Trace Elements in Manure

Purpose:

Whenever soil profiles are examined for nutrient trace elements, it has been demonstrated that the metals tend to accumulate in the topsoil. Soil properties affect plant uptake of trace-elements and the solubility and losses to surface and groundwater. When biosolids, compost or fertilizers are applied to land, they are affected by guidelines that regulate the amount of trace elements that can be applied to the land base.

The purpose of the study was to compare the impact of land application of manure, applied at rates needed to match crop requirements with that of regulated land applied residuals such as sewage biosolids, compost and pulp and paper biosolids.

Additionally, this study set out to:

- provide a baseline data set for concentrations of 21 metals and 2 non-metal elements,
- survey livestock feeding practices that would help to compare the inter-relationships of metals concentration with feeding and farm practices
- determine the current state of knowledge with a literature review

Methods:

Manure from 12 different livestock classifications were sampled and analyzed for nutrients, trace elements and physical parameters. Types of manure sampled included dairy where copper footbaths were used (DC), dairy with no copper footbaths (DN), beef-feedlot (BF), beef-cow/calf (BC), swine-finishers (SF), swine-weaners (SW), swine-sow (SS), poultry-layers (PL), poultry-broilers (PB), poultry-turkeys (PT), sheep, (S) and performance horses (H).

Trace elements evaluated included aluminum (Al), antimony (Sb), arsenic (As), barium (Ba), beryllium (Be), cadmium (Cd), calcium (Ca), colbalt (Co), Chromium (Cr), copper (Cu), iron (Fe), lead (Pb), magnesium (Mg), mercury (Hg), molybdenum (Mo), nickel (Ni), selenium (Se), silver (Ag), strontium (Sr), titanium (Ti), vanadium (V), and zinc (Zn).

Nutrients evaluated included total nitrogen, ammonium nitrogen, total phosphorus, potassium, pH, total organic and inorganic carbon and dry matter.

In addition to testing nutrients, a phone survey was conducted with farm cooperators to obtain details about feeding, bedding, manure management and sanitary practices that could affect levels of trace elements found in the manure.

Results:

The premise on starting the study was that trace elements in livestock manures would be relatively low for any elements not fed in the ration.
From the manure samples analyzed in the study, the pattern of variability in trace element content of manure was similar to that of nutrient content. The variation with-in site was much smaller than between-sites.

Several of the trace elements (including mercury, beryllium, cadmium, and cobalt) were at or below detection levels in most manure samples tested and other elements (including lead, silver and antimony) were found at trace levels in some of the manures. Copper and zinc concentrations were high in swine and poultry (especially turkey) manures.

From the literature review conducted, it was confirmed that the primary sources of trace elements came from feed supply, followed by water supply, contamination from within barns (i.e. chewed wood) and/or fields (i.e. scrap metal) and from trace element loading (i.e. fields that were previously apple orchards sprayed with copper sulfates).

Adequate trace elements in feed are essential for healthy livestock production. Excess supplementation results in manures with high levels of these minerals. Most of the toxic trace elements in manures originate in the feed and in particular from mineral phosphorus.

Zinc and Copper are included in monograstric (swine and poultry) diets at much higher levels than minimum requirement for "normal" performance since when fed at higher levels they promote growth.

