National Organic Standards Board
Crops Subcommittee
Petitioned Material Proposal
Carbon Dioxide
August 6, 2024

Summary of Petition:

Carbon dioxide (CO_2) was petitioned in 2020 to be added on the National List of Allowed and Prohibited Substances, for use as a plant or soil amendment at §205.601(j). The same petition requested the addition of carbon dioxide at §205.601(a) of the National List for use as an algicide, disinfectant, and sanitizer, including uses in irrigation systems, to acidify irrigation water. The petition heavily focused on the use as an algicide, disinfectant and sanitizer in irrigation systems, and did not provide enough information about the material as a plant or soil amendment. Under "the intended use or current use of the substance" the petitioner stated "Carbon dioxide is used in a water pH adjustment process. Dissolved carbon dioxide in water makes carbonic acid, which reduces water pH, therefore increasing H+ concentration and neutralizing bicarbonates. Water pH adjustment is common practice in agriculture. Irrigation water sources are usually alkaline and with bicarbonates above the maximum desired levels for proper irrigation water quality."

In 2022, the NOSB recommended the National Organic Program add carbon dioxide at §205.601(a) but requested a full-scope technical report (TR) to address the sections of the petition requesting the addition of carbon dioxide at §205.601(j), as a plant or soil amendment, before making a second recommendation.

The 2023 technical report outlined the specific use of the petitioned material as an atmospheric adjustment in indoor production. In the report, we find that ambient air contains 350-450 ppm CO_2, while the optimal concentration of CO_2 for plant growth in a greenhouse environment is 800-1000 ppm (Poudel & Dunn, 2017; Thomson et al., 2022; Wang et al., 2022). As plants grow, they metabolize CO_2 in the air of the greenhouse, depleting it to 100-250 ppm during peak CO_2 consumption. Venting the greenhouses to allow more atmospheric CO_2 in disrupts the temperature control. Natural turnover of air by venting may help to moderate CO_2 levels during warm months, but venting is usually not practical during colder periods or in colder regions, and supplementation is needed.

Subcommittee Review winter 2024:
Because there was not enough information in the petition about the importance or need for the substance to be listed as a crop or soil amendment, the Subcommittee has been hesitant to recommend its listing. The TR only listed its use as a plant or soil amendment in indoor production. The Subcommittee recognizes that this petition highlights the lack of clear standards pertaining to indoor and container production, which inhibits the NOSB from fully evaluating petitions for substances used in this type of production.

One member stated experience with the substance, noting that its use increases production potential, while another questioned its necessity, i.e., Is this material truly necessary for organic production or is it used as a booster like synthetic fertilizers or substance of high solubility? The Crops Subcommittee contacted organic greenhouse transplant and nursery producers and found that CO_2 was not needed nor supported for use. These producers were in the Southeast where average temperatures are warmer, and venting is less limited compared to colder climates. The Crops Subcommittee requested a greater explanation of the greenhouse gas effects of this material in its manufacture and use and how it ties to climate change.

Spring 2024 Public comments:
There were eight written comments for the spring 2024 Board meeting in Milwaukee. Four commenters supported the listing of synthetic carbon dioxide as a plant or soil amendment stating that it meets Organic Foods Production Act (OFPA) criteria, and four commenters opposed the listing. There was equally mixed support in oral comments, but no comments came from direct users of this material.

Spring 2024 NOSB Board meeting review:
Discussion at the spring meeting centered around the essentiality of this material. Other important discussions included the potential increase of carbon dioxide production. Would listing this material create a demand for supply that would justify the manufacturing of carbon dioxide? The lead stated that all synthetic CO_2 in the market is a by-product of other manufacturing processes. Given the mixed support, the proposal was sent back to Subcommittee for additional work, and so it could solicit additional feedback from stakeholders.

