# Arsenic in Poultry Litter: Organic Regulations

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Most of the arsenic used as an antibiotic in commercial broiler production ends up in the litter. Using this litter as a soil amendment is not prohibited by the National Organic Program, but 7CFR §205.203(c) of the Rule requires that "the producer must manage plant and animal materials to maintain or improve soil organic matter content in a manner that does not contribute to contamination of crops, soil, or water by plant nutrients, pathogenic organisms, heavy metals, or residues of prohibited substances." Poultry litter applied at agronomic levels, using good soil conservation practices, generally will not raise arsenic concentrations sufficiently over background levels to pose environmental or human heath risks. However, recent studies show that more than 70% of the arsenic in uncovered piles of poultry litter can be dissolved by rainfall and potentially leach into lakes or streams. Thus, organic producers must take care when they handle and apply poultry litter.

*Manure and wood chips used for turkey bedding are composted and used for fertilizer on adjacent pastures. Photo by Jeff Vanuga, USDA NRCS.*

Many organic producers use poultry litter—fresh, composted, or as pellets—as a fertilizer and a source of organic matter. Much of this litter comes from commercial broiler operations, which use arsenic as a feed additive to control parasites and increase weight gain. Most of this arsenic does not accumulate in the poultry meat, but is excreted by the birds. As a result, almost 90% of the arsenic fed to poultry ends up in the litter. Because this heavy metal has the potential to build up in the soil, cause health problems for farm workers and produce consumers, and be transported to adjacent lakes or streams, many organic farmers and their certifiers are concerned that using commercial poultry litter is not compliant with the National Organic Standard.

Their concerns about organic compliance center on 7 CFR §205.203(c) of the National Organic Program Regulatory Text.(1)

> The producer must manage plant and animal materials to maintain or improve soil organic matter content in a manner *that does not contribute to contamination of crops, soil, or water*

*by plant nutrients, pathogenic organisms, heavy metals, or residues of prohibited substances.* (Italics added.)

Arsenic also appears on the National List of Prohibited Non-synthetic Substances in §205.602(a).

To understand when and how arsenic in poultry litter can contaminate crops, soil, or water, we need to examine the following questions.

- What is the source of the poultry litter?
- How much arsenic is in poultry litter?
- How much arsenic is added to the soil when you apply poultry litter?
- How often is poultry litter applied to the same land?
- How do soil type and soil management affect the movement and toxicity of arsenic?
- How does increasing soil organic matter affect the potential for arsenic runoff or leaching?
- What is the potential that arsenic from applied poultry litter will contaminate rivers, streams, lakes, or groundwater?
- How does arsenic in soil affect crop growth and food safety?
- Other than poultry litter, what else can contaminate the soil with arsenic?
- How can you remediate arsenic-contaminated soils?

***Litter collected following a single flock of birds typically contains 30 to 50 ppm arsenic.***

***Microbiologist Patricia Millner and technician Michael Bzdil collect compost samples to analyze in the lab. Photo by Stephen Ausmus, USDA ARS.***

## What is the source of the poultry litter?

Arsenic, in the forms of roxarsone and arsenilic acid, is an additive in the feed of conventionally-raised broilers. It is used to control protozoan parasites known as coccidians and to enhance weight gain.(2) Feeding arsenic to laying hens is prohibited. Organic regulations prohibit feeding arsenic to birds raised for organic certification. Therefore, you can be sure that you are not using poultry litter containing arsenic by getting it from layer operations or from organic poultry farms. You can also use other methods to enhance the nutrient content of your soil, such as green manure crops, cattle manure, compost, or a mixture of organically-approved inputs, such as fish emulsion, blood meal, and rock phosphate. (Use care when selecting sources of rock phosphate, since it can be contaminated with arsenic, lead, and cadmium.)

## How much arsenic is in poultry litter?

Roxarsone is added to poultry feed at the rate of 22.7 to 45.4 grams per ton, or 0.0025 to 0.005 percent.(3) Most of the roxarsone passes through the birds and is excreted unchanged.(4) Each broiler excretes about 150 milligrams of roxasone during the 42-day growth period in which it is administered.(5) Litter collected following a single flock of birds can contain from 1 to 70 milligrams of arsenic per kilogram of litter, with 30 to 50 milligrams per kilogram commonly found (also expressed as 30 to 50 ppm or 0.003 to 0.005 percent arsenic).(4, 5, 6, 7) Often, poultry houses are only partially cleaned following each flock of birds, increasing the arsenic concentration in the litter.

