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

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.

Ferric Phosphate

Crops

Identification of Petitioned Substance

Chemical Names:
Ferric phosphate

Other Names:
$FePO_4$; Ferric orthophosphate; Ferric phosphate hydrate; Iron (III) phosphate

Trade Names (includes EPA Reg No.):
Sluggo® (67702-3)
Sluggo® Plus (67702-24)
Antixx Plus (67702-24)
Brandt Antixx Plus (67702-24)
Bug-N-Sluggo® (67702-24)
Ferti-Lome (67702-3)
Ferti-Lome Plus (67702-24)
Garden Safe (67702-3)
Loveland Sluggo® (67702-3)
Miracle-Gro Slug & Snail (67702-3)
Monterey Sluggo® Maxx (67702-55)
Monterey Sluggo® Plus (67702-24)
Monterey Sluggo® (67702-3)
Natria Garden Granules (67702-24)
Natria Snail & Slug (67702-3)
Natural Guard Slug & Snail (67702-3)
Sluggo® Maxx (67702-55)
Whitney Farms Slug & Snail (67702-3)

CAS Numbers:
10045-86-0 (anhydrous)

Other Codes:
EPA PC 034903

Summary of Petitioned Use

This limited scope technical report provides updated technical information to the National Organic Standards Board (NOSB) to support the sunset review of ferric phosphate, listed at 7 CFR 205.601(h)(1). This technical report focuses on alternatives to ferric phosphate as slug and snail bait, in organic crop production. Additionally, we report on the toxicity of EDTA, used as a formulant in ferric phosphate products.

W. Neudorff GmbH KG (referred to as "Neudorff" in the remainder of this report) originally petitioned the NOSB in 2003, requesting that ferric phosphate be added to the *National List of Allowed and Prohibited Substances* (hereafter referred to as the "National List") for use as a slug and snail bait (W. Neudorff GmbH KG, 2003). In 2005, the NOSB recommended that ferric phosphate be added to the National List (NOSB, 2005), and the National Organic Program (NOP) added it, effective 2006 (71 FR 53299, September 11, 2006).

In 2009, Steptoe & Johnson LLP submitted a revised petition (originally submitted in 2008), requesting that the NOSB reconsider the decision to include ferric phosphate at § 205.601(h) (Steptoe & Johnson, LLP, 2009). The petitioner noted that ferric phosphate was formulated with ethylenediaminetetraacetate (EDTA) or related salts and should not be allowed in organic production. The petition referenced a 2007 NOSB decision not to allow sodium ferric hydroxyl EDTA, partially due to concerns about EDTA (NOSB, 2012a).

According to Neudorff (2010), Steptoe & Johnson's 2009 petition was almost identical to a petition submitted in Europe by a manufacturer of a competing slug and snail pesticide, Lonza/Harlan Laboratories in 2008. Neudorff also claimed that Lonza financially contributed to research articles cited in the petition, including Zheng et al. (2008); and Edwards et al. (2009).

After reviewing comments in favor of continuing to allow ferric phosphate, the NOSB voted to continue its listing (NOSB, 2012b). The NOSB also noted the 2012 limited scope technical report *Ferric Phosphate*, in their discussion. The NOSB stated that ferric phosphate was a generic ingredient, which should be considered separately from any other ingredients (NOSB, 2012a). Furthermore, they considered EDTA an inert, allowed under § 205.601(m)(1) (NOSB, 2012a). As an aside, combining the petitioned substance ferric phosphate with EDTA does not likely result in appreciable sodium ferric hydroxyl EDTA.

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

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

There are a number of materials that could be alternatives to ferric phosphate mollusk baits. Below, we give a brief review of how they are used and also provide a comparison of their effectiveness. Then, we will list materials that may be allowed for use in organic agriculture. In this review, we often compare substances that cannot be used in organic agriculture with those than can be used. These comparisons were an important part of the publications we reviewed, and we maintain them here in order to preserve the integrity of the original research.

Alternatives to ferric phosphate mollusk baits include biocontrols, barriers, repellents, botanical contact sprays, drenches, and other baits without ferric phosphate as the active ingredient (Barua et al., 2021; Klein et al., 2020; Mc Donnell et al., 2016). Several of these alternatives can be used simultaneously in an Integrated Pest Management (IPM) Program. For instance, a trap crop could be used with a cinnamon oil contact spray. Trap crops make groups of slugs easier to target (Capinera, 2018; Jesiolowski, 1992).

There are a large number of plants that have molluscicidal activity. For example, Kloos & McCullough (1982) reviewed studies by others on hundreds of different plants with molluscicidal activity. Later reviews by this pair of authors reportedly described approximately 600 different plants.[1] However, because synthetics have been readily available, most of the plants on this list were never commercially developed. A number of them, such as *Aconitum*, *Nux vomica*, and poison ivy (*Toxicodendron radicans*) are quite toxic to humans and other mammals. Many of the plants were only tested against aquatic snails, which are not the major problem in organic agriculture (Grossman, 1988). However, some herbs, such as rosemary or thyme, are either repellent or antifeedant to terrestrial mollusks (see *<u>List of nonsynthetic alternative materials</u>*, at the end of this evaluation question).

Some nonsynthetic products have been commercially developed that have some effectiveness for slug and snail control in some crops and in some situations. Many of these have limited applications. For instance, a slug or snail barrier is not useful to protect a field of wheat but might be effective in an orchard. Orchids growing in greenhouse containers could be protected with a caffeine drench; however, caffeine would be too expensive to use in a field crop. Nematodes can protect field crops because they live in the soil, but they would not be effective in orchards where snails occur in trees. Horticultural oil (or possibly vegetable oil) could be used as a barrier in orchards to protect against snails, but it would not be effective if used on a wheat crop. Repellents and barriers are not generally effective in grain fields where slugs are already present before the crop is planted.

For the greatest number of crops and situations, the only commercially available organic standalone replacement for ferric phosphate bait is sulfur bait. There are very few publications comparing ferric phosphate and sulfur baits, but in those publications, the baits had similar effectiveness (Capinera, 2018; Orcal, 2017). An advantage of ferric phosphate bait over many materials is that it is effective in the wet conditions where slugs and snails thrive (Capinera, 2018).

Biocontrols

Biocontrols, such as nematodes in the genus *Phasmarhabditis* could be useful, but they are expensive and limited for specific situations (Rae et al., 2007). In the UK, these nematodes have been used to control slugs in lettuce, cabbage, asparagus, brussels sprouts, and celery (Grubišić et al., 2018; Rae et al., 2007). Slugs and snails may avoid the nematodes, and biocontrols can be more effective when combined with attractive baits in a push-pull IPM program (Wynne et al., 2016). The nematodes may also be incompatible with pesticides such as essential oils (Barua et al., 2020).

[1] Other papers such as (Grossman, 1988) and many others refer to a book chapter written by Kloos & McCullough in 1987. However, we were unable to obtain a copy of this book chapter.

Other biocontrols include:

- predatory snails (Wilen & Flint, 2018)
- predatory carabids (Fisher et al., 1976)
- parasitic flies (Barua et al., 2021; Murphy et al., 2012)

However, predatory carabid beetles and parasitic flies are not sold for mollusk control. Predacious snails may not be available in all areas. Conservation biocontrol habitat could be used to encourage the beetles. Unfortunately, the same habitat that encourages beetles also encourages slugs and snails (Barua et al., 2021; Wilen & Flint, 2018).

Barriers

Barriers are of two kinds, physical or chemical. The USDA organic regulations states:

> *§ 205.206 Crop pest, weed, and disease management practice standard.*
>
> …
>
> *(b) Pest problems may be controlled through mechanical or physical methods including but not limited to:*
>
> *(1) Augmentation or introduction of predators or parasites of the pest species;*
>
> *(2) Development of habitat for natural enemies of pests;*
>
> *(3) Nonsynthetic controls such as lures, traps, and repellents.*

Physical barriers may have additional properties. For example, copper strips can be physical barriers, but their repellent effect may be electrochemical. To be effective, copper strips need to be wide (Oregon State University Extension Service, n.d.). Most copper strips sold in garden stores are too narrow to be effective (Oregon State University Extension Service, n.d.). Diatomaceous earth acts like a physical barrier, although it is also a desiccant. Barriers are used to keep slugs and snails away from plants (Wilen & Flint, 2018). Some barrier materials such as hydrated lime have greater effectiveness than ferric phosphate baits (Capinera, 2018); however, hydrated lime is not allowed in organic agriculture for this use. Manufacturers typically produce copper metal through methods that are classified as synthetic [see the 2022 technical report, *Copper Products (Fixed Coppers and Copper Sulfate)* (NOP, 2022)]. As the USDA organic regulations do not discuss the use of physical barriers with additional properties, it is unclear whether copper strips should be considered a pest control input, or something akin to fencing (farm infrastructure).

Chemical barriers and chemical repellents have similar actions. Chemical repellents are often applied directly to the plant. But chemical repellents are sometimes used as barriers. In Florida, researchers measured the effectiveness (measured as mortality) of chemical barriers for control of the leatherleaf slug, *Leidyula floridana* (see Table 1, below) (Capinera, 2018).

Table 1: Mortality rates following the application of several chemical barrier substances (Capinera, 2018).

Material	Mortality rate
Hydrated lime	100%
Fumed silica	40%
Sulfur dust	25%
Diatomaceous earth	20%
Wood ash	10%
Iron phosphate	50%

The same study also reported rates of leaf consumption, or herbivory. Diatomaceous earth and silica did not reduce feeding damage, but sulfur dust and hydrated lime did.[2] Barrier sprays of cinnamon oil (Snail and Slug Away) were effective in reducing slug access to plants and were 100% lethal as a contact spray.

Horticultural oil barriers were more effective than ferric phosphate or metaldehyde baits in protecting citrus orchards from the white snail, *Helicella candeharica*, in Iran (Sepasi et al., 2019). Horticultural oil was a more effective repellent (80.3%) than metaldehyde (41.2%) against the citrus brown snail, *Caucasotachea*

[2] Diatomaceous earth is a nonsynthetic substance and may be used in organic production for control of mollusks. Silica can exist in a range of forms. Some forms, such as precipitated silica are synthetic, and not allowed in organic production for the control of mollusks. Hydrated lime (a synthetic substance) is allowed for plant disease control, but not as a molluscicide.

lencoranea (Kheirodin et al., 2012). Neither horticultural oils nor metaldehyde are currently allowed for mollusk control in organic production. However, it is possible that nonsynthetic vegetable oils could be used as an alternative to horticultural oils.

Schüder et al. (2003) tested a number of biorationals (materials derived from natural sources), and mulches as barriers or repellents against slugs and snails. The most effective products were garlic extract, cinnamamide, and urea formaldehyde. Copper metal strips also had high efficacy. Cinnamamide and urea formaldehyde are synthetic substances not allowed for organic control of mollusks.

Waterglass (sodium silicate) and copper foil barriers were used on flowerpots to reduce access of *Arion vulgaris* slugs to a bait of fresh strawberries. The liquid sodium silicate solution was applied to paper tape encircling a plastic pot. Copper foil slowed slug access, but the waterglass barrier reduced damage in a field situation by 50% (Watz & Nyqvist, 2021). Sodium silicate is allowed for use as a flotation agent in post-harvest handling of tree fruits and fiber processing [7 CFR 205.601(l)].

Repellents and lethal contact sprays

Essential oils such as clove, mint, cinnamon, and lemongrass can be effective slug and snail repellents (Mc Donnell et al., 2016). Contact sprays of garlic, clove, and cinnamon extracts are among the most effective that have been tested (Capinera, 2018; Mc Donnell et al., 2016; Schüder et al., 2003).

Sprays of cinnamon oil (Snail and Slug Away) were more effective in killing slugs compared to either sulfur baits or iron phosphate baits (Capinera, 2018). Extract of yucca, *Yucca schidigera*, (Slug Yuc) was effective at protecting orchids from the snail *Zonitoides arboreus* in Hawaii (Hollingsworth & Armstrong, 2003).

