Heavy Metals in Fertilizers Used in Organic Production

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EXECUTIVE SUMMARY

Heavy metals in fertilizers and other soil inputs are a threat to the sustainability of farming practices. Heavy metals may be taken up by plants and be present in edible tissue. Some heavy metals will be toxic to plants themselves. The presence of heavy metals in some fertilizers can also indicate the presence of prohibited sources and ingredients. The Organic Materials Review Institute (OMRI) is evaluating its current standards to develop a standard for evaluating fertilizers and soil inputs. The following paper provides a brief history of standards development with respect to contaminants found in soil amendments used in organic agriculture, an overview of several metals, descriptions of various regulations that govern heavy metals in soil amendments, and recommended policies and methodologies for OMRI's *Generic Materials List* and *Operating Manual.* Recommended policies are based on a no-net-load basis. The second choice is based on standards established by Agriculture Canada and the Washington State Department of Agriculture.

Introduction

The risks and problems posed by heavy metals in fertilizers and other soil inputs have increasingly drawn the attention of farmers, environmental organizations, consumers, and public policymakers. This study examines a wide spectrum of soil amendments and fertilizers used in organic agriculture, including biosolids, major nutrient fertilizers, industrial wastes, composts, liming materials and micronutrient sources with a focus on inputs used in organic agricultural production in the United States. The results isolated several classes of inputs that were of concern, and showed that the majority of inputs were of little concern in terms of heavy metals loading. Phosphate ores, biosolids, some industrial wastes, wood wastes, animal manures—particularly poultry manure in large-scale confinement broiler operations (57) and micronutrients fertilizers were the most likely to contain significant levels of heavy metals (3, 6, 14, 22).

While most of these sources are prohibited for use in organic production, mined minerals, animal manures, and micronutrients all can be contaminated with arsenic, cadmium, and lead. The presence of heavy metals can also support other evidence of the use of prohibited materials. Elevated lead, cadmium, zinc, and copper can be indicative of sewage sludge. High chromium levels can indicate the use of leather by-products. Lead paint from demolished houses can turn up in wood ash, and copper chromium arsenate treated wood might also be used as a wood source.

While the US EPA has promulgated standards for sewage sludge and some industrial by-products, there are no Federal limits on heavy metal contaminants that are generally applied to all fertilizers. Concerned stakeholders succeeded in persuading state and industry regulators to evaluate risk, and produce standards for heavy metals content in soil inputs. (3,4,9) Many states simply adopted current USEPA biosolids requirements (40 CFR 503) as the basis for their standards. (7) Other agencies began the process of evaluating information and producing a more adequate set of standards, including requirements for a variety of different matrices, after discovering that the biosolids standards were not always appropriate. (3,4,5,9).

Three different approaches were used to set limits: adoption of existing standards (USEPA 503's), risk analysis (CDFA, Oregon, AAPFCO) and cumulative loading (Canada, WSDA). Most limits are within an order of magnitude when viewed using typical application rates, suggesting that the three approaches are consistent and valid. While many conventional agriculture regulations are based on risk assessment models, organic agriculture generally takes a more precautionary approach.

The organic community is now faced with the challenge of defining and adopting standards for heavy metal contaminants in soil amendments. OMRI is taking this on because of the requirements in the National Organic Program. The soil fertility and crop nutrient practice standard in the NOP requires that [t]he 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." (7 CFR 205.203(c), emphasis added). The National List further prohibits natural sources of arsenic (7 CFR 205.602(b)) and lead salts (7 CFR 205.602(d)). Thus the NOP generally and specifically prohibits the application of certain heavy metals. OMRI's advantage, a great deal of research on the subject has already been completed. The main issue is to decide just how to frame a functional and justifiable standard.

HEAVY METALS BACKGROUNDS IN THE CONTIGUOUS UNITED STATES:

Some heavy metals pose greater health concern than others, due to toxicity and higher likelihood of exposure, therefore more information is available on them. Information on Arsenic, Cadmium, Chromium, Lead, Mercury and nickel has been included. The other elements listed (Co, Cu, Mo, Se and Zn) are often necessary trace minerals.

Table 1 Heavy Metal Background Levels in the United States				
metal	**unit**	**average**	**range**	**third quartile (smoothed) 75th percentile**
arsenic	ppm	7.2	<0.1-97	6.83
cadmium*	ppm	0.4	0.05-1.0	
cobalt	ppm	9.1	<3-70	
chromium	ppm	54	1-2000	53.2
copper	ppm	25	<1-700	23.4
mercury	ppm	0.09	<0.01-4.6	0.0739
lead	ppm	19	<10-700	19.8
molybdnenum	ppm	0.97	<3-15	
nickel	ppm	19	<5-700	18.7
selenium	ppm	0.39	<0.1-4.3	0.393
zinc	ppm	60	May-00	65.7
Sources: 41, 42, 44 (cadmium only)				

Arsenic (As):
Arsenic is generally present in soils at low levels. Mining and smelting also account for elevated ambient levels. (44) Elevated levels in agricultural soils are often linked to the application of copper and lead arsenate historically used as fungicides, insecticides; arsenic acid used as herbicides and defoliants; and the use of copper-chromium arsenate as a treatment for service lumber such as fence poles, trellises, and raised beds. Lead arsenate was used on cropland, golf courses, fruit and nut trees, and many other applications, until the invention or organochlorine pesticides to control chewing insects (late 1940's). (44, 47) It is minimally soluble. (44) Plant uptake is minimal, even in highly contaminated soils (uptake factor 0.01-0.10)(22,44); phytotoxicity occurs at high levels, with legumes the most sensitive (40-200 ppm, depending on soil chemistry). (44, 48) Arsenic levels in Pacific NW orchards are in the range of 20-600 ppm. (22, 48) Arsenic is currently fed to some chickens as a growth stimulant and coccidiostat (at approximately 50 ppm). (39) Processed manure can contain no more than 41mg/kg (dry weight basis) (57) Long known to be a carcinogen, as well as a direct toxin, human health effects from ingestion of water at exposures of 0.4 mg/kg/day over 6 months to a year can show toxic effects. (22) Little direct ingestion comes from plant materials. (22)

Cadmium (Cd):
Cadmium is generally present in soils at low to very low levels (0.1 to 0.5 ppm). (44) Higher levels are seen in sedimentary soils (0.1 to 25 ppm) and some volcanic shields. (44,49) It tends to be moderately mobile in soil systems, with plant uptake resulting. (28, 44, 45, 46, 49) Typical daily national intake of Cd through diet is 20-40 mcg Cd/day. (44) WHO sets a daily intake limit of 70 mcg/day. (44) Human uptake issues include ingestion, inhalation, and absorption. (44) Crops that are of concern for cadmium uptake include green crops including lettuce, spinach, celery and cole crops (heavy accumulators.), and some root crops, including potatoes and the carrot family (moderate accumulators). (44, 45,46,47) Sources include biosolids, some

phosphate ores, some micronutrient ores, and some industrial wastes. (44) Available Zinc level affect cadmium uptake; cadmium complexes with zinc and becomes technically insoluble when there is enough excess zinc in the soil matrix. (38)

