAS) by the U.S. Food and Drug  
121 Administration (FDA) as a direct food substance [7 CFR 184.1193] and as a general use feed additive [21  
122 CFR 582.1193]. The Food Safety Inspection Service (FSIS) approves calcium chloride as a tenderizing agent  
123 in meat products [9 CFR 424.21]. Calcium chloride is exempt from tolerance as an active or inert ingredient  
124 in pesticidal products by the U.S. Environmental Protection Agency (EPA) [40 CFR 180.940] and was  
125 previously classified as List 4B on the obsolete list of inert ingredients (US EPA, 2004). The EPA has also  
126 registered antimicrobial pesticides for indoor use where calcium chloride is labeled as an active ingredient  
127 (US EPA, 2020a).  
128

#### 129 **Action of the Substance:**

130 In solution, calcium chloride disassociates into ionic divalent calcium ( $\text{Ca}^{2+}$ ) and monovalent chloride ( $\text{Cl}^+$ )  
131 in a 2:1 ratio of chloride to calcium. When the aqueous solution is fed to plants by foliar application, the  
132 disassociated ions penetrate the plant cuticles via aqueous pores (Schönherr, 2000). The rate of diffusion  
133 depends on several factors, including the waxiness of the plant cuticles, temperature, humidity, and  
134 whether a surfactant is used. The role of calcium in plant nutrition is complex.  
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136 Calcium is responsible for cell wall development and accounts for firmness in fruit (P.K. Hepler & Wayne,  
137 1985; Shear & Faust, 1970; Simon, 1978). How calcium is taken up by plants and is transported to the cell  
138 walls has been studied extensively. The movement of calcium ions ( $\text{Ca}^{2+}$ ) are thought to be taken up by the  
139 roots and move through the xylem in aqueous solution to be metabolized in plant tissue (Demarty et al.,  
140 1984). Experiments showed that  $\text{Ca}^{2+}$  rapidly responds to light and serves as a second messenger for cell  
141 growth in light-stimulated responses (P.K. Hepler & Wayne, 1985).  $\text{Ca}^{2+}$  binds to cross-linked negative  
142 regions in pectin, creating a rigid structure in plant cell walls (Hepler & Winship, 2010). Boron plays a key  
143 role in calcium metabolism through interaction with plant polysaccharides (Matoh & Kobayashi, 1998).  
144

145 Calcium's relation to fruit formation indicates that it plays a reproductive role (Hepler & Wayne, 1985).  
146 Pollen tubes are particularly dependent on  $\text{Ca}^{2+}$  for structural support at pollination (Hepler & Winship,  
147 2010). Uptake and transport varies by species, growth stage, soils, temperature, moisture, plant hormones,  
148 and the availability of other nutrients (Albrecht & Smith, 1952; Shear & Faust, 1970; Simon, 1978; P.K.  
149 Hepler & Wayne, 1985; Hocking et al., 2016).  
150

151 Calcium chloride is relatively soluble compared with most other sources of calcium—such as calcium  
152 acetate, calcium carbonate, calcium sulfate, and calcium phosphate—and can be taken up by both the roots  
153 and leaves (Albrecht & Jenny, 1931; Kadir, 2005; Kazemi, 2014; Poesch, 1937; Reid & Padfield, 1975). See  
154 *Evaluation Question #11* for more information on other calcium sources. In certain crops—most significantly  
155 apples—calcium is mobile through the plant's xylem for only a short period early in the growing season,  
156 making it less available to the fruit (Marschner, 1974; Simon, 1978). Only a few sources of calcium are  
157 available through the leaves, and then only under certain limited conditions (Shear & Faust, 1970). Calcium  
158 chloride is one of the few soluble sources of calcium that can be translocated from leaves to fruit during the  
159 growth and maturation stage when soil calcium is relatively unavailable (Chittenden et al., 1969).  
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161 Foliar applications of calcium are often more effective in highly leached tropical and sub-tropical soils.  
162 Lychee fruit in Pakistan treated with calcium chloride and borax had less fruit cracking than a no-treatment  
163 control (Haq et al., 2013). Papaya fruit quality was also improved by foliar applications of calcium (Madani  
164 et al., 2016).  
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166 Looking at the nutrients individually, an excess of calcium can cause poor germination and slower growth.  
167 Excess calcium may also manifest itself as a deficiency of other nutrients, particularly iron and

168 phosphorous (White & Broadley, 2003). In general, plants are less sensitive to excess calcium than to  
169 excesses of other nutrients, so an excess of calcium rarely presents a problem (Parnes, 1990).

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171 The chloride moiety's mode of action in plant physiology is even more complicated than that of calcium.  
172 As mentioned above, chlorine is an essential element for plant growth (Brady, 1984; Broyer et al., 1954).  
173 Excess chlorine can induce abiotic plant stress that adversely affect yield and quality (Geilfus, 2018). The  
174 symptoms of excess chlorine can result in toxicity that, in most crops and soils, can only be corrected by a  
175 reduction of plant-available chloride. While plants can grow and thrive over a broad range of calcium  
176 levels, even a small difference in soil and plant levels of chlorine could mean the difference between a  
177 limiting deficiency and a toxic excess. Chlorine deficiencies are relatively rare; toxic excesses are more  
178 common.

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180 When applied to fruits and vegetables post-harvest, calcium chloride reacts with natural pectin. The result  
181 of the reaction is firmer fruit and less decay. In algae, calcium chloride is used to cross-link alginate gels,  
182 making their structure more stable (Saltmarsh, 2000). Calcium chloride's mode of action as a foliar feed is  
183 by transport through the aqueous pores of the leaves. Waxier cuticles permit less diffusion of calcium  
184 chloride into leaves when applied as a foliar spray than do leaves of less waxy plants (Schönherr, 2000).

#### 185 186 **Combinations of the Substance:**

187 Commercial grade anhydrous calcium chloride is 94–97 percent  $\text{CaCl}_2$ , the chief impurity being calcium  
188 hydroxide ( $\text{Ca}(\text{OH})_2$ ) (O'Neil, 2013). It forms mono-, di-, tetra-, and hexahydrates (O'Neil, 2013; Vrana,  
189 2014). Food grade anhydrous calcium chloride is between 93.0 percent and 100.5 percent  $\text{CaCl}_2$  and food  
190 grade calcium chloride dihydrate is between 99.0 percent and 107.0 percent  $\text{CaCl}_2 \cdot 2\text{H}_2\text{O}$  (Food Chemicals  
191 Codex Committee, 2018). Naturally occurring impurities of concern are acid-insoluble matter, arsenic,  
192 fluoride, lead, and magnesium and alkali salts.