Carvone extracted from caraway seeds is an effective repellent against the slug, *Arion lusitanicus* (Frank et al., 2002). However, because of its volatility, it did not protect lettuce against slugs in one study (Frank et al., 2002).

Copper fungicides such as copper hydroxide can be mollusk repellents. They can be combined with baits in a push-pull IPM method (Capinera & Dickens, 2016). However, copper products are not allowed for mollusk control in organic production.

Soil drenches

Mc Donnell et al. (2016) tested 11 essential oils and pine oil in laboratory petri dishes for control of the snail *Cornu* (*Helix*) *aspersa*. They applied the materials at a concentration of 1%. The best materials were oils of:

- cinnamon
- clove
- garlic
- lemongrass
- peppermint
- spearmint
- pine

With these materials, the mortality of eggs and juvenile snails reached 100% (Mc Donnell et al., 2016). Clove oil was the most potent, followed by pine, spearmint, garlic, peppermint, cinnamon, and lemongrass. As a drench in potting media, clove oil at 0.116% was 100% lethal to eggs and juveniles with a one-day exposure.

A 2% caffeine drench killed 95% of the orchid snail, *Zonitoides arboreus* (Hollingsworth et al., 2003). Caffeine solutions as low as 0.01% significantly reduced slug feeding (Hollingsworth et al., 2003).

Baits

Sulfur baits have similar effectiveness compared to iron phosphate baits when tested against the Florida leatherleaf slug, *Leidyula floridana* (Capinera, 2018) or *Deroceras* sp. (Orcal, 2017). See Focus Question 4

(below) for further discussion. Researchers tested the bait products, *Sluggo*® (ferric phosphate), *Niban* (boric acid) and Bug Geta (carbamate-methiocarb) for efficacy against the giant African snail, *Lissachatina fulica*. In choice tests, Bug Geta gave 69.2% mortality, Sluggo® (49.2%), and Niban 48.3% (Smith et al., 2013). Carbamate-methiocarb is not an allowed synthetic molluscicide in organic agriculture. Boric acid is only allowed for use in organic production as a structural insecticide (§ 205.601(e)(3)). These materials (and others described below) are used to show how ferric phosphate compares with other substances.

Baits of neem seed oil up to 700 mg/kg had no effect on the snails *Limicolaria aurora* and *Archachatina marginata* (Ebenso, 2003). Extracts of neem bark and root were lethal at 500 mg/kg (Ebenso, 2003).

Ferric phosphate bait (52.2%) was more effective than metaldehyde in protecting citrus orchards from the citrus brown snail, *Caucasotachea lencoranea* (Kheirodin et al., 2012). Capinera & Rodrigues (2015) tested baits of metaldehyde, ferric phosphate, sodium ferric-EDTA, and boric acid on the Florida leatherleaf slug, *Leidyula floridana*. Metaldehyde was most effective, followed by the iron baits. Boric acid was ineffective because the slugs would not eat it. Capinera (2013) tested the above baits on the Cuban brown snail, *Zachrysia provisoria*. Metaldehyde produced more mortality and acted faster, but the iron baits effectively reduced feeding. Boric acid was the least effective (Capinera, 2013). Metaldehyde, sodium ferric-EDTA, and boric acid are not allowed for mollusk control in organic production.

Other baits that researchers have tested (but not developed further), have active ingredients such as limonene (Agrahari & Singh, 2013), neem (Ebenso, 2003), and quackgrass (Hagin & Bobnick, 1991). These are not useful for the average organic farmer since the farmers would have to make their own baits. The essential oil and neem baits do not produce mortality or stop feeding. They instead prevent pest reproduction (Agrahari & Singh, 2013).

List of nonsynthetic alternative materials

<u>Nonsynthetic oils</u>

- Essential oils (Klein et al., 2020)
- Carvone (caraway seed oil) (Frank et al., 2002)
- Cinnamon oil (Capinera, 2018; Mc Donnell et al., 2016)
- Clove oil (Mc Donnell et al., 2016)
- Lemongrass oil (Mc Donnell et al., 2016)
- Myrrh oil (Barua et al., 2021)
- Thyme oil (Mc Donnell et al., 2016)
- Peppermint oil (Mc Donnell et al., 2016)
- Rosemary oil (Klein et al., 2020)
- Spearmint oil (Mc Donnell et al., 2016)
- Products containing these materials are included in the OMRI Products List (OMRI, 2023).

<u>Nonsynthetic biorationals</u>

- Caffeine (Hollingsworth et al., 2002)
- Diatomaceous earth (Capinera, 2018; Jesiolowski, 1992)
- Extract of neem bark (Ebenso, 2003)
- Garlic extract (Mc Donnell et al., 2016; Schüder et al., 2003)
- Wood ash (Capinera, 2018; Jesiolowski, 1992)
- Pine oil (Mc Donnell et al., 2016)
- Yucca extract (Hollingsworth & Armstrong, 2003)

<u>Nonsynthetic botanical baits</u>

- Quackgrass (Hagin & Bobnick, 1991)
- Sesbania (Barua et al., 2021)

<u>Nonsynthetic antifeedants</u>
Slugs and snails do not like to feed on these plants. When methanol extracts were prepared, only *Salvia officinalis* and *Valerianella locusta* extracts significantly prevented slug feeding on rape seedlings (Barone & Frank, 1999; Barua et al., 2021).

- *Geranium robertianum*
- *Lepidius sativum*
- *Origanum vulgare*
- *Salvia officinalis*
- *Saponaha officinalis*
- *Thymus vulgaris*
- *Trifolium repens*
- *Valerianella locusta*

<u>Nonsynthetic toxic and repellent extracts (Barua et al., 2021)</u>
Commercial availability for some of these materials is uncertain.

- Japanese knotweed, *Fallopia japonica*
- Canadian Goldenrod, *Solidago canadensis*
- Tree of Heaven, *Ailanthus altissima*
- Camellia, *Camellia oleifera*
- *Gleditsia amorphoides*
- Soap bark tree, *Quillaja saponaria*

<u>Nonsynthetic biocontrols</u>

- Parasitic flies (Murphy et al., 2012)
- Parasitic nematodes (Rae et al., 2007)
- Predaceous beetles (Fisher et al., 1976; Wilen & Flint, 2018)
- Predacious snails (Barua et al., 2021)
- Parasitic nematodes and predacious snails for mollusk management are sold commercially but may not be available in all areas. Predacious beetles and parasitic flies are not sold for mollusk control (Wilen & Flint, 2018).