To find out how much arsenic is in the poultry litter that you intend to use, have your soil or manure testing laboratory check your litter samples for arsenic (it may be listed on the soil test request form by its chemical symbol, As). You can ask for this test when you submit your litter for the standard analysis of plant-available nutrients. Depending on the laboratory, the test for arsenic will be labeled either as "arsenic" or as "total recoverable metals," where arsenic is one of several metals analyzed. A soil test for arsenic will range from $5 to $20 per sample, depending on whether you are using a state or private soil testing laboratory.

## How much arsenic is added to the soil when you apply poultry litter?

The amount of arsenic added to the soil depends on how much arsenic is in the litter and how much litter you apply. Calculation 1 (see below) provides an example for determining how much arsenic you apply to the

**Calculation 1. Example calculation for determining the amount of arsenic added to the soil when applying broiler litter**

In this example, we will assume that you want to apply 150 pounds of nitrogen per acre, using broiler litter that contains 60 pounds of nitrogen per ton and 35 ppm of arsenic.

- 150 pounds of nitrogen needed / 60 pounds of nitrogen provided per ton of litter = 2.5 tons of litter needed to supply 150 pounds of nitrogen
- 2.5 tons of litter x 2 = 5 tons of litter needed to supply 150 pounds of nitrogen during the year of application (*Only about one-half of the nutrients added as organic matter are available to plants during the first year following application.*)
- 5 tons per acre x 2,000 pounds per ton = 10,000 pounds of litter per acre (*This calculation converts tons of litter to pounds of litter.*)
- 10,000 pounds of litter per acre x 35 ppm arsenic = 10,000 pounds of litter/acre x 0.000035 parts arsenic = 0.35 pounds of arsenic per acre (*Note: 35 part per million (ppm)= 35/1,000,000 = 0.000035.*)
- 0.35 pounds of arsenic per acre /2,000,000 pounds of soil per acre* = 0.000000175 pounds of arsenic per pound of soil = 0.175 ppm arsenic in the soil (**One acre of soil to the plow depth of 6 inches weighs approximately 2,000,000 pounds.*)

Thus, 0.35 pounds of arsenic added to an acre of soil to a depth of 6 inches would result in soil that contains 0.175 ppm arsenic.

***Composting concentrates arsenic in poultry litter. Water and carbon dioxide lost during composting reduce the litter volume by 25 to 50% and the litter weight by 40 to 80%. Thus, poultry litter that contains 30 ppm arsenic before composting will contain 50 to 150 ppm arsenic after composting.***

**Calculation 2. Worksheet for determining arsenic additions to the soil**

Use numbers from soil test results and fill in the blanks below.

Amount of nitrogen needed by crop __A__

Amount of nitrogen in one ton of poultry litter__B__

1. Calculation 1: __A__ / __B__ = __C__ tons of litter
2. __C__ x 2 = __D__ tons of litter needed per acre to supply the nitrogen needs of the crop
3. __D__ x 2,000 pounds per ton = __E__ pounds of litter per acre
4. __E__ x 0.000035 parts arsenic = __F__ pounds of arsenic per acre
5. (__F__ /2,000,000 pounds of soil per acre) x 1,000,000 = __G__ ppm arsenic in the soil

soil when you use arsenic-containing litter. Calculation 2 provides a worksheet to determine these amounts for your own fields.

To determine the actual amount of arsenic that you are applying with a given load of poultry litter, submit a sample of your soil and the litter to a laboratory for analysis. Then perform the calculations provided below based on crop nutrient needs and using the laboratory values provided for soil nutrients, nutrient content of the litter, and arsenic content of the litter.

## How often is poultry litter applied to the same land?

***Arsenic is present naturally in all soils. While concentrations in undisturbed soils range from 0.1 to 97 ppm, soils typically have natural concentrations well below 10 ppm.***

Many growers regularly use poultry litter. If you do this with poultry litter containing arsenic, arsenic will build up in the soil. Unlike nutrients that are removed from the soil at predictable rates by crop harvests, heavy metals such as arsenic may or may not be taken up by crops and removed from the field through harvests.

You can use the template below to develop a table for monitoring the potential buildup of arsenic in each of your fields. For these records, assume that arsenic accumulates in the soil and is not lost or removed over time.

Only a few states regulate the application of arsenic-contaminated poultry litter, with 23 states having action levels for soils contaminated with arsenic.(8) Maximum acceptable arsenic levels in soils vary widely from state to state. For agricultural soils, action levels range from 2.4 ppm in Arkansas to 500 ppm in Montana, while action levels for residential soils range from 0.4 ppm in Illinois to 40 ppm in Colorado. South Carolina, which has a large poultry industry, has set 41 ppm (dry weight basis) as the maximum concentration of arsenic in poultry litter to be applied to land, with no more than 37 total pounds of arsenic ever to be applied.(9) In contrast, the maximum allowable concentration of arsenic in compost is 10 ppm in Italy, 13 ppm in Canada, 15 ppm in the Netherlands, and 25 ppm in Denmark.(10) Soil arsenic levels of 10 ppm can have a phytotoxic effect (cause plants to die).

A producer applying litter containing 25 ppm of arsenic, at the rate of 5 tons per acre per year, will be able to make similar applications for 3 years before reaching the residential action level in Illinois, for 19 years before reaching the agricultural action level in Arkansas, and 148 years before reaching the maximum arsenic application levels in South Carolina. It would take 80 years of such poultry litter applications to reach the phytotoxic level of 10 ppm.

**Monitoring applications of litter containing arsenic**

To monitor the amount of arsenic added to the soil through the use of poultry litter, keep records using the following headings and data entries.

*Heading:* Amount of arsenic in poultry litter applied to the soil (ppm)

*Data entries:* ***Date*** ***ppm Arsenic***

*Heading:* Amount of litter per acre applied to each field (tons)

*Data entries:* ***Date*** ***Field*** ***Tons of litter applied per acre***

*Heading:* Amount of arsenic applied to each field (pounds per acre) during each application

*Data entries:* ***Date*** ***Field*** ***Pounds of arsenic added per acre in field***

*(Use calculation F from the worksheet in Calculation 2, above)*

*Heading:* Amount of arsenic applied to each field (pounds per acre) over time

*Data entries:* ***Keep a running total of all applications to determine the total amount of arsenic added per acre over time.***

**Soil Science Basics**

- ✓ Soil chemical interactions involve positive charges binding to negative charges
  - Soil organic matter is usually negatively charged.
  - Soil minerals have more positive charges at a low or acid pH and more negative charges at a high or alkaline pH.
- ✓ Chemicals that are attached to soil particles are not readily available for plant uptake, so soil particles moved by erosion carry the attached chemicals with them.
- ✓ Chemicals that do not bind to soil particles (because they are of the same charge as the soil particle) remain dissolved in the soil water.
  - These dissolved chemicals can be readily taken up and used by plants.
  - Dissolved chemicals can be transported over the soil surface by runoff water or downward through leaching.

**Arsenic Chemistry and Soil Chemistry**

- ✓ Arsenic is negatively charged and serves as a site for holding or "exchanging" positively charged ions or cations.
- ✓ Arsenic has various forms depending on its access to oxygen.
  - Arsenic found in dry soils is called *arsenate*.
  - Arsenic found in wet soils is called *arsenite*. *Arsenite* has more negative charges than does *arsenate*.
- ✓ *Arsenite* is much more toxic than *arsenate*.
- ✓ Arsenic interacts with soil particles.
  - Arsenic and organic matter repel each other because they are both negatively charged.
  - Arsenic bonds to positively charged minerals such as iron oxides.
  - Arsenic and organic matter compete with each other for binding sites on positively-charged soil minerals.
  - Certain types of organic matter, such as humic acid, can decrease the absorption of arsenic.
  - *Arsenate* bonds more readily to soils than does *arsenite*.
  - Because *arsenite* bonds poorly to soil particles, it is more mobile in the environment.
  - *Arsenate* replaces and competes with phosphorus for plant uptake — as a result, an arsenic excess can be misdiagnosed as a phosphate deficiency.

## How do soil type and soil management affect the movement and toxicity of arsenic?

Chemical and microbial reactions readily transform roxarsone into inorganic forms of arsenic.(13) These inorganic forms are then subject to a variety of chemical and biological reactions in the soil. Soil mineralogy, soil moisture, soil pH, and microbial reactions all determine arsenic mobility, its uptake by plants, and its toxicity. To help you understand these interactions and how they affect the availability of arsenic, the box above provides basic information on soil and arsenic chemistry.