Chromium (Cr):
Chromium usually appears most commonly in the environment as a trivalent salt (Cr-III or Cr^{3+}). (53) Found in air, water, soil and some foods, it is an essential trace element, aiding in the metabolism of carbohydrates, etc. (54) It is found in foods such as cole crops, brewers yeast and cereal grains. (53) Hexavalent Chromium (Cr_6) is the byproduct of industrial applications, including steel making, tanning, plating, and textiles. (54) Considered by the USEPA to be a carcinogen, (Cr-VI or Cr^{6+}) is readily absorbed by the body, and can lead to ulceration of the liver, nasal septum and (54) Action of stomach digestion tends to change Cr_6 to Cr_3, but Cr_6 is a strong oxidizer and can damage cell walls easily. (55) Sources of Cr_6 in the fertilizer stream include steel manufacturing, tannery wastes, leather by-product, and sewage sludge. (52,53) Chromium attaches tightly to soil particles, and the usual exposure pathways are due to exposure to dusts, sediments, etc. (52, 54)

Lead (Pb):
Lead easily accumulates on soil surface because of its low solubility in typical environmental contexts, and plant uptake factors are low (0.01-0.1). (44) Even though FDA's Total Diet Studies (1994-96) reveal that lead uptake in 2-5 year olds dropped 96 percent since the previous study (1982-84), lead persists in a problematic way in the environment. FDA's "tolerable" level for lead in children's daily diet load is 6 mcg. Lead follows calcium and iron pathways when there are deficiencies in those metals. Carrots grown in highly contaminated soils (old orchard crops) have shown significantly elevated lead levels. (55) Gasoline, lead-acid batteries, old paint, pesticide and industrial applications are sources of lead pollution. (44) Demolition waste processed into wood products can be a source of lead found in fertilizers.

Mercury (Hg):
Mercury's solubility in soil and water is quite low. (44) Plant accumulation is quite low (0.01-0.1). (44) Atmospheric movement of mercury from coal combustion can contribute up to 50% of accumulation in organic soils. (44,56) Other sources include the chlorine industry, pulp/paper, mining/extraction, sewage sludge, and compost incinerators. (44,56) Plants in direct contact with cinnabar or other mercury-containing strata can show high accumulations, but under normal circumstances, little accumulation is seen. (44) Generally, mercury accumulates at the tips of root hairs, and does not significantly translocate to leaves and fruit. (56) It is more likely a problem in sludges and sediments, where aquatic life accumulates and store (44).

Nickel:
Nickel is moderately soluble in soil and water. (22) Plant transfer coefficient: 0.01-0.1. (44) Inhalation of nickel fumes from processing causes respiratory cancers; little direct evidence of toxicity by ingestion. (22) It is a necessary trace element for some microbes, plants and invertebrate

Copper:

Copper is an essential trace element that is also applied as a fungicide, algicide, molluscicide, and to control crustaceans. Environmental contamination from copper generally originates from mining and smelting operations. Copper is allowed in organic farming, with restrictions on its use to minimize copper accumulation (7 CFR 205.601(a)(3), 205.601(d)(3), 205.601(i)(1), and 205.601(i)(2). Accumulation of copper in the soil can result from contaminated soil amendments as well as from pesticidal use. In order to properly monitor and prevent copper accumulation, copper needs to be restricted in fertilizers as well as in pesticides.

Zinc:
Zinc, like copper, is an essential trace element that can be toxic to plants in excess. Many zinc bearing fertilizers are highly insoluble, and crops amended with these materials can show noticeable zinc deficiencies. (31) Insoluble zinc materials do not appear to become significantly more soluble over long periods of time. (31) Little research has been done on the effects of high zinc loads from fertilizers over long time periods. (31)

Solubility of metals (the form in which they exist in the material, plus environmental conditions when applied) has a significant effect on plant availability and leaching. (31) Many industrial wastes (frits, slags, etc) are insoluble. (31) Others, such as ashes are more readily soluble. (31)

Heavy Metal Standards In Fertilizers

In the 1920s, scientists realized that the accumulation of elemental contaminants in soils from the use of fertilizers and pesticides can be an irreversible agronomic problem. However, standards were not set until the 1970s, when the US EPA and Environment Canada put forward the first limits on the levels of heavy metals in sewage sludge and other biosolids.

In the United States, fertilizers are regulated on a state-by-state basis. The Association of American Plant Food Control Officials (AAPFCO) publishes a model law intended to harmonize the regulations in all of the 50 states. Canada regulates fertilizers on a Federal basis, but provinces may have more restrictive standards. AAPFCO evaluated the risk analyses produced by USEPA, The Fertilizer Institute, The World Health Organization, and CDFA, and produced a set of guidelines for their fertilizer manufacturers. Canada, meanwhile began the process of reevaluating of their 1979 biosolids policy. They produced a standard based on no significant increased loading over a specific time period (45 years), and back-calculated to provide acceptable heavy metals loading numbers. Various states have adopted these, or a version of these standards, including California, Oregon, Washington, Vermont, Minnesota, Texas, and others. Following is a description of several approaches to heavy metals loading in soil inputs:

Canada

In 1979, Canada developed a set of heavy metals standards including 9 metals (As, Cd, Co, Hg, Mo, Ni, Pb, Se, Zn) for biosolids, as a response to concerns about sewage sludge. (18) Between 1993 and 1995, the standards were reevaluated in response to studies produced by CDFA and USEPA, with the view of using them for all soil inputs, and they were found to be adequate for all fertilizer materials. (18) Canada uses a minimal cumulative soil loading approach. (19) Calculations are made based on major nutrients (NPK), or the major micronutrient (Fe, or Zn, for instance). (19) Loading rates are on a dry weight basis. (19) The critical loading period is 45 years. (19) Ceiling acceptable levels tables are provided and inputs that fall below those limits expressed as ppm per unit (1%) of main major nutrient or main micronutrient. major nutrient loading on a dry weight basis is calculated using ppm per unit (1%) to yield a final total loading sum. If this sum is below the total loading sum on the chart, it may be applied. (19) These are national laws, and many provinces have further laws. (6) Current standards are clearly based on Canada's original biosolids rules. The dry weight basis reporting seems to be as a response to the biosolids focus of the original rules and the mandate to cover all inputs less than one rule. Two classes of materials are broken out:

- Sludge, compost and other byproducts
- Fertilizers and supplements

Note: Canada is conducting an extensive review of risk analysis data and methods generated by USEPA, The European Union, California, and AAPFCO to compare and validate their current methodology. (6)

California

In 1992, California began subjecting arsenic, cadmium and lead content in soil inputs to risk analysis, using both standard CDFA and USEPA risk models. The USEPA produced a "forward risk assessment" of phosphate and micronutrient fertilizers, assessing 9 metals (As, Cd, Cr, Cu, Pb, Hg, Ni, Vn, Zn). The Weinberg group, at the behest of The Fertilizer Institute developed risk-based concentrations for 12 metals (the above, plus Co, Mo, Se).

California limits three heavy metals, As, Cd, and Pb, based on risk-assessment. (33, 32) Values are calculated as ppm per unit (1%) of main major nutrient or micronutrient. (33) They provide standards for 5 classes of materials:

- micronutrient materials (guaranteed Zn, Mn, Fe),
- phosphate fertilizers,
- specialty fertilizers with no nutrient claims with less than 6% available phosphorus
- specialty fertilizers with less than 6% available phosphorus that make micronutrient claims
- hazardous waste used as fertilizer.