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194 Storage is crucial to retain the form and consistency of calcium chloride. Because calcium chloride is  
195 hygroscopic, it absorbs moisture from the air, depending on relative humidity and temperature (Patnaik,  
196 2003). The lump and granular products are subject to agglomeration, and even the flaked form—produced  
197 with a superficial anhydrous coating to prevent caking—can clump under moist conditions or with high  
198 humidity (Vrana, 2014). Commercial- and industrial-grade sources of calcium chloride will use anti-caking  
199 agents, such as Prussian blue (ferric ferrocyanide), Prussian yellow (sodium ferrocyanate), and various  
200 chromates and phosphates (Ramakrishna & Viraraghavan, 2005). Formulations for de-icing will also  
201 include anti-freeze agents (including some made from glycol ethers) and corrosion inhibitors to impede  
202 rust on de-icing equipment and vehicles (Fay & Shi, 2012).

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204 Wetting agents and surfactants may increase the uptake of foliar applied calcium chloride (Schönherr,  
205 2000). For that reason, some brand name products recommend blending calcium with adjuvants, including  
206 various glycol ethers, non-ionic surfactants, pinene polymers, and silicone-based wetting agents.  
207 Commercial products containing calcium chloride are often formulated with micronutrients, such as boron.  
208 Boron is particularly important for the transport of calcium in apples (Faust & Shear, 1968). Similar  
209 synergistic responses are found between calcium chloride and boron for other fruits and fruit vegetables as  
210 well, including lychee (Haq et al., 2013) and tomatoes (Haleema et al., 2018; Rab & Haq, 2012). Some  
211 calcium chloride products are also formulated with magnesium sulfate or Epsom salts (OMRI, 2020).

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213 Humic acids are sometimes added to improve nutrient uptake, and has been shown to be effective in  
214 improving tomato quality (Kazemi, 2014). Ammonium sulfate and urea also have been used as additives to  
215 calcium chloride foliar feeds, but at least one study showed them to be ineffective in improving calcium  
216 transport in apples (Shear & Faust, 1970). Various pesticides are sometimes added in tank mixes to reduce  
217 the number of orchard passes. Thus, commercial foliar feed products may be formulated with various  
218 wetting agents, spreaders, and other adjuvants.

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221 **Status**

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**Historic Use:**

Calcium chloride was first discovered in the 15<sup>th</sup> century, but industrial applications were not explored until the late 18<sup>th</sup> century (Vrana, 2014). The invention of the Solvay process to produce sodium carbonate resulted in calcium chloride as a by-product (Solvay, 1887). When the Solvay process was first introduced to the United States, calcium chloride had little commercial value. Most early uses were non-agricultural, including use in fire suppression, refrigeration systems, anti-freeze, cement curing, and dust suppression. It has a long history of use as a desiccant and preservative in the post-harvest handling of dried fruits and vegetables (Stone, 1919).

Calcium chloride has been used to conserve ammonia nitrogen in manure since the 1920s (Heck, 1931; Witter & Kirchmann, 1989). Confined Animal Feeding Operations (CAFOs) may use calcium chloride to stabilize ammonia in poultry litter, swine slurry, or dairy lagoons (Buchanan et al., 2003; Shi et al., 2001; Ullman, 2005). Calcium chloride may be mixed with manure at the time of spreading or application or top-dressed on the soil following application. Researchers found calcium chloride to be relatively effective in retaining ammonia in poultry litter (Kithome et al., 1999; Nahm, 2005) but less effective with cattle (Husted et al., 1991) and swine manure (Nahm, 2005). Conserving ammonia reduces greenhouse gas emissions and improves the fertilizer value of the manure by retaining a higher nitrogen content. Evidence suggests that calcium chloride may be effective in the sorption of soluble phosphorous from manure to precipitate as calcium phosphate, but differences were seen based on manure and soil type (Bolster & Sistani, 2009).

Greenhouses have used calcium chloride as a way to treat calcium deficiencies in potted plants since at least the 1930s (Poesch, 1937). Calcium chloride's solubility makes it a preferred choice for supplying calcium to plants grown in hydroponic systems, compared to calcium nitrate (Goble, 2018).

The use of calcium chloride as a foliar treatment for bitter pit in organic apple production is relatively recent compared with its uses in non-organic production. In the 1950s, the link between bitter pit and cation imbalances was first put forward as a working hypothesis (Garman & Mathis, 1956). Prior to 1969, calcium deficiencies in apple orchards were primarily addressed through the application of pulverized limestone in both organic (Rodale, 1970) and conventional (Childers, 1975) systems. Experimental foliar treatments of calcium as bitter pit treatment began in New Zealand in the 1960s. The preferred foliar treatment was with calcium nitrate (Kidson et al., 1963) Early attempts to correct the deficiency with soil applications of calcium met with little success (Chittenden et al., 1969).

After almost twenty years of research from that initial observation, researchers were able to predict the correlation between the levels of available calcium and other cationic nutrients and the incidence of bitter pit (Wills et al., 1976). The conclusion was that the condition was treatable by application of calcium chloride as a post-harvest dip (Reid & Padfield, 1975; Sharples et al., 1979). Apple producers were using calcium chloride as a foliar treatment of apples before peer-reviewed science supported its efficacy. Calcium chloride was allowed for foliar treatment of apples by most, but not all certification agents operating in the U.S. prior to implementation of the National Organic Program (USDA, 2001). A 2001 review of the literature found most of the peer-reviewed articles supporting pre-harvest foliar application of calcium chloride were published in the late 1990s (Conway et al., 2001).

**Organic Foods Production Act, USDA Final Rule:**

As noted above, calcium chloride appears on the National List of nonsynthetic substances prohibited for use in organic crop production with the following annotation: "brine process is natural and prohibited for use except as a foliar spray to treat a physiological disorder associated with calcium uptake" [7 CFR 205.602(c)]. Calcium chloride appears on the National List of nonagricultural (nonorganic) substances allowed as ingredients in or on processed products labeled as "organic" or "made with organic (specified ingredients or food groups) without a restrictive use annotation" [7 CFR 205.605(a)]. Nonsynthetic calcium chloride is implicitly allowed in organic livestock production because it is not included on the National List of nonsynthetic substances prohibited for use in organic livestock production [7 CFR 205.604].