Synthetic materials that are specifically permitted for slug and snail control

- Ferric phosphate [§ 205.601(h)(1)] (Puritch et al., 1995)
- Elemental sulfur [§ 205.601(h)(2)] (Orcal, 2017)

Synthetic materials allowed for pest control purposes at 7 CFR 205.601
While effective for slugs and snails, they are not currently allowed for this purpose.

- Copper hydroxide plant disease [§ 205.601(b)(3)] (Capinera & Dickens, 2016)
- Elemental sulfur plant disease [§ 205.601(i)(10)] (Capinera, 2018)
- Horticultural oil plant disease [§ 205.601(i)(7)] (Kheirodin et al., 2012)
- Hydrated lime plant disease [§ 205.601(i)(4)] (Capinera, 2018)

Conclusion
There are many products to discourage slugs and snails in various niche situations, but these often have disadvantages as well. For instance:

- Essential oils are volatile and must be applied often.
- Continuous use of lime can make soil alkaline.
- Continuous use of sulfur dust can make soil acidic.
- Most biocontrols are not commercially available.
- Many plant extracts are not commercially available.
- Biocontrols such as nematodes are commercially available, but they are expensive, and incompatible with pesticides such as essential oils.

Most of these products are not meant to be standalone products but gain effectiveness for use in an IPM Program. Some products, such as hydrated lime, are not allowed for use as a mollusk control in organic production.

Baits have the advantage that they can be used both in fields and orchard situations. A major advantage of iron phosphate baits is that they are effective in wet conditions, exactly the conditions that encourage slugs and snails. They are relatively inexpensive and do not have to be reapplied often. They effectively reduce slug and snail feeding (Capinera, 2018). The only other alternative product for organic production that can be used as a standalone treatment over a wide range of crops and conditions is sulfur bait (Orcal, 2017). Even so, baits are more useful as part of an IPM program incorporating cultural controls and resistant species (Bowen & Mendis, 1995).

<u>Evaluation Question #12:</u> Describe any alternative practices that would make the use of the petitioned substance unnecessary [7 U.S.C. 6518(m)(6)].
Examples of cultural practices are listed in the USDA organic regulations within the *Crop pest, weed, and disease management practice standard* at 7 CFR 205.206(a) and (b). These cultural methods include those used to enhance crop health and prevent weed, pest, or disease problems without the use of substances. Examples include the selection of appropriate varieties and planting sites; proper timing and density of plantings; irrigation; and extending a growing season by manipulating the microclimate with green houses, cold frames; or wind breaks.

Other cultural practices may include, but are not limited to, crop rotation, mulching with fully biodegradable materials, mechanical cultivation, augmentation or introduction of predators or parasites of the pest species; development of habitat for natural enemies of pests; nonsynthetic controls such as lures, traps, and repellents; sanitation measures and management practices which suppress the spread of disease organisms. In many cases, these cultural practices alone are not sufficient on their own to prevent damage due to mollusks in all cases. Organic producers must demonstrate that these cultural practices were insufficient to prevent or control crop pests (including mollusks) before using ferric phosphate bait or the only other synthetic slug and snail bait currently allowed in USDA organic crop production, elemental sulfur.

Handpicking
The ultimate physical control is handpicking. This approach is useful in gardens and organic farms with small crop acreage. It is very labor intensive, and the work has to be done at night. In one instance, one Oregon couple destroyed 7,148 slugs in two months (Jesiolowski, 1992).

Traps
Traps can be effective in protecting small areas and monitoring large ones. A 4-inch wide, 10-inch-deep hole in the ground covered with a board can trap slugs. Overturned clay pots, boards with raised strips to provide hiding places underneath are useful. Pitfall traps are commercially available, and can be baited with beer (Quarles, 2007; Wilen & Flint, 2018). Traps can also be baited with fermenting bread dough, but beer has the advantage that it may drown the mollusks (Veasey et al., 2021).

Hagnell et al. (2006) found that homemade traps made of ice cream boxes were just as effective as commercially available box traps. Traps were baited with beer. A homemade trap made from a one-liter soda bottle was ineffective.

Barriers
Barriers are discussed in *Evaluation Question #11* (above). The disadvantage of many barriers such as diatomaceous earth, wood ashes, and others is that they are less effective in wet conditions where slugs and snails thrive (Quarles, 2007).

Plowing
One of the best cultural controls is plowing. But plowing is being replaced by no-till methods that preserve soil and reduce CO2 emissions that lead to global warming. Planting seeds deeper can reduce slug damage

in some cases. Planting wheat seeds at 4 cm (1.6 in) instead of 2 cm (0.8 in) is as effective as a broadcast bait of methiocarb in reducing slug damage (Glen & Wilson, 1995).

Rotation and timing of planting
Crop rotations can help protect against slugs. At least one crop in the rotation should not attract slugs. For instance, if winter wheat is being grown, there should not be a summer crop such as rape that attracts slugs (Moens, 1989).

Timing of planting and harvesting can also be effective. Planting potatoes earlier and harvesting earlier can reduce damage (Glen & Wilson, 1995). In citrus groves, drip irrigation instead of overhead irrigation can reduce snail damage (Quarles, 2007). Resistant species should be planted when slug risk is high. Resistant potatoes such as Maris Piper and Pentland Dell have enzymes that produce quinones that give slugs indigestion (Johnston & Pearce, 1992). However, slugs and snails prefer seeds and small seedlings that have not had time to produce defensive chemicals (Quarles, 2007).

In general, mulching is a good agronomic practice; however, it attracts slugs and snails. Crop producers may need to balance mollusk control, weed control, water retention, and other needs of specific sites. For instance, mulch might be used even though it attracts slugs, if there is a drought. Preserving water would be more important than preventing slug damage (Quarles, 2007).

Gardens and fields should be kept free of weeds, debris, leaves, discarded containers and other trash that provide slug and snail hiding places (Quarles, 2007). Mowing in vineyards can reduce slug and snail populations and damage. Mowing reduces humidity that encourages mollusks and removes places where mollusks could otherwise hide from birds and other predators (Egleton et al., 2021).

Fertilization practices can be helpful. Increasing silicon content of wheat to 2% by adding allowed silicate solutions significantly reduced slug feeding (Griffin et al., 2015).

Focus Questions Requested by the NOSB

<u>Focus Question 1:</u> When used in ferric phosphate products, does EDTA chelate heavy metals in soils? Are there studies that show the combination of ferric phosphate and EDTA (chelator) cause toxic effects in soil microorganisms, including earthworms, or plants?
The NOSB requested that we refrain from using calculations derived from Neudorff's soil residue estimates for ferric phosphate bait products, provided to the NOSB in 2010 (W. Neudorff GmbH KG, 2010). Furthermore, the NOSB requested that we not include other extrapolated or conjectural values, except those from published literature. We have followed these instructions except where straightforward conversions are used. However, as a result, it is not possible for us to include a direct comparison of heavy metal extraction from soil using ferric phosphate bait products containing EDTA with published studies using much larger concentrations of EDTA. Still, we provide information that we hope we can give the reader some sense of scale.

EDTA heavy metal chelates
Ethylenediaminetetraacetic acid (EDTA) forms chelates with heavy metals in soils (Grčman et al., 2003; Udovic & Lestan, 2007). It is therefore possible that some of the EDTA in ferric phosphate bait pellets could also form chelates with heavy metals, where they are present and when EDTA is available to bind.

For example, Grčman extracted contaminated soil with 2920 mg EDTA per kg of soil. The extraction removed 22.7% of lead (Pb) (249.7 mg), 7% of zinc (Zn) (56 mg), and 39.8% of cadmium (Cd) (2.19 mg). Similarly, Udovic & Lestan (2007) used 3650 mg EDTA/kg soil for soil remediation in soil contaminated with lead. This treatment removed approximately 39.8% of the 1504 mg/kg soil.

The amount of EDTA that would be present in soil from the use of slug baits is small compared to the treatments used by Grčman (2003) and Udovic & Lestan (2007). Neudorff disclosed that 5 grams of Ferramol/Sluggo® contained (W. Neudorff GmbH KG, 2010):

- 50 mg of iron (ferric) phosphate
- 54 mg of EDTA, or alternatively 112 mg of ethylenediamine-N,N′-disuccinic acid (EDDS)

This amount is recommended for application to 1 square meter of ground.

The amount of heavy metals that could be chelated by the EDTA from this product in soil would depend on a variety of factors, including:

- the presence of heavy metals and competing metals in the soil
- the amount of the EDTA that dissolves into the soil, from the ferric phosphate product
- the distribution of the ferric phosphate product within the soil profile, due to farming practices, animal activity, and other abiotic processes
- the characteristics of the soil
- the amount of time since the treatment was made

The actual distribution of EDTA from the product would depend on the factors noted above. It would initially occur at the soil surface but isolated within the granules. Over time, we expect the distribution of the product (and EDTA) would migrate. However, we found no studies that quantitatively determined the amount of EDTA that would be mobilized in the soil by ferric phosphate bait products, and where in the soil profile it would exist at different points in time. However, we discuss later how earthworms are known to pull bait pellets into their burrows, which can be quite deep (see *Do earthworms forage on the surface and eat bait pellets*, below).

While the amount of heavy metals extracted is likely to vary depending on the factors noted above, the EDTA treatment used by Grčman (2003) and Udovic & Lestan (2007) would likely expose soil to many thousands of times more EDTA than ferric phosphate baits, applied at labeled rates. For example, Grčman's study used 2920 mg of EDTA per one kg of soil (Grčman et al., 2003). For reference, soil density typically ranges from between 1.1 and 1.6 g/cm^3 (see Table 2, below). Even a thin layer (1 cm) of soil, covering one square meter of area has a mass of 11-16 kg. In both of these studies, the heavy metals that were chelated were only a fraction of the total amount of EDTA used, which was applied directly to the soil. In a ferric phosphate bait containing 54 mg of EDTA applied to one square meter of soil, the EDTA could chelate only a fraction of its own weight in heavy metals. Therefore, when used in ferric phosphate baits, EDTA likely only chelates a very small quantity of heavy metals when they are present.

Table 2: Ideal bulk densities for different soil textures (USDA NRCS, 2023).

Soil texture	Ideal bulk density (g/cm^3)	Mass of 1 cm soil x 1 m^2 (kg)
Sand, loamy sand	<1.6	<16
Sandy loam, loam	<1.4	<14
Sandy clay loam, clay loam	<1.4	<14
Silt, silt loam	<1.4	<14
Silty clay loam	<1.4	<14
Sandy clay, silty clay	<1.1	<11
Clay	<1.1	<11

<u>Effect of lead on earthworms, assuming it was made bioavailable through chelation with EDTA</u>

For the following sections, we focused on lead as a representative heavy metal, because it often occurs in soil, and toxicological information is generally available (U.S. EPA, 2023).

Exposure of *Eisenia fetida* earthworms to lead concentrations of 40-2500 mg/kg of soil was not lethal to the earthworms, although it did slow their rate of growth (Žaltauskaitė et al., 2020). For comparison, the average lead concentration in U.S. soil is 26 mg/kg (U.S. EPA, 2023). The EC_{50} for slowed growth rate of *E. fetida* in acidic soils is 460 mg/kg of lead (Wijayawardena et al., 2017).[3]

[3] The EC_{50} is the concentration of a substance that produces a half-maximal response; that is, a response that is halfway between the baseline and maximum, after a specified time.

Effect of EDTA on lead uptake by plants

EDTA itself can be toxic to plants, and it can also increase the amount of heavy metals absorbed by plants. Grčman et al. (2003) found that addition of 10 mmol/kg (2920 mg/kg) of EDTA to soil increased the lead uptake of Chinese cabbage by >94-fold.

