Screening Evaluation of Heavy Metals in Inorganic Fertilizers

Minnesota Department of Health
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INTRODUCTION

The Minnesota Department of Health (MDH) conducted the following screening evaluation at the request of the Minnesota Department of Agriculture (MDA) to assess potential health risks from hazardous constituents in inorganic fertilizers. This evaluation included an assessment of heavy metals data for micronutrient and phosphate fertilizers in Minnesota, and the identification of products of potential concern (i.e., screening).

The specific aims of this evaluation were to: (1) evaluate risk assessments and standards (risk-based concentrations) that have been used to assess potential health risks from heavy metals in fertilizers, (2) recommend methods for screening fertilizers in Minnesota, and (3) identify fertilizer products of potential concern. The results and recommendations in this report will be used by the MDA and MDH to provide updated information to the public about potential risks from products, and to continue appropriate screening of products to protect public health.

The MDA is the lead state agency for regulation of fertilizers in Minnesota, including fertilizer storage, handling, distribution, use and disposal (MS 18C.201). For questions regarding fertilizer regulations (e.g., registration) and product testing, contact the MDA Pesticide and Fertilizer Management Division at (651) 201-6379. For information about potential health risks from exposures to hazardous constituents in fertilizers, contact the MDH Health Risk Assessment Unit at (651) 201-4899.

BACKGROUND

The presence of heavy metals in inorganic fertilizers is well established (US EPA 1999a; CDFA 2004; WSDA 2007). Analytical testing of a wide range of fertilizer products shows that some phosphate and micronutrient fertilizers, and liming materials contain elevated levels of arsenic, cadmium, and lead compared to other fertilizer types (e.g., nitrogen, potash, gypsum). A few waste-derived fertilizer products also have been shown to contain elevated (part per trillion) levels of dioxins (WDE 1999, US EPA 1999b).

More than 54 million tons (110 billion pounds) of commercial fertilizers and liming materials were consumed in the US in 1996, with over 2 million tons consumed on farms in Minnesota (US EPA 1999a). The bulk of these fertilizers are applied in agricultural settings (croplands); however, some commercial fertilizers are used by consumers around the home (e.g., micronutrient and phosphate fertilizers applied on lawns and gardens).

Heavy metals occur naturally in soils and in source materials used to manufacture fertilizers. In addition, heavy metals (and other hazardous constituents) occur in products from the addition of recycled industrial wastes (e.g., steel mill flue dust, mine tailings) to fertilizers. Federal statutes allow some reclassified industrial wastes to be used in the manufacture of fertilizers, provided that such use constitutes “beneficial recycling,” and that the concentrations of hazardous constituents in the resulting fertilizers do not exceed the treatment standards specified for wastes (40 CFR 266.20).

Risk assessments conducted by the US Environmental Protection Agency (US EPA) and others have concluded that the hazardous constituents in inorganic fertilizers generally do not pose risks to public health or the environment (US EPA 1999b; Weinberg 2001; CDFA 1998 and 2004). Of the large number of fertilizer products evaluated, only a few have been found to have contaminant levels high enough to be considered a potential health concern (i.e., arsenic or dioxins in some micronutrient and liming materials). Testing of fertilizer products by states generally has supported this conclusion (CDFA 2007; WSDA 2007).

Screening Evaluation (1999)

In 1998-99 MDA collected and analyzed over 80 micronutrient and phosphate fertilizers for arsenic, lead, and cadmium. Based on these data and concerns about potential health risks, MDA requested that MDH conduct a screening evaluation.

In April 1999 MDH completed the evaluation using risk-based concentrations (CA RBCs) developed by the California Department of Food and Agriculture to screen Minnesota fertilizers for arsenic, lead, and cadmium. CA RBCs were determined to be appropriate for a screening-level analysis to identify products of potential concern in Minnesota.

All of the products tested were below the CA screening limits with the exception of three – Ironite, Ironite Superferrite, and Glorious Gardens Rock Phosphate. MDH was particularly concerned about these products because they were available to consumers for use around the home, and children could be exposed to elevated levels of heavy metals (e.g., via direct contact with heavy metals in fertilizers applied on lawns and gardens).

MDH's 1999 screening evaluation recommended: (1) reviewing the product labels to determine if the information is complete, accurate, and understandable, (2) continuing to test micronutrient and phosphate products for arsenic, cadmium, and lead, and (3) sharing the results and evaluation with state and federal agencies. Further action taken by MDA and/or voluntary action by the fertilizer manufacturers, resulted in the removal of all three products from sale in Minnesota (for a list of follow-up activities conducted by the MDA and MDH from 1999-2007, see Appendix I).

Health Effects

Health effects associated with exposures to lead, arsenic, cadmium, mercury, and dioxins are well documented by federal and international health and environmental agencies, including the US EPA, the US Public Health Service, and the World Health Organization. It is beyond the scope of this report to provide a comprehensive review of the scientific literature on adverse health effects associated with exposures to these chemicals (for a summary of information about adverse health effects, see Appendix II).

Several factors influence whether adverse health effects will occur from an exposure to a hazardous chemical. These factors include the dose (how much), the duration (how long),

and how a person comes into contact with it. Additional factors include exposures to other chemicals, age, gender, diet, family traits, lifestyle, and state of health.

Heavy metals and dioxins have several different chemical forms (species and congeners, respectively) that influence their fate and transport in the environment, bioavailability, and toxicity. Heavy metals and dioxins are relatively persistent in the environment, and they also bioaccumulate in the food chain. US and international health and environment agencies generally consider it prudent public health practice to further reduce exposures to persistent, bioaccumulative, and toxic (PBT) pollutants, such as mercury, lead, and dioxins.