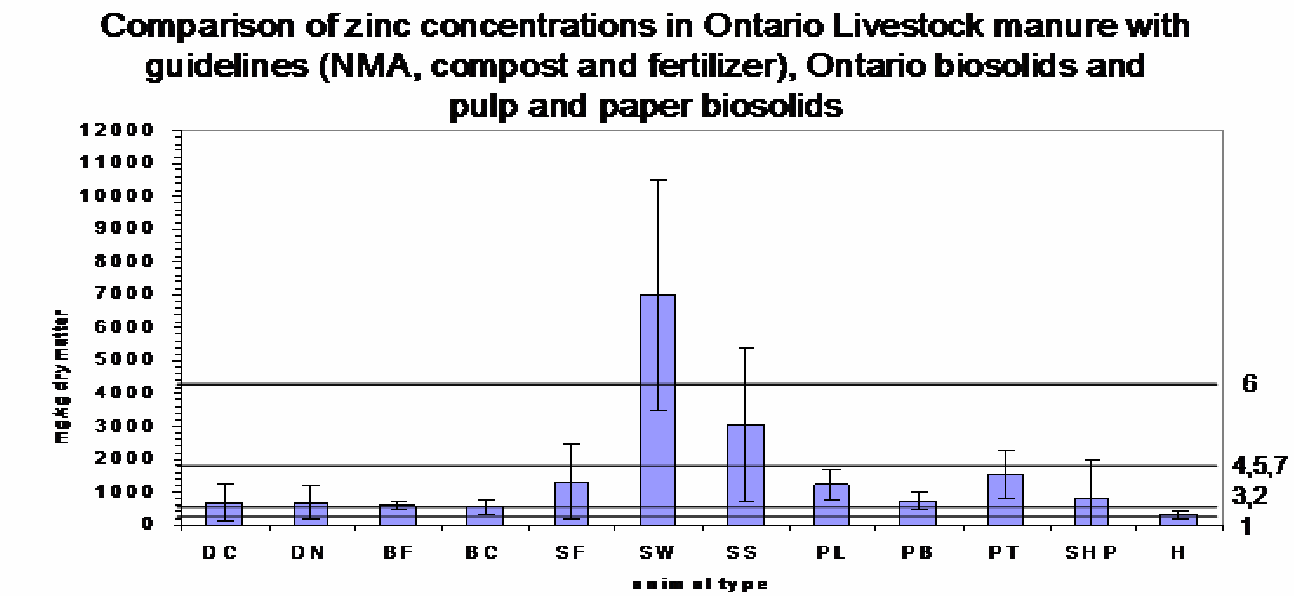
Horse manure samples in the study were particularly high in chromium, nickel, aluminum and iron. The source of nickel and chromium is not clear, but race harness bits used in the industry are often nickel or chrome plated and may have contributed to the concentration of these two metals.

With all the livestock manures studied, when manure was applied at typical rates to meet crop requirements over a rotation, none of the trace elements would exceed the levels of those regulated for sewage biosolids. There were a few swine-weaner manure sites where the level did exceed the limits if manure was applied every year to meet continuous grain corn requirements. Although the manure from swine-weaner was measured separately, there are not many facilities where swine-weaner manure would be stored separately. In most cases the storages would also contain swine-sow manure which would dilute the copper and zinc levels.

Livestock manure varies in dry matter content. Swine-sow manure will be very dilute, while poultry-broiler manure will be concentrated. This affects application rates so that looking at the results from a dry-matter basis perspective will not give a clear indication of actual risk of different manure types to exceed trace element allowable levels. Manure application rates, whether following BMP's or Nutrient Management Act O.Reg 267/03, are most often determined by the phosphorus content of the manure matched to the rate required to meet crop needs of the rotation. The current high fertilizer value of manure ensures that in general it is treated as a valuable resource and l not as a waste product. This also balances trace element levels and buildup in the soil.

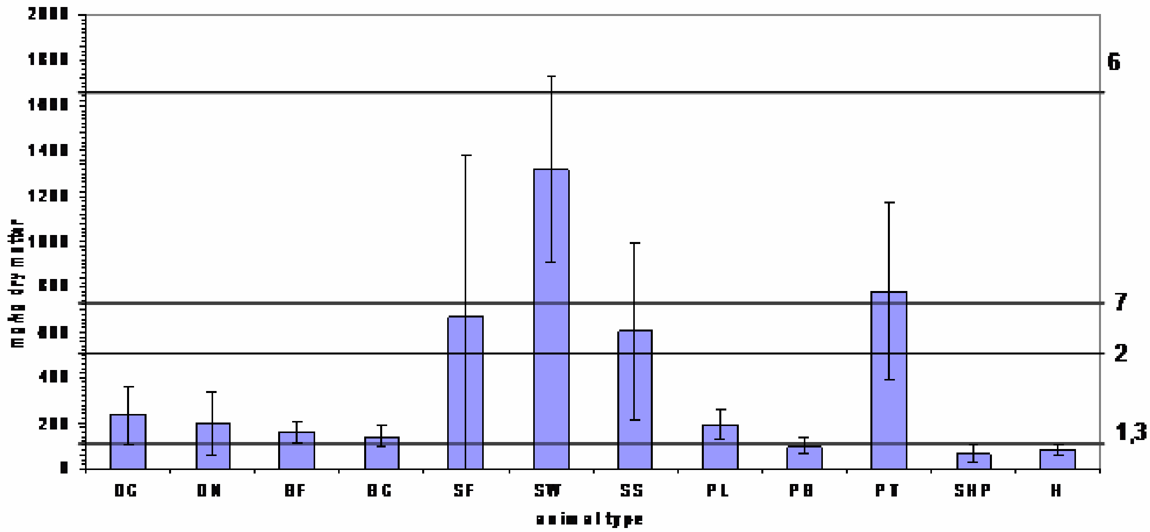
The study also determined that manure cannot be used to make class A compost under the current MOE compost guidelines, where limits are based on soil background concentration levels. If the guideline were applied to manure, the feed would have to meet the same metals concentration limits as the end product. Compost standards may need to be re-evaluated to ensure that on-farm composting will not require the addition of a large amount of slow biodegradable bulking materials and/or excessive testing to meet standards the end product was not intended to meet.

The graphs below show a comparison of zinc and copper (dry matter basis) concentration in the livestock manure analyzed in the study, and illustrate how they compare to the different standards and guidelines.



Comparison of Zinc limits (mg/kg DM):
1=pulp and paper biosolids (165)
2=Ontario biosolids survey results (470)
3=compost guidelines class A (500)
4=compost guidelines class B (1850)
5=fertilizer guidelines (1850)
6=O.Reg 267/03 to 8T/ha/5yr (4200)
7=O.Reg 267/03 to 22T/ha/5yr (1850)

Comparison of Copper concentrations in Ontario Livestock manure with guidelines (NMA, compost and fertilizer), Ontario biosolids and pulp and paper biosolids



<u>Comparison of Copper Limits</u> (mg/kg DM):
1=pulp and paper biosolids (138)
2=Ontario biosolids survey results (552)
3=compost guidelines class A (100)
4=compost guidelines class B (no reg)
5=fertilizer guidelines (no reg)
6=O.Reg 267/03 to 8T/ha/5yr (1700)
7=O.Reg 267/03 to 22T/ha/5yr (760)

Table 1 and Table 2 demonstrate the rate of manure application that would be allowed based on the trace element concentration from the manure samples. The lowest number for each livestock type indicates the limiting trace element. For most livestock types that element is zinc. Table 1 shows the rates on a dry matter basis in metric.

In Table 2 the same information is presented in a slightly different way. The average dry matter content for each livestock type has been included to convert the application rates from a dry matter basis (tonnes/ha) to an imperial “as-applied” basis (tons/ac for solid and gal/ac for liquid manure). For example, in the swine-finisher manure the allowable application per 5 years is 24,113 gallons for zinc. Where manure is applied to a field on a yearly basis the application rate limit for copper would be just over 4,800 gal/ac per year. However, if crop rotation determined that manure would be applied 3 years in 5, then the application rate limit for copper for swine-finisher manure would be just over 8,000 gal/ac.

Table 1. The Total 5-Year Allowable Manure Application (On a dry weight basis) Based On Average Trace Element Concentration In Livestock Manures From The Study And O. Reg 267/03 Limits For Sewage Biosolids Application

	Element		As	Cd	Co	Cr	Cu	Hg	Mo	Ni	Pb	Se	Zn
Manure Type		Ave DM	**Allowable manure application** (tonnes per hectare per 5 years on a dry weight basis)										
Dairy	Liquid	7.8	1,376	374	537	580	59	176	123	222	777	107	44
	Solid	20.7	740	228	836	169	69	192	138	82	1,400	105	59
Beef	Feedlot	22.2	959	582	1,015	377	86	194	94	136	2,704	83	55
	Cow/calf	19.7	810	282	536	166	96	150	61	71	741	167	61
Swine	Finisher	7.4	834	920	1,311	2,188	20	523	60	500	2,572	99	25
	Weaner	2.7	377	233	1,082	1,551	10	202	41	280	3,131	64	5
	Sow	1.8	716	202	625	1,949	22	125	55	429	1,690	55	11
Poultry	Layers	35.6	1,592	895	1,068	675	71	298	72	197	1,208	78	27
	Broilers	61.4	211	1,228	2,089	917	138	506	118	308	3,098	106	45
	Turkeys	39.1	921	216	397	603	17	330	47	251	1,177	58	22
Sheep		33.9	1,787	340	518	622	205	285	173	269	4,847	58	39
Horse		31.0	549	291	481	112	163	270	156	49	524	299	111