**International**

277 *Canadian General Standards Board (CGSB) Permitted Substance List*

278 Calcium chloride appears on the Canadian Organic Regime's Permitted Substances List, Table 4.2, under  
279 the listing for "Calcium" with the following annotation for origin and usage: "Calcium chloride derived  
280 from naturally occurring brines and not chemically treated" (CAN/CGSB, 2020).

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282 Regarding the interpretation of what is "derived from naturally occurring brines and not chemically  
283 treated," the Organic Federation of Canada's Standards Interpretation Committee (SIC) published the  
284 following Question and Answer (OFC-SIC, 2020):

285  
286 **"Is calcium chloride made from the purification of naturally occurring brine allowed  
287 under the listing of 'Calcium' in Table 4.2?" (384)**

288 "Yes and No. Yes. Calcium chloride that is purified from naturally occurring brine via  
289 evaporation is allowed. Such calcium chloride may be used to address nutrient  
290 deficiencies and physiological disorders. No. Other purification processes of naturally  
291 occurring brine that involve additional processing steps (e.g., bromine removal, sulphur  
292 oxide addition, use of strong acid precipitation agents or lime, etc.) render the calcium  
293 chloride synthetic according to the COS (see 'Mined Minerals, unprocessed' in Table  
294 4.2)."

295  
296 **Version 2020**

297 "Yes. Calcium chloride that is purified from naturally occurring brine via evaporation is  
298 allowed. Such calcium chloride may be used to address nutrient deficiencies and  
299 physiological disorders."

300  
301 *CODEX Alimentarius Commission, Guidelines for the Production, Processing, Labelling and Marketing of  
302 Organically Produced Foods (GL 32-1999)*

303 Calcium chloride does not explicitly appear on Table 1: "Substances for use in soil fertilizing and  
304 conditioning." It does appear in Table 4: "Processing aids which may be used for the preparation of  
305 products of agricultural origin referred to in section 3 of these guidelines" with the annotation that it can be  
306 used as a coagulation agent for plant products, and as a firming and coagulation agent in cheese making  
307 (FAO/WHO Joint Standards Programme, 2007).

308  
309 *European Economic Community (EEC) Council Regulation, EC No. 834/2007 and 889/2008*

310 Calcium chloride solution is permitted as a fertilizer and soil conditioner on Annex I with the condition of  
311 use for foliar treatment of apple trees after identification of deficit of calcium (Organic Production and  
312 Labelling of Organic Products with Regard to Organic Production, Labelling and Control, 2008). The  
313 regulation does not specify compositional or source requirements.

314  
315 *Japan Agricultural Standard (JAS) for Organic Production*

316 Calcium chloride appears on Table 1 of the Japanese Agricultural Standard for Organic Plants (Japanese  
317 Agricultural Standard for Organic Plants, 2017). The listing does not have criteria to limit source or use.

318  
319 *IFOAM – Organics International*

320 <http://www.ifoam.bio/en/ifoam-norms>

321 Appendix 2 (Fertilizers and Soil Conditioners) of the IFOAM Standards includes calcium chloride with no  
322 conditions for use (IFOAM, 2014).

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

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327 **Evaluation Question #1: Indicate which category in OFPA that the substance falls under: (A) Does the  
328 substance contain an active ingredient in any of the following categories: copper and sulfur  
329 compounds, toxins derived from bacteria; pheromones, soaps, horticultural oils, fish emulsions, treated  
330 seed, vitamins and minerals; livestock parasiticides and medicines and production aids including**

331 netting, tree wraps and seals, insect traps, sticky barriers, row covers, and equipment cleansers? (B) Is  
332 the substance a synthetic inert ingredient that is not classified by the EPA as inerts of toxicological  
333 concern (i.e., EPA List 4 inerts) (7 U.S.C. § 6517(c)(1)(B)(ii))? Is the synthetic substance an inert  
334 ingredient which is not on EPA List 4, but is exempt from a requirement of a tolerance, per 40 CFR part  
335 180?

336  
337 Calcium chloride is being reviewed for crop use as a fertilizer and soil amendment [7 USC 6508(b)]. It may  
338 also be used as a pesticide inert or active ingredient. Depending on the source and manufacturing process,  
339 it may be synthetic or nonsynthetic. Only calcium chloride from the brine process is considered  
340 nonsynthetic (NOSB, 1996). Other naturally occurring sources exist, such as antarcticite, chlorocalcite,  
341 ghiaraitite, sinjarite, and tachyhydrite as well as sea water, but these sources are not commercially available  
342 in the United States. Synthetic sources, such as those from the Solvay or hydrochloric acid processes, do not  
343 appear on the National List and are prohibited for use in organic crop production [7 CFR 205.105(a)]. The  
344 reasons for considering them synthetic are reviewed in *Evaluation Question #2*. Synthetic calcium chloride  
345 is allowed under 7 CFR 205.601(m) as an EPA 2004 List 4 inert ingredient. It is exempt from the  
346 requirement of a tolerance when used as an inert ingredient pre- and post-harvest [40 CFR 180.910].

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

352  
353 The most prevalent process used to manufacture calcium chloride is by brine extraction. Calcium chloride  
354 from natural brine sources accounted for approximately 70–75 percent of the supply in 1983, with synthetic  
355 sources declining in importance since that time (Kemp & Keegan, 2012). The Solvay process accounts for  
356 about 15–20 percent of commercial supply of calcium chloride. The basic processes have been unchanged  
357 for more than 40 years. These methods were described in detail in the 2001 TAP Review considered by the  
358 NOSB (USDA, 2001) and are briefly summarized here.

359  
360 *Brine Extraction*

361 Brine deposits in Michigan are the primary source of calcium chloride sold in the United States. The brine  
362 process is considered an extraction process under NOP Guidance 5033 §4.6. The brine in the Michigan  
363 Basin contains bromine, magnesium, sodium, and other impurities in addition to calcium and chlorine. The  
364 basinal brine from Michigan has an unusually low pH and high calcium content found in only a few sub-  
365 surface deposits in the world (Warren, 2017). Chlorine, bromine, and iodine are in the brine as  
366 disassociated chloride (Cl<sup>-</sup>), bromide (Br<sup>-</sup>), and iodide (I<sup>-</sup>) ions (i.e., halide ions). One early method used to  
367 remove impurities was to superheat and supersaturate the solution to 190°C, then cool it to below 175°C  
368 under pressure. The solution was then crystallized and reduced to fine particles. The original method was  
369 able to achieve above 75 percent purity of CaCl<sub>2</sub> (Smith, 1928).