The standards were incrementally tightened, with the strictest version effective January 1, 2004. (33)

Oregon

Oregon's standards are based on the TFI and USEPA risk analysis data. (4) A study of risk analysis (and a commissioned study of various factors in developing fertilizer standards by Curtis and Smith at OSU. (22)

Their standards provide calculations for five metals (As, Cd, Pb, Hg, and Ni) in six classes of materials:

- guaranteed available phosphorus fertilizers with no micronutrient claims,
- one guaranteed micronutrient claim with no available phosphate claims,
- two or more micronutrient claims with no guaranteed available phosphorus,
- guaranteed available phosphorus plus 1 guaranteed micronutrient,
- guaranteed available phosphorus claim plus 2 micronutrients,
- no guaranteed phosphorus plus no guaranteed micronutrient claims.

(21)

Washington

Washington adopted the Canadian standards in 1998. (28) Because of the uneasiness of stakeholders in regards to the calculation as ppm per unit (1%) of major nutrient, this portion of the Canada standards was dropped. (8) Washington also expressed Canada's 45 year cumulative load ceiling as a "maximum acceptable annual addition of metals to soil per year." (29) Nine metals are monitored (As, Cd, Co, Hg, Mo, Ni, Pb, Se, and Zn) (26)

Every commercial fertilizer sold in Washington must be registered with the state. Each registration includes a report stating the total heavy metals content for each metal and application rates. The WSDA maintains a database of all registered fertilizers, and calculates loading rates based on maximum application levels. (26) Fertilizers that are disqualified are noted. (30) Bulk fertilizers and composts, which are not required to register, are monitored, and a database of typical values is maintained. (9) Depending on the situation, some listed metals (Co, Mo, Se and Zn) may have variances given for them. (8) They are plant nutrients, and areas in the eastern region of the state are deficient in these metals. About 2% of fertilizer applications are denied outright due to heavy metals standards. Some materials are relabeled with different application levels, which allows them to be listed. (30) Washington does not break commercial fertilizers into classes, nor do they tie the metals content to the major guaranteed nutrients. (30) Note: WSDA is discussing reevaluating their standards to compare and contrast them to the current risk-based standards from other organizations. (8,9)

AAPFCO:

The Association of American Plant Food Control Officials (AAPFCO) is a non-profit membership organization that includes the various state officials responsible for the establishment of a Model Fertilizer law and set standards that defined maximum acceptable levels of contamination–including ceiling heavy metals content–in fertilizer materials. (35) The *Seattle Times* published a series of articles in 1997 that alerted WSDA and other AAPFCO officials of possible problems with heavy metals in fertilizers (3). WSDA first responded by adopting the Canadian standards. After further research, several problems were perceived with current standards. It was found that under Canada's rule, superphosphate fertilizers could contain as much as 171 ppm cadmium, and the proposed California rule would allow nearly 300 ppm, while the USEPA biosolids rule would allow a maximum amount of 21 ppm Cd (7 CFR 503). When applied to hard rock phosphate (tricalcium phosphate) the maximum allowed is lower, as the application rate is significantly higher. Canada allows 1.8 kg/ha.of Cd. It was felt that further research was needed to establish understandable and scientifically justifiable standards for heavy metals in fertilizers, composts and other soil amendments. (3, 38)

Using risk analysis studies from CDFA, the Weinberg Group (for The Fertilizer Institute) the World Health Organization, and USEPA, they determined that, in almost all cases, metals content in fertilizer is far below levels of concern in risk analysis. Their screening levels are based on exposures via uptake, ingestion or absorption, with farm families and workers being at the highest risk. (3, 4, 40)

Officials established ceiling levels for two classes of product, phosphate bearing fertilizers, and micronutrient fertilizers, with the metals levels tied to the percentage of guaranteed nutrient in the material. (35, 3, 4) Calculations show that, considering losses incurred by leaching, plant uptake, erosion, etc, there is no significant added loading to the average soil background level of heavy metals for a period of about 100 years. (3)

AAPFCO established allowable levels at the 80th percentile, meaning that 80% of the fertilizers are at or below the ceiling levels for heavy metals. AAPFCO sets standards for As, Cd, Co, Hg, Mo, Ni, Pb, Se, and Zn. (35)

USEPA :
The EPA has established legal limits for pollution from a variety of waste materials, including, biosolids, solid waste and hazardous waste. Each type of waste is specifically identified and regulated separately. EPA divides fertilizers that they regulate as biosolids, fertilizers from (industrial) wastes, and manure as fertilizer (10,11,12) USEPA produced a white paper based on risk assessment methods that concluded industrial waste did not generally serve as a significant source of heavy metals contamination in the fertilizer stream. (4) However, it did reveal several areas that needed further study, including some industrial wastes that make their way into the fertilizer stream, some of which have had specific variances allowed from the RCRA hazardous waste laws (specifically slag, frit and cyclone residue from the steel fabrication industry) (10) Some states, most notably Texas, applies EPA's biosolids standards to all classes of materials (7).

Biosolids:
The most common standard used by officials to regulate heavy metals in fertilizers are based on the US EPA's limits for biosolids found in 40 CFR 503. The standards are based on risk / benefit analysis and are expressed as a limit of net loading. Biosolids are seen as a source of copper, zinc, chromium, cadmium, and mercury. (45) More effective treatment of biosolids has reduced the levels of heavy metals since the time the biosolids regulations were promulgated. Ceiling concentrations are expressed as mg/kg on a dry weight basis (DWB) for allowable concentrations in the biosolids, for cumulative loading (kg/hectare) for single applications, and annual pollutant loading rate. (11) Biosolids standards are expressed as total loading, and can pose some fairly significant problems for organizations attempting to regulate micronutrient and phosphorus product. Monitored metals include As, Cd, Cr, Cu, Pb, Hg, Mo, Ni, Se, Zn. (11)

Fertilizers made from (industrial) waste:
Most industrial wastes are not considered hazardous waste. A small portion of industrial waste considered hazardous makes its way into the fertilizer stream. Of this, most of the material is used as a source for zinc. (12, 15) Industrial waste is regulated under RCRA, with specific limits and requirements published for substances that are considered hazardous waste. (10) Interestingly, the heavy metals that are regulated under RCRA are measured by availability (TCLP) rather than by total metals content, making it impossible to compare RCRA regulations with other fertilizer regulations, which all require total metals analysis, rather than extractable metals. (10) RCRA was designed to both encourage recycling and reuse of industrial materials, while at the same time protecting the environment and human health from exposure to chemical hazards. As with biosolids, the US EPA targeted the fertilizer market as potential way to dispose of waste products. Slag and cyclone material from steel production and slag from brass foundries

is exempt from hazardous waste regulation. (10, 15) These waste streams are often used as to manufacture zinc fertilizers. (12)

Zinc-based fertilizers:
USEPA re-evaluated zinc fertilizers in response to concerns from stakeholders. (15) A final rule (CFR 40 Parts 261,266, 268 and 271) was added to the CFR in July of 2002. Metals contaminants are expressed as maximum allowable levels per unit (1%) of zinc content. Metals covered are As, Cd, Cr, Pb, Hg. Many of these zinc sources provide zinc with little availability. (31)

COMPARISON OF STANDARDS:

Following are a series of charts comparing the above standards. The charts are divided by class, and are charted separately, depending on the basis of the different standards.

