Screening Evaluation of Arsenic, Cadmium, and Lead Levels in Minnesota Fertilizer Products

Minnesota Department of Health
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INTRODUCTION

This report summarizes the results of a screening evaluation of arsenic, cadmium, and lead in fertilizer products. This evaluation was conducted by the Minnesota Department of Health (MDH), at the request of the Minnesota Department of Agriculture (MDA), to evaluate potential health risks from fertilizer products sold in Minnesota (MDA 1998a; MDH 1998a).

This report includes: (i) the measurements of arsenic, cadmium, and lead in 81 unique fertilizer products sampled by the MDA in 1997-98; (ii) an evaluation of potential health risks from these products; (iii) a discussion of the limitations and uncertainties of this evaluation; and (iv) recommendations regarding the potential health risks from these products.

This evaluation was completed by reviewing data and documents from the Minnesota Department of Agriculture and by consulting with the US Environmental Protection Agency (EPA). In addition, the MDH reviewed information from the California Department of Food and Agriculture, Canadian Food Inspection Agency, US Department of Agriculture, Washington State Department of Health, and several fertilizer companies.

The MDA is the lead state agency for the regulation of fertilizer, including storage handling, distribution, use and disposal of fertilizer. For the Minnesota statute, see the Appendix.

BACKGROUND

The presence of arsenic, cadmium, and lead in certain inorganic fertilizers has been well established (WSDH 1997, 1998a). Analytical testing on a wide range of fertilizer products has revealed that phosphate fertilizers and micronutrient fertilizers tend to contain higher levels than other fertilizer types, such as potash, limestone, and gypsum. Of the micronutrient fertilizers, the highest levels tend to be found in zinc, iron, and manganese products. In Minnesota, most of these products are used for commercial crop production, and a few products are used by consumers around the home (e.g., lawns, gardens, shrubs).

The University of Minnesota recommends application rates for fertilizers in Minnesota (Rosen et al., 1992; Rehm et al., 1994). These rates are based on Minnesota-specific data about soil characteristics and crop nutrient requirements. Micronutrient fertilizers are typically spread over large agricultural areas in relatively small quantities per area. While the metals in these products may be diluted in the soil, they also may accumulate in the upper layers which are used to grow food for animal and human consumption.

Arsenic, cadmium, and lead are commonly found at low levels in the soil, water, dust, air and food; therefore, exposures are an aggregate of multiple sources and pathways. Exposure to these metals through ingestion of plants depends on many variable and complex factors, including bioavailability, plant uptake, soil properties, and food intake. In addition, exposure may occur through incidental ingestion, inhalation and dermal contact with the product or contaminated soil.

Health Effects

Arsenic, cadmium, and lead may be toxic to humans, depending on exposure (e.g., concentration, duration, route of exposure), metal toxicity, and individual characteristics, such as age, gender, and health status.

Arsenic is known to cause cancer in humans, and therefore, is classified as a Group A carcinogen by the US EPA (EPA 1999a). Arsenic, depending on the dose, also causes damage to the nervous and gastrointestinal systems, and causes developmental effects in animals (ATSDR 1998). Cadmium is classified as a probable human carcinogen (Group B1) by inhalation (EPA 1999a); however, only limited data are available to determine if it causes cancer in humans. Cadmium is also known to cause damage to the kidney, liver, and nervous systems (ATSDR 1997b). Lead has been shown to cause damage to the nervous and cardiovascular systems, and the kidneys (ATSDR 1997a). Children are more susceptible to lead toxicity than adults. The Centers for Disease Control has established an action level of 10 micrograms per deciliter of blood; however, there is no established “safe level” or threshold for lead exposure.

Standards for Metals in Fertilizers

No federal standards have been established for metals in inorganic fertilizers. The US EPA has established risk-based limits for metals in sewage sludge (“503 Rule”); however, these standards are inappropriate for inorganic fertilizers because they do not account for differences in matrices (organic vs. inorganic), bioavailability, and exposure. As a result, the 503 Rule standards may underestimate the potential for health risks from the use of inorganic fertilizers (EPA 1998).

The US EPA is currently conducting a risk assessment to evaluate potential health risks from inorganic fertilizers (EPA 1999b). This assessment will include a Monte Carlo analysis of multiple exposure pathways for dioxin and 11 metals, including arsenic, cadmium, and lead. Although the US EPA does not plan to develop standards for fertilizers, their assessment will evaluate the potential for health risks from inorganic fertilizer products, and will comment on the appropriateness of using other standards (see below). The US EPA expects the assessment will be completed by May 1999.

In 1998 the California Department of Food and Agriculture and Heavy Metal Task Force completed a multi-pathway risk assessment for arsenic, cadmium, and lead in inorganic fertilizers (CDFA 1998). As part of the assessment, risk-based concentrations (RBCs) were developed for arsenic, cadmium, and lead using a probabilistic approach (probability density functions) to estimate the "safe" concentrations of metals in phosphate and micronutrient fertilizer products. This assessment evaluated risks to children and adults, and included an ingestion pathway for vegetables and fruits. In addition, this assessment was conducted using many standard risk assessment methods (e.g., negligible cancer risk of 10^{-5}; US EPA reference dose and cancer unit risk values; US EPA exposure factors).

Although no other states have developed risk-based standards, Washington has adopted standards developed in Canada for metals in soil. These standards are based on the maximum cumulative metal additions to soils; therefore, they are not risk-based (CFIS 1997a,b,c). The standards were developed by multiplying average background concentrations of metals in Canadian soil by a factor (2 to 8) to account for such parameters as metal toxicity, bioavailability, and plant uptake. On an interim basis, the Canadian standards have been recommended for use by states by the Association of American Plant Food Control Officials (AAPFCO).

Limited information is available regarding the criteria and data used to develop the above standards. For example, there is no documentation about the background concentrations used for calculations or the rationale used to determine the multiplying factors (CFIS 1997b). Therefore, it is difficult to determine if these standards are appropriate for inorganic fertilizers and protective of human health.

Laboratory Results

The results of the MDA investigation are provided in Tables 1-2 in the Appendix (MDA 1998b; 1998c). Samples were collected from 81 primary (nitrogen, phosphate, and potassium) and micronutrient fertilizer products in the Fall of 1997 and Spring of 1998. Analyses were conducted for arsenic, cadmium, and lead. Duplicate analyses were conducted by an independent laboratory to confirm the results for 10% of the samples (MDA 1998d).

The results show measurable concentrations of lead, cadmium, and arsenic in 22%, 8.6%, and 3.7 % of the products, respectively. [1] The maximum concentrations of lead, cadmium and arsenic were 11,600 parts per million (ppm), 194 ppm, and 6020 ppm, respectively. The micronutrient fertilizers generally had higher levels of metals than the phosphate fertilizers. The cadmium levels for most of the phosphate

[1] Measurable is defined as above the detection limit (20 ppm) for lead and cadmium, and 41 ppm for arsenic.

fertilizers were low compared to fertilizer samples from other states (WSDH 1998a). This is attributed to the fact that Minnesota phosphate fertilizers are derived from southeast sources which tends to be low in cadmium (MDA 1999).

Most (98%) of the products sampled in this investigation are used for commercial crop production and spread over large agricultural fields. Two products (Ironite, Glorious Gardens Rock Phosphate) are sold directly to consumers for use around the home. Ironite contained arsenic (mean 4387 ppm) and lead (mean 2723 ppm). Glorious Gardens Rock Phosphate contained cadmium (106 ppm) and arsenic (8 ppm).

SCREENING EVALUATION

The MDH conducted this evaluation by using the risk-based concentrations (RBCs) developed for inorganic fertilizers in California. Acceptable concentrations were determined for each product by multiplying the percent of micronutrient or phosphate by the RBC for each metal. The MDH compared the acceptable concentrations to the measured concentrations to determine which products exceeded the standards (For the concentrations, see the Appendix, Table 3).

While these standards are based on some assumptions which may not be appropriate for Minnesota (e.g., agricultural practices, climate), many of these assumptions are based on probability density functions. This is likely to reduce the potential for extreme values to bias risk estimates. The RBCs were developed using a uniform distribution for micronutrient requirements between 1 and 10 pounds per acre per year. This is consistent with recommendations for farmers provided by the University of Minnesota, College of Agriculture (Rehm et al., 1994). In addition, some conservative assumptions are used in the model to account for uncertainty (e.g., plant and soil ingestion rates, exposure frequency and duration).

All of the products were below the California standards, with the exception of the three products in the table (below).

Product	Metal	Acceptable Concentration (ppm)	Measured Concentration (ppm)
Ironite[a]	Arsenic Lead	698 3321	3540-6020 3400
Ironite Superferrite[b]	Arsenic	659	6190
Glorious Gardens Rock Phosphate[a]	Cadmium	48	106

[a]Sold to consumers for use around the home.
[b]Used primarily by lawn care companies as a lawn and turf fertilizer.

These same three products also exceed the Canadian standards. This evaluation assumed that the product was applied annually for 45 years (time assumption used for the Canadian standards), and applied at the rate that is recommended on its label (for Ironite, 1-5 pounds per 100 square feet; for Ironite Superferrite, 15 pounds per 1000 square feet; and for Glorious Gardens, 2-5 pounds per 100 square feet). One other product (sample #1345) which did not exceed the California standards, did exceed the Canadian standard for lead. This product has been voluntarily removed from sale by the manufacturer (VPG 1998).

The MDH is particularly concerned about the products that are available to consumers and marketed for residential use because of the potential for high exposures around the home (e.g., products as shown in above table). Consumers may use more of the product than the label recommends or they may apply the product unevenly. These techniques would result in concentrated areas of the product on the lawn, in soil, or in a vegetable garden, in turn resulting in food chain and other exposures greater than estimated in this evaluation.

In addition, products, which are available for residential use may be applied in areas where children play. Children may be directly exposed to the product on treated lawns or in bare soil. Children (1 to 6 years) are at greater risk from these products than adults because of certain behaviors that increase their potential for exposure (e.g., hand to mouth activity), and because of their greater sensitivity to lead toxicity. Children may also be exposed to these products through direct ingestion.

Adults may be exposed directly to these products during application. If the products are applied with the hands, exposures may occur through inhalation, ingestion (incidental), and dermal contact. Fertilizers are typically applied around the home 1-2 times a year; and therefore, these exposures are likely to be short term.

The Ironite product label has been recently revised to remove misleading information and to reduce the recommended application rate (WSDH 1998b). As of October 1998, product with the old label was available in Minnesota stores (MDA 1998b). This label suggests that consumers may apply 2 to 3 times the amount recommended for beneficial results (Ironite 1998).

The Arizona Department of Health Services completed a health risk assessment for residential use of Ironite (ADHS 1998). The assessment concluded that residential use of this product in gardens, lawns, or shrubs does not pose a health risk to children or adults. This assessment, however, is limited because it does not consider potentially important exposure pathways (e.g., ingestion of edible plants, direct exposure during application), and it assumes that label recommendations are followed by consumers. These assumptions are likely to underestimate exposure and potential health risks from Ironite.

In addition, Rust Environment and Infrastructure (St. Paul, Minnesota) conducted a health risk assessment which concluded that Ironite is safe for residential use (REI 1998). This assessment included an evaluation of cancer and non-cancer effects of metal exposures for adults and children, and an evaluation of the ingestion pathway for crops. This assessment, however, did not evaluate potentially important exposure pathways for children (e.g., incidental ingestion of the product; inhalation of soil/dust). In addition, the assessment of acute toxicity from accidental ingestion of the product by a child is based on lethal doses, which do not account for more subtle adverse effects that may occur at much lower levels (e.g., lead). The assessment also assumes the arsenic in this product has a low bioavailability (18.3%). While it may be true that the form of arsenic in this product (arsenopyrite) has been shown to have low bioavailablity in experiments (in vitro), invivo bioavailability is poorly understood.

This assessment concludes that cancer risk estimates for arsenic exposures in adults and children are 4.3E-07 and 1.6E-06, respectively. Because these risk estimates are based on some assumptions which may not be conservative or appropriate given the level of uncertainty, it is possible that the risks from this product may approach levels of health concern.

In addition to residential use of inorganic fertilizers, many of these products are used by farmers for commercial crop production. Direct exposures by inhalation during fertilizer application is less likely to be a health concern because the farmers typically have bulk fertilizers custom applied or use mechanized handling systems (e.g., tractors with cabs, spreaders) which reduces the potential for exposure. However, farmers typically use greater quantities of fertilizers; apply them more frequently than consumers; and may come into contact with them while transferring or pouring the product prior to application.

LIMITATIONS

The risk-based standards used in this evaluation were developed for California, and therefore, are based on some assumptions about agricultural practices and climate conditions (e.g., precipitation) which may not apply to Minnesota. For example, the fraction of land planted for vegetable and root crops (e.g., beets, potatoes) is likely to be higher in Minnesota than the California (MDA 1998e). Likewise, the fraction of tree and vine crops is likely to be lower in Minnesota. In addition, the average annual precipitation in Minnesota is higher than estimated for California (UMN 1999). These factors may underestimate or overestimate risk estimates for Minnesota.

In addition, the California standards assume that the soil type is silt loam throughout the state. This type was selected because it is a conservative approximation based on the fate and transport of metals in California soils. This soil type may be representative of some Minnesota soils; however, there are many soil types in the State with unique characteristics (e.g., pH, bulk density) which affect the bioavailability, plant uptake, and fate and transport of metals.

In addition, exposures to background concentrations of arsenic and cadmium were not evaluated in the California risk assessment. Background levels of these metals are found in multiple media (e.g., food, soil, water), and exposure is an aggregate of multiple sources and pathways. This limitation may have underestimated exposures for these metals.

For many of the products, only a single sample was used for evaluation. It is possible that the levels in these products vary over time, and that the measured concentration is not representative of the typical or average concentration. However, it is possible that there may be other metals or contaminants in these products which were not tested for. The US EPA has evaluated numerous data on inorganic fertilizers, and has identified arsenic, cadmium, and lead as the primary metals of health concern.

The uptake of metals in plants is dependent on several complex factors, which are poorly understood, including bioavailability, soil characteristics (e.g., metal concentration), and the type of plant. Although the model uses many reasonable estimates for these factors, there is uncertainty related to the variable conditions that may be present throughout and between states.

Some parameters used to develop the California standards were not fully explained in the risk assessment. For example, the slopes used to estimate soil to plant transfer were not included. Cadmium bioavailability for plants was assumed to have a coefficient of 1, despite the fact that zinc concentrations have been demonstrated to reduce cadmium plant uptake (Chaney 1998).

Despite these limitations, the California standards are risk-based, and they were developed specifically for inorganic fertilizers. These standards provide a reasonable method for screening products that contain arsenic, cadmium, and lead at levels of potential health concern.

CONCLUSIONS

In summary:

- In 1997-98 the Minnesota Department of Agriculture sampled 81 fertilizer products for arsenic, cadmium, and lead. Three products -- Ironite (arsenic, lead), Ironite Superferrite (arsenic), and Glorious Gardens Rock Phosphate (cadmium) -- exceeded the California risk-based standards for inorganic fertilizers. These three products also exceeded the Canadian standards for metals.

- Ironite and Glorious Gardens Rock Phosphate are used by consumers around the home (e.g., gardens, lawns, and shrubs). The MDH is particularly concerned about these products because of the potential for high direct contact exposures to children. Consumers may use more of the product than is recommended on the label or they may apply the product unevenly, which may result in food chain and other exposures greater than estimated in this evaluation.

- The micronutrient fertilizers in this investigation generally had higher levels of arsenic and lead than the phosphate fertilizers. Micronutrient fertilizers are typically spread over large agricultural areas in relatively small quantities per area. While the metals in these products may be diluted in the soil, they also may accumulate in the upper layers which are used to grow food for animal and human consumption.

- The US EPA is currently conducting a risk assessment to evaluate potential health risks from inorganic fertilizers. This assessment will include an analysis of multiple exposure pathways for dioxin and 11 metals, and is expected to be complete by May 1999.

- A limitation of this screening evaluation is that it uses California standards based on agricultural practices and other factors that may not be appropriate for Minnesota. However, these standards were developed using probability density functions, which are likely to reduce the potential for extreme values to bias risk estimates. In addition, many of the assumptions (e.g., plant and soil ingestion rates, exposure frequency and duration) are conservative to account for uncertainty, and are very likely to be adequately protective.

- Many of these products are used by farmers for commercial crop production. Direct exposure by inhalation is less likely to be a health concern because the farmers typically use equipment (e.g., tractors, spreaders) which reduces the potential for exposure. However, farmers typically use greater quantities of fertilizers; apply them more frequently than consumers; and may come into contact with them while transferring or pouring the product prior to application.

RECOMMENDATIONS

1) Labels of micronutrient and phosphate fertilizers available to consumers should be reviewed 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 identified in this evaluation. If these labels are not satisfactory, the manufacturer should be notified that the product will no longer be registered for sale in Minnesota

2) Continue to monitor micronutrient and phosphate fertilizers which have not been tested for arsenic, cadmium, and lead. This includes new and existing products, and especially products which are available to consumers for use around the home.

3) Re-sample the products that exceeded the California standards and were tested only once. These data should be reviewed to evaluate the metal concentrations and to assess potential health risks.

4) Share this report with other state and local agencies, including the Minnesota Pollution Control Agency, University of Minnesota Extension Service, the US EPA, Consumer Product Safety Commission, and the Occupational Safety and Health Administration.

5) After the US EPA completes a risk assessment for inorganic fertilizers (expected in May 1999), review the evaluation and recommendations, and determine if any additional steps are needed to address potential health risks from these products.

REFERENCES

ADHS 1998. Human Health Risk Assessment for Long-term Residental Use of Ironite Lawn and Garden Nutrient Supplement. Arizona Department of Health Services, Bureau of Epidemiology and Disease Control (October 8, 1998).

ATSDR 1998. Draft Toxicological Profile for Arsenic. US Department of Health and Human Services, Agency for Toxic Substances Disease Registry (August 1998).

ATSDR 1997a. Draft Toxicological Profile for Lead. US Department of Health and Human Services, Agency for Toxic Substances Disease Registry (August 1997).

ATSDR 1997b. Draft Toxicological Profile for Cadmium. US Department of Health and Human Services, Agency for Toxic Substances Disease Registry (September 1997).

CDFA 1998. Development of Risk-Based Concentrations for Arsenic, Cadmium, and Lead in Inorganic Commercial Fertilizers. Prepared for the California Department of Food and Agriculture and the Heavy Metal Task Force by the Foster Wheeler Environmental Corporation (March 1998).

CFIS 1997a. Standards for Metals in Fertilizer and Supplement Products: How to Calculate Acceptable Concentrations. Fertilizer Section, Canadian Food Inspection Agency (October 1997).

CFIS 1997b. Metal Standards for Fertilizer and Supplement Products in Canada: Derivation of the Standards and Background Information. Fertilizer Section, Canadian Food Inspection Agency (October 1997).

CFIS 1997c. Development of the Canadian Standards for Metals in Fertilizers and Supplements. Fertilizer Section, Canadian Food Inspection Agency (December 1997).

Chaney 1998. Personal Correspondence from Dr. Rufus Chaney to Chuck Stroebel. US Department of Agriculture (December 1998).

Ironite 1998. Product label on Ironite (Fall 1997).

MDA 1998a. Office Memorandum from Paul McNelly to Larry Gust. Request for Risk Assessment (February 3, 1998).

MDA 1998b. Report of Heavy Metal Analysis of Commercial Fertilizers Distributed in Minnesota. Minnesota Department of Agriculture (April 20, 1998).

MDA 1998c. Office Memorandum from Paul McNelly to Chuck Stroebel. Spring 1998 Heavy Metal Analysis. Minnesota Department of Agriculture (July 15, 1998).

MDA 1998d. Office Memorandum from Andy Butzer to Paul McNelly. As, Cd, and Pb Comparison Data. Minnesota Department of Agriculture (August 19, 1998).

MDA 1998e. Minnesota Agricultural Statistics. Minnesota Department of Agriculture (1998).

MDA 1999. Conversation with Paul McNelly, Minnesota Department of Agriculture (January 1999).

MDH 1998a. Letter from Larry Gust to Paul McNelly. Re: Conducting an Evaluation of Arsenic, Cadmium, and Lead in Inorganic Fertilizers (May 1, 1998).

Rehm, G; Schmitt, M.; Munter, R. 1994. Fertilizer Recommendations for Agronomic Crops in Minnesota. University of Minnesota Extension Service (1994).

REI 1998. Product Safety Risk Assessment of Ironite, a Nutritional Lawn Supplement. Rust Environment and Infrastructure (June 1998).

Rosen, C.J.; Munter, R.C.; 1992. Nutrient Managment for Commercial Fruit and Vegetable Crops in Minnesota. University of Minnesota Extension Service (1992).

UMN 1999. Web site (http://www.soils.agri.umn.edu/research/climatology) for Climatology Working Group, University of Minnesota and Department of Natural Resources (February 1999).

US EPA 1998. Memorandum from Chuck Stroebel to Inorganic Fertilizer File. RE: Conversation with Dave Fagen. US Environmental Protection Agency (December 1998).

US EPA 1999a. Integrated Risk Information System (IRIS) Files for arsenic, cadmium, and lead. US Environmental Protection Agency (January 1999).

US EPA 1999b. Memorandum from Chuck Stroebel to Inorganic Fertilizer File. RE: Conversation with Becky Diass. US Environmental Protection Agency (January 1999).

VPG 1998. Letter from Christina Brown to Mr. McNelly regarding Hi-Yield Ionate, Lab no. 1345, Batch #33071 (March 12, 1998).

WSDH 1997. Preliminary Screening Survey for Metals and Dioxins in Fertilizers, Soil Amendments, and Soils in Washington State. Washington State Department of Ecology (November 1998).

WSDH 1998a. Screening Survey for Metals in Fertilizers and Industrial By-Product Fertilizers in Washington State. Washington State Department of Ecology (December 1997).

WSDH 1998b. Memorandum from Chuck Stroebel to Inorganic Fertilizer File. Notes on Conversation with Denise Laflamme, Washington State Department of Health (1998).

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APPENDIX

Table 1: Metal Levels in Minnesota Fertilizers (Samples Collected , Fall 1997)

Sample		Results (ppm)*		
Number	Product	Arsenic	Cadmium	Lead
1324	35.5% Zinc	<41	<20	39
1325	14.3% Boron	<41	<20	<20
1326	90% Sulfur	<41	<20	<20
1327	36% Magnesium	<41	<20	84
1328	32% Manganese	<41	<20	<20
1329	25.2% Copper	<41	<20	<20
1330	0-0-50	<41	<20	<20
1331	0-0-62	<41	<20	<20
1332	0-2-0	<41	<20	<20
1333	Calcium Sulfate, 17% Sulfur	<41	<20	<20
1334	10-50-0	<41	<20	<20
1335	11-0-0	<41	<20	<20
1336	0-0-22	<41	<20	<20
1337	40% Iron	<41	29	1160
1338	10% Iron	<41	65	2270
1339	0-0-60	<41	<20	<20
1340[a,b]	1-0-0, 4.5% Iron	3540	<20	2360
1341	6-0-0	<41	<20	41
1342	6-2-0	<41	<20	54
1343	12-6-6	<41	<20	<20
1344	19% Iron	<41	<20	<20
1345[c]	10% Iron	<41	<20	1040
1346	.5-.5-.5, Manure	<41	<20	<20
1347[a,b]	1-0-0, 4.5% Iron	3600	<20	3400
1348	Aluminum Sulfate, 14.4% Sulfur	<41	<20	<20
1350	Minor Elements, 1% S, 2% Iron	<41	<20	<20
1351	15% Iron	<41	<20	303
1352	28-0-0	<41	<20	<20
1353	10-34-0	<41	<20	<20
1354	10-34-0	<41	<20	<20
1355	50% Iron	<41	<20	589
1356	29% Manganese	<41	<20	29
1357	25.2% Copper	<41	<20	<20
1358	36% Magnesium	<41	<20	24
1359	20.5% Boron	<41	<20	<20
1360	25.2% Copper	<41	<20	<20
1361	19-5-0-22S	<41	<20	<20
1362	90% Sulfur	<41	<20	<20
1363	34-0-0	<41	<20	<20
1364	0-0-60	<41	<20	<20
1365	18-46-0	<41	<20	<20
1366	11-52-0	<41	<20	<20
1367	0-0-22-22S	<41	<20	<20
1368	21-0-0-24S	<41	<20	<20

Table 1: Metal Levels in Minnesota Fertilizers (Samples Collected , Fall 1997)

Sample Number	Product	Results (ppm)* Arsenic	Cadmium	Lead
1369	21-0-0-24S	<41	<20	<20
1370	46-0-0	<41	<20	<20
1371	46-0-0	<41	<20	<20
1372	0-46-0	<41	<20	<20
1373	10% Boron	<41	<20	<20
1374	Ammonium Sulfate	<41	<20	<20
1375	36% Zinc	<41	126	11600
1376	58% Magnesium	<41	<20	<20
1377	14.9% Boron	<41	<20	<20
1378	0-2-0	<41	<20	<20
1379	4-5-4, compost	<41	<20	<20
1380	11-52-0	<41	<20	<20
1381	0-0-50-17S	<41	<20	<20
1382	46-0-0	<41	<20	<20
1383	10-30-0	<41	<20	<20
1384	10-30-0	<41	<20	<20

Method Detection Limits: Arsenic 41 ppm, Cadmium 20 ppm, and Lead 20 ppm; Samples Analyzed by Atomic Absorption.

[a] Product Available to Consumers
[b] Samples from Identical Products
[c] Product Discontinued by Manufacturer

Samples Collected and Analyzed by the Minnesota Department of Agriculture.
59 Unique Products Total.

Table 2: Metal Levels in Minnesota Fertilizers (Samples Collected, Spring 1998)

Sample		Results (ppm)*		
Number	**Product**	**Arsenic[e]**	**Cadmium**	**Lead**
1406	0-0-60	<1	<20	<20
1407	18-46-0	2.5	<20	<20
1408	21-0-0-24S	<1	<20	<20
1409	46-0-0	<1	<20	<20
1410	3.25% Iron, liquid	<1	<20	<20
1423	4% N, 1% Iron, liquid	<1	<20	<20
1428	90% Sulfur	1.4	<20	<20
1429[b]	35.5% Zinc	<1	50	161
1430[b]	36% Zinc	17	192	9350
1432	0-46-0	3.4	<20	<20
1435[b]	50% Iron	14.8	<20	462
1436	25.2% Copper	<1	<20	<20
1437	25.2% Copper	<1	<20	<20
1438	12% Zinc, 12% Sulfur	63	65	1870
1439	20% Zinc	28	194	682
1517	35.5% Zinc	<1	<20	<20
1647	0-0-60	14.4	<20	<20
1705[a]	0-3-0	8	106	<20
1706	2-0-0, 4.25% Iron	6190	28.9	2650
1768	8-10-0	8.2[d]	<20	71.2
1918[b,c]	10% Iron	248	<20	886
1919	19% Iron	<1	<20	<20
1920[a,b]	1-0-0, 4.5% Iron	6020	28	2410
1921	6% Iron, liquid	2.7	<20	<20
1922	15% Iron	23.9	<20	198
1966	21-0-0-24S	3.7	<20	<20
1970	19% liquid nitrogen	1.6	<20	<20

*Method Detection Limits are 1 ppm for Arsenic, and 20 ppm for Cadmium and Lead; Samples Analyzed by Atomic Absorption.

a Product Available to Consumers
b Duplicate Analyses from Spring 1998 Sampling
c Product Discontinued by Manufacturer
d High Interference; Analysis Run Twice
e Method Detection Limit is <1 ppm (Lower Than First Sampling)
The Dectection Limit for Cadmium and Lead is 20 ppm.

Samples Collected and Analyzed by the Minnesota Department of Agriculture
22 Unique Products Total.

Table 3: Acceptable vs Measured Concentrations of Metals in Fertilizers

Sample #	% Micronutrient (M) or Phosphate (P)	Type	Metal	RBC[a]	Acceptable[b] Level (ppm)	Measured[c] Level (ppm)
1324	35.5	M	Pb	738	26,199	39
1327	36	M	Pb	738	26,568	84
1337	40	M	Pb	738	29,520	1160
	40	M	Cd	134	5360	29
1338	10	M	Pb	738	7380	2270
	10	M	Cd	134	1340	65
1340	4.5	M	As	155	698	3540**
	4.5	M	Pb	738	3321	2360
1341	NA	NA	Pb	NA	NA	41
1342	2	P	Pb	97	194	54
1345	10	M	Pb	738	7380	1040
1347	4.5	M	As	155	698	3600**
	4.5	M	Pb	738	3321	3400**
1351	15	M	Pb	738	11,070	303
	15	M	Cd	134	2,010	50
1355	50	M	Pb	738	36,900	589
1356	29	M	Pb	738	21,402	29
1358	36	M	Pb	738	26,568	24
1375	36	M	Pb	738	26,568	11,600
	36	M	Cd	134	4824	126
1407	46	P	As	19	874	2.5
1428	NA	NA	As	NA	NA	1.4
1429	35.5	M	Pb	738	26,199	161
1430	36	M	Pb	738	26,568	9350
	36	M	Cd	134	4824	192
	36	M	As	155	5580	17
1432	46	P	As	19	874	3.4
1435	50	M	As	155	7750	14.8
	50	M	Pb	738	36,900	462
1438	12	M	As	155	1860	63
	12	M	Cd	134	1608	65
	12	M	Pb	738	8856	1870
1439	20	M	As	155	3100	28
	20	M	Cd	134	2680	194
	20	M	Pb	738	14,760	682
1647	NA	NA	As	NA	NA	14.4
1705	3	P	As	19	57	8
	3	P	Cd	16	48	106**
1706	4.25	M	As	155	659	6190**
	4.25	M	Cd	134	570	28.9
	4.25	M	Pb	738	3,137	2650
1768	10	P	As	19	190	8.2

Table 3: Acceptable vs Measured Concentrations of Metals in Fertilizers

	10	P	Pb	97	970	71.2
1918	10	M	As	155	1550	248
	10	M	Pb	738	7380	886
1920	4.5	M	As	155	698	6020**
	4.5	M	Cd	134	603	28
	4.5	M	Pb	738	3321	2410
1921	6	M	As	155	930	2.7
1922	15	M	As	155	2325	23.9
	15	M	Pb	738	11,070	198
1966	NA	NA	As	NA	NA	3.7
1970	19	NA	As	NA	NA	1.6

Minnesota Statute

Minn. Stat. 18C.201 PROHIBITED FERTILIZER ACTIVITIES. Subd. 1. states, "Storage, handling, distribution, or disposal. A person may not store, handle, distribute, or dispose of a fertilizer, rinsate, fertilizer container, or application equipment in a manner: (1) that endangers humans, damages agricultural products, food, livestock, fish, or wildlife; (2) that will cause unreasonable adverse effects on the environment..."