Effect of lead on microorganisms, assuming it was made bioavailable through chelation with EDTA

Some microorganisms are more sensitive to lead than others. Sobolev & Begonia (2008) found both low (1 ppm; 1 mg/kg) and high (500-1000 ppm) lead exposures in soil changed the composition of the soil microbial community. Denitrifying bacteria were especially sensitive to lead.

The toxicity of lead to microorganisms varies with species and experimental conditions. Some microbes become quickly resistant and are actually used to remove lead from the environment. Atuchin et al. (2023) used a consortium of the microorganisms *Achromobacter denitrificans, Rhizobium radiobacter*, and *Klebsiella oxytoca* to remove 91.13 mg lead/liter of culture solution.

Toxicity of iron-EDTA chelates in mollusk baits

Do earthworms forage on the surface and eat bait pellets?

Earthworms ingest large amounts of organic matter and are important in soil formation (Gavin et al., 2012). Some worms, such as *Lumbricus terrestris* are known to forage on the surface of soil and eat meal-based slug bait pellets (Dummett et al., 2023). Generally, the earthworm *Lumbricus terrestris* collects surface materials, and then pulls them to a depth of 25-75 cm in their burrows (Edwards & Arancon, 2022).

Gavin et al. (2012) conducted field studies at 15 locations over three years. They found that the average time it took for earthworms to entirely remove 10 slug and snail meal-based bait pellets from the soil surface, protected from the rest of the field by a plastic, 18.9L bucket was:[4]

- 5.77 days for 4% metaldehyde product
- 4.92 days for 5% metaldehyde product
- 5.99 days for 1% ferric phosphate product (Sluggo®)

The number of pellets used per arena was 2–3X the standard labelled rate (Gavin et al., 2012).

Gavin et al. (2012) found that worms begin foraging several hours after sundown, and either sampled food on the surface, or pulled it down into their burrows, apparently intentionally selecting foods. Worms engulfed pellets 20% of the time on the surface and rejected them 10% of the time. The rest of the time, worms pulled the baits they encountered into their burrows. Once in the burrow, it was unclear what happened to the pellets. In other field observations, some worms were able to remove up to three pellets an hour (Gavin et al., 2012).

Citing other studies, Gavin et al. (2012) note that earthworm density in perennial and no-till cropping systems ranged from:

- 82–251 worms/m^2, in perennial ryegrass (*Lolium perenne*) systems
- 2–343 worms/m^2, in continuous conventional and no-till corn
- 400 worms/m^2, in bluegrass/clover
- 1300 worms/m^2, in dairy pasture and manure

Again, referencing other studies, Gavin et al. (2012) noted that rotary cultivation can reduce earthworm populations by 60–70%, and in some cases with repeat cultivation, cause near complete elimination of earthworms.

Effect of iron-EDTA chelates on earthworms

The European Food Safety Authority describes the toxicity of iron (ferric)-EDTA chelates to earthworms (EFSA, 2015). For example, the LC_{50} of the ferric phosphate bait, Sluggo®, to the earthworm *Eisenia fetida* is

[4] Gavin et al. (2012) also found other invertebrates consuming baits at the surface, including beetles, centipedes, sowbugs. However, earthworms were responsible for the majority of bait consumption.

>1000 mg/kg dry soil.[5] Since the product contains 1% iron chelate, the acute toxicity of undiluted ferric-phosphate-EDTA chelate is >10 mg/kg dry soil. Edwards et al. (2009) determined that the LD_{50} of ferric phosphate-EDTA chelates to the earthworm *Eisenia fetida* was 78.16 mg/kg soil.[6]

In a recent study with complicated results, Dummett et al. hypothesized that worms would feed on field soil less, in the presence of slug pellets (Dummett et al., 2023). They also hypothesized that *Lumbricus terrestris* would become less active burrowers when exposed to slug pellets. Their study consisted of two parts: a field experiment and a laboratory experiment. In their field study (zero-till wheat field), the authors exposed earthworms to the following slug and snail pellets for 14 days:

- control (no product)
- TDS Major (4% metaldehyde)
- Sluxx HP (ferric phosphate + EDDS)
- mixture of TDS Major and Sluxx HP

Supporting the authors' hypotheses, there was a significant decrease in feeding activity by worms in plots treated with either product, relative to the control in the surface horizon (0–25mm) after four weeks (Dummett et al., 2023). Dummett et al. did not include specific number averages. However, based on their figures, the control treatment had an average of over 20% higher feeding activity in this zone (surface horizon), compared with all of the treatments. Below 2.5 cm, feeding activity was similar between treatments and the control. Worms were fewer and had significantly lower biomass in the plots treated with metaldehyde or ferric phosphate in the field study (Dummett et al., 2023).

Sixteen weeks after treatment, Dummett et al. (2023) measured earthworm abundance again. They found that there was no difference in the number of worms or biomass in the control and the ferric phosphate + EDDS treatment. However, the number of worms (but not biomass) was lower in the plots treated with the metaldehyde product.

While one might assume that the lower biomass and smaller number of worms was due to ferric phosphate toxicity, this is unlikely the case. Dummett et al. (2023) also conducted a laboratory study using the same products. In contrast to the field study, they found no differences in earthworm biomass after 72 hours of burrowing. They also did not find a significant difference in total burrowing activity between treatments. However, the authors did find that earthworms exposed to ferric phosphate + EDDS pellets burrowed more deeply, triggering an avoidance response (Dummett et al., 2023). The authors found that there was no evidence that slug pellets resulted in some kind of mobility disorder. Dummett et al. proposed that the avoidance response to ferric phosphate might explain why worms were less abundant in the field studies (avoidance vs. toxic) at 4 weeks, but then normalized after 16 weeks. The authors inferred that the worms may have moved down in the soil profile temporarily (Dummett et al., 2023).

<u>Effect of iron-EDTA chelates on plants and microorganisms</u>

We were unable to find published studies on whether iron chelate mollusk bait products cause negative effects on plants and microorganisms. However, there are studies of iron chelates from other sources added to soil, and studies on the effects of EDTA on plants and microorganisms. Toxic levels of EDTA are many times the EDTA application rate in the baits. For instance, Scher et al. (1984) found that 100 mg/kg of iron-EDTA added to soil reduced soil concentrations of the biocontrol microbe *Pseudomonas putida*.