TABLE 2
COMPARISON OF RISK-BASED STANDARDS HEAVY METALS IN FERTILIZERS
MAXIMUM ALLOWABLE CONCENTRATION (AS PPM PER UNIT (1%) OF P_2O_5)
MACRONUTRIENTS (N, P)

Standard	As	Cd	Co	Pb	Hg	Mo	Ni	Se	Zn
AAPFCO	13	10	3,100	61	1	42	250	26	420
CDFA	2	4		20					
OSDA	9	7.5		43	0.7		175		

TABLE 3
COMPARISON OF RISK-BASED STANDARDS HEAVY METALS
IN MICRONUTRIENT FERTILIZERS
MAXIMUM ALLOWABLE CONCENTRATION (AS PPM PER UNIT (1%) OF Fe, Zn)
MACRONUTRIENTS (N, P)

Standard	As	Cd	Co	Cr	Pb	Hg	Mo	Ni	Se	Zn
AAPFCO	112	83	23,300		463	6	300	1,900	180	2,900
CDFA	13	14	3,100		61	1	42	250	26	420
OSDA	76	61			340	4.5		1,330		
US EPA	0.3	14		0.6	2.8	0.3				

The risk-based approach is based on concentrations of metals in each product modeled upon their typical metals and nutrient content. The disadvantage is that a complex modeling of fertilizer types, multiple application scenarios and theoretical cumulative loading figures must be developed. (22) The result of these method applications is a complex series of formulas for which each metal must be calculated as a parts per million for each unit (1%) of major macro- or micro-nutrient.

A different set of standards must be applied to each class of soil amendment, including macronutrient sources (usually based on Phosphorus content), micronutrient sources and soil amendments that do not make nutrient claims, such as mulches, composts, biosolids and other similar products.

Ceiling numbers are generated from various exposure scenarios, generally assuming a 1:100,000 basis for risk. Cancer causing agents are based on a ratio of 1:1,000,000. (22, 40) Other numbers are then factored in, depending on the stakeholders' recommendations. (4) Thus, California's ceiling levels are lower than AAPFCO's. In all cases, however, risk analysis showed that nearly all of the fertilizer application levels were significantly below the 1:100,000 risk ratio.

While the ceilings have some specific significant variations worth noting, all are within an order of magnitude of each other. Safety factors include such considerations as multiple applications of the same product, applications multiple products containing the same contaminant, multiple exposures through application plus ingestion, and ambient exposure from applications on nearby sites.

In all methods, including both risk-based and cumulative net loading, the authors have taken into account leaching, plant uptake and erosion factors in projecting cumulative soil loading. (3,4,6,9) All methods factor in multiple applications. An acceptable maximum net loading amount and period is established, either by extrapolating from risk based loading, or calculating back from a maximum allowable cumulative load.

Calculating maximum allowable levels of heavy metals per application is a simpler proposition than a risk-based approach. (22). Concentration of each heavy metal in the fertilizer material is calculated in ppm, along with the application rate. If the total applied heavy metals is below the limit, all is well. Advantages for this method include a fairly simple and straightforward calculation, and a system that covers all types of amendments. Because the method is loading-based, it is possible that it does not account for other risks such as application exposure. Both Canada and Washington are reevaluating their data against the many other methods developed since their methods were promulgated. (6,9)

It is difficult to directly compare the two different methods as presented, because of the different direction of their focus. In appendix 1, you wil find charts comparing the methods, using the theoretical application of three materials: 1) rock phosphate with 30% phosphorus (approximately 3% available phosphorus) for macronutrient-based fertilizers, 2) compost, for inputs with no nutrient claims, and 3) zinc sulfate, for micronutrient-based fertilizers. I have used Arsenic, Cadmium and Lead for illustration. Note that the projected OMRI limits from plan 1 are included in these charts, as are extrapolation to 50 years of continuous application. The charts also compare the long-run total average soil load that results of application after a 50 year period.

RECOMMENDATION

Few of the materials that apply for OMRI listing are of concern for heavy metals contamination. Materials that could pose problems include the following:

- Mined minerals, including rock phosphate, granite dusts, and greensands
- Processed manure products, particularly poultry manure

- Humate products, particularly unprocessed lignite.
- Wood ashes contaminated by demolition wastes and arsenic treated lumber
- Micronutrient and trace mineral products

Even without a significant number of products to deal with, it is clear from the difficulty that the review committees are having assessing heavy metals content that the need for a standard of some sort is evident. A specific standard that can be applied to all materials will speed the evaluation process, as well as help to establish a more solid base from which to work with both certification agencies and petitioners.

Provided are several plans for OMRI's Staff and Advisory Council to evaluate for inclusion in the OMRI *Generic Materials List* and *Operating Manual*. Plans 1 and 2 are based on the adoption of an existing no net load plan. The no net load plans generally show higher total loads than the risk-based plans. In response to your request, I have included as the first and second plan a program based on no net load. The third plan is modeled on a risk-based plan, back calculated to provide a single upper allowable limit.

Plan 1: Adopt the WSDA standards format with some changes

- Drop the total cumulative loading numbers by 25% to back out the plant uptake, erosion, and other factors to produce a more straightforward no net loading standard.
- Keep the 45 (nominally 50) year interval.
- Establish classes of materials trace minerals, ores, mined minerals, industrial wastes, sulfur, lignosulfonates, humic acid derivatives, composts, liming materials, concentrates, manures, and macro nutrient sources from ores such as Chilean nitrate, phosphate rock, potassium chloride, and greensand.
- Establish average loading rate for each class based on currently available data.
- Set maximum loading rate at 80^{th} percentile—that is, 80% of studied materials are at or below set loading rate.
- Add a 25% safety factor, dropping the limit that much further for multiple applications, such as was originally proposed by WSDA.
- This standard will be stricter than WSDA USEPA 503's Canada, but may be less strict than California, Oregon, and AAPFCO.

Advantages:

- It is based on a current standard that establishes a single number for each class; all of the calculation is done in advance, and makes an unambiguous standard for certifiers and evaluators
- A large database of materials already exists (WSDA fertilizer registration, and OMRI application materials)

Disadvantages:

- A significant amount of up-front work is required.
- Numbers are based on class, rather than individual application. Some products may be eliminated that would otherwise be included (highly concentrated products with higher than average application rates, for instance)

- The approach differs from any other established standard (more strict net loading figures than those currently established, and based on specific classes, rather than individual materials)
- This plan establishes loading rates that are less than the no net load systems, and more than the risk based systems.

Plan 2: Adopt the WSDA program in its entirety. Washington's program is based on the Canadian program, which is based on no net gain for 45 years. Washington chose to discard Canada's formulas basing contaminant loading on the main nutrient, which makes the calculation scenario somewhat simpler. A variation is to modify the standards to reflect a 100-year no net gain and reduce the allowable metals loading by half.

Advantages:

- The standards are already established and require no additional calculation or justification.
- The standards are based on no net loading.
- WSDA has a big database of fertilizers and also conducts brand name review for organic inputs.
- These are essentially the standards that OMRI already is using for micronutrients.

Disadvantages:

- This plan provides loading rates that are lower than USEPA 503's, are equal to other no net load plans, and higher than risk analysis.
- Each product must be calculated individually, based on amount of heavy metals and application rate, making it less clear to subscribers and users.
- WSDA and Canada are currently reevaluating their standards, and may modify their current standards when the evaluation is completed, leaving OMRI without a direct reference standard.

Plan 3: Adopt AAPFCO's plan. Although primarily risk based, they have calculated that materials used in an average fashion under their standards and conditions will not significantly increase the average soil load over a 100-year period. Calculate actual net loads for different classes, and adapt them to a no net degradation policy.