Understanding the basic concepts of arsenic and soil chemistry will help you manage your soil to favor arsenic bonding to soil particles, minimizing its movement and availability to plants. When arsenic is bound to soil minerals, it is relatively immobile. However, it may be transported by erosion. When arsenic is dissolved in water, it can be taken up by plants and is subject to runoff or leaching. Thus, dissolved arsenic is more likely to damage the environment, affect crop growth, or endanger animal and human health than is arsenic that is bound to soil particles.

Arsenic is more likely to bind to soil particles in soil that is (14, 15)

- Field-moist or dry
- Neutral to slightly acidic in its reaction or pH

- Rich in iron, aluminum, manganese, or limestone

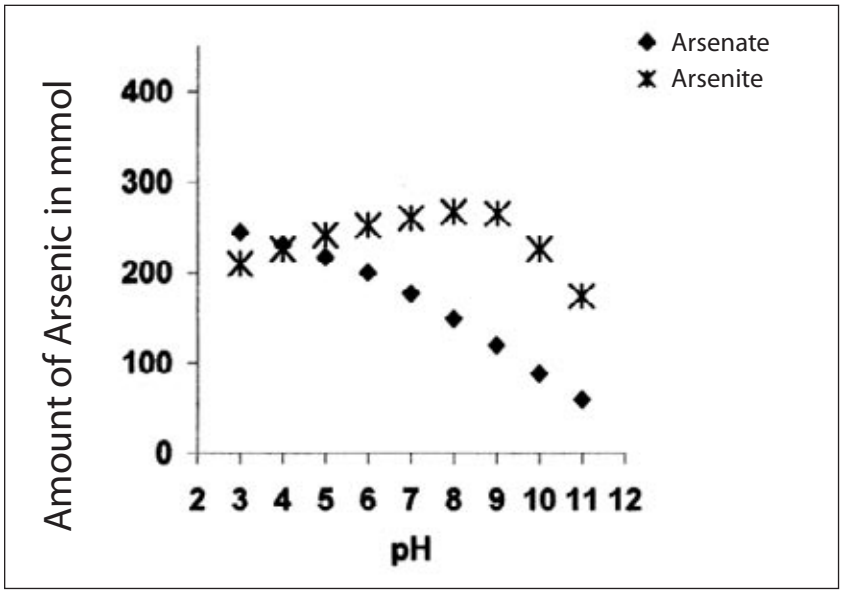
Arsenic is more likely to be soluble in soil that is

- Wet or muddy
- Alkaline, but without limestone mineralogy
- Relatively high in concentrations of phosphate or nitrate
- Sandy

In wet soils that have a high (alkaline) pH, soil chemistry will favor arsenite over arsenate, resulting in high arsenic toxicity.

In practical terms, if you add poultry litter containing arsenic to upland, arable soils that have loamy or clay-like textures, a neutral or semi-acid pH, and are not subject to waterlogging, the arsenic will be relatively stable in the soil and have a relatively low toxicity. In contrast, if you add poultry litter containing arsenic to soils that are wet, alkaline, or have a sandy texture, the arsenic will have a high toxicity and a high potential for contaminating ground or surface water through leaching and runoff. Plant uptake of arsenic will be greatest on sandy soils with low to moderate levels of organic matter and excessive amounts of phosphorus or nitrate.

The greatest risk of contamination from arsenic in poultry litter comes when litter is removed from the poultry house but not mixed with soil. This happens when the litter is stacked in piles before spreading, or when it is applied to the soil and not mixed in through tillage, rotary cultivation, or the use of an aerator. In the Delmarva Peninsula (adjacent parts of Delaware, Maryland, and Virginia), the area with the second-highest concentration of poultry production in the U.S., research shows that arsenic easily leaches from poultry litter when it is either piled in windrows or has been recently applied to the soil surface. In both cases, arsenic is not able to bind to the soil. Consequently, rainfall readily dissolves the arsenic, making it subject to runoff and leaching.(16, 17)




*Solubility of arsenite and arsenate in relation to soil acidity (pH).(14)*

**Arsenic and erosion**

While soluble or dissolved arsenic poses the greatest risk for environmental contamination, wind or water erosion can transport arsenic-contaminated soil particles into rivers and streams and contaminate them. Wind can also blow contaminated soil into homes and buildings.

