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North East Biosolids & Residuals Association

Cooperatively promoting the environmentally sound recycling of biosolids and other residuals

Information Update:

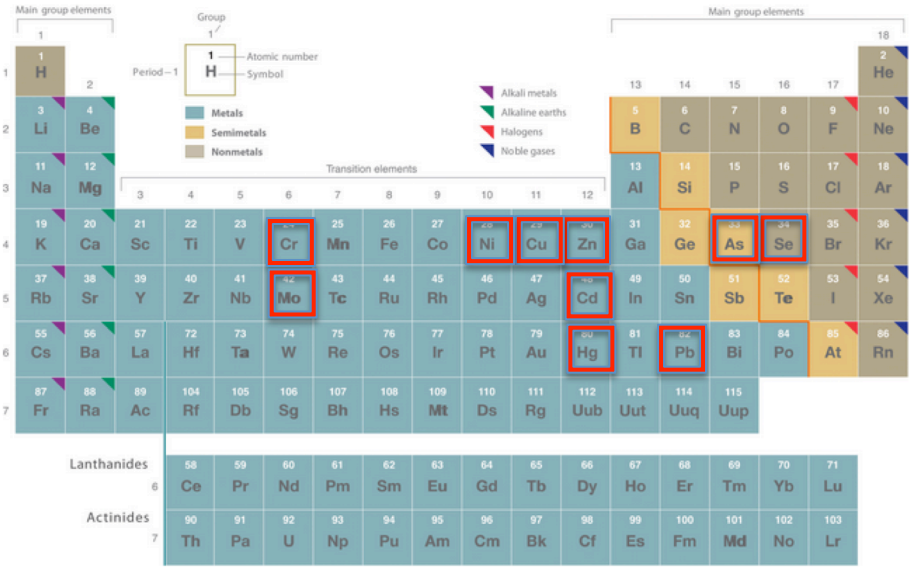
Metals in Biosolids, Other Soil Amendments, & Fertilizers

August 28, 2015

What about the heavy metals in biosolids?

Biosolids contain traces of basic elements, such as heavy metals, as well as other trace contaminants. Trace elements, including heavy metals, occur naturally in soils, fertilizers, other soil amendments, and elsewhere in varying amounts. Living things in our environment, from trees and grasses to humans, contain heavy metals and trace contaminants. Some metals, in the right quantity, are vital nutrients for plants and animals (e.g. copper and zinc). However, high concentrations of some elements and other contaminants can pose a risk to public health or the environment. The concern is not that heavy metals and other contaminants exist in fertilizers, manures and biosolids, but at what levels they exist.

Decades of research and risk assessment have led to regulatory standards for elements and other contaminants that potentially pose risk in the environment. In 1993, in the federal biosolids regulation 40 CFR Part 503, the U. S. EPA established numerical concentration limits in land-applied biosolids for ten elements (the limit for chromium was later withdrawn). Most states have done additional risk assessments and established identical or similar numerical limits for the same elements and, in some states, additional contaminants of potential concern. In addition, risk assessments have been conducted on hundreds of other contaminants and elements of potential concern in biosolids, but regulatory limits have been set only for those elements and other contaminants that have been found in biosolids at high enough levels to warrant concern and limitation. Just because there is no regulatory limit for an element or other contaminant does not mean it has not been studied; it likely has been – and been found to not pose risk. The current regulatory limits ensure that high levels of potentially harmful elements and other contaminants will not occur in biosolids that are applied to soils.



Periodic Table of the Elements. Regulated elements (including "heavy metals," semimetals or metalloids, etc.) are outlined in red.

Today, more than twenty years after the promulgation of the EPA Part 503 rule, the levels of trace elements of true concern (e.g. the heavy

metals cadmium, lead, and mercury) in biosolids are low. Wastewater treatment facilities impose restrictions on what can be discharged to their sewers, so that dangerous materials do not threaten the treatment facilities' biological processes and the quality of the cleaned water and biosolids.

Today, biosolids are widely sold as valuable soil amendments and fertilizers. All such products are routinely tested for the regulated elements (heavy metals) of concern. The operators who produce and test the biosolids are required to certify that the biosolids have been treated and tested and meet regulatory standards. Improper certification can lead to large fines and jail time. Product quality and safety are ensured.

What are the levels of heavy metals of concern in biosolids compared to other soil amendments?