Subcommittee Review summer 2024:
A Board member with greenhouse production experience explained that heating the greenhouse with liquid propane created an amount of carbon dioxide, and instead of venting this by-product to the outside, it was vented into the production area to aid in raising carbon dioxide levels. This was done prior to OFPA and the organic standards. Without the petitioned listing, venting this by-product of carbon dioxide is not allowed in organic production.
According to the TR, there was a supply chain shortage of carbon dioxide in 2022. The shutdown of ethanol plants, contaminations in high-producing wells, and pandemic supply chain issues were attributed to the shortages (TR, 2023 lines 822-827). The recent shortage entertains the idea that the listing of carbon dioxide at §205.601(a) could lead to the increase in manufacturing processes to produce more carbon dioxide. In consideration of this concern the Subcommittee is proposing an annotation to restrict this substance to be sourced as a byproduct.

Category 1: Classification

1. For CROP use: Is the substance _____ **Non-synthetic** or ___X___ **Synthetic?**
   Is the substance formulated or manufactured by a process that chemically changes a substance extracted from naturally occurring plant, animal, or mineral sources? [OFPA §6502(21)] If so, describe, using NOP 5033-1 as a guide.

Carbon dioxide is the byproduct of many chemical and biological processes with fuel combustion and fermentation being the most prominent. The combustion of natural gas results in CO_2 and water vapor and CO_2 may be produced as a by-product of carbohydrate fermentation by yeast in the production of ethanol or alcoholic beverages (TR, 2023).

2. Reference to appropriate OFPA category:
   Is the substance used in production, and does it contain an active synthetic ingredient in the following categories: [§6517(c)(1)(B)(i)]; copper and sulfur compounds; toxins derived from bacteria; pheromones, soaps, horticultural oils, fish emulsions, treated seed, vitamins and minerals; livestock parasiticides and medicines and production aids including netting, tree wraps and seals, insect traps, sticky barriers, row covers, and equipment cleansers; or (ii) is used in production and contains synthetic inert ingredients that are not classified by the Administrator of the Environmental Protection Agency as inerts of toxicological concern?

CO_2 does not contain an active ingredient in any of the categories listed above. However, it is listed on 2004 EPA List 4A and was not revoked under NOP 5008, Guidance: Reassessed Inert Ingredients. As an insecticide, "carbon dioxide is exempted from the requirement of a tolerance when used after harvest in modified atmospheres for stored insect control on food commodities" per 40 CFR 180.1049 (TR, 2023).

Category 2: Adverse Impacts

1. What is the potential for the substance to have detrimental chemical interactions with other materials used in organic farming systems? [§6518(m)(1)]

At normal temperatures, CO_2 does not break down into simpler compounds, and it is not very reactive. While unlikely to be an issue in organic crop production, CO_2 can react with hydrogen gas to form carbon monoxide (CO). It can also react with ammonia to form ammonium carbamate, which when dehydrated then forms urea (TR, 2023).

2. What is the toxicity and mode of action of the substance and of its breakdown products or any contaminants, and their persistence and areas of concentration in the environment? [§6518(m)(2)]

According to the TR, higher concentrations of CO_2 can benefit plants, but soil composition, nutrient availability, plant species, and plant genetics all influence the response. The technical review referenced a study finding that plants in growth chambers showed symptoms of toxicity when subjected to 2000 ppm CO_2. It can also be toxic to microorganisms, and animals at significantly elevated levels. No information that specifically indicated that carbonate (CO_3^{2-}) or bicarbonate (HCO_{3-}) ions, formed from the dissolution of CO_2 in water, are toxic to plants.

3. Describe the probability of environmental contamination during manufacture, use, misuse or disposal of such substance? [§6518(m)(3)]

CO_2 used in agriculture will largely be derived from fossil fuels, previously stored in the lithosphere, and will re-enter the carbon cycle temporarily persisting or concentrating in one of the three other major reservoirs: the terrestrial biosphere, the hydrosphere (oceanic reservoir), or atmosphere. Gaseous CO_2 is relatively stable in the atmosphere.

CO_2 plays an essential role in soil pH and aquatic environments because of the carbonic-acid system. In contact with water, a proportion of CO_2 dissolves until equilibrium is reached between CO_2, bicarbonate (HCO_{3-}), carbonate (CO_3^{2-}), and carbonic acid (H_2CO_3). A greater proportion of CO_2 shifts the equilibrium to the formation of carbonic acid resulting in lower pH (TR, 2023).