In an on-going case, residents in Prairie Grove, Arkansas, filed a lawsuit against poultry growers in the area when they found that dust in their homes had high levels of arsenic. They claim that this arsenic is responsible for cancers affecting several area residents.

## How does increasing soil organic matter affect the potential for arsenic runoff or leaching?

Interactions between soil organic matter, soil minerals, and arsenic are complex. Almost all of the scientific studies of the interactions between arsenic, soil minerals, and soil organic matter have used purified forms of these components.(18, 19) However, agricultural soils are a complex mixture of soil minerals and organic compounds; thus, experiments with pure compounds do not clearly predict what will happen in natural, mixed systems. Recent research, conducted with dissolved organic matter from natural systems in Colorado, indicates that organic compounds tend to displace arsenic bound to iron oxides, resulting in the release of dissolved arsenic into the soil. This process not only increased the amount of dissolved

*Compost containing turkey manure and wood chips from bedding material is dried and then applied to pastures for fertilizer. Photo by Jeff Vanuga, USDA NRCS.*

arsenic but also its availability and toxicity, since the organic matter displaced arsenite more readily than arsenate.(20) In another study, kaolinite clay coated with humic acid absorbed more arsenic than did pure kaolinite clay.(21) These results seem to indicate that organic matter will enhance arsenic sorption in temperate soils but will increase arsenic solubility in highly weathered soils.

## What is the potential that arsenic from applied poultry litter will contaminate rivers, streams, lakes, or groundwater?

For arsenic to cause contamination, it must be transported from the field where it was applied to a body of water. To reduce the risk of arsenic runoff, do not apply or store litter containing arsenic within 100 feet of lakes or streams. At least 50 feet of this buffer strip should be in permanent vegetation.(22) To minimize the movement of arsenic into the groundwater, do not apply arsenic-bearing poultry litter to sandy soils with low organic matter content or to soils with underlying karst geology (limestone with caves and sinkholes).

## How does arsenic in soil affect crop growth and food safety?

Plants differ in their sensitivity to arsenic. Peas and beans are very sensitive to arsenic in the environment, while some species of ferns accumulate large quantities of arsenic without apparent adverse effects.(12, 23, 24) Some plants are arsenic-resistant or can block arsenic uptake by their root systems.(25) Still other food crops accumulate arsenic at levels that raise human health concerns. Since plants take up arsenic primarily by their roots, the highest level of arsenic accumulation is usually in roots and tubers, such as carrots and potatoes. Signs of arsenic phytotoxicity vary among plant species, but these typically include leaves dying back from their tips, stunting, and sterile or abnormal fruits and seeds, similar to phosphorus deficiencies.(14)

Plants react to arsenic at much lower doses than those necessary to have an impact on human health. That is, most plants die before they produce a food product that is toxic when consumed in normal amounts.

## Other than poultry litter, what else can contaminate soil with arsenic?

The use of commercial broiler litter as a fertilizer or soil amendment is not the only organic input likely to cause arsenic buildup in the soil. Rock phosphate, various igneous rocks applied for "sulfur" and "iron" deficiencies, and waste from copper-chromium arsenate (CCA) treated lumber can also result in high levels of arsenic contamination. In addition, organic standards do not regulate the condition or quality of soils being converted to organic production. Although now illegal, arsenic pesticides were once used on cotton, rice, and fruit. Sewage sludge also often contains arsenic waste products from industry.(26) As mentioned above, the natural background level of arsenic in soils varies considerably

***In 1993, the National Food Authority set the current health limits for human consumption of arsenic at 1 mg per kilogram of food (dry weight) or 1 ppm.***

### Phosphorus and arsenic

Phosphorus and arsenic are chemically very similar. They both bind to iron and aluminum oxides, both major components of the clay coatings on soil aggregates. Since phosphorus is much more abundant in agricultural soils than is arsenic, it crowds arsenic off binding sites, increasing the solubility and mobility of arsenic.