Bloem et al. (2017) showed that addition of 1050 kg/ha (21.42 lbs./1000 ft^2) of EDTA to soil reduced the growth rate of oilseed rape. This amount is >2000 times the application rate of EDTA (0.01 lbs./1000 ft^2) in 1% ferric phosphate baits such as Sluggo®. Wallace et al. (1955) found that EDTA was toxic to beans at 200 lbs./acre. That amount is 4.58 lbs./1000 ft^2 and is 458 times the application rate of EDTA in Sluggo® (W. Neudorff GmbH KG, 2010). Based on these examples, the EDTA in iron chelate baits is unlikely to cause phytotoxicity.

[5] The LC_{50} is the exposure concentration of a substance (typically expressed in milligrams per kilogram of body weight) needed to kill 50% of the animals in a population within a specific period.

[6] The LD_{50} is the internally administered dose (typically expressed in milligrams per kilogram of body weight) needed to kill 50% of the animals in a population within a specific period.

Focus Question 2: Is there new information (since the 2012 limited scope report) about the effects of EDTA (or other chelating agents) on the toxicity of ferric phosphate to non-target organisms, including earthworms and dogs?

There are some studies that relate to EDTA and ferric phosphate-EDTA or EDDS bait products that have been published since the 2012 *Ferric Phosphate* technical report. Notably, these include: Gavin et al. (2012) and Dummett et al. (2023), which together better characterize the behavior of worms around bait pellets (discussed previously in *Toxicity of iron-EDTA chelates in mollusk baits*). The European Food Safety Authority (EFSA) has since published information on the toxicity of iron phosphate-EDTA mollusk baits to earthworms (EFSA, 2015). Duo et al. (2019) measured EDTA toxicity on the earthworm, *Eisenia fetida.* Buhl et al. (2013) published an analysis of the toxicity of ferric phosphate-EDTA baits on dogs.

Toxicity to earthworms

According to the authors of the 2012 *Ferric Phosphate* technical report, the company W. Neudorff GmbH KG sponsored a field study to evaluate the effects of Neu1166M, a slug and snail bait product (NOP, 2012). The NOP provided the original field study report to us, which was carried out by Lührs in 2009 (Lührs & Schabio, 2009). Lührs' field study showed that if there were any adverse effects of ferric phosphate EDTA chelate baits on earthworms, they did not occur at an application rate of 200 kg/ha in field situations, as measured at one month, seven months, and one year after application. However, authors of the 2012 *Ferric Phosphate* technical report believed the results were inconclusive since the first sampling date may have been too late to detect more immediate impacts on earthworms (NOP, 2012).

In contrast, Dummett et al. (2023) was able to observe effects on worms after 4 weeks. As discussed previously, Dummett et al. concluded that a commercial ferric phosphate product was not toxic to worms at the quantities they tested, but that worms avoided them, possibly by moving lower in their burrows. By 16 weeks, worms had returned to a distribution similar to the control treatment.

Interestingly, despite the avoidance behavior noted by Dummett et al. (2023) and decreased feeding noted by Edwards et al. (2009), Gavin et al. (2012) noted that earthworms removed pellets from the soil surface within a matter of days. It was not clear what the worms did with the pellets in the majority of cases, however. It is possible that the differences between these experiments related to different field conditions and the different commercial products used.

According to EFSA, the LC_{50} of the commercial bait Sluggo® to the earthworm *Eisenia fetida* is >1000 mg/kg dry soil. Since the product contains 1% iron chelate, the acute toxicity of the iron chelate was >10 mg/kg dry soil, based on EFSA's evaluation.

A 2013 National Pesticide Information Center Fact Sheet states that beetles and earthworms are not affected by 2x label rates of 1% ferric phosphate baits (Buhl, Bond, et al., 2013).

A more recent experiment measured the toxicity of EDTA itself to earthworms. Duo et al. (2019) found toxic effects of EDTA to the earthworm, *Eisenia fetida*. Earthworm containing soil in a turfgrass plot was treated with 0, 5, 10, and 15 mmol EDTA. Concentrations greater than 5 mmol caused a significant loss of weight over a 35-day period. The 5 mmol treatment also caused a 37% decrease in the rate of earthworm survival over a 35-day period.

The amounts used by Duo et al. (2019) are equivalent to:

- 5 mmol: 1460 mg EDTA/kg soil
- 10 mmol: 2920 mg EDTA/kg soil
- 15 mmol: 4380 mg EDTA/kg soil

Toxicity to dogs

The classic study of ferric phosphate-EDTA chelate mollusk bait impact on dogs was published by Buhl et al. (2013). Over a period of 11 years from 2001 to 2011, there were 195 reports of dogs exposed to ferric phosphate baits in the U.S., with 83% of these reports (179) received between 2009–2011 and 80% of the total reports originating on the West Coast. Most of these reports were calls to National Poison Control Centers. Buhl et al. (2013) studied 56 of these reports in detail. In 60% of the cases, no poisoning symptoms were seen. In cases where the weights were recorded, the median dog weight was 7.3 kg (16 lb.). In 20% of cases, dogs ate from containers of the product. In 64% of cases, exposure occurred during or after application of the product. Amounts ingested in each case were not measured, but the maximum ingestion was 0.91 kg (2 lb.). Clinical observations of those dogs that did exhibit poisoning symptoms were vomiting, diarrhea, and lethargy. No dogs died. For comparison, in this same period of time, there were reports of 35 dog deaths due to ingestion of metaldehyde mollusk baits (Buhl, Berman, et al., 2013).

Ferric phosphate slug and snail baits are not a major source of toxic dog exposures. There were 55,804 dog poisoning exposures reported to the National Poison Centers in 2021 (Gummin et al., 2022). The number poisoned by mollusk baits were not specified. Iron phosphate mollusk baits caused roughly 60 reported exposures per year between 2009 and 2011 (Buhl, Berman, et al., 2013).

Ferric phosphate by itself has very low toxicity in part because it is nearly insoluble in water (1.86×10^{-12} g/liter @ 25C) (EFSA, 2015). That is about 1/1000th of a nanogram in a liter of water. It is well known that EDTA and other chelating agents make ferric phosphate more soluble and increases the bioavailability of ferric ions. Adding EDTA in a mole ratio of 0.5 EDTA to 1 ferric phosphate increases bioavailability of iron by a factor of three (Buhl, Berman, et al., 2013). Despite EDTA enhancement of the commercial baits, Buhl et al. (2013) reported that no dogs died even after eating two pounds of ferric phosphate bait.

Haldane & Davis, (2009) treated five dogs that consumed 150 g (0.33 lb.) to 650 g (1.43 lb.) of ferric phosphate bait containing EDTA. Doses of bait were 6000 mg/kg to 33000 mg/kg. All dogs survived.

<u>Focus Question 3:</u> Are there ferric phosphate products that are formulated without chelating agents?
Reagent grade ferric phosphate does not include a chelating agent; however, it may not be legal to use as a pesticide in most applications. Furthermore, a bait made from ferric phosphate (without EDTA) would be less effective (NOP, 2010). If using reagent grade ferric phosphate, iron bioavailability to mollusks would be comparatively less, and it would also not include feeding stimulants that are added to commercial baits (NOP, 2012; Puritch et al., 1995). The EPA also does not allow an unregistered pesticide to be used in commercial crop production unless it meets exemption criteria recorded in the Federal Insecticide, Fungicide, and Rodenticide Act (FIFRA) Section 25b [*i.e.,* 25(b) exempt].

Inert ingredients are not listed on pesticide labels, and there is no way to determine the presence or absence of an EDTA inert in a product by viewing the label or MSDS. But it is unlikely that a manufacturer would try to sell a ferric phosphate bait without a chelating agent. Adding EDTA in a mole ratio of 0.5 EDTA to 1 iron phosphate increases bioavailability of iron by a factor of three (Buhl, Berman, et al., 2013). Ferric phosphate baits without a chelating agent would be less effective and would likely not be commercially viable (Henderson, 1989; NOP, 2010).

The ferric phosphate mollusk bait formulation initially approved for organic agriculture was NEU1165. This product contained 1% ferric phosphate, and 1% EDTA. It is being sold throughout North America as Sluggo® (NOP, 2012; W. Neudorff GmbH KG, 2010). A modification is Sluggo® Plus, which has 0.07% spinosad added to the formulation (California Department of Pesticide Regulation, 2023).

There are currently 21 ferric phosphate mollusk bait products listed by OMRI for organic production (OMRI, 2023). Except for Sluggo® Maxx products, all of these baits contain either 1% or 0.97% ferric phosphate and are either Sluggo®, Sluggo® Plus, or a rebranding of these formulations (California Department of Pesticide Regulation, 2023). Since Sluggo® contains 1% EDTA, all of the products with the same EPA registration number contain 1% EDTA (NOP, 2012) (see *Identification of Petitioned Substance*, above). Sluggo® Maxx contains 3% ferric phosphate, but the maximum label application rate is one-third that of Sluggo® (California Department of Pesticide Regulation, 2023).

<u>Focus Question 4:</u> Do sulfur-based slug management products provide an effective alternative to ferric phosphate? Do they also include chelating agents?

Sulfur as an effective alternative

Orcal (2017) tested the effects of baits containing 4% metaldehyde, 1% ferric phosphate (Sluggo®), and 1% sulfur (BioSul) against the field slugs, *Deraceras* and *Arion* in Oregon hydrangea fields. They calculated two measures of efficacy:

- The number of slugs foraging and caught in beer traps was an estimate of feeding suppression. The fewer slugs caught compared to controls, the more feeding suppression (sick slugs do not feed and thus are not caught).
- The other measure of efficacy was the number of dead slugs found in the experimental plots.

Metaldehyde was the most effective for both measures of efficacy (Orcal, 2017). Sluggo® and BioSul were equally effective for feeding suppression. BioSul was slightly more effective than Sluggo® in causing mortality.

Capinera (2018) tested a number of products to protect plants against the leatherleaf slug, *Leidyula floridana*, in Florida. The most effective product was a commercial spray of cinnamon oil applied directly on the leatherleaf slug. Metaldehyde baits (Correy's Slug and Snail Pellets) were compared to 1% ferric phosphate baits (EcoSense Slug and Snail Pellets) and 1% sulfur baits (Bug Geta). All baits were sprinkled around the plants to be protected. When mortality was measured after 7 days, the metaldehyde bait killed 95% of the slugs, the sulfur bait killed 40%, and the iron phosphate bait killed 50%. The difference in mortality between sulfur and iron phosphate was not statistically significant. But the iron phosphate significantly reduced leaf consumption compared to the sulfur bait (Capinera, 2018).

A University of California Pest Notes factsheet states that iron phosphate baits lead to less snail and slug feeding than sulfur baits (Wilen & Flint, 2018).

Do sulfur-based slug management products contain chelating agents?

Chelating agents in pesticide products are often considered inert ingredients. EPA regulations do not require pesticide manufacturers to disclose inert ingredients on product labels. Therefore, it is not possible to identify whether sulfur-based slug management products contain chelating agents as inert ingredients. However, inert ingredients on 2004 EPA List 4 are allowed in pesticides used in organic production [7 CFR 205.601(m)], provided that they are not revoked within NOP 5008 (*Reassessed Inert Ingredients*) (NOP, 2011). EDTA is included on this list (U.S. EPA, 2015). Therefore, it is possible that sulfur-based slug management products could contain EDTA.

OMRI lists many sulfur-based slug management products along with other elemental sulfur pesticide products (OMRI, 2023b). These include products labelled for use as a fungicide, insecticide, acaricide, as well as slug and snail baits. Some of these elemental sulfur products do contain EDTA. However, due to confidentiality, OMRI can only provide generic information, and cannot disclose the formulation of specific products. Therefore, it is unknown whether sulfur-based slug management products do or do not contain chelating agents.

No other sources of information were found that provide information.

Report Authorship

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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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