Advantages:

- Although the AAPFCO standards are primarily risk-based, it acknowledges the need for no significant cumulative loading.
- The final net loading numbers appear to be significantly lower than those of the loading based systems, except California.

Disadvantages:

- Because it is promulgated by representatives of the fertilizer industry, critics still accuse the numbers of being set too high, allowing too many existing products, and therefore are ineffective at protecting the environment.

- Some calculation would be necessary to ascertain the actual total net loading for each class; then the same set of calculations from plan one would need to be performed.
- Unless materials classes are established, as in plan 1, each metal will need to be calculated based on the predominant nutrient.
- Composts and other inputs without specific nutrient claims would need to be dealt with under another program until AAPFCO's compost policy is solidified.

LABORATORY ANALYSIS:

Problems with widely varying matrices can produce varying results in laboratory analysis. This can pose problems with accuracy and repeatability from both lab to lab and from sample to sample. Combining matrix issues with widely differing analytical methods can make any system of limiting heavy metals application meaningless. AAPFCO is currently performing a research project on extraction and detection methods with the aim of producing the most complete, repeatable, and universal extraction and detection methods for soils and amendment materials. Until their research is complete, staff recommends that OMRI require the following USEPA procedures. These are commonly used in certified environmental laboratories, and even though they do pose some complete extraction problems, they are repeatable, and will help to reduce lab-to-lab variability.

Extraction: EPA 3000 series. This is a concentrated nitric acid digestion, with the addition of concentrated hydrochloric acid (HCl) if necessary. It is designed to solublize the sample as completely as possible, thereby measuring **Total Metals**. This is currently the most exhaustive extraction that has been through full validation. It is in general use in certified laboratories. There are some matrix issues. Mercury is digested by a different method. (EPA 4000 series)

It is **not** a DTPA, TCLP or other dilute acid or detergent extraction. These methods are designed to measure acid extractable, detergent extractable, or "available" metals. Designed to mimic natural extractive processes, they have little relation to the total metals in a sample. Soil conditions can change dramatically in ways that make metals more or less available, so the total metal load is important. All of the standards examined in this paper require total metals methods, except USEPA, which requires TCLP extraction on hazardous waste-based fertilizers. Their justification is that TCLP is the most rigorous method mimicking what might occur in the environment, therefore the resulting numbers are more meaningful in terms of environmental hazard. (8)

Detection: USEPA 6000-7000 series: This is the standard method for certified environmental laboratories, has significant QA/QC methods built into it, and has shown good lab to lab repeatability. It designates the best detection paradigm for each metal. Detection devices include inductively-coupled plasma (ICP), mass spectrophotometry, atomic absorption and graphite furnace/atomic absorption. Most labs use the first two technologies which produce lower detection limits, and lend themselves to faster turnaround times.

CONCLUSIONS:

OMRI's materials evaluation process may be facilitated if there was a set of heavy metals standards in soil inputs in place. A variety of standards currently exist based on one of two approaches; either 1) risk analysis 2) maximum net soil loading. No net loading systems would be easier to adapt to OMRI's requirements, however they all appear to result in higher end loads than the risk based systems. Either system can be accommodated to OMRI's requirements by calculating net loads for various classes of materials.

Establishment of acceptable cumulative loading numbers, and applying them to classes of materials would best serve OMRI. Ease of use, understandability by all stakeholders, and a connection with current research make this plan the most viable. However, any of the systems could be adapted to serve OMRI, depending on how much up-front work is acceptable, and how important it is to make the method understandable for all stakeholders. For instance, the crop materials review panel need only know whether a given material is within the heavy metals threshold.

OMRI could also establish its own standard based on a no-net-load basis (Plan 1 and the consultant's recommendation). Such an approach would establish a series of classes, such as composts, processed manures, micronutrients, humic acid derivatives, phosphate rocks, liming materials, and then establishing a no-net-gain limit for each class, using typical and maximum application rates for the class. By establishing a limit at the 80^{th} percentile, it would help assure that few, if any materials would be over the limit. OMRI files and the WSDA database already provide much data about heavy metals content of fertilizers and other inputs that could be used to generate these limits. An upper cumulative load limit could be established using the current WSDA program. The advantage to this method would be the establishment of a "hard" number for each class, thus avoiding calculations for every material based on each individual application rate. Stakeholders, including Review committees, certifiers, growers, and manufacturers will find these regulations clear and simpler to use.

A simpler, less costly approach would be to adopt the Canada / WSDA standard. Although there is some conversation about the high values allowed, the program is set up as no net load over a 45-year period. Canada / WSDA do apply typical uptake / erosion / leaching methodology to their loading calculations, as do all of the other methods assessed. (3,4,6) An easy variation would be to simply halve the allowable loading numbers. This should back out the assumptions made regarding net loss of metals by soil over time.

Finally, OMRI could adopt AAPFCO's model fertilizer bill limits, calculating typical loading rates, and apply those numbers to the classes from the above plan. Such an approach would also be labor-intensive at the beginning.

Specific laboratory analyses must be required of each applicant. For methodology, I recommend the EPA 3000 series for extractions, and the EPA 6000/7000 series for total metals. Methods that involve dilute acid and/or detergent digestions should not be included; these produce "extractable," rather than "total" metals. Environmental conditions can change, thereby making metals more or less available. AAPFCO is currently evaluating various methods for total digestion and extraction. OMRI should follow this progress closely and be prepared to adopt their recommendations when their research is complete. There are certainly some problems with the current EPA total metals extraction methods, due to the wide differences in matrices, but the method is the best that is currently available, and moreover, it is in current use among the majority of laboratories, which makes lab to lab variation much less of a problem. (36,37)

The EPA 3000/6000-7000 series are used by a large number of laboratories, and are designed to measure total metals within the limits of the method. Even with the built in matrix problems that can occur, at least the results will be comparable from lab to lab. If OMRI wishes to require EPA 3000/6000-7000 "*or equivalent,*" OMRI should require copies of the laboratory procedures to insure equivalency.

Staff will need to work with the Advisory Council to format these proposed standards into OMRI *Operating Manual* language once OMRI has settled on a specific approach. Any attempt to revise the *Operating Manual* using multiple scenarios would require more effort than developing a standard based on a single agreed upon approach.