Susceptible Populations

Infants and children generally may be more vulnerable to chemical exposures than adults because they eat, breathe, and drink more per pound of body weight. In addition, young children exhibit unique behaviors, such as mouthing objects and crawling on floors (or lawns). These factors increase the potential for contact with contaminants on surfaces, and in dust and soil.

Infants and children also may be more sensitive to chemical toxicity because their bodies are growing and developing. From birth through childhood, children differ from adults in their ability to absorb, metabolize, and excrete contaminants. For example, adverse health effects from lead differentially affect children because their brain is developing, and lead is more readily absorbed by their digestive systems (ATSDR 2007). Lead exposure in children may cause learning problems, reduce intelligence, and also increase the risk of attention-deficit/hyperactivity disorders.

In addition, pregnant women are a population of potential concern because fetuses may be exposed to chemicals during critical stages of human development. While limited information is available to evaluate the developmental effects from exposures to many chemicals, lead and mercury are well-established developmental toxicants.

Fertilizer Laws & Regulations

State fertilizer laws generally require product registration and/or licensing to assure that statements made on the label are correct. Most state fertilizer regulations also include general statements about product adulteration and prohibition against including any product that is harmful to plants, animals, humans or the environment.

MDA is the lead state agency responsible for the regulation of fertilizers in Minnesota, including their storage, handling, distribution, use and disposal (MS 18C.201). All fertilizer products for agricultural use in Minnesota are required to be licensed (e.g., primary fertilizers, liming materials). Prior to licensing a product, MDA reviews the available product claims and available test data to determine if the nutritive information on the label is accurate.

MDA also registers specialty fertilizers, which include nearly all micronutrient and phosphate fertilizers used by consumers around the home and garden. The registration

process includes a review of product labels and available test data to determine whether the nutritive claims are accurate. In addition, MDA reviews data on non-nutritive constituents (e.g., heavy metals) if this information is submitted by a fertilizer manufacturer (however, submitting this information is not a requirement in Minnesota). An increasing number of manufacturers voluntarily submit heavy metals data to MDA prior to product registration – likely due to more stringent regulations in other states (e.g., California, Washington, and Oregon) that require this type of information. Over the last decade MDA also has tested over 150 micronutrient and phosphate fertilizers for heavy metals.

Land applications of agricultural liming materials from certain sources (e.g., wood or coal fly ash that may contain heavy metals and/or other potentially hazardous constituents) are required to obtain a regulatory permit from the Minnesota Pollution Control Agency (MPCA). Prior to issuing a permit, MPCA evaluates the available laboratory data for hazardous constituents, and then they establish appropriate permit conditions (e.g., maximum application rates, requirements for routine testing of materials, procedures for handling/storage). Permits approved by the MPCA are forwarded to the MDA for licensing, as noted above.

California, Washington, and Oregon have adopted specific regulatory requirements regarding hazardous constituents in inorganic fertilizers (e.g., limits for metals; requirements for product testing and reporting). These states also maintain on-line fertilizer product databases that include information about the nutritive and non-nutritive (heavy metal) constituents in fertilizer products (for web resources, including links to fertilizer reports and product databases, see Appendix III).

Federal statutes allow some reclassified industrial wastes to be used in the manufacture of fertilizers, provided that such use constitutes "beneficial recycling," and that the concentrations of hazardous constituents in the resulting fertilizers do not exceed the treatment standards specified for wastes (40 CFR 266.20). No other federal statutes apply specifically to inorganic fertilizer composition, with the exception of a narrowly-focused rule that applies to zinc (micronutrient) fertilizers made from secondary hazardous materials (US EPA 2002).

Minnesota Arsenic Limit

In 2003 the Minnesota Legislature passed an arsenic limit for fertilizers (MS CH 18C). This statute prohibits registration of fertilizers containing arsenic levels greater than 500 parts per million (ppm) in Minnesota. Note this limit is not health-based, and therefore, cannot be used to imply that products below 500 ppm arsenic are safe (i.e., for products used by consumers around homes and gardens).

RISK ASSESSMENTS & STANDARDS

MDH prepared the following summary of risk assessments and standards (risk-based concentrations) that have been used by states and others to assess potential health risks

from hazardous constituents in fertilizers. The following are highlights of key developments since the 1999 Screening Evaluation.

US Environmental Protection Agency

In August 1999 the US EPA released the draft report, "Estimating Risk from Contaminants Contained in Agricultural Fertilizers" (US EPA 1999b). This assessment used a probabilistic (Monte Carlo) model to estimate the incremental increase in lifetime cancer and non-cancer risks from exposures to hazardous constituents in fertilizers and other agricultural soil amendments.

US EPA evaluated the most commonly used macronutrient fertilizers, which contain nitrogen, phosphorus, and potassium (NPK or primary fertilizers); micronutrient (e.g., zinc, iron) fertilizers; and soil amendments (materials applied to the land primarily to enhance soil characteristics rather than as plant food). US EPA's analysis included 9 metals: cadmium, lead, arsenic, chromium, mercury, nickel, vanadium, copper, and zinc, as well as 17 dioxins. To represent the wide range of climate conditions in areas where fertilizers are applied, this analysis included data for fertilizers used on different types of crops grown in 29 meteorological regions within the US, including regions in the Midwest and Minnesota. US EPA's analysis was a "forward risk assessment" that was not designed to calculate risk-based concentrations or limits for hazardous constituents in fertilizers.