370  
371 Iodine is the heaviest stable halide in the brine and can be concentrated by centrifugation (Lauterbach &  
372 Ober, 2011). Iodide in an acidified solution is removed first in liquid phase by ion exchange. The first ion  
373 exchange media used was activated charcoal (Chamberlain & Boundy, 1935). Later methods used  
374 quaternary ammonium type anion resins (Glenn, 1960). Activated charcoal is still used, particularly where  
375 iodine concentrations are relatively low (Lauterbach & Ober, 2011).

376  
377 Bromine is also removed from the brine. The superheated and supersaturated solution treated with sulfur  
378 dioxide (SO<sub>2</sub>) gas yields hydrogen bromide, and sulfuric acid:



381  
382 Once the halides heavier than chlorine are removed, the free chlorine gas can be used to liberate the free  
383 ionic bromide as bromine gas. The bromine gas is then blown out of the solution with air (Hooker, 1939).  
384 Calcium chloride purity was subsequently increased in a similar way by the removal of the other halogens.  
385 The calcium chloride from the natural brine is crystallized as a double salt with magnesium chloride



386 (CaCl<sub>2</sub>·2MgCl<sub>2</sub>·6H<sub>2</sub>O), with magnesium chloride having the greater concentration. To separate the double  
387 salt, calcium oxide (CaO), otherwise known as lime, is introduced to the solution prior to evaporation and  
388 crystallization (Collings, 1932). The lime disassociates in aqueous solution to form calcium hydroxide  
389 (Ca(OH)<sub>2</sub>), otherwise known as slaked lime, hydrated lime, or milk of lime (Speight, 2002). The magnesium  
390 chloride is also converted to magnesium hydroxide, facilitating its removal from the natural brine (Faith et  
391 al., 1975). The magnesium hydroxide is precipitated and filtered. Less than 1 percent of the added lime  
392 remains in the brine (USDA, 2001). Sodium chloride solubility decreases next and is precipitated when the  
393 calcium chloride concentration reaches approximately 35 percent (Mavity, 1976). The remaining calcium  
394 chloride liquor is then evaporated through a double- or triple-effect vacuum evaporator. Settlers and  
395 centrifuges are used to remove unwanted alkali chlorides, particularly sodium chloride (Miller, 1991).  
396 Calcium sulfate (CaSO<sub>4</sub>), precipitated as scale, is removed by high-pressure water jets and chemical  
397 solvents (Mavity, 1976). A final high-temperature evaporation results in a final product that will be  
398 between 78–94 percent calcium chloride (Vrana, 2014).

399  
400 In evaluating the brine process using NOP Guidance 5033, §4.6, the following criteria are considered:  
401  
402 

- Calcium chloride has not been transformed into a different substance via chemical change. While  
403 calcium and chloride in solution undergoes structural change into crystalline form, this is not  
404 considered a chemical change.
- Calcium chloride occurs in nature.
- The synthetic materials used to extract, separate, and isolate the calcium and chlorine in the brine  
407 go through a removal step and ultimately have no technical or functional effect on the final calcium  
408 chloride product.

409  
410 The answer in NOP Guidance 5033-1 step 2b is “Yes,” at the end of brine extraction calcium chloride meets  
411 all criteria described at §4.6 of NOP 5033.

412  
413 The final calcium chloride has not undergone a chemical change in that it is not chemically different from  
414 how it naturally occurs in the source material. Although calcium chloride is structurally different in that  
415 the water and impurities have been removed (i.e., it is crystalline calcium chloride rather than calcium and  
416 chloride ions in solution), other products of crystallization have been considered non-synthetic by the  
417 NOSB. Examples include sea salt (sodium chloride), nigari (magnesium chloride and magnesium sulfate),  
418 and potassium sulfate from saltwater evaporation and crystallization.

419  
420 *Solvay Process*

421 The second most prevalent method for making calcium chloride is by the Solvay process (Solvay, 1887). As  
422 with the brine process, calcium chloride is considered a byproduct, in this case of the manufacture of  
423 sodium bicarbonate (Speight, 2002). The Solvay process involves five reaction steps that use ammonia as a  
424 catalyst and sodium chloride, calcium carbonate, and water as initial reactants (ESAPA, 2004; Speight,  
425 2002). While the process is intricate and involves multiple steps, it can be represented as (Kemp & Keegan,  
426 2012):



429  
430 Evaluating the Solvay process using NOP Guidance 5033-1, sodium chloride and calcium carbonate are  
431 transformed into sodium carbonate and calcium chloride via a chemical change, rendering products of the  
432 chemical reaction synthetic.

433  
434 *Hydrochloric Acid Method*

435 A third method currently used to produce industrial quantities of calcium chloride involves adding  
436 hydrochloric acid to calcium carbonate, producing calcium chloride and carbonic acid (Krohn et al., 1987):



439

440 Evaluating the hydrochloric acid method using NOP Guidance 5033-1, calcium carbonate has been  
 441 transformed into a different substance via acidulation with hydrochloric acid. The chemical change makes  
 442 calcium chloride derived from this process synthetic.  
 443

444 **Evaluation Question #3: Discuss whether the petitioned substance is formulated or manufactured by a**  
 445 **chemical process, or created by naturally occurring biological processes (7 U.S.C. § 6502 (21)).**  
 446

447 Calcium chloride may be manufactured by one of two chemical processes, which were described above, or  
 448 extracted from natural brine. It is not created by naturally occurring biological processes. The NOSB  
 449 determined that calcium chloride extracted from brine is nonsynthetic and that non-brine processes were  
 450 synthetic (NOSB, 1996).  
 451

452 **Evaluation Question #4: Describe the persistence or concentration of the petitioned substance and/or its**  
 453 **by-products in the environment (7 U.S.C. § 6518 (m) (2)).**  
 454

455 As an ionic salt, calcium chloride readily dissolves in water and is not persistent or concentrated. The  
 456 calcium and chloride moieties are elemental, persist in the environment, and are regarded as dissolved  
 457 solid pollutants reportable under the Clean Water Act (US EPA, 1995). Although persistent, calcium and  
 458 chlorine are also ubiquitous in the environment, are constituents of living organisms, and pose little risk to  
 459 the environment (Housenger, 2016; OECD, 2002).  
 460