Trace elements (including heavy metals) of potential concern in modern biosolids have been reduced to low, safe concentrations. Data compiled from the scientific literature by NEBRA in 2015 provides comparisons between biosolids and other soil amendments and fertilizers (Table 1; see also the associated NEBRA spreadsheet "Metals & Other Contaminants in Biosolids, Other Soil Amendments, & Fertilizers," available at http://www.nebiosolids.org/resources/#/heavy-metals-trace-elements/). They indicate that, while biosolids often have somewhat higher concentrations of some elements than average agricultural soils, animal manures, and many fertilizers, the differences are not large. For some elements, the concentrations in manures or specialty fertilizers – and even in some natural soils – are greater than in average biosolids products.

Keeping contaminants out of wastewater

A very clear trend in biosolids quality can be seen in the concentrations of regulated elements in land-applied sewage sludges and biosolids over time, as industrial pretreatment and source reduction has kept these contaminants of concern out of wastewater. The result has been a dramatic reduction in trace element levels over the past 40 years, as shown in this WHO 2001 compilation and 2009 U. S. EPA data:

Trends in metal concentrations of wastewater solids (sewage sludge) produced by wastewater treatment plants in the U. S., with comparison to U. S. EPA limits for low-metals biosolids

Year	As	Cd	Cr	Cu	Pb	Hg	Mo	Ni	Se	Zn
1976[1]	-	110	2620	1210	1360	-	-	320	-	2790
1979[2]	7	69	429	602	369	3	18	135	7	1594
1987[3]	12	26	430	711	308	3	-	167	6	1540
1988[4]	10	7	119	741	134	5	9	43	5	1202
1996[5]	12	6	103	506	111	2	15	57	6	830
2009[6]	6.9	2.6	80.2	553	76.2	1.2	15.3	48.3	7.0	970
EPA low metals limit (503, Table 3)	41	39	NS[7]	1500	300	17	NS[7]	420	36	2800

[1 – 5] World Health Organization (WHO) 2001 compilation, which cites the following data sources: [1] 150 treatment plants in Northeast and North Central states (Sommers, 1977); [2] USEPA 40 city survey (U.S. Environmental Protection Agency, 1989); [3] 64 treatment plants across the U. S. (Pietz et al., 1998); [4] USEPA national sewage sludge survey of 200 treatment plants (U. S. Environmental Protection Agency, 1990); and [5] >200 treatment plants throughout USA (Pietz et al., 1998). [7] U. S. EPA targeted national sewage sludge survey, 2009.

What is the chance that any particular load of biosolids will have contaminants in excess of the regulatory limit?

Tests of biosolids show that there is some variability in the concentrations of contaminants – including heavy metals – from one biosolids to another and from the same biosolids material over time. However, these variabilities are not large, because biosolids are formed through a continuous process – wastewater treatment – that involves a lot of mixing. In addition, biosolids are further treated and mixed over several days, so that momentary higher or lower concentrations coming into a wastewater treatment facility are evened out.

In the 2000s, the New Hampshire Department of Environmental Services compiled hundreds of test results from 23 different biosolids produced at wastewater treatment facilities of all sizes around the state. UNH Professor Thomas Ballestero conducted statistical analyses on the test results and, for each contaminant, determined the mathematical probability of any test result ever exceeding the state's conservative regulatory or guidance limit. For every contaminant, the probability was low: on the order of 0 to 5%. Which means that NH biosolids are safe for land application. And especially safe, because the NH limits are lower – more strict – than the risk-based federal limits.

The contribution of trace contaminants from any soil amendment or fertilizer depends on the rate of application and the properties of the amendment and soil.

When considering the impacts and potential risks associated with applying trace elements (e.g. heavy metals) to soils, it is important to remember:

- Elements occur naturally in soils.
- Elements added to soils will remain in the environment; they do not break down. However, depending on their chemistry and that of the soil, some elements may move from soil to groundwater, surface water, the atmosphere, or into biological organisms (food chain).
- Heavy metals and semimetals tend to bind strongly in biosolids and in soils (especially soils with organic matter) at the mid-range pH of agricultural sites; thus, they are usually considered to be permanent additions to the soil and are not likely to impact plants or water. In comparison, metals in mineral fertilizers are more mobile in soil, especially soil with little organic matter. Biosolids bring binding capacity with them; indeed, biosolids are sometimes used to reduce the availability – through binding - of metals in soils where metals are at unusually high concentrations (e.g. lead in urban soil).

The total mass of any particular trace element applied depends on the application rate of the fertilizer or soil amendment. Moss et al. noted this in their 2002 report: "When comparing metal contributions from land-applied materials, however, it is important to remember that application rates vary; mineral fertilizer application rates are generally much lower than biosolids or manure application rates, and the impacts from fertilizer contributions on a per-site basis should be considered accordingly. The higher metal concentrations in fertilizers are generally offset by the small amount of these concentrated materials that must be applied. Manure application rates are similar to application rates for biosolids, however, and, therefore, the applied metals can be similar for the two products on a per-site basis."

Kupper et al. (2014) also recognized this in their evaluation of heavy metal additions to soils from land application of source-separated organics (e.g. food scraps) digestate and compost in Switzerland. "For Co, Cu, Ni and Zn, manure was the main source [of metals additions to agricultural soils] (52%, 50%, 55% and 72% of the total for Co, Cu, Ni and Zn, respectively). Mineral fertilizer contributed the major

part of the Cd and the Cr loads (33% and 42% of the total for Cd and Cr, respectively) and aerial deposition of the Pb load (53% of the total). The contribution to the total heavy metals input into agricultural soils of Switzerland associated to compost and digestates was between 2% (Cd) and 22% (Pb)." This research did not include evaluation of biosolids products.

Most biosolids are applied, by law, at the agronomic rate, the rate by which the crop being grown gets the amount of nitrogen (N) it needs and no more. This limits the total amount of trace contaminants, such as heavy metals, that are applied. Other soil amendments and fertilizers are not *required* to be applied at the agronomic rate, although it is becoming more of a standard practice for all farms to practice such nutrient management.

What should biosolids managers do with this information?

Producers and managers of biosolids products are advised to remain vigilant in helping monitor and reduce the inputs to wastewater systems of any contaminants of potential concern. By law, they must conduct routine tests for regulated elements and other contaminants at certified labs, submit results to regulatory agencies, and certify biosolids quality. When biosolids are land applied, they monitor soil quality and test for trace elements and other contaminants that may be locally of concern.

If biosolids and other soil amendments are properly tested and applied, it is possible to safely use them year after year indefinitely, providing critical organic matter and nutrients while recycling a local resource, stimulating carbon storage in soil, reducing demand for chemical fertilizers, and improving the economics of farm and land management.

Summary

The issue of heavy metals in biosolids has been thoroughly addressed:

- Research & risk assessment have determined safe levels for natural heavy metals and other contaminants in soils and biosolids.
- Regulations have incorporated these risk assessments and set limits where limits are needed.
- Operators certify, under penalty of law, that the biosolids they produce have been tested and meet regulatory standards.
- Pretreatment programs protect the quality of wastewater, the functioning of treatment plants, and the quality of biosolids by prohibiting, under penalty of law, the discharge of dangerous levels of contaminants to sewers.
- The concentrations of heavy metals in modern biosolids are low – well below regulatory, risk-based standards and do not pose a risk to public health and the environment when applied to soil in accordance with regulations.
- Even with the variability of heavy metals levels in biosolids, there is only a very low probability of any particular biosolids truckload exceeding regulatory standards, because modern biosolids have heavy metal concentrations well below the regulatory standards.

For more information, references, and data, contact the NEBRA office:
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This project made possible, in part, through special support from Casella Organics and Lystek.

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The North East Biosolids and Residuals Association (NEBRA) *is a 501(c)(3) non-profit professional association advancing the environmentally sound and publicly supported recycling of biosolids and other organic residuals in New England, New York, and eastern Canada. NEBRA membership includes the environmental professionals and organizations that produce, treat, test, consult on, and manage most of the region's biosolids and other large volume recyclable organic residuals. NEBRA is funded by membership fees, donations, and project grants. Its Board of Directors are from MA, ME, NH, NY, and Nova Scotia. NEBRA's financial statements and other information are open for public inspection during normal business hours. For more information: http://www.nebiosolids.org.*

TABLE 1: Metals in Biosolids, Other Soil Amendments, & Fertilizers (NEBRA, 2015)