Arsenic (As) Cadmium (Cd), Chromium (Cr), Copper (Cu), Mercury (Hg), Molybdenum (Mo), Nickel (Ni), Lead (Pb),Selenium (Se), Zinc (Zn)

Table 2. The Total 5-Year Allowable Manure Application (on an as-is basis) Based On Average Trace Element Concentration In Livestock Manures From The Study And O. Reg 267/03 Limits For Sewage Biosolids Application

			As	Cd	Co	Cr	Cu	Hg	Mo	Ni	Pb	Se	Zn
		Ave DM*	**Allowable manure application** (tons or gallons per acre per 5 years on an as-applied basis)										
Dairy	Liquid	7.8 (L)	1,579,990	429,445	616,610	665,984	67,747	202,092	141,235	254,911	892,189	122,863	50,523
	Solid	20.7 (S)	16,039	491	1,799	364	148	413	297	176	3,013	226	127
Beef	Feedlot	22.2 (S)	19,409	1,169	2,040	758	173	390	189	273	5,434	167	111
	Cow/calf	19.7 (S)	18,474	639	1,214	376	217	340	138	161	1,678	378	138
Swine	Finisher	7.4 (L)	1,005,522	1,109,208	1,580,622	2,637,987	24,113	630,561	72,340	602,831	3,100,961	119,360	30,142
	Weaner	2.7 (L)	1,245,761	769,926	3,575,366	5,125,132	33,044	667,490	135,481	925,233	10,346,093	211,482	16,522
	Sow	1.8 (L)	3,548,931	1,001,235	3,097,880	9,660,429	109,045	619,576	272,613	2,126,385	8,376,667	272,613	54,523
Poultry	Layers	35.6 (S)	20,092	1,122	1,338	846	89	373	90	247	1,514	98	34
	Broilers	61.4 (S)	1,544	892	1,518	666	100	368	86	224	2,251	77	33
	Turkeys	39.1 (S)	10,583	246	453	688	19	376	54	286	1,343	66	25
Sheep		33.9 (S)	23,685	447	682	818	270	375	228	354	6,378	76	51
Horse		31.0 (S)	7,957	419	692	161	235	389	224	71	754	430	160

Arsenic (As) Cadmium (Cd), Chromium (Cr), Copper (Cu), Mercury (Hg), Molybdenum (Mo), Nickel (Ni), Lead (Pb),Selenium (Se), Zinc (Zn)
*(S) = solid manure where allowable application is in tons/acre
(L) = liquid manure where allowable application is reported in gallons/ac

Summary:

The study found elevated concentrations of some metals in certain types of manure in comparison to the concentration limits set for non-agricultural source materials. In particular, concentrations were elevated for copper in poultry (especially turkey) manure, and zinc and copper in swine-weaner manure. Zinc and Copper are included in monograstric (swine and poultry) diets at much higher levels than minimum requirement for "normal" performance since when fed at higher levels they promote growth. Copper and Zinc are elevated in some livestock diets because they are substituted for antibiotics and used as a prophylactic (compound that guards against disease).

With all the livestock manures studied, it was determined that when manure was applied at typical rates, to meet crop requirements over a rotation, none of the trace elements exceeded the levels of those regulated for sewage biosolids.

The study also determined that manure cannot be used to make class A compost under the current MOE compost guidelines, where limits are based levels that are no higher than those found in soil. Manure composts are not intended to be a soil replacement, however compost standards may need to be re-evaluated.

Next Steps:

Consultation with the livestock industry will determine if there are alternative feeding strategies that will maintain current production gains but reduce nutrient output (particularly of copper and zinc) in livestock manure. Work is already being done to determine the impact of phytase on copper and zinc availability and to find alternative sources of zinc (including organic) that have higher bioavailablity, could be fed at lower rates, and result in equal or improved production gains.

Acknowledgements:

Farm Cooperators from 59 farms across Ontario
Nutrient Management Directed Research Program (OMAFRA)
MOE Standards Development Branch
Soil Resource Group - Guelph

Project Contacts:

Please contact Christine Brown at christine.brown@omafra.gov.on.ca for more information on this study.