461 Calcium and chlorine cannot be considered biodegradable (OECD, 2002). However, they are nutrient  
 462 elements that are consumed and sometimes accumulated or concentrated by various organisms. For  
 463 example, calcium chloride is readily metabolized by *Bacillus* species and other soil microorganisms,  
 464 sometimes sequestering carbon dioxide to make calcium carbonate (Anbu et al., 2016). Earthworms  
 465 forming calcium carbonate while metabolizing available calcium was demonstrated in the 1930s, and was  
 466 first documented by Charles Darwin in the 1880s, when he observed that earthworms of various species  
 467 converted vegetable matter into calcite (CaCO<sub>3</sub>) (Robertson, 1936).  
 468

469 **Evaluation Question #5: Describe the toxicity and mode of action of the substance and of its**  
 470 **breakdown products and any contaminants. Describe the persistence and areas of concentration in the**  
 471 **environment of the substance and its breakdown products (7 U.S.C. § 6518 (m) (2)).**  
 472

473 The EPA did not require a quantitative risk assessment for human health effects of calcium chloride used  
 474 as an antimicrobial pesticide in enclosed spaces as a moisture absorber. The reasons given were the lack of  
 475 exposure and hazard concerns. The EPA concluded that there were no risks of concern for human health or  
 476 non-target organisms (Chen & Parsons, 2016). As a direct food additive that is Generally Recognized As  
 477 Safe (GRAS), calcium chloride is regarded by experts as posing reasonable certainty of no harm under  
 478 conditions of intended use in food (Klaassen, 2001). The acute and chronic toxicity of calcium chloride is  
 479 summarized in Table 2.  
 480

481 **Table 2. Toxicity of Calcium Chloride**

Study	Results	Source
Acute oral toxicity	LD <sub>50</sub> Rat: 10 g/kg LD <sub>50</sub> Mouse: 1,940 mg/kg LD <sub>50</sub> Rabbit: 1,384 mg/kg	(US NLM, 2020)
Acute subcutaneous toxicity	LPLD Cat: 249 mg / kg LPLD Dog: 274 mg / kg	(US NLM, 2020)
Acute intravenous toxicity	LD <sub>50</sub> Mouse: 42.4 mg/kg	(Syed & Hosain, 1972)
Subchronic toxicity	NOAEL Rat: > 2,000 mg / kg over 12 months	(OECD, 2002)
Developmental toxicity / Teratogenicity	NOEL Maternal Rat: 176 mg / kg NOEL Maternal Mouse: 189 mg / kg NOEL Maternal Rabbit: 169 mg / kg	(OECD, 2002)
Genetic toxicity	Negative ( <i>Salmonella typhimurium</i> )	(OECD, 2002)

482  
483 When heated to decomposition, hydrated calcium chloride emits toxic fumes of hydrogen chloride or  
484 hydrochloric acid (HCl) (Lewis & Sax, 1996). The mono-, di-, tetra-, and hexa-hydrate forms decompose at  
485 260°, 175°, 45.5°, and 30°C, respectively (Patnaik, 2003).

486  
487 **Evaluation Question #6: Describe any environmental contamination that could result from the**  
488 **petitioned substance's manufacture, use, misuse, or disposal (7 U.S.C. § 6518 (m) (3)).**  
489

490 Because this review is only of the nonsynthetic brine-derived source, the environmental impacts of the  
491 manufacturing processes for the Solvay process and hydrochloric acid method are not under consideration  
492 here. In the Michigan Basin, the brine is found in sandstone formations formed in the middle Paleozoic era  
493 (Schaetzl, 2020). The first producing brine well was drilled in 1841 (Cook, 1914; Kieta, 2018). The basin  
494 contains about a trillion tons of brine (Schaetzl, 2020). It has been referred to as an inexhaustible supply  
495 (Cook, 1914). At 1983 extraction rates, the Michigan Basin deposits would take more than 1,000 years to be  
496 depleted (Kemp & Keegan, 2012; Schaetzl, 2020). The U.S. Geological Survey has not published brine  
497 extraction rates since then because the data was withheld to avoid disclosing proprietary company data.  
498 There is no indication that extraction has increased to a significant degree.  
499

500 The brine used to make calcium chloride contains several other halogens and alkali elements. The bromine,  
501 chlorine, iodine, lithium, magnesium, sodium, and potassium are recovered and used for industrial and  
502 commercial purposes. A certain amount of the spent brine is unusable. Environmental concerns with the  
503 manufacturing process were not considered until the last quarter of the 20<sup>th</sup> century (Kieta, 2018). Waste  
504 disposal from brine-extraction of calcium chloride is a growing concern, as spent brine is injected  
505 underground into deep wells for solution mining (US EPA, 1999). These injection wells are categorized by  
506 the US EPA as Class II and are currently unregulated at the Federal level (US EPA, 2020b). Class II injection  
507 wells are intended for oil- and gas-related brines. Michigan has approximately 1,250 active Class II  
508 injection wells, with over half used for brine disposal (MEGLE, 2020). With these wells, brine disposal may  
509 be combined with the waste brines created by hydraulic fracturing (fracking) for oil and gas. Deep-well  
510 injection will often have a mix of hazardous substances, including radioactive material (US EPA, 2020b).  
511 Concerns with deep well injection include groundwater contamination and increased seismic activity  
512 (Folger & Tiemann, 2016). Intensive pumping and cracked casings in aging brine wells were linked to  
513 contamination of fresh groundwater (Dumouchelle et al., 1987). Dow Chemical, the largest producer of  
514 calcium chloride from brine in the U.S., was linked to soil damage and groundwater contamination caused  
515 by at least three historic brine spills (Michigan DEQ, 2015).  
516

517 Agricultural use of calcium chloride poses relatively little risk of environmental contamination in  
518 comparison with its use as a de-icer. Environmental incidents involving the agricultural use and misuse of  
519 calcium chloride were not found in a thorough search of the literature. However, careless loading and  
520 mixing of foliar spray rigs near open water pose risks of runoff and potential chloride accumulation and  
521 saline pollution of fresh water. The adverse impact of such misuse is localized in nature. Calcium is already  
522 the most common cation found in fresh surface water on a global scale and is widely distributed (OECD,  
523 2002). On the other hand, chloride is more variable in its occurrence in fresh surface water, with local  
524 geological factors determining background levels, and human use factors from pollution having greater  
525 influence on sensitive ecological systems. For that reason, chloride is used as an indicator of water  
526 pollution from human activity (Hawkins & Judd, 1972; Sonzogni et al., 1983). The Great Lakes in North  
527 America are seen as being at risk from growing chloride pollution (Chapra et al., 2009, 2012; Sonzogni et  
528 al., 1983). Calcium chloride as a de-icer was identified as one of the top sources of chloride pollution  
529 (Chapra et al., 2012). Smaller bodies of water – ponds, lakes, brooks, and streams – have less buffering  
530 capacity than major bodies of water and often have sensitive species adapted to a relatively pristine  
531 ecosystem. Many small lakes and ponds have seen even the most salt-tolerant native freshwater species not  
532 survive heavy salt run-off incidents (Hawkins & Judd, 1972).  
533

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

537  
538 Calcium chloride has ionic bonds and dissolves easily into  $\text{Ca}^{2+}$  and  $2 \text{Cl}^-$ . These ions in solution can then  
539 form ionic bonds with other available cations and anions. Calcium is a secondary plant nutrient, and  
540 soluble calcium in the soil is readily taken up by plants. Chlorine is a halogen that is highly reactive.  
541 Sodium chloride is a significant contaminant of the natural brine source of calcium chloride. Addition of  
542 sodium chloride to the soil can have adverse effects on plants, soil structure, and cation balance (Awada et  
543 al., 1995).

544  
545 Calcium chloride solution introduced to smectite clay soils under laboratory conditions inhibited  
546 adsorption of four pesticides not used in organic production (Li et al., 2006). While it is not possible to infer  
547 how calcium chloride will interact with any specific substances used in organic production based on the  
548 study, the authors noted that calcium chloride's strong hydration impedes the direct contact of aromatic  
549 rings with opposing clay siloxane surfaces.

550  
551 The application of calcium chloride as a foliar feed is a response to a deficiency in calcium uptake by  
552 plants. Such deficiency results from a complex set of factors including soil nutrient levels, pH, cation  
553 exchange capacity, and others.

554  
555 In addition, iron and phosphorous in the soil may be immobilized by the addition of calcium (White &  
556 Broadley, 2003).

557  
558 **Evaluation Question #8: Describe any effects of the petitioned substance on biological or chemical**  
559 **interactions in the agro-ecosystem, including physiological effects on soil organisms (including the salt**  
560 **index and solubility of the soil), crops, and livestock (7 U.S.C. § 6518 (m) (5)).**

561  
562 Calcium chloride's impact on microorganisms and soil biology is complex and depends on various factors.  
563 Some microorganisms are inhibited while others thrive after calcium chloride is introduced under  
564 experimental conditions (Greaves, 1922; Greaves & Carter, 1922; Winslow & Dolloff, 1928; Albrecht &  
565 Jenny, 1931; Sindhu & Cornfield, 1967; Anbu et al., 2016). Calcium chloride was found to be more toxic to  
566 coliform bacteria than potassium chloride or sodium chloride, and less toxic than magnesium chloride  
567 (Winslow & Dolloff, 1928). The researchers found that mixtures of the different salts in different  
568 proportions could have either beneficial or antagonistic effects on microbial growth as measured by carbon  
569 dioxide production.

570  
571 Another study found that nitrification—the bacterial conversion of ammonia nitrogen to nitrite and nitrate  
572 forms by oxidation—was suppressed by calcium chloride, while mineralization—the release of nitrogen  
573 from organic matter by biodegradation—was increased by a small but statistically significant amount  
574 (Sindhu & Cornfield, 1967).

575  
576 Various *Bacillus* species in soil form calcium carbonate as a form of mineral calcite in a process known as  
577 Minerally Induced Calcium Carbonate Precipitation (MICCP). Calcium chloride was found to be more  
578 efficient than calcium oxide, calcium acetate, and calcium nitrate to carry out MICCP under laboratory  
579 conditions (Achal & Pan, 2014). There is increased interest in MICCP as a possible way to sequester soil  
580 carbon (Anbu et al., 2016).

581  
582 Calcium chloride was not included in the original study that established the salt index (Rader et al., 1943).  
583 No peer-reviewed source that replicated the Rader method was found that compared the osmotic pressure  
584 caused by calcium chloride in plant leaves with that of sodium nitrate ( $\text{NaNO}_3$ ). An alternative method to  
585 estimate the salt index is to compare the electrical conductivity of a fertilizer with sodium nitrate (Jackson,  
586 1958):

587  
588 
$$\text{Estimated Salt Index (ESI)} = (\mu\text{mhos Fertilizer solution} / \mu\text{mhos } 0:1 \text{ percent NaNO}_3) \times 100$$

589  
590 Calcium chloride has a higher electrical conductivity and thus a higher salt index than sodium nitrate using  
591 the Jackson method (Isono, 1984; Haynes, 2010). At  $20^\circ\text{C}$ , the electrical conductivity of a 1 percent solution

592 of calcium chloride is 15,700  $\mu\text{mhos}$  and a 1 percent solution of sodium nitrate has an electrical  
593 conductivity of 10,600 (Haynes, 2010). Using the formula above, the Jackson salt index for calcium chloride  
594 is 148.11. However, the higher salt index from electrical conductivity does not necessarily result in greater  
595 osmotic pressure on the leaves. For example, application rates of materials vary widely, and calcium  
596 chloride is usually applied at a much lower rate than sodium nitrate or potassium chloride. Additionally,  
597 some materials with low salt indices – such as anhydrous ammonia – can be toxic to plants in ways other  
598 than exerting osmotic pressure on leaves (Murray & Clapp, 2004).

600 Calcium chloride's efficacy as a readily available calcium source has been studied extensively. Some of  
601 William Albrecht's early experiments on the role of calcium in base cation saturation ratios and cation  
602 balancing used calcium chloride as a calcium source (Albrecht & Davis, 1929; Albrecht & Jenny, 1931;  
603 Albrecht & Smith, 1952). While Albrecht's later work focused on limestone and gypsum as preferred  
604 sources of calcium, particularly in neutral and acidic soils, he recognized that calcium chloride went into  
605 solution and was taken up more rapidly as a chloride salt, and also recognized chloride's acidifying role  
606 (Albrecht & Smith, 1952).