Because of the chemical similarity of phosphorus and arsenic, plants confuse the two chemicals. Plants take up arsenic and metabolize it as though it were phosphorus. Many mychorrhizal fungi facilitate plant uptake of phosphorus and also increase plant uptake of arsenic. In sandy soils, phosphorus additions stimulate plants to take up additional arsenic. However, in silt or clay soils, phosphorus applications mobilize arsenic but decrease its uptake.

— from 0.1 to 97 ppm — with soils derived from igneous parent material tending to have higher natural concentrations. If you are buying land and do not know the history of pesticide or sewage sludge use on the farm, you should have the soil tested to determine the level of arsenic in it. Producers farming soil that contains relatively high levels of arsenic should be particularly mindful when using commercial broiler litter as a fertilizer or soil amendment.

## How can you remediate arsenic-contaminated soil?

If you are managing litter applications carefully, you will probably never need to remediate your soils. As discussed above, there is often little relationship between the total arsenic content of your soil and the amount of arsenic that is bio-available or readily taken up by plants. If you want to know the amount of arsenic taken up by your crop, you can send plant tissue samples to a soil and plant tissue analysis laboratory. For more information on soil remediation, see *Arsenic Treatment Technologies for Soil, Waste, and Water*, a comprehensive document on arsenic remediation methods developed by the U.S. Environmental Protection Agency.(27)

Plants that can take up large quantities of arsenic —called hyperaccumulating plants — are being examined for possible use in the bioremediation of arsenic-contaminated soils.(23, 24) In bioremediation, hyperaccumulating plants are used to extract arsenic from soil to reduce its concentration. Following their harvest, the hyperacculating plants need either to be disposed of as hazardous waste or, preferably, subjected to processes that extract the arsenic from the plant tissue for use by industry. While not hyperaccumulators, poplar trees, cottonwoods, corn, sunflowers, ryegrass, and prairie grasses have been used in phytoremediation projects to remove arsenic from the soil.(27)

## Summary

Arsenic in poultry litter poses a contamination risk to organic crops and soil. At a minimum, organic producers should use practices that are not high risk, according to the following risk assessment table. While the NOP rule is not clear regarding the use of poultry litter containing arsenic as a fertilizer or soil amendment, an accredited certifying agent might require that a farm plan address the potential arsenic contamination of soil and water posed by broiler litter. Such a plan would involve documentation to certify that management practices are not contributing to environmental degradation or health risks.

***Soil Geology and Mineralogy***

***For information about your local soil geology and mineralogy, contact your county offices of the Natural Resources Conservation Service, Soil and Water Conservation, or Cooperative Extension.***

***Proper waste management on the farm is essential for environmental protection. Photo by Bob Nichols, USDA NRCS***

**Arsenic Risk Assessment**

| Risk Factor | None | Low | Med | High |
|---|---|---|---|---|
| *Source of poultry litter* | | | | |
| Commercial broiler house | | | X | |
| Layer operation | X | | | |
| Organic operation | X | | | |
| *Amount of arsenic in the litter* | | | | |
| Less than 41 ppm | | X | | |
| Greater than 41 ppm | | | | X |
| *Soil conditions where arsenic-containing litter is applied* | | | | |
| Moisture content is field-moist or dry | | X | | |
| Soils are wet, subject to waterlogging, or runoff | | | | X |
| Clay soils | | X | | |
| Silt or loam soils | | | X | |
| Sandy soils | | | | X |
| Alkaline soils | | | X | |
| Karst or limestone, cave-like mineralogy | | | | X |
| *Litter application method* | | | | |
| Litter is stacked in an uncovered pile. | | | | X |
| Litter is covered and stacked on sand or silt without a cement or clay pad. | | | | X |
| Litter is applied to the soil surface without incorporation AND rainfall occurs within a week. | | | | X |
| Litter is applied and immediately incorporated or disked into the soil. | | X | | |
| *Litter application or storage location* | | | | |
| Within 300 feet of a stream or water body that does not have a riparian buffer | | | | X |
| Between 100 and 300 feet of a stream or water body with a riparian buffer | | | X | |
| Greater than 300 feet from a stream or water body | | X | | |
| *Monitoring of litter applications* | | | | |
| Good records are kept of arsenic concentrations and application amounts to each field. | | X | | |
| Records of litter arsenic concentrations and application amounts to each field are incomplete. | | | | X |
| Maximum amount of arsenic added to the soil exceeds 5 ppm or the state maximum. | | | | X |

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