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HEAVY METALS IN SEWAGE SLUDGE
Inquiry Response No. 114
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INQUIRY: What are the levels of heavy metals in sewage sludge from the Pig's Eye Treatment Plant (St. Paul, MN), and what are the impacts of its use as a fertilizer?

KEY RESOURCES:*

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BACKGROUND: In an experimental program sludge from the Pig's Eye Treatment Plant is being applied to agricultural fields, and the effects studied. If land-spreading of treated sewage sludge can be shown to be safe, expanded use of this disposal method is expected to follow. The advantage of this disposal method is that it converts a serious problem (sewage sludge disposal) into a benefit (a soil conditioner or fertilizer). This report summarizes the research program, the measured levels of heavy metals in sludge and in crops, and the recommended levels of heavy metals in soil. Factors effecting safe levels of metals are also discussed.

RESPONSE:

Structure of the Research Program

Research has been done on the concentrations and movement of heavy metals in sewage sludge (from the Pig's Eye Treatment Plant) which has been applied to soils growing agricultural crops. Comparisons have been made of the heavy metals content of grain silage (corn) and animals produced from land which recived 0, 15, 30, and 45 metric tons per hectare applications of the Pig's Eye sewage sludge. One metric ton (1000 kg) per hectare is equivalent to about one-half short ton (2000 lbs.) per acre. The corn silage has been harvested and fed to milking goats and lambs. These goats began eating silage produced in this manner about two years ago. They will be sacrificed this fall, and an analysis will be made of their body parts and organs (e.g., liver, kidneys, muscle). Lambs fed on this silage for 90 days have been sacrificed and their organs similarly analyzed. Also, the milk from the goats has been analyzed and physical parameters have been recorded, including production volumes and weight gains.

Overall, after two cropping years, no significant effects in these animals has been observed. The corn silage shows some increase in cadmium and other metals. However, many experts believe that cadmium will have detectable effects on animal health before it has an effect on plant growth in species such as corn.

*A key resource is a person who knows the technical aspects of the topic being considered and has indicated a willingness to answer questions on the topic from legislators.

Metals in Pig's Eye Sewage Sludge

The metals from sewage sludge which have the most potential for danger and could affect animal production and plant growth are cadmium, zinc, nickel, and copper. The average levels reported in Pig's Eye sewage sludge for the past two years are shown in Table 1.

TABLE 1

TWO-YEAR AVERAGE HEAVY METAL CONTENT IN PIG'S EYE SEWAGE SLUDGE

Metal	Levels (ppm)
Zinc	2000
Cadmium	150
Copper	700
Nickel	230
Lead	1000
Chromium	700

SOURCE: Telephone conversation with Professor William E. Larson, 7/23/80.

The corn yield has changed very little due to sludge spreading, though it appears that there is a slight increase in the yield as compared to the commercially fertilized crops. This increase is apparent only when comparing the 45 metric ton per hectare applications to fertilized crops.

The sewage sludge used has received primary treatment (settling) and secondary treatment (activated digestion). Normally in this process, lime is added to aid filtration. However, since this raises the pH of the soil, and the purpose of the research is to obtain effects without artificially raising the pH, all of the work has been done with unlimed sludge, or limed sludge which has subsequently been treated to lower its pH.

Metals in Corn Crops Using Pig's Eye Sludge

Table 2 reports the levels of heavy metals in the corn grown on acreage where sludge was applied at 45 metric tons per acre compared to acreage where no sludge was applied at all. Though the levels of some metals increase, others decrease. The most dramatic increases are for cadmium and zinc in the stover. The situation should be less severe in the sludge which the farmers in this area obtain because the lime addition not only dilutes the sludge, but typically raises the pH from about 6.0 to 7.2. At the higher pH the soil is more basic and the metals are less water soluble and thus less amenable to uptake by the plant.[1]

TABLE 2

HEAVY METAL LEVELS IN CORN PLANTS

(in ppm)

	Sludge Applied at 45 Metric Tons/Hectare				Control No Sludge Applied			
	Stover	Leaf	Grain	Cob	Stover	Leaf	Grain	Cob
Zinc	145	115	69	80	20	22	34	18
Cadmium	9.0	7.06	.23	2.0	<.31	<.26	<.15	.1
Copper	5.79	8.50	.36	1.8	4.79	7.54	1.03	2.3
Nickel	2.77	.60	.84	1.6	2.09	.74	.33	1.8
Lead	1.80	1.61	<.35	<.5	1.64	1.47	--	<.5
Chromium	2.33	.42	<.16	.90	1.89	.88	<.16	1.52

SOURCE: Telephone conversation with Professor William E. Larson, 7/23/80.