In the atmosphere, CO_2 absorbs longwave radiation coming from the earth's surface, causing warming known as "the greenhouse effect." Greenhouses usually have a CO_2-use efficiency of less than 60%, meaning that over 40% of the CO_2 that is added is released into the atmosphere without being ever incorporated into plant biomass.

4. Discuss the effect of the substance on human health. [§6517(c)(1)(A)(i); §6517(c)(2)(A)(i); §6518(m)(4)].

According to the TR, CO_2 can be defined as a toxicant since it induces unconsciousness, respiratory

failure, inflammation, and sensory impairment. Instances of CO_2 poisoning are exceedingly rare events. The concentrations found in nature, in typical industrial settings, or used in greenhouses, are far lower than any of the concern levels listed above and are not a threat to human health. Adverse effects generally begin following exposure to 1% or greater CO_2, while background atmospheric levels are approximately 0.04% and enriched greenhouse atmospheres are approximately 0.1%. Confined areas like mines, silos, or fermentation chambers, for example, may be environments where CO_2 concentrations can surpass 1%, sometimes significantly. The current OSHA Permissible Exposure Limit (PEL) for 8-hour exposure to gaseous CO_2 is 5,000 ppm, or 0.5%.

5. Discuss any effects the substance may have on biological and chemical interactions in the agroecosystem, including the physiological effects of the substance on soil organisms (including the salt index and solubility of the soil), crops and livestock. [§6518(m)(5)]

Lowering the pH to 6.0-6.8 can improve the bioavailability of some nutrients, such as iron, zinc, boron, and manganese. Cation availability can also increase due to increased weathering of parent material and minerals, therefore affecting soil chemistry. In wet environments or where large amounts of irrigation are used, these effects can leach these available cations (TR, 2023).

At low concentrations (up to about 1200 ppm), CO_2 is generally safe and has low toxicity, and can have substantial beneficial effects to plants. However, at moderate concentrations (1200 ppm to several percent, depending on duration and tolerance of a given species, CO_2 can cause toxic effects in plants and animals. At high levels (>~50%), it can be toxic to microorganisms as well.

Decreasing water pH can increase the toxicity of copper for *Arenicola marina*, an aquatic segmented worm.

6. Are there any adverse impacts on biodiversity? (§205.200)

Applying CO_2 at higher than optimum levels could cause toxicity to a wide variety of organisms. This situation is unlikely, however, because it would also begin to exert negative growth effects on crops, thus defeating the purpose of its use.

Category 3: Alternatives/Compatibility

1. Are there alternatives to using the substance? Evaluate alternative practices as well as non-synthetic and synthetic available materials. [§6518(m)(6)]

There is no substitute for gaseous CO_2 in plant biology. It is an essential component of the photosynthesis process.

It is possible to produce CO_2 nonsynthetically using fermentation processes or extraction from natural CO_2 wells but the prevalence and availability of different CO_2 production streams is difficult to define, is determined by regional industry and transport infrastructure, and by the nature of the commodified raw chemical material market because many streams may be combined. Previous written comments have indicated that inadequate infrastructure and costly transport restricts the source of nonsynthetic carbon dioxide. The commentor also stated fermentation businesses were often using the $CO_2$for carbonating fermented beverages.

2. In balancing the responses to the criteria above, is the substance compatible with a system of sustainable agriculture? [§6518(m)(7)]

The Crops Subcommittee initially had questions regarding the greater explanation of the overall greenhouse gas effects of this material in its manufacturing and use, especially how it ties into climate change for this particular petitioned usage. CO_2 can be used for agriculture without adding harm to the environment. Because it is a byproduct of multiple manufacturing processes, the "production" of CO_2 is occurring regardless of its use in organic agriculture. If it weren't used, it would be released into the atmosphere. Although its use does not substantially reduce emissions because the CO_2 is only temporarily stored in the plant and then re-enters the carbon cycle. In reflection of this information the Crops Subcommittee proposes an annotation to restrict its use to byproduct sources.

Classification:
Carbon Dioxide is already on the national list and classified as synthetic.

National List Motion:
Motion to add carbon dioxide at §205.601(j) with the annotation: must be sourced as a byproduct.
Motion by: Logan Petrey
Seconded by: Jerry D'amore
Yes: 6 No: 2 Abstain: Recuse: Absent: 1