US EPA's assessment concluded that, based on the data available, hazardous constituents in fertilizers generally do not pose harm to human health or the environment. Of the large number of fertilizer products evaluated, only a few had contaminant levels high enough to be a potential health risk (i.e., arsenic and dioxins in select liming agents from recycled sources, and micronutrient fertilizers). The analysis also concluded that exposures via the food chain were one of the main contributors to the total (albeit small) risks from inorganic fertilizers, with the highest exposures for adult farmers and children of farmers. Other receptors (e.g., adult and child residents, recreational anglers, home gardeners) were anticipated to have lower exposures through fewer pathways, and thus lower risks compared to farm families.

In 2002 US EPA promulgated a narrowly-focused rule for zinc fertilizers made from recycled hazardous secondary materials (US EPA 2002). This rule was aimed at fertilizers representing less than one-half of one percent of fertilizers on the US market. The rule established technology-based limits for five metals (i.e., lead, cadmium, arsenic, mercury, and chromium). These limits are considerably lower than the RBCs that have been developed by California and others (below). This rule also established a limit for dioxins of eight parts per trillion, that was considered the average "background" level in US soils.

California

In 2002 the California Department of Food and Agriculture (CDFA) implemented regulations to limit the addition of arsenic, cadmium, and lead in inorganic fertilizers (CDFA 2001, 2004). These limits (risk-based concentrations or RBCs) were phased in

over time, with the most stringent limits for phosphate fertilizers effective on January 1, 2004.

Table 1: California Risk-Based Concentrations (RBCs) for Inorganic Fertilizers

Metal	Micronutrient Fertilizers (ppm per 1%)	Phosphate Fertilizers (ppm per 1% P_2O_5)
Arsenic	13	2
Cadmium	12	4
Lead	140	20

* Note: An RBC is the maximum "acceptable" level for a given metal in a fertilizer product at 1% of the nutrient level (P_2O_5, zinc, iron, manganese); ppm = parts per million

CA RBCs are based on a 1998 risk assessment conducted by a consultant for the California Department of Food and Agriculture (CDFA 1998). The assessment used deterministic and probabilistic (Monte Carlo) models to estimate risks for multiple exposure scenarios and pathways (e.g., ingestion, inhalation, and dermal pathways). The assessment also used standard risk assessment methods (e.g., peer reviewed toxicity values, exposure factors), as well as some parameters specific to California croplands to estimate upper-bound risks. Similar to the US EPA 1999 risk assessment, the analysis concluded that the primary population of concern was adult and children farm families.

The CA RBC for lead is based on an analysis using the US EPA Integrated Exposure Uptake Biokinetic Model for lead in children. California revised their original assessment to use a guideline of 5 micrograms per deciliter (ug/dl) of lead in blood (CDFA 2007). This guideline, which is 50% lower than CDC guideline of 10 ug/dl, was selected to be health protective for screening purposes because the available scientific evidence has not identified a safe level of lead exposure for children (ATSDR 2007; CDC 2007).

In 2004 CDFA performed a reevaluation the CA RBCs to validate assumptions in the 1998 risk assessment, based in part on field research conducted at University of California Riverside. CDFA determined that the actual concentrations of metals in soils and plant tissues were considerably lower than those used in the 1998 risk assessment (i.e., actual risks were determined to be significantly lower than the risk estimates from the model). CDFA also surveyed the presence of six other metals (cobalt, copper, mercury, molybdenum, nickel, and selenium) in phosphate and micronutrient fertilizers to assess the necessity of limiting addition of these metals to agricultural soils. The results indicated that the concentrations of these metals were low in the products and that there was no need to limit their addition to soils. CDFA concluded that the CA RBCs are adequately protective of human health and the environment, and that the RBCs adopted in 2001 should remain in effect (CDFA 2004).

The Fertilizer Institute

In 2000 The Fertilizer Institute (TFI), an industry trade organization, commissioned a risk assessment of 12 metals and radium 226 in phosphate and micronutrient fertilizers (TFI

2000). Metals that were selected for evaluation included: arsenic, cadmium, lead, chromium, cobalt, copper, mercury, molybdenum, nickel, selenium, vanadium, and zinc.

TFI's consultant used a deterministic model and "reasonable maximum exposure assumptions" to calculate RBCs. Similar to the US EPA and CDFA risk assessments, this analysis concluded that farmers and their families have the highest potential for exposure (and therefore, this was the focus of their risk analysis).

TFI's analysis compared data for metals in their fertilizer product database and reported no exceedances for metals in phosphate fertilizers; however, they did note exceedances for arsenic and lead in micronutrient fertilizers (TFI 2000). They stated that "because of the health protective methodology employed in the screening evaluation, and because exceedances occur only at the maximum arsenic and lead concentrations, a firm conclusion regarding health risks from micronutrient products in questions required closer evaluation." They recommended further evaluation of these products, and concluded that "metals in inorganic fertilizers [in general] do not pose post-application harm to human health." Note TFI's analysis did not include an evaluation of potential risks from exposures to dioxins.

American Association of Plant Food Control Officials

In 2001 the American Association of Plant Food Control Officials (AAPFCO) adopted risk-based concentrations for 9 metals in fertilizers (AAPFCO 2001). AAPFCO is an organization of fertilizer officials from each of the 50 US states, Canada and Puerto Rico (i.e., officials who are involved in the administration of fertilizer laws and regulations).