Recommended Concentrations of Heavy Metals

The Minnesota Pollution Control Agency (MPCA), several states, and the United States Environmental Protection Agency (U.S. EPA) have recommended levels of heavy metals in sludge which are not to be exceeded when applied to agricultural crops. Table 3 identifies the recommended MPCA concentrations of heavy metals on a dry weight basis. At concentrations above these levels, pretreatment is recommended. The MPCA also recommends limits on total metal additions to soils (see Table 4).[2]

TABLE 3

RECOMMENDED MAXIMUM CONCENTRATIONS OF HEAVY METALS IN SLUDGE WITHOUT PRETREATMENT FOR LAND SPREADING

Metal	Levels (ppm)
Zinc	1750
Chromium	900
Copper	850
Lead	500
Nickel	100
Cadmium	20
Mercury	5

SOURCE: MPCA Recommendations for Application of Municipal Wastewater Sludges on Land, August 1978.

However, many of the levels recommended by the MPCA, EPA, and other states are based on inadequate data. Generally, these levels are conservative, in order to prevent adverse impact on the public health.[3] Affects attributable to both metal type and concentration are of considerable uncertainty and much research is being done around the country on the appropriate application levels of sludge containing heavy metals and other contaminants.

As a result of the Minnesota Waste Management Act of 1980, the MPCA must develop regulations to govern such things as application methods, contaminant levels, and soil conditions for sites at which sludge is to be applied. Currently, reasonable practices and levels for Minnesota are identified in the MPCA document "Recommendations for Application of Municipal Wastewater Sludges on Land." This document identifies such factors as the separation distances from individual dwellings, residential developments, waterwells, major road rights-of-way, airports, and surface water. In addition, depending upon soil texture, there is a minimum separation from groundwater and bedrock. Separation from surface water also depends upon the texture of the soil and the time of year during which application occurs. For example, separation distances from surface water are highest during November and April for both the coarse, and the medium and fine soil textures.[4]

Soil Factors in Sludge Spreading

In terms of soil type, it is recommended that "sludge should not be applied to very coarse sands or gravel soils" nor to highly organic soils (e.g., peat) unless they are adequately drained.

Though the MPCA document is only a recommendation, MPCA permits are required and many of these recommendations are conditions for allowing spreading of sludge on agricultural soils. Required soil test data, for example, include texture (by USDA classification), organic matter in the soil, extractable phosphorus, exchangeable potassium, pH, lime requirement (up to pH 6.5 only), and soluble salts.[5]

Nitrogen levels in sludge may become the limiting factor in determining both optimum application and dose rates for land application of sludge after excess heavy metal concentration has been reduced. Southern Minnesota has had problems with contamination by nitrogen compounds of the water supply in areas with sandy soils, and particularly in the areas where karst formations make these nitrogen compounds immediately available to groundwater.[6]

Current volume limitations of sludge from the Pig's Eye Treatment Plant applied to agricultural soil are seven tons per acre per year of dry sludge. Currently, Pig's Eye sludge is 80 percent water, so that a 30 ton per acre maximum of this wet sludge is expected to keep the metal and nitrogen levels below or near the MPCA recommended levels. In most cases for sludge from out state areas, nitrogen concentration rather than heavy metals content limits the application rate (5 to 20 tons per acre).[7]

Migration and Contamination of Groundwater

Where the soil is very coarse and sandy, and has a very low cation exchange capacity, and where a shallow watertable exists, the danger of metals contaminating groundwater is higher than in more organic or fine soils. Cation exchange capacity is an index which identifies the amount of ions with positive charge (e.g., heavy metals) that are retained by the soil. Highly organic soils have high cation exchange capacity. However, with respect to land application of sludge, cation exchange capacity is best viewed as a general, but imperfect indicator of soil components that limit the solubility of heavy metals. The current evidence is that metal ions do not move beyond the zone of incorporation.[8]

Table 4 identifies the total recommended metal additions in pounds per acre as a function of soil cation exchange capacity. Sludge application to nondedicated agricultural sites should be terminated when the sum addition of any one metal equals the recommended total for that particular metal and soil. Metal additions above those levels listed in Table 4 or above two pounds of cadmium per acre per year will require crop tissue monitoring and specific approval of the Director of the MPCA.

As has been noted in other research (i.e., research at the Illinois Institute of Natural Resources on PCBs) the ability of soil to absorb certain metals and other contaminants is a function of the soil organic matter level.

Table 5 shows the relationship between a cation exchange capacity and soil organic matter level.

TABLE 4

TOTAL RECOMMENDED METAL ADDITIONS
(lbs./acre)

	Soil Cation Exchange Capacity (milliequivalents/100 grams)		
Metal	0-5	5-15	15
Lead	500	1000	2000
Zinc	250	500	1000
Copper	125	250	500
Nickel	50	100	200
Cadmium	5	10	20

SOURCE: MPCA Recommendations for Application of Municipal Wastewater Sludges on Land, August 1978.

TABLE 5

CATION EXCHANGE CAPACITY
(milliequivalents/100 gms)

Texture	Low (<2%)	Medium (2-4%)	High (>4%)
Coarse	0 - 5	5 - 15	5 - 15
Medium	5 - 15	5 - 15	>15
Fine	>15	>15	>15

SOURCE: MPCA Recommendations for Application of Municipal Wastewater Sludges on Land, August 1978.

The MPCA recommendations suggest accurate records be kept for each site on the quantity of sludge applied per year and cumulatively, as well as the quantity of metals applied per year and cumulatively.[9] Long-term applications of sludge high in sodium can cause a deterioration of soil structure and result in increased erosion and runoff. Where necessary, appropriate tillage operation should be performed to promote infiltration of sludge liquid and rainfall.

In addition, there are guidelines on cropping practices, pH control, potassium fertilization, public access, and monitoring. Different recommendations are also provided for sludge spreading on nondedicated nonagricultural sites, sludge spreading on dedicated application sites and sludge spreading in reclamation of unproductive land.

Overview

Research indicates that accumulation of heavy metals in plant tissue is generally confined to the leafy portions of vegetative tissue, leaving the storage tissue (fruit or tuber) relatively free of metals uptake. Thus, lettuce is an accumulator of metals whereas potatoes or carrots (peeled) are excellent nonaccumulators and may be very desirable crops for utilizing sludge-amended soils.[10] The recommendations for maximum and cumulative levels of sludge spread on soils, soil conditions, and application practices and sites are reviewed periodically and are changed as the knowledge of their effects and acceptability is increased.

FOOTNOTES:

1. Telephone conversation with Professor William E. Larson, Department of Soil Science, University of Minnesota, July 23, 1980.
2. Recommendations for Application of Municipal Wastewater Sludges on Land. Minnesota Pollution Control Agency, August 1978.
3. Larson, op. cit.
4. MPCA Recommendations, op, cit.
5. Ibid.
6. Letter from Matt Walton, Director, Minnesota Geological Survey, University of Minnesota, to John Malinka, Director, Science and Technology Research Office, Minnesota Legislature, September 27, 1979.
7. Telephone conversation with Steven A. Stark, Division of Water Quality, Minnesota Pollution Control Agency, September 10, 1980.
8. Telephone conversation with Robert H. Dowdy, Department of Soil Science, University of Minnesota, September 11, 1980.
9. MPCA Recommendations, op. cit.
10. Larson, W.E., and Dowdy, R.H., "The Availability of Sludge-Borne Metals to Various Vegetable Crops," J. Environmental Quality, 4 (2): 278-282 (1975).

REFERENCE:

1. Utilization of Sewage Wastes on Land, U.S. Department of Agriculture, Science and Education Administration, Agricultural Research, St. Paul, Minnesota, 1979.

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