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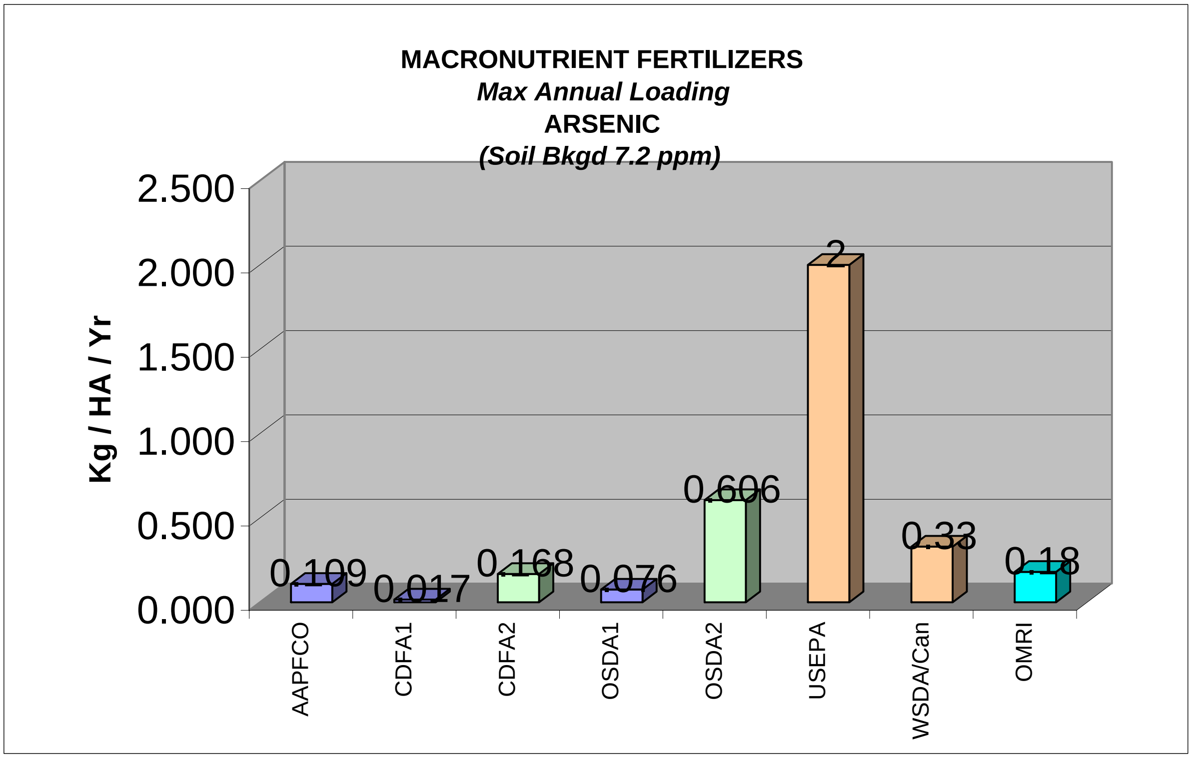
MACRONUTRIENT FERTILIZER
Metals Loadings per single application
Oct. 19, 03

Formula:

Kg / Hectare = (ppm metal /1,000,000) X % Ph X Application Rate Fertilizer X 0.454 kg/lb X 2.47 Ac / Hectare

				ppm	%Ph	App Rate
	AAPFCO	0.109		13	30	250
hi-phos	CDFA1	0.017		2	30	250
low-phos	CDFA2	0.168		15	1	10000
hi-phos	OSDA1	0.076		9	30	250
low-phos	OSDA2	0.606		54	1	10000
bio-solids	USEPA	2	max load		30	100
	WSDA/Can	0.33	max load			
Proposed	OMRI	0.18	max load			



Risk based maximum load (based d on 250 lbs/acre 30% Rock phosphate single application)

Risk based max. load no nutrient claims (compost@ 10,000 lbs/ac

Maximum cumulative loading basis (45 year period - kg / HA / year)

Proposed OMRI max cumulative annual loading (50 yr period, kg / HA)

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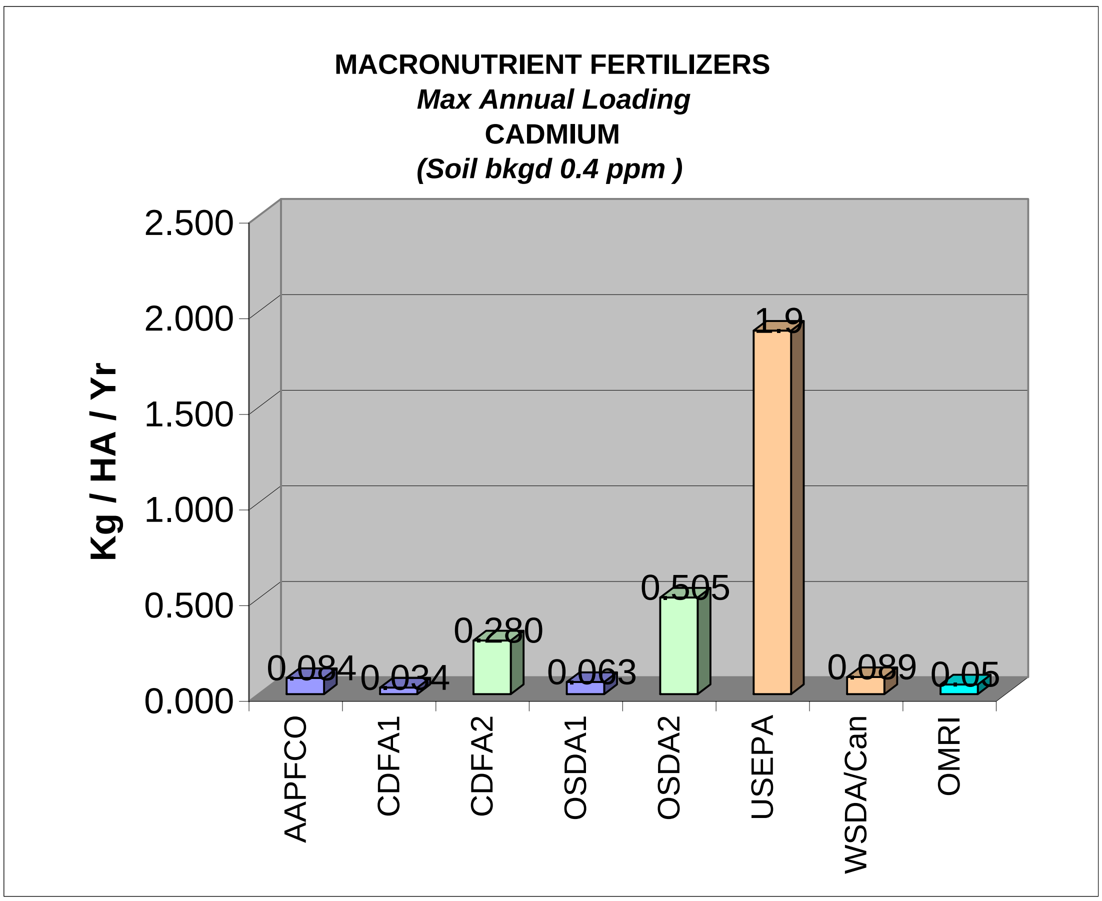
				ppm	%Ph	App Rate
	AAPFCO	0.084		10	30	250
hi-phos	CDFA1	0.034		4	30	250
low-phos	CDFA2	0.280		25	1	10000
hi-phos	OSDA1	0.063		7.5	30	250
low-phos	OSDA2	0.505		45	1	10000
bio-solids	USEPA	1.9	max load			
	WSDA/Car	0.089	max load			
Proposed	OMRI	0.05	max load			



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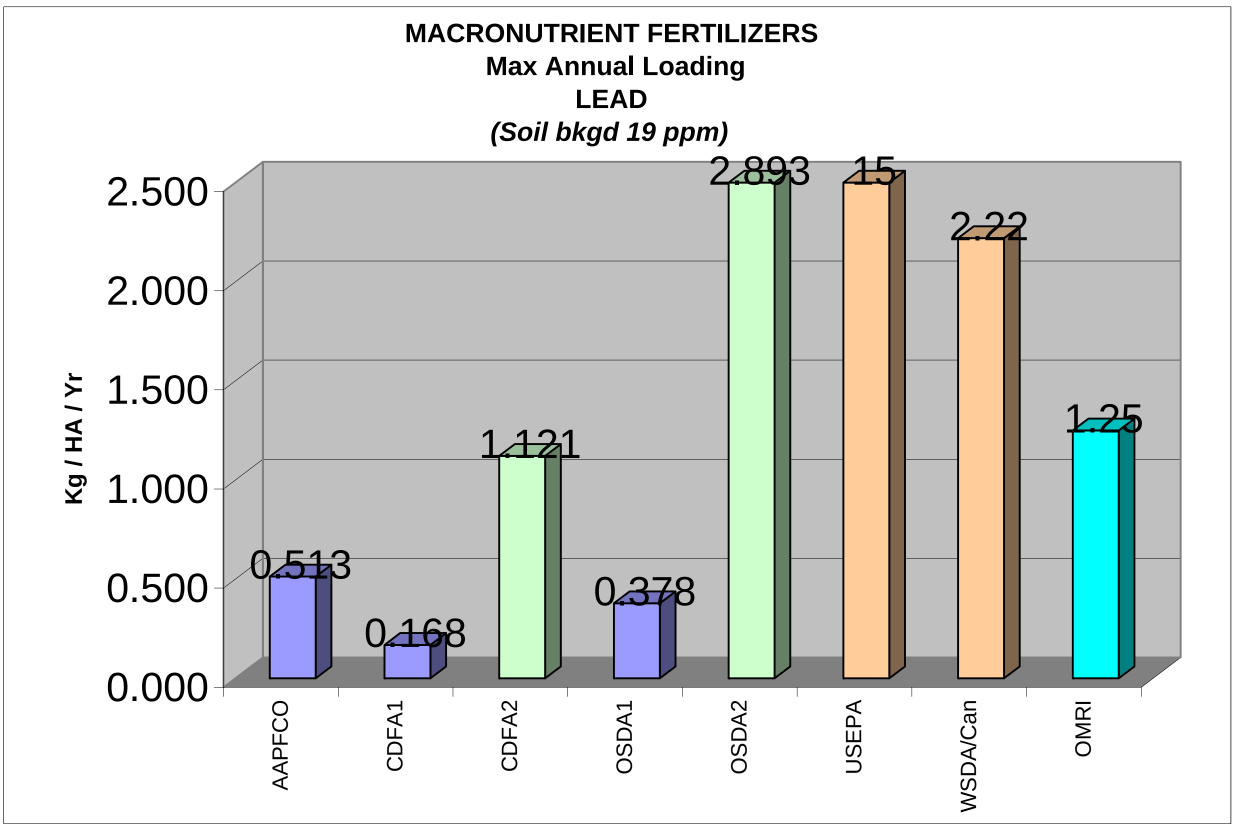
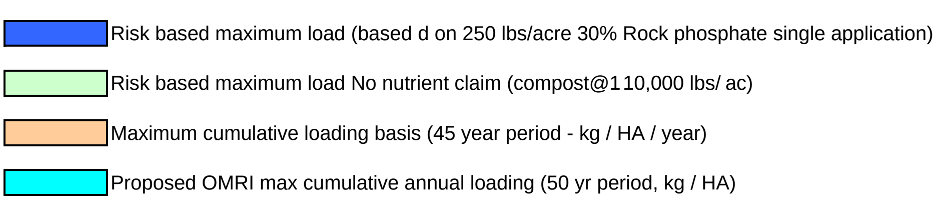
				ppm	%Ph	App Rate	Compost
							3
	AAPFCO	0.513		61	30	250	
hi-phos	CDFA1	0.168		20	30	250	
low-phos	CDFA2	1.121		100	1	10000	
hi-phos	OSDA1	0.378		45	30	250	
low-phos	OSDA2	2.893		258	1	10000	
bio-solids	USEPA	15	max load				
	WSDA/Car	2.22	max load				
Proposed	OMRI	1.25	max load				





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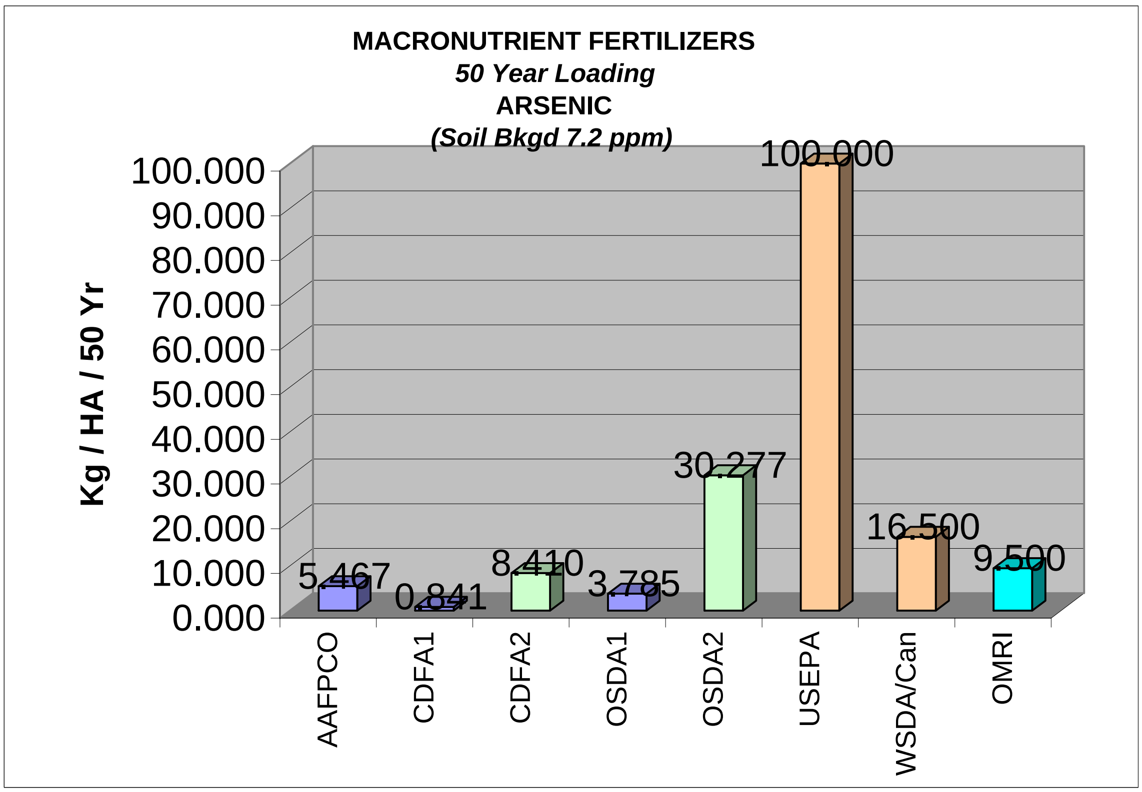
Metals Loadings per single application
Oct. 19, 03

Formula:

Kg / Hectare = (ppm metal /1,000,000) X % Ph X Application Rate Fertilizer X 0.454 kg/lb X 2.47 Ac / Hectare

			ppm	%Ph	App Rate	Years		
	AAFPCO	5.467	13	30	250	50		
hi-phos	CDFA1	0.841	2	30	250	50		
low-phos	CDFA2	8.410	15	1	10000	50		
hi-phos	OSDA1	3.785	9	30	250	50		
low-phos	OSDA2	30.277	54	1	10000	50		
bio-solids	USEPA	100.000		30	100	50	2	max load/yr
	WSDA/Can	16.500				50	0.33	max load/yr
Proposed	OMRI	9.500				50	0.19	max load/yr



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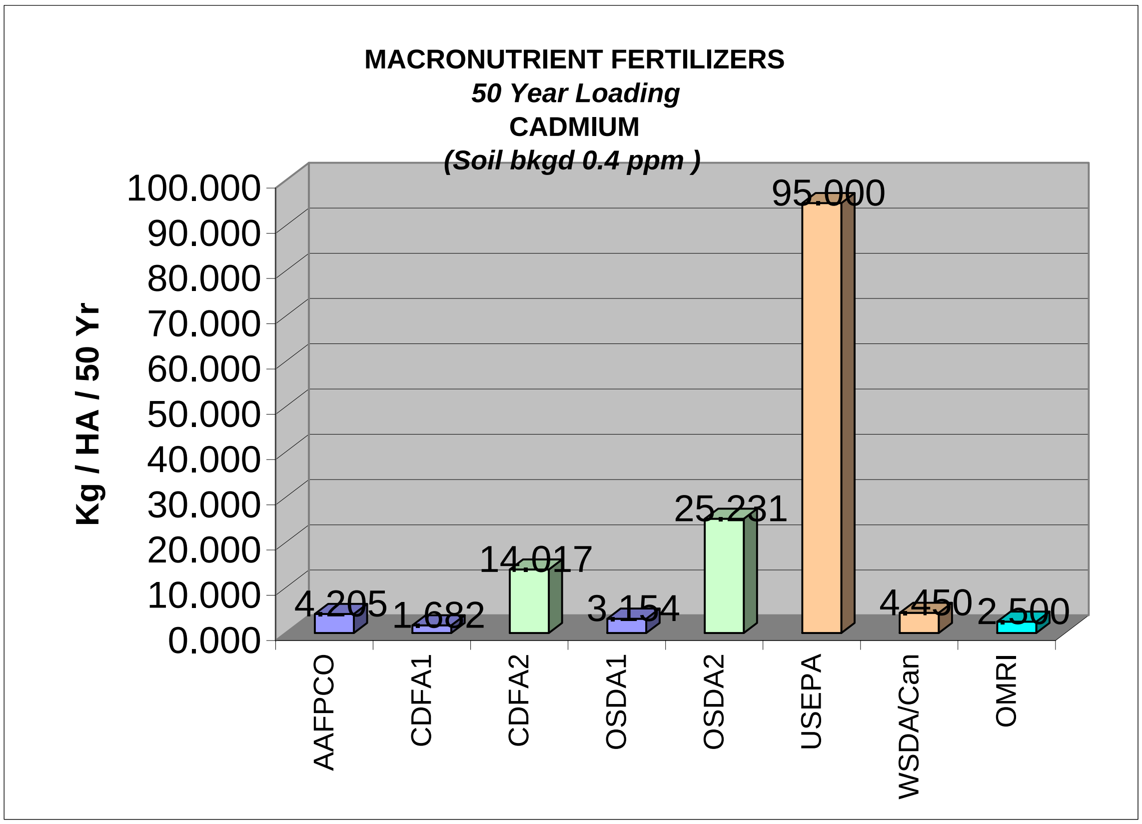
			ppm	%Ph	App Rate	Years		
	AAFPCO	4.205	10	30	250	50		
hi-phos	CDFA1	1.682	4	30	250	50		
low-phos	CDFA2	14.017	25	1	10000	50		
hi-phos	OSDA1	3.154	7.5	30	250	50		
low-phos	OSDA2	25.231	45	1	10000	50		
bio-solids	USEPA	95.000				50	1.9	max load
	WSDA/Car	4.450				50	0.089	max load
Proposed	OMRI	2.500				50	0.05	max load



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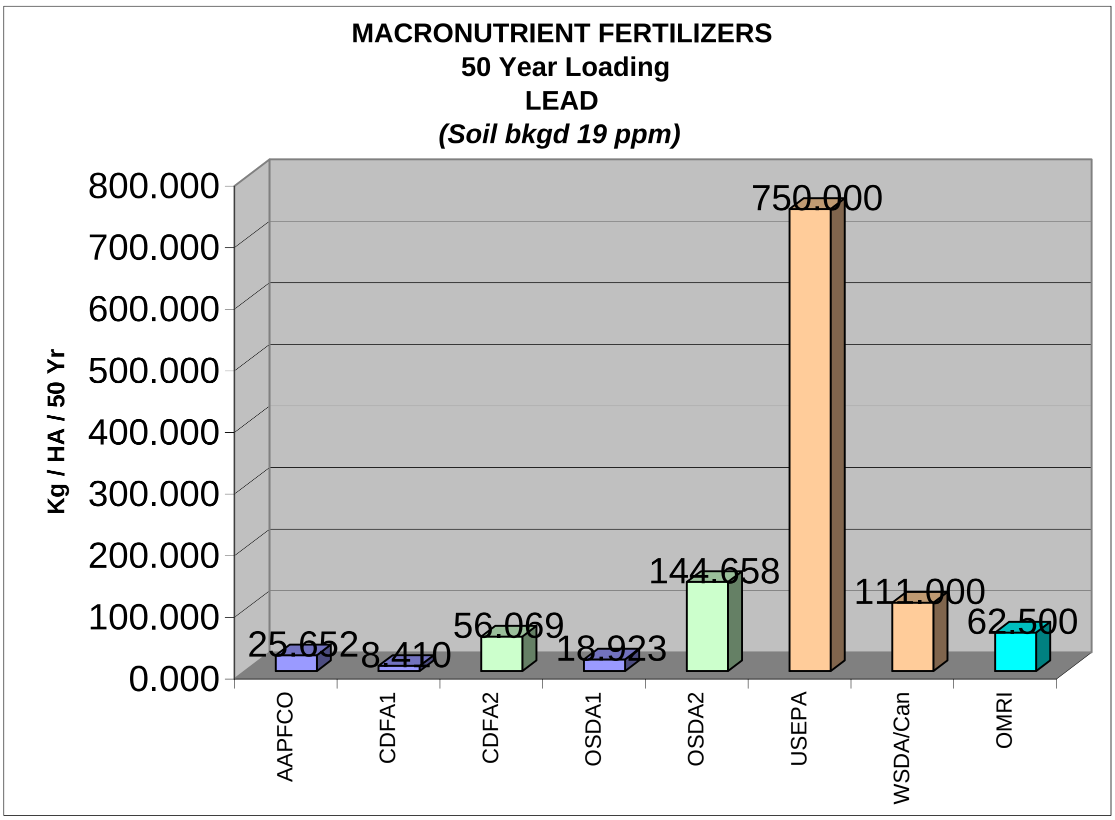
			ppm	%Ph	App Rate	Years		
	AAPFCO	25.652	61	30	250	50		
hi-phos	CDFA1	8.410	20	30	250	50		
low-phos	CDFA2	56.069	100	1	10000	50		
hi-phos	OSDA1	18.923	45	30	250	50		
low-phos	OSDA2	144.658	258	1	10000	50		
bio-solids	USEPA	750.000				50	15	max load
	WSDA/Car	111.000				50	2.22	max load
Proposed	OMRI	62.500				50	1.25	max load



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Proposed OMRI max cumulative annual loading (50 yr period, kg / HA)