Table 2: AAPFCO Risk-Based Concentrations for Inorganic Fertilizers

Metals	NPK (ppm per 1% P_2O_5)	Micronutrient (ppm per 1% micronutrient)
Arsenic	13	112
Cadmium	10	83
Cobalt	136*	2228*
Lead	61	463
Mercury	1	6
Molybdenum	42	300
Nickel	250	1,900
Selenium	26	180
Zinc	420	2,900

*Tentative (proposed for adoption in 2007)

The AAPFCO RBCs are based a collaborative analysis between the consultants that prepared the CDFA and TFI risk assessments (Weinberg 2001). This analysis was based on recalculated RBCs for upper and lower bound conditions using soil-water distribution coefficients (Kd values) from two sources: (1) the original 1998 CDFA risk assessment (derived from Baes and Sharp), and (2) the 1999 US EPA risk assessment (derived from a variety of sources in the scientific literature). These recalculations also took into account the correlation between Kd values and the plant uptake factors for metals (this important

aspect had not been taken into account in previous evaluations). No other changes were reported in the reevaluation of the RBCs.

AAPFCO RBCs were determined by selecting the midpoint between the 90th percentile RBCs for the upper and lower bound estimates for each metal. AAPFCO concluded that this approach could be defended as a "health protective standard." Note that the AAPFCO RBCs for arsenic, cadmium, and lead are considerably higher than the RBCs adopted in California.

AAPFCO's RBCs were developed to promote consistent screening methods across states for evaluating heavy metals in fertilizers. While the state of Oregon has adopted a modified (more stringent) version of the AAPFCO RBCs into rule, it is not clear how many other states are currently using these standards. US EPA has stated that they do not necessarily accept or dispute the validity of the AAPFCO RBCs as accurate indicators of potential risks (US EPA 2002).

SCREENING EVALUATION (2008)

MDH conducted the following screening evaluation at the request of the MDA. This evaluation is based on an assessment of the current scientific literature, analysis of heavy metals data (1999-2007) for Minnesota fertilizers, and consultation with MDA, other states, and US EPA.

Comparison of Standards (RBCs)

The CA RBCs for arsenic, lead, and cadmium are considerably more stringent than AAPFCO and TFI RBCs. This is attributed primarily to differences in key model parameters (i.e., Kd values, plant uptake factors, and fertilizer application rates) in the risk assessment models.

The CA RBCs are limited to three metals (arsenic, cadmium, and lead); whereas AAPFCO, TFI (and US EPA's 1999 risk assessment) considered a broader suite of metals. TFI, AAPFCO, and US EPA's analyses also were based on a consideration of a broader range of environmental conditions (e.g., soil types, climate, crops) that are likely to be more representative of national conditions (but may or may not be representative of specific areas or states, including Minnesota).

The CA, AAPFCO, and TFI RBCs are based on the farm family exposure scenario, which was found to reflect the highest exposures. All three assessments assume that the farm family scenario is protective for other exposure scenarios (e.g., home gardeners).

US EPA has stated that the probabilistic methodology used by CDFA was generally consistent with their 1999 risk assessment. They also state that the general findings of their assessment did not differ dramatically from those of the TFI analysis. In general, they noted that there is considerable uncertainty associated with risk-based standards for fertilizers (US EPA 2002).

Limitations of Assessments
While all three risk assessments (CDFA 1998; US EPA 1999; TFI 2000) considered multiple exposure pathways/scenarios for adults and children in their analyses, none of these assessments specifically evaluated risks to young children from incidental ingestion of product (e.g., via direct contact with fertilizer applied on a lawn or garden). Given the high levels of lead and arsenic that have been found in some micronutrient products, it is possible that this is an important exposure scenario – especially for the fertilizer products that are available to consumers for use around the home.

Young children's behaviors (e.g., crawling, hand-to-mouth activity) may result in frequent or high levels of contact with hazardous constituents in products. Given the fact that there is often no information on product labels to warn parents about potential risks from these products, and concerns regarding children's susceptibility, this is a critical data gap in all three risk assessments.

As mentioned previously, the risk assessments assume that the farm family exposure scenario is protective for other exposure scenarios (e.g., home gardener); however, this assumption may not be protective for products used around the home. For example, fertilizer applications by consumers are less likely to involve tilling; and therefore, metals and other hazardous constituents may accumulate at the soil surface where exposures more likely to occur. In contrast, tilling on agricultural land is likely to reduce the levels of metals in surface soils due to blending and mixing to greater depths in soil columns.

In addition, the risk assessments (above) evaluated incremental risks from metals in fertilizers; however, with the possible exception of lead, the risk estimates do not account for exposures from other sources (e.g., exposures to metals in drinking water, food, house dust, toys and other consumer products).

Also, the TFI and CDFA risk assessments did not evaluate potential health risks from dioxins in fertilizers. US EPA and the State of Washington have reported that a small number of waste-derived products have elevated levels of dioxins (US EPA 1999b, WDE 1999). CDFA conducted a follow-up evaluation of dioxin levels in soils and micronutrient products in 2004, and generally found very low levels in micronturient products. CDFA concluded that they do not anticipate any adverse impact from the addition of such low dioxin levels to cropland soils, and regulations need not be established to set standards for dioxins in fertilizers (CDFA 2004).

Recommended Screening Method
MDH recommends using the CA RBCs (CDFA 2001) to evaluate Minnesota fertilizers for arsenic, cadmium, and lead. The CA RBCs are based on standard risk assessment methods (e.g., probabilistic model, toxicity values, exposure factors) that are generally consistent with MDH and US EPA. In addition, at screening level, it is good general practice to use more stringent criteria or values to error on the side of protecting public health. This approach tends to overestimate rather than underestimate risks (at least for the exposure pathways that were evaluated by CDFA).

MDH recognizes that the CA RBCs are based on some California-specific model parameters (e.g., crop and soil types) that may or may not be appropriate for Minnesota. Fertilizer products that exceed CA RBCs should be evaluated further using site-specific (Minnesota) data, where available. The level of this evaluation should be determined in the context of MDA and MDH agency resources and priorities, and overall risks to public health and the environment.

Further evaluation by MDA may include the following: (1) validating heavy metal content in the products of potential concern; (2) evaluating product labels to determine whether the information is complete, accurate and understandable; (3) analyzing the recommended product application rates for Minnesota; and (4) assessing the amount and patterns of use of these products in Minnesota.

Further evaluation by MDH may include: (1) evaluating the toxicity and bioavailability of the toxic species in products of potential concern, and (2) assessing potential exposure pathways. At this time MDH believes that the development of a refined Minnesota-specific risk model for hazardous constituents in fertilizers is not necessary (given that reasonable models to evaluate risks have already have been developed and the concerns are associated with a small number of products).

MDH was not able to identify a risk-based concentration for dioxins in inorganic fertilizers; and at this time data are not available to evaluate dioxin concentrations in Minnesota inorganic fertilizers. The Minnesota Pollution Control Agency has developed a risk-based screening reference value of 20 parts per trillion for dioxins in soil (MPCA 2007). When/if product data become available for dioxins in Minnesota products, MDH recommends conducting further evaluation (i.e., assessing dioxin concentrations in products, application rate(s), and background levels of dioxins in Minnesota soils).

Screening Evaluation of Minnesota Fertilizers

MDA tested over 170 micronutrient and phosphate fertilizers for heavy metals from 1999-2007 (for data on specific products, see MDA 2008). Approximately 40 percent of these products were determined to be available for use by consumers around the home, and the remaining 60% were for agricultural use.

Methods

MDH compared the measured concentrations of arsenic, cadmium, and lead (from a single analysis for most products) to the CA screening limit (i.e., calculated using the CA RBCs). This analysis included all product data collected by the MDA from 1999-2007. In a few cases where duplicate samples from a single product were available, the maximum metal concentration was used for the evaluation. MDA's data set included some products that are no longer registered for use in Minnesota (e.g., former Ironite, Glorious Garden's Rock Phosphate).

Results

Of the large number of fertilizer products sampled, most had low levels of arsenic, cadmium, lead, and mercury (i.e., many samples were below the laboratory method

reporting limits). In addition, all sampled products with the exception of those noted in Table 3 were below the CA screening limits.

Table 3: MN Fertilizer Products that Exceeded the CA Screening Limits

Product	Metal(s) of Potential Concern	CA Screening Limit (ppm)	Measured Concentration (ppm)[1]
Frit Micronutrient Fertilizer (10% Fe)	Lead	1400	2270
Frit Micronutrient Fertilizer (36% Zn)[2]	Lead	5040	11,600
Vegi-Max Micro Mix (12% Zn)	Lead	1690	1870
Ironite (1-0-0)[2]	Arsenic Lead	38 630	4520 4210
Glorious Gardens Rock Phosphate (0-3-0)	Cadmium	12	108
Hi-Yield Ionate Soil Acidifier	Arsenic	130	248
Ironite Pro-Formula 2 (2-0-0)	Arsenic Lead	55 595	6190 2650
Ironite Plus (12-10-10)[2]	Arsenic Lead	24 240	312 344
Vol Cana Phosphate	Lead	60	100
Daphos	Cadmium Arsenic	12 6	46 11.7

[1] Source MDA 2008

[2] Products that are currently licensed for sale in Minnesota. These products have been reformulated from new source materials, and new data supplied by the manufacturer indicates that they are below the CA screening limits.

All of the products in Table 3 are either: (1) no longer licensed for sale in Minnesota, or (2) reformulated from new source materials and new data supplied by the manufacturer indicates that they are below the CA screening limits.

Since formerly licensed products may continue to be stored and used by consumers (and therefore pose some degree of risk), MDH has included data for all products that exceeded the CA screening limits.

The evaluation also identified lead levels of potential concern (hundreds of ppm) in a few micronutrient consumer products below the CA screening limit (e.g., Country Cottage Soil Acidifier Iron Sulfate, 392 ppm and Iron Sulfate, 219 ppm). Country Cottage Soil Acidifier Iron Sulfate is no longer licensed for sale in Minnesota.

Potential Health Risks

In general MDH has concluded that the hazardous constituents in inorganic fertilizers are not likely to pose risks to public health. Of the large number of products that have been evaluated, only a few appear to be of potential concern (e.g., exposures to arsenic and lead in micronutrient fertilizers; and dioxins in a few products). These products have low application rates, and they often are used in agricultural settings where the potential for young children to have direct contact with hazardous constituents is low (albeit possible).

MDH remains concerned about children's potential exposures to a few consumer products that have elevated levels of lead -- including some products below the CA screening limits. As noted previously, children are especially vulnerable to the effects from exposures to lead and other heavy metals (CDC 2007; ATSDR 2007a; ATSDR 2007b). In addition, aggregate exposures to these metals occur from multiple sources (e.g., lead in drinking water, soil, dust, consumer products, including toys).

At this time there are no Minnesota-specific data to evaluate the levels of dioxins in fertilizers and soil amendments (e.g., micronutrients, liming materials). Based on data from the State of Washington (WDE 1999) and the US EPA (US EPA 1999), MDH cannot rule out the possibility that there are potential risks from dioxins in a few waste-derived products (i.e., products derived from steel mill flue dust).

Generally, MDH considers it prudent public health practice to prevent and avoid exposures to lead, arsenic and dioxins, were possible, especially for susceptible populations (i.e., children). At this time there is no information available on product labels regarding hazardous constituents in fertilizer products in Minnesota, so consumers may not be aware of potential concerns. Fertilizers are generally considered by the public to be "safe" – at least relative to pesticides and other products that are widely recognized by the public to be associated to have some risk from high exposures.

METALS ACCUMULATION IN SOILS

The following section provides information regarding the potential for metals to accumulate in fertilizer-amended soils. This information should be viewed in the context of product and site-specific information, such as the concentrations of metals in products, background metal concentrations soils, soil types and chemistry, metal leaching potential, and other available data.

In 1999 US EPA evaluated the potential for nine metals to accumulate in soils using data for several fertilizer types (e.g., primary and gypsum fertilizers; micronutrient and phosphate fertilizers; liming materials) (US EPA 1999a). US EPA calculated the average annual addition rates of metals to soil assuming average, high, and maximum fertilizer application rates. Fertilizer applications were assumed to be made every year (with the exception of liming materials, which were every three years), and the analysis also assumed no leaching of metals from the soils. US EPA compared these estimates to US EPA biosolid limits and Canadian limits for metals additions to soil (CFIA 1997).

US EPA concluded that the product average annual addition rates did not exceed the US EPA biosolid limits, and they only rarely exceeded the Canadian limits (i.e., the rate at which annual additions would be expected to double the average level of background concentrations in soil over 45 or fewer years). The few instances where the estimates exceeded the Canadian limits were for products assumed to be applied at the maximum rate (e.g., for arsenic in liming materials assumed to be applied every three years at 15,000 lbs/acre; and micronutrient (iron) fertilizers assumed to be applied every year at

30 lbs/acre). With respect to arsenic, US EPA's analysis indicated that it would take over 20 years of repeated annual applications at the maximum rate to double the soil concentrations (US EPA 1999a). The application rates recommended for Minnesota are generally lower than high and maximum values used in US EPA's evaluation (UMN 2008).

The analysis (above) is based on agricultural settings, and therefore, may not be appropriate for drawing inferences about applications made in residential areas. Misuse or uneven applications of fertilizers by consumers may result in higher than estimated metals accumulation in soils (compared to agricultural applications that often use more mechanized, precise methods of application). In addition, mixing and tilling of soil in agricultural areas are likely to lower the concentrations of metals (e.g., lead) at the soil surface where children may be exposed. Therefore, assumptions used for this analysis may not allow for direct inferences regarding metals accumulation resulting from consumer applications of fertilizers.

MDH is not aware of any Minnesota studies that measured heavy metal accumulation in soils from applications of inorganic fertilizers (either to cropland or residential soils). The University of California Riverside conducted a soil survey to measure arsenic, lead, and cadmium accumulation in fertilizer-amended agricultural soils in seven vegetable production regions of California. The survey results found that the concentrations of these metals were mostly within 1967 baseline agricultural soil levels, with a few exceptions that were attributed to diffuse sources other than fertilizers (CDFA 2004). This analysis provides limited information for conclusions regarding the potential for metals accumulation resulting from consumer applications of fertilizers.

Arsenic Contaminated Soils

Elevated levels of arsenic have been found in some residential soils in South Minneapolis, Minnesota (ATSDR 2006). Several potential sources of arsenic exist in this area, including treated wood, arsenical herbicides and inorganic fertilizers. Unfortunately, historical records related to these sources (e.g., the types, amounts, and locations of fertilizer applications by consumers) generally are not available, and therefore, it is not possible to determine the exact relative contribution from specific sources.

It is possible that use of inorganic fertilizers contributed to elevated arsenic concentrations in areas of South Minneapolis (and other residential areas of Minnesota/US); however, the relative contribution of arsenic from this source is likely low compared to other sources in the area (e.g., treated wood, arsenical herbicides, off-site activities). Unfortunately, limited information is available to quantitatively evaluate the relative contributions of arsenic from these sources.

With respect to the potential for future contamination, the measured arsenic concentrations in the fertilizer products evaluated in this report are considerably lower than those measured in the 1999 evaluation; and generally, these products are not likely

to result in accumulation of arsenic above typical background levels for Minnesota soils (assuming applications are made by consumers at recommended rates).

LIMITATIONS

MDH is aware that there are several limitations associated with this screening evaluation. The conclusions and recommendations that follow should be evaluated in the context of the following:

- The CA RBCs that were used to evaluate MDA data were developed using some California-specific model parameters, and therefore, are based on some assumptions about agricultural practices and environmental conditions that may or may not apply to Minnesota. If further refined analysis is determined to be warranted, for example, MDA could evaluate Minnesota-specific data for key model parameters (e.g., soil characteristics, plant uptake) or conduct field studies to measure actual concentrations of metals in Minnesota fertilizer-amended soils. The level of analysis should be evaluated in the context of MDA and MDH agency resources and priorities, and overall risks to public health and the environment.

- The levels of nutritive and non-nutritive constituents in fertilizer products vary over time (e.g., due to changes in raw materials; blending); however, this evaluation is based on the analysis of a single sample from each product (with a few exceptions). This may result in an overestimate or underestimate of risks. Many of the imported fertilizer materials in Minnesota come from Canada, however, some of materials are obtained from countries where quality assurance and quality control procedures may not meet US standards. For example, the state of Washington reported that a raw fertilizer material obtained from China contained over 20% (200,000 ppm) cadmium (WDE 2000). This underscores the importance of ongoing testing and evaluation of fertilizers of potential concern.

- No analysis has been conducted for dioxins in Minnesota fertilizers (e.g., waste-derived fertilizers and liming materials).

CONCLUSIONS

MDH has concluded that generally the hazardous constituents in inorganic fertilizers are not likely to pose risks to public health. Of the large number of products that have been evaluated, only a few appear to be of potential concern (e.g., exposures to arsenic and lead in micronutrient fertilizers; and dioxins in a few products). These products have low application rates, and they often are used in agricultural settings where the potential for young children to have direct contact with hazardous constituents is low (albeit possible). In addition, most of the products that exceeded the CA screening limits are either: (1) no longer licensed for sale in Minnesota, or (2) reformulated from new source materials and below the CA screening limits.

Formerly licensed products that exceed the CA screening limits may continue to be stored and used by consumers in Minnesota, and therefore could pose some degree of risk. In addition, children may be exposed to elevated levels of lead in a few licensed consumer products -- including some products that are below the CA screening limits. Children have been shown to be especially vulnerable to the effects from exposures to lead other heavy metals.

At this time there are no product-specific data to evaluate the levels of dioxins in Minnesota fertilizers and soil amendments. Based on available data, MDH cannot rule out the possibility that there are potential risks from dioxins in a few waste-derived Minnesota products.

Generally, MDH considers it prudent public health practice to avoid exposures to lead, arsenic and dioxins, were possible, especially for susceptible populations, such as children. Limited or no information is available on product labels regarding hazardous constituents in fertilizer products in Minnesota, so consumers may not be aware of potential health risks. The results and recommendations in this report will be used by the MDA and MDH to provide updated information to the public about potential risks from products, and to continue appropriate screening of products to protect public health.

For a screening level analysis of inorganic fertilizers, MDH considers it prudent public health practice to use the more health protective CA RBCs. As new products are identified of potential concern in the future, further analysis of product-specific information may be necessary (e.g., validating heavy metal analyses; evaluating product labels; determining the recommended product application rates for Minnesota). The level of analysis should be evaluated in the context of MDA and MDH agency resources and priorities, and overall risks to public health and the environment.

RECOMMENDATIONS

1. Continue testing fertilizers of potential concern for arsenic, cadmium, and lead. Fertilizers of potential concern include micronutrient and phosphate fertilizers, and liming materials with special emphasis on: (a) waste-derived products, and (b) products available to consumers for use around the home.

2. Review heavy metal analysis data supplied by fertilizer manufacturers; validate data for a subset of fertilizers.

3. Periodically review fertilizer product databases from other states (California, Oregon, Washington) to identify products that are licensed for use in Minnesota and that contain elevated levels of arsenic, cadmium, or lead.

4. Test waste-derived fertilizers and soil amendments (liming materials) for dioxins – especially products available to consumers for use around the home.

5. Use CA RBCs for routine screening of fertilizer products. For products with levels that exceed the CA screening limits, conduct further analysis of product and Minnesota-specific data.

6. Provide updated information to the public about potential risks from products. Consumers should avoid using products that contain elevated levels of lead and arsenic in areas where children may be exposed.

7. Review fertilizer product labels that exceeded the CA screening limits to determine if the information is complete, accurate, and understandable. Labels also should be evaluated to determine if the precautions are consistent with the concerns in this evaluation.

8. Share this report with other federal and state agencies, including the Consumer Product Safety Commission, US EPA, and Minnesota Pollution Control Agency.

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APPENDIX I: List of MDA & MDH Activities (1999 to 2007)
Metals in Fertilizers

The following is a chronology of activities conducted by the MDH and MDA to address potential concerns about exposures to arsenic, lead, and cadmium in micronutrient and phosphate fertilizers. Note: This is not a comprehensive list of all activities related to addressing concerns about hazardous constituents in fertilizers in Minnesota. For more information, contact the MDA Pesticide and Fertilizer Management Division at (651) 201-6379.

- MDA confirmed that the three products of potential concern identified in the MDH 1999 Screening Evaluation were no longer licensed for sale in Minnesota.

- Where Ironite was reported to be for sale in stores, MDA took enforcement actions by issuing "stop sale" orders. Note: Ironite products that are currently available in stores are being produced by a new company. MDA analysis of the new Ironite products in 2006 indicates that arsenic and lead levels in these products are very low, and therefore, these products are not considered by MDH to be a health concern.

- MDH developed a fact sheet (web page) to inform consumers about the potential health risks from exposures to elevated levels of arsenic and lead in Ironite products; and the results of the 1999 Screening Evaluation. MDH also shared the results of the screening evaluation with state and federal agencies, including the MDA, Minnesota Pollution Control Agency, Consumer Product Safety Commission, and the US Environmental Protection Agency.

- MDA continued to test micronutrient and phosphate fertilizers for arsenic, cadmium, and lead, and reported their data via the MDA web site. MDA also added mercury to their list of heavy metals for analysis.

- MDH submitted comments to the US EPA on their proposed 2001 draft rule for zinc fertilizers made from recycled hazardous secondary materials. MDH requested that the US EPA remove the proposed exemption for fertilizers derived from mining wastes. US EPA did not remove the exemption; however, US EPA did acknowledge potential concerns about arsenic and lead in products available to consumers in the final rule (US EPA 2001).

- On at least an annual basis, MDA and MDH have reviewed state and federal documents (e.g., US EPA 1999, CDFA 2004, Weinberg 2001) to keep abreast of activities and policy initiatives related to hazardous constituents in fertilizers.

- MDA requested that MDH conducted a follow-up evaluation (this evaluation) to update the fertilizer screening methods and evaluate data.

APPENDIX II: Health Effects from Heavy Metals & Dioxins

The following is a summary of the adverse health effects associated with exposures to arsenic (inorganic), cadmium, lead, mercury, and dioxins. This report does not include a comprehensive list of all adverse health effects. For more information about potential adverse effects from exposures to these chemicals, contact the MDH Health Risk Assessment Unit, (651) 201-4899, or see the citations in the reference section of this report.

Arsenic (Inorganic)
MDH, US EPA, and the US Public Health Service have identified arsenic as a known carcinogen (Group A). High arsenic exposures have also been shown to damage the nervous and gastrointestinal systems, and to cause developmental effects in laboratory animals (ATSDR 2007a). Perhaps the single-most characteristic effect of long-term oral exposure to inorganic arsenic is a pattern of skin changes. These include patches of darkened skin and the appearance of small "corns" or "warts" on the palms, soles, and torso, and are often associated with changes in the blood vessels of the skin. Arsenic is naturally occurring in environmental media (e.g., air, water, soil), and found in some consumer products (e.g., CCA treated wood used for playground equipment).

Cadmium
Exposures to high levels of cadmium in food or water severely irritate the stomach, and may lead to vomiting and diarrhea, and sometimes death. Eating lower levels of cadmium over a long period of time can lead to a build-up of cadmium in the kidneys (ATSDR 1999). If exposures reach a high enough level, cadmium may cause kidney damage, and also cause bones to become fragile and break easily. Animals eating or drinking cadmium sometimes get high blood pressure, iron-poor blood, liver disease, and nerve or brain damage. Cadmium naturally occurs in soil and in ore/rock used to make fertilizers (e.g., phosphates), and depending on the soil conditions, may be readily taken up by crops and other plants.

Lead
The main target for lead toxicity is the nervous system, both in adults and children. Long-term exposure of adults to lead at work has resulted in decreased performance in some tests that measure functions of the nervous system (ATSDR 2007b). Lead exposure also may cause weakness in fingers, wrists, or ankles. Lead exposure also has been shown to cause small increases in blood pressure, particularly in middle-aged and older people. At high levels of exposure, lead can severely damage the brain and kidneys in adults or children and ultimately cause death. In pregnant women, high levels of exposure to lead may cause miscarriage.

Children are more susceptible to lead toxicity than adults because of effects on nervous system development. The US Centers for Disease Control and Prevention (CDC) has established a guideline of 10 micrograms per deciliter (ug/dl) of blood; however, scientific evidence indicates that there is no “safe level” or threshold for lead exposure in

children. Approximately 310,000 US children between the ages of 1 and 5 years are believed to have blood lead levels equal or greater than 10 ug/dl (ATSDR 2007b).

Mercury

The nervous system has been shown to be especially sensitive to methyl mercury found in fish and mercury vapor. However, the inorganic form of mercury that is likely to be found in inorganic fertilizers is considered to be less toxic because it does not pass easily from the blood into the brain. Ingestion of high levels of inorganic mercury causes damage to the kidneys and gastrointestinal effects (ulcers, stomach distress) (ATSDR 1999).

Dioxins

Laboratory studies have shown that exposure to dioxins cause a broad range of health effects, with the severity of the effect depending on dose, age, gender, and species (ATSDR 1998). The observed health effects include changes in the level or activity of enzymes and hormones, organ weight changes, altered reproduction and normal development of offspring, and immune dysfunction. High doses cause a failure of animals to grow, called wasting disease, which is fatal. Low doses cause small changes in cell function-such as changes in levels of thyroid hormones or enzyme activity. Doses to the fetus or young animal may also delay or harm development of tissues and the nervous system.

Several studies suggest that workers exposed to high levels of dioxins over many years have an increased risk of developing cancer. The relationship of apparent increases in cancer in these occupationally exposed populations to calculations of general population risk remains uncertain. Animal studies have conclusively shown that the most toxic form of dioxin (2,3,7,8-TCDD) is a carcinogen capable of increasing the incidence of tumors at multiple sites. The US EPA, National Toxicology Program and the International Agency for Cancer Research have characterized 2,3,7,8-TCDD as a "human carcinogen."

APPENDIX III: List of Web Resources

The following are web resources from states and others with information about metals in fertilizers.

Minnesota
Minnesota Department of Agriculture (product data available)
http://www.mda.state.mn.us/chemicals/fertilizers/heavymetals.htm

Minnesota Department of Health
http://www.health.state.mn.us/divs/eh/risk/studies/metals.html

California
California Department of Food and Agriculture (product data available)
http://www.cdfa.ca.gov/is/fflders/fertilizer.html

Washington
Washington State Department of Agriculture (product data available)
http://agr.wa.gov/Pestfert/Fertilizers/Metals.htm
http://agr.wa.gov/pestfert/fertilizers/ProductDatabase.htm

Oregon
Fertilizer Product Database (product data available)
http://www.oda.state.or.us/dbs/heavy_metal/search.lasso
Administrative Rule Development
http://www.oregon.gov/ODA/PEST/docs/pdf/fertmetalpaper.pdf

US Environmental Protection Agency
Background Report on Fertilizer Use, Contaminants, and Regulations
http://www.epa.gov/oppt/pubs/fertilizer.pdf

Estimating Risk from Contaminants Contained in Agricultural Fertilizers (Draft Report)
http://www.epa.gov/epaoswer/hazwaste/recycle/fertiliz/risk/