Extractable Heavy Metal Levels in the Profiles of Soils Used for Corn Production
Michigan State University Agricultural Experiment Station and Cooperative Extension Service
Research Report

D. L. Mokma, B. D. Knezek, L. S. Robertson, Crop and Soil Sciences

Issued April 1980
8 pages

April, 1980

32.64

RESEARCH
REPORT 396
FROM THE MICHIGAN STATE UNIVERSITY
AGRICULTURAL EXPERIMENT STATION EAST LANSING

Farm Science

Extractable Heavy Metal Levels in the Profiles of Soils Used for Corn Production

Effect of additions of nickel on corn plants. Rates, from left to right, are 58, 118, 294, 586, 1760, 3522, 5282 and 0 pounds per acre.

Extractable Heavy Metal Levