FAQs About Cadmium in Fertilizer:

Cadmium Contamination in Plants

What is cadmium and why is it in fertilizer?

A natural metallic element, cadmium (Cd) is generally present in the earth's crust at low levels. On average, the metal concentration is about 0.15 milligrams (mg) per kilogram (kg) of soil.[1] However, cadmium is present at elevated levels in some soils, rocks, metal ores (especially zinc, copper, and lead ores), fossil fuels (especially coal), human and animal waste, and as an impurity in phosphate rock.

Fertilizer contains cadmium because phosphate rock is used as an essential feedstock of industrially produced fertilizer.

How much cadmium is present in phosphate rock?

Cadmium concentrations vary significantly by geography. Phosphate rock deposits in Florida used to produce fertilizer range from 3 to 20 mg Cd/kg rock, those in North Carolina range from 20 to 51 mg Cd/kg rock, and those in Idaho range from 40 to 150 mg Cd/kg rock with an average of 92 mg/kg—the highest average cadmium in phosphate rock used for fertilizer in the world.[2]

In sedimentary rock, or rock laid down by water, the average cadmium concentration in 35 samples from 20 countries was found to be about 21 mg Cd/kg rock. The sample range was from <1 to 150 mg Cd/kg rock. In igneous rock, or rock formed by the extrusion of magma, the average cadmium concentration in 11 samples from 9 countries was much lower, or about 2 mg Cd/kg rock. Unfortunately, about 85 % of world fertilizer production occurs from sedimentary deposits that normally contain higher levels of cadmium.[1]

How much cadmium is present in fertilizer?

The amount of cadmium transferred from rock to fertilizer depends on the fertilizer manufacturing process. In single superphosphate and triple superphosphate manufacturing processes, all of the cadmium transfers to the fertilizer. In wet process phosphoric acid processing, about 55 to 90 % of the cadmium transfers to the fertilizer.[2]

Where does the cadmium go?

Soil cadmium levels in the US and around the world have steadily increased from applying phosphate rock fertilizers and organic fertilizers from compost, municipal sludge, and/or animal waste.

Cadmium present in fertilizer will do one of, or a combination of, three things:

- 1.) it will be taken up by the plants and stored in the leaves, roots, stems, fruit and seeds, making the cadmium available to humans and animals;
- 2.) it will remain in the soil, accumulating over time; or
- 3.) it will leach from the soil into the groundwater or be carried with the irrigation runoff into surface waters.

None of these represent a desirable outcome and all have the potential to increase human exposure and contamination of our environment. Plants readily take up cadmium into their leaves, stems, roots and tubers, and to a lesser extent their seeds, grains, and fruits. Many complex and interactive factors influence this uptake. Cadmium concentrations are typically higher in leaves than in other parts of the plant, but translocation varies by species and environment.

What factors influence plants' Cd uptake?

Factors that tend to increase plant uptake of cadmium include, but are not limited to, the following:

- buildup of cadmium in the soil over time
- higher rate and frequency of fertilizer application
- higher concentration of cadmium in fertilizer
- the solubility of the fertilizer
- decreasing pH (more acidic) soil
- higher organic matter
- higher cationic exchange capacity (strangely can also decrease uptake under some circumstances)
- higher soil salinity (Cd^{+2} salts)
- chlorine in the irrigation water
- a lower ratio of zinc to phosphorous availability

However, it is difficult to accurately predict cadmium availability for plant uptake. The rate of uptake will vary not only with the type of plants cultivated, but also with different cultivars of the same types of plants grown under the same conditions.[2]

Do plants take up other contaminants?

Food crops can take up other metals—some from fertilizer (chemical or sewage sludge), some from environmental contamination, and some even from natural high background concentrations in soils.

Common metals found in leafy green vegetables and root crops such as radish and carrot include arsenic, chromium, copper, lead, manganese, nickel, thallium, and zinc. The concentrations of these metals vary widely from element to element and according to different plant types. Soil to plant transfer factors decrease from manganese > zinc > cadmium > copper > lead.[2] In other words, manganese transfers to plants more easily than does cadmium, but cadmium transfers much more easily than lead.

Arsenic is commonly found in shellfish, fish, rice, and mushrooms. Thallium is frequently found in kale, although it may also be found in lettuce and spinach.[3] The source of thallium is less well defined but cement kiln dust that contains thallium has been recycled to use as a liming agent in some agricultural soils.

How much Cd is actually in vegetables?

Cadmium can be found in measurable and often elevated levels in vegetables throughout North America, Europe, and parts of Asia. The World Health Organization (WHO), the European Union (EU), and a number of other countries have been studying the presence of cadmium in food for almost two decades. The EU has established food safety limits for cadmium (and other pollutants) in a variety of foods. These limits aren't necessarily protective of health, but are based on best management practices in agriculture and a philosophy of "as low as reasonably achievable."

The EU limits cadmium in vegetables and fruit to 0.05 mg/kg, with the exceptions of stem and root vegetables, which have a limit of 0.10 mg/kg, and leafy vegetables and herbs, which have a limit of 0.20 mg/kg.[4] However, the EU enforcement program is finding test samples that exceed current limits. Food safety limits cited above will likely be revised to reflect health risk-based levels following the phase in of the new limits mandated in fertilizer.

The US Food and Drug Administration (FDA) monitors a number of common food contaminants (including cadmium) as part of the Total Diet Study, often called the market basket study, but does very little to minimize potentially harmful metals. The latest information from market baskets collected and analyzed in the years from 2006 through 2011 shows considerable cadmium in our food with the highest levels in sunflower seeds, spinach, lettuce, potatoes, liver, wheat and other grains, along with other leafy and stem vegetables. Typically leafy greens show some level of cadmium.[6]

Do we see the same level of cadmium in our vegetables in the Northwest?

In 2016, PPRC conducted a small study to compare cadmium levels in retail and home grown produce in Washington and Oregon with the levels of cadmium found in the EU and by the US FDA. For financial reasons, PPRC's study was not designed as a statistical sampling study but as an indicator study to determine if cadmium levels in our leafy green vegetables were at or above the levels found in the EU and may represent a potential risk to Northwest residents over time. The study focused on greens but also included a single snapshot of some other veggies.

As expected, spinach and lettuce, along with mixed greens, herbs, and carrots, showed significant levels of cadmium. These levels did not differ between organically grown and conventionally grown vegetables, a finding that reflects the trends seen in the scientific literature. One of the interesting findings was that leafy radish tops showed significant cadmium uptake while the cadmium in radishes was below detection limits. This finding is also confirmed in the literature.

The vegetables with only a small number of samples (< than 5 samples) were interestingly mostly below detection limits but cannot be considered truly negative for cadmium; even a vegetable known to have high uptake will not show consistency across all samples.

PPRC also collected a few soil samples in association with the produce samples collected in home gardens. The few findings provide limited information but do raise some concerns. Screening soil samples may not be sufficient to identify levels of concern in food. This is largely because the common analytical methods used by regulatory agencies for screening soil often have detection limits that are too high to correlate with the way we measure food, which represents a direct exposure. For example, soil measured with a cadmium level of less than 1 mg Cd/kg soil (< 1 ppm and about the level of detection usually reported in environmental monitoring) may still result in significant cadmium uptake.

Table 1.1. Samples of Cadmium Levels in Common Leafy Greens from Northwest Grocery Stores

Product	Cd > Lowest Detectable Quantity	Mean (mg Cd/ kg)	range (mg Cd/kg)
Mixed greens	100%	0.43	---
Spinach	89%	0.19	<0.053 to 0.47
Lettuce	64%	0.14	<0.043 to 0.34
Kale	50%	0.059	<0.043 to 0.080
Chard	100%	0.19	<0.073 to 0.22
Cilantro	67%	0.19	<0.046 to 0.20

In the European Union, the current Food Safety Limit for cadmium is 0.20 mg Cd per kg. The results of the above study suggest that the cadmium levels found in leafy green vegetables in Northwestern grocery stores are often near or above this Food Safety Limit.

*All food samples were collected and processed by FDA protocols and analyzed in an FDA food-certified analytical laboratory. Complete analytical findings may be found in the summary table at wwwpprc.org.

Is cadmium present in other foods?

Yes, cadmium does accumulate in foods other than vegetables. Cadmium can be a concern in a wide variety of food including grains and cereals (especially wheat), rice, seeds such as sunflower or flax, mushrooms, animal-based foods (especially organ meats), and in fish and shellfish. All of these, as well as drinking water, can contribute to our body burden of the metal. Although natural sources of cadmium exist, higher levels typically result from anthropogenic activities.

Is the level of cadmium in our food harmful to our health?

The simple answer is likely yes, but the seriousness of that yes varies. A number of complicating factors make some population groups more sensitive than others. Also, the amount of cadmium consumed varies a lot by eating habits and even within one type of food.

As we learn more about cadmium absorption and storage in the body, we find that the safe body burden of cadmium, usually measured by urinary excretion, continues to go down. For example, urinary excretion levels of cadmium that were considered asymptomatic not so many years ago have dropped from 10 to 2 µg/l .[7] Adverse health effects are currently estimated to start when urinary excretion levels reach the range of 0.5 to 1 µg/g creatinine, a level that roughly corresponds to the excretion rate of the 75th percentile of the US population 20 years and older.[8] Because cadmium accumulates in the body, even very low levels of the metal appear to have the potential to trigger negative health effects over time.

Risk assessment studies suggest that cadmium in food may be significant as low as 0.005 mg Cd/kg produce (5 µg/kg or 5 ppb). In 2011, the European Food Safety Authority established a provisional tolerable weekly intake (PTWI) level of 2.5 µg/kg body weight. This translates to an intake level of about 17 to 25 µg Cd per day for an adult and less for children.

The primary purpose of PPRC's sampling effort, with a focus on leafy greens, was to determine if it was likely that people in the Northwest exceed the PTWI. PPRC found measurable cadmium in 25 of 37 leafy green samples (68%). Almost a quarter of those samples revealed cadmium levels at or above the current EU Food Safety Limit of 0.20 mg Cd/kg. Our sampling study suggests that people who heat a healthy diet, or a diet that includes daily recommended servings of vegetables, may approach or even exceed the PTWI.

This report, however, is not meant to serve as argument against eating vegetables. The standard American diet—grains (especially wheat), potatoes, animal-based foods—may also contribute cadmium without the corresponding immune boosting micro-nutrients in vegetables.

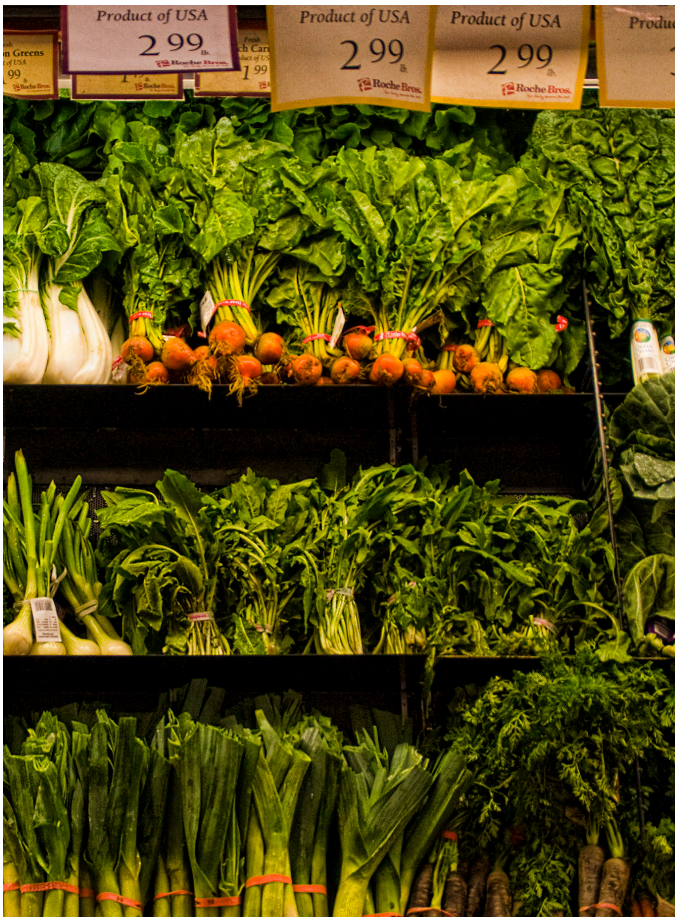
The US Agency for Toxics Substances and Disease Registry (ATSDR) lists an oral minimum risk level (MRL) of 0.1 µg/kg/day.[10] The MRL is a level below which no adverse effects are expected even in the most sensitive populations. To achieve that level of cadmium as our average intake, much work is needed to reduce cadmium inputs into our food supply.

How can I choose vegetables with less cadmium?

Looking carefully at the cadmium concentration in foods shown in the FDA Total Diet Study and the PPRC sampling study reveals that cadmium contamination varies considerably in foods. This variation occurs between brands and even within a brand, depending on supplier sources from season to season. Unfortunately, at the present time, no reliable way exists to predict cadmium content for the consumer. Conventional and organic grown foods, natural grocers, commodity retailers, farmers markets, and home gardens can and often do show wide discrepancies in soil cadmium to plant uptake.

While more testing with widely published data may provide a clearer picture of our exposure risks, the long-term solution to these risks is to reduce the amount of cadmium allowed at the source (fertilizers—phosphate rock, organic, and compost) and to promote better soil management practices.

For more information on growing your own vegetables, see another fact sheet in this series, *FAQs About Cadmium in Fertilizer: Reducing Cadmium Exposure in Your Garden.*



**** For more information on cadmium and other heavy metals, visit www.pprc.org***

Disclaimer

This series of fact sheets on cadmium in fertilizer is not intended to discourage growing or eating vegetables. Vegetables are critical to life; the healthiest and tastiest ones often come from gardens. The information presented here is intended to help provide a better understanding of cadmium, how it gets into our food supply, how it can affect our health, and how we can minimize our exposure.

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