	BIOSOLIDS				SEPTAGE	SOILS		MANURES			WOOD ASH		COMPOSTS		FERTILIZERS - Traditional			FERTILIZERS - Natural & Organic			OTHER LAND APPLIED RESIDUALS	
	Regulatory Standard, U. S. EPA Part 503, Table 3	U. S. Sewage Sludge (not just biosolids) (EPA 2009, TNSSS)	New England Biosolids (NEBRA, 2001)	Reference Biosolids: New Hampshire (NH DES, 2012)	Average Septage (NH DES, 2001)	U. S. Planted/Cultivated Soils, All States (Smith et al., 2013)	Ontario Typical Range (ON Ministry of Env., 1993)	Manures (Alloway ed., 2013)	Liquid Pig Manure (Hölzel et. al. 2012)	Poultry Manure (Moss et. al., 2000)	Electrical Generator Wood Ash (NEBRA, 2001)	Home Wood Ash (Majeau et al., 2013)	U.K. Home Compost (Smith, 2009)	Greenwaste Compost, Germany (Amlinger 2004 in Smith, 2009)	Nitrogen Fertilizers (Alloway, ed. 2013)	Phosphatic Fertilizers (Alloway, ed. 2013)	Commercial Fertilizers (Washington Dept. of Ag., 2008 - 2014)	Natural Rock Phosphate (Washington Dept. of Ag)	Greensand (Washington Dept. of Ag)	Horn & Hooves (Möller & Schultheiss, 2014)	Paper Mill Residuals (M. Payne, 2001 -2003)	Ice Cream Plant Washwater (M. Payne, 2000-2001)
	low-metals standard	Mean	Range of means for MA, ME, NH, VT,	Mean of annual means (n = 81)	Mean (8 studies)	Mean (n= 1543)	Mean	World Range	Range (n = 305)	Mean	Mean	Mean (n = 25)	Mean (n = 64)	Mean (n = 490)	World Range	World Range	Mean (n=5)	1 sample	Mean (n=1)	Mean (N=13)	Mean (n=12 +)	Mean (n=4)
As	41	6.94	2 - 9	5.52	4.7	6.3	11	3 - 150		13	7	5			1 - 120	2 - 1200	15.7	110	16.2		0.8	1
Cd	39	2.64	2 - 3	4.08	7.6	0.3	0.71	0.3 - 0.8	0.08 - 5.3	2.4	6.3	3.2	1.77	0.70	0.05 - 8.5	0.1 - 170	34.5	2.9	0.609	< 0.2	3.67	1
Cr	no stnd	80.16	17 - 32	27.10	25.6	33.0	58	5.2 - 55	1.1 - 32.0		14	14	28	27	3 - 19	66 - 600				10.9	9	11.4
Cu	1500	553.13	310 - 490	385.76	1117	19.4	41	2 - 60	22.4 - 3387.6	465	45	214	52	33	1 - 15	1 - 300				34.7	20	23.8
Pb	300	76.19	49 - 91	32.71	102	20.1	45	6.6 - 350	2.0 - 26.7	46	39	39	124	61	2 - 1450	7 - 225	20.2	81	12	17.8	5	1.9
Hg	17	1.23	1 - 2	0.86	2.9	0.03	0.13	0.09 - 26	0.01 - 0.11		0.06	0.035		0.27	0.03 - 3	0.01 - 1.2	0.1	3.8	< 0.04	< 0.05	0.16	0.1
Mo	no stnd	15.30	7 - 13	10.39	-	0.9	1.0	0.05 - 3		19	4.7	3			1 - 7	0.1 - 60	41.7	< 3.8	4.39	< 5.4	3	2
Ni	420	48.32	18 - 26	20.87	20.1	15.5		7.8 - 30	3.1 - 97.3	16	19	17	18	18	7 - 38	7 - 38	84.0	66	45.4	6.03	13	7.6
Se	36	7.00	2 - 6	5.29	2.1	0.4	0.93	2.4			0.63	0.35				0.5 - 25	0.2	9.3	1.61	< 2.2	0.35	1
Zn	2800	970.01	419 - 663	730.36	727	58.9	120	15 - 250	93 - 8239	602	537	1319	240	168	1 - 42	50 - 1450	3818	120	127	179	173	29.40

All data in mg/kg (parts per million). Orange indicates a contaminant value greater than (>) the reference biosolids contaminant value (NH biosolids means, 2012.
More notes & details: See NEBRA spreadsheet "Metals & Other Contaminants in Biosolids, Other Soil Amendments, & Fertilizers," available at http://www.nebiosolids.org/resources/#/heavy-metals-trace-elements/)