607  
608 When added to biomass made into biochar, calcium chloride shows the potential to increase carbon  
609 sequestration. One study using pyrolyzed chicken manure found that calcium chloride prevented carbon  
610 loss, though less effectively than ferric chloride ( $\text{FeCl}_3 \cdot 6\text{H}_2\text{O}$ ) (Xiao et al., 2018).

611  
612 Plants with calcium deficiencies are often more susceptible to plant pathogens (Simon, 1978). Symptoms of  
613 calcium deficiencies include the cracking of fruit, water-soaked tissues, pits and cavities, necrosis of young  
614 tissues, and necrosis of leaf tissue (Simon, 1978; White & Broadley, 2003). Blossom end rot of tomatoes has  
615 been understood since the 1940s as caused by a cation imbalance and low calcium relative to magnesium,  
616 potassium, and sodium (Lyon et al., 1942). Calcium chloride has been observed to play a preventive or  
617 salutary role in inhibiting some opportunistic plant pathogens. It was observed to reduce damping off  
618 caused by various fungal pathogens of soybean (*Glycine max*) seedlings grown in pots, while potassium  
619 chloride and magnesium chloride did not (Albrecht & Jenny, 1931). Pre-harvest foliar application of  
620 calcium chloride improved the calcium content, reduced the incidence of anthracnose and increased the  
621 antioxidant activity of papayas grown in Malaysia (Madani et al., 2016). An Egyptian study showed that  
622 potatoes (*Solanum tuberosum*) treated with calcium chloride mixed with commercial baking yeast  
623 (*Saccharomyces cerevisiae*) significantly reduced incidence of early blight (*Alternaria solani*) compared with a  
624 no-treatment control, and outperformed sodium bicarbonate as an alternative treatment (El-Mougy &  
625 Abdel-Kader, 2009).

626  
627 Calcium chloride is also effective as a blossom thinner on apples (Long, 2002). However, there are no  
628 products currently registered with the EPA that are labeled for that purpose (US EPA, 2020a).

629  
630 **Evaluation Question #9: Discuss and summarize findings on whether the use of the petitioned**  
631 **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)**  
632 **(i)).**

633  
634 Most of the studies that evaluate the environmental impact of calcium chloride are related to its use as a  
635 de-icing agent and dust suppressant. Because calcium chloride is composed of a weak base and a strong  
636 acid, it has an acidifying effect and will reduce pH (Witter & Kirchmann, 1989). In comparison with sodium  
637 chloride, salinization and alkalization were expected to be reduced by substitution of calcium chloride  
638 (Brandt, 1973). Calcium chloride can cause damage to vegetation, such as growth inhibition, scorched  
639 leaves, and even plant death (Fay & Shi, 2012). Sensitivity of plants to excess chloride is species- and even  
640 variety-specific. Some plants are adapted to growing in conditions of high salinity and may suffer from  
641 chlorine deficiencies. However, most cultivated plants of economic importance are not adapted to saline  
642 conditions. Often, salt damage is caused by excess sodium, though a review of the literature found that salt  
643 sensitivity may be more an outcome of excess chlorine than excess sodium in certain species, such as  
644 grapes (*Vitis* spp.) (Greenway & Munns, 1980).

645

646 Calcium chloride can run off into surface water and leach into groundwater (Fay & Shi, 2012; Harless, 2012;  
647 Ramakrishna & Viraraghavan, 2005). In surface water, calcium chloride can be toxic to freshwater aquatic  
648 organisms (Harless et al., 2011; OECD, 2002). Table 3 summarizes the ecological toxicity of calcium  
649 chloride.

650  
651

**Table 3. Eco-toxicity of Calcium Chloride**

Study	Results	Source
Effective concentration: algae	EC <sub>50</sub> 72 hr <i>Selenastrum capricornutum</i> : 2,900 mg / L	(OECD, 2002)
Effective concentration: invertebrate	EC <sub>50</sub> 48 hr <i>Daphnia magna</i> : 1,062 mg / L	(OECD, 2002)
Lethal concentration: invertebrate	LC <sub>50</sub> 48 hr <i>Daphnia magna</i> : 2,770 mg / L*	(OECD, 2002)
Lethal concentration: amphibian	LC <sub>50</sub> 24 hr Wood frog ( <i>Rana sylvatica</i> ): 4.85 g / L	(Harless et al., 2011)
Lethal concentration: fish	LC <sub>50</sub> 96 hr Fathead minnow ( <i>Primephales promelas</i> ): 4,630 mg / L*	(OECD, 2002)

652 \*EPA test methods

653

654 **Evaluation Question #10: Describe and summarize any reported effects upon human health from use of**  
655 **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**  
656 **(m) (4)).**

657

658 Calcium chloride is generally considered nontoxic to mammals. As pointed out in *Approved Legal Uses of the*  
659 *Substance*, it is GRAS as a direct food additive and as such considered not likely to cause harm when  
660 intentionally consumed (Chen & Parsons, 2016; Harrison, 2018; Housenger, 2016; Klaassen, 2001; Tran,  
661 2016). As a salt, it can have some deleterious effects on human health, with serious local effects by all routes  
662 of exposure (Inchem, 2012). Handling precautions are minimal. Open cuts are affected in ways similar to  
663 other salts (Mavity, 1976). Prolonged skin contact with calcium chloride can lead to chemical burns (Saeed  
664 et al., 1997).

665

666 Three cases of calcium chloride necrosis from topical exposure were reported prior to 1957 (Zackheim &  
667 Pinkus, 1957). The authors regarded the cases as uncommon. Four patients who had their parathyroids  
668 removed, and were given intravenous calcium chloride to treat symptomatic hypocalcemia (calcium  
669 deficiency), suffered from skin necrosis (Lin et al., 2007). The authors noted that such necrosis was found in  
670 only those four patients (out of 96 patients treated), and that renal disease may have been a complicating  
671 factor.

672

673 Consumers are widely exposed to calcium chloride as a direct food additive, in medications, and through  
674 direct purchase of de-icing agents and condensation traps (OECD, 2002). The greatest risk to human health  
675 is as an irritant. Nothing in the literature suggests that agricultural use will pose an additional adverse  
676 effect beyond these multiple avenues of exposure.

677

678 **Evaluation Question #11: Describe all natural (nonsynthetic) substances or products which may be**  
679 **used in place of a petitioned substance (7 U.S.C. § 6517 (c) (1) (A) (ii)). Provide a list of allowed**  
680 **substances that may be used in place of the petitioned substance (7 U.S.C. § 6518 (m) (6)).**

681

682 Calcium chloride from brine is considered nonsynthetic, but it is not the only source of nonsynthetic  
683 calcium allowed in organic production. Other natural (nonsynthetic) sources of calcium include: calcium  
684 carbonate (limestone, dolomite, and oyster shells), calcium sulfate (gypsum), and calcium phosphate (rock  
685 phosphate and bone meal) (Parnes, 1990). Calcium deficiencies appear to be correlated with the  
686 replacement of organic fertilizers with non-organic fertilizers (Marschner, 1974).

687

688 Calcium deficiencies in apple orchards were historically addressed by the application of pulverized  
689 limestone in both organic (Rodale, 1970) and non-organic systems (Childers, 1975). With severe cases of

690 calcium deficiencies, soil application was found to be ineffective (Chittenden et al., 1969). Due to  
 691 differences in solubility – which leads to variable rates at which calcium is made available to a crop – the  
 692 use of another nonsynthetic source of calcium in place of calcium chloride may be unrealistic. Initial  
 693 studies for foliar feeds used calcium acetate (Askew et al., 1960). Calcium nitrate also grew in popularity  
 694 and became the preferred foliar treatment of apple producers (Kidson et al., 1963). Both calcium acetate  
 695 and calcium nitrate, however, are prohibited for use in organic production. Calcium chloride received  
 696 attention because of its relatively low cost and higher calcium content. One of the earliest trials comparing  
 697 calcium nitrate with calcium chloride foliar treatments of apples noted that calcium chloride caused more  
 698 burning of leaves, but had a comparable reduction of bitter pit incidence to calcium nitrate (Chittenden et  
 699 al., 1969).

700  
 701 Various other nonsynthetic substances have been used to stabilize ammonia in manure, including peat and  
 702 zeolites (McCrary & Hobbs, 2001; Witter & Kirchmann, 1989). Other natural salts used for halopriming  
 703 include calcium sulfate and sodium chloride (Sher et al., 2019; Singh et al., 2015).

704  
 705 A list of product manufacturers, along with their contact information, that provide USDA Organic  
 706 compliant calcium alternatives is available from the Organic Materials Review Institute (OMRI, 2020).  
 707 OMRI also maintains an approved products list. Products on this list appear within a generic category. The  
 708 table below includes the number of calcium-derived products listed by OMRI at the time of this report. The  
 709 solubility of calcium in these products will likely vary from calcium chloride. Significant variations in  
 710 solubility between calcium sources is the determining factor when identifying true calcium chloride  
 711 alternatives.

712

713 **Table 4. Summary of Calcium Sources Approved by OMRI as of January 2021**

Generic category	Number of products
Calcium	11
Calcium carbonate	49
Dolomite, mined	18
Limestone	32
Gypsum, mined sources	61
Calcium sulfate	10
Phosphate rock	28
Bone meal	24
Oyster shell lime	2
<b>Calcium chloride</b>	<b>46</b>

714

715 Natural (nonsynthetic) sources of chloride include compost, manure, potassium chloride, and sodium  
 716 chloride.

717

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

720

721 The principal alternative practice to foliar application of calcium chloride would be to increase the amount  
 722 of available calcium in the soil by applying the substances named in *Evaluation Question #11*. Practices that  
 723 increase plant-available calcium in the soil include conservation and improvement of organic matter, which  
 724 in turn increases both biological activity and cation exchange capacity. One hypothesis is that a calcium  
 725 deficiency can be caused by excess hydrogen (Albrecht, 1941; Albrecht & Smith, 1952). Calcium deficiency  
 726 in plants may occur in situations where there is sufficient calcium in the soil, but it is not going into  
 727 solution or being taken up by the roots because of insufficient water or soil moisture and oxygen (Olle &  
 728 Bender, 2009). Timely watering and mulching to retain soil moisture can help the transport of soil calcium.  
 729 For example, night misting with water was found to reduce the incidence of lettuce tip burn (Cox &  
 730 Dearman, 1981).

731

732 Another alternative practice is the use of varieties that are more efficient at producing under conditions of  
733 low calcium availability or within a wide range of cation nutrient ratios. Some apple varieties have been  
734 observed to be more susceptible to bitter pit than others (Garman & Mathis, 1956). The same principle can  
735 be applied to pears, tomatoes, and other crops that are susceptible to calcium deficiencies that are treatable  
736 by foliar feeding of calcium chloride. Apple varieties that are more tolerant to low calcium conditions  
737 represent a limited portion of available varieties. The development of additional tolerant varieties, for  
738 apples and other crops affected by calcium deficiency, requires experimentation and research on the  
739 selection of varieties for such conditions.

740  
741 In addition to using limestone or gypsum for increasing soil application of calcium, other comparable  
742 strategies of calcium foliar treatment to control bitter pit in apples include summer pruning, delayed  
743 harvest, and fruit thinning (Van der Boon, 1980). While summer pruning and fruit thinning reduced the  
744 incidence of bitter pit and slightly increased marketable yield in one study conducted in the Netherlands,  
745 these practices were labor intensive. It is notable that this study used calcium nitrate and not calcium  
746 chloride as the foliar treatment for comparison.

747  
748 Various calcium deficiencies have been attributed to imbalances in other available nutrients. Bitter pit in  
749 apples may be the result of an imbalance caused by excess magnesium and potassium as much as by a  
750 shortage of calcium (Garman & Mathis, 1956). Balancing cations in a situation where there is excess may  
751 then be accomplished by reducing the amounts of magnesium or potassium applied. However, in soils that  
752 are high in magnesium or potassium, this may not be a practical solution. Similar yield- and quality-  
753 impairing production problems caused by cation imbalances have been observed in a wide range of crops,  
754 from alfalfa to tomatoes. The literature on cation balancing with calcium, potassium, magnesium, and  
755 sodium with different crops grown on different soils is extensive and beyond the scope of this Technical  
756 Report.

757  
758 Post-harvest treatment with calcium chloride can be used to treat bitter pit in apples (Reid & Padfield, 1975;  
759 Sharples et al., 1979). In a comparison of pre- and post-harvest treatments, pre-harvest foliar feeds were  
760 shown to be more effective, but best practice for optimal fruit quality in apples uses both (Conway et al.,  
761 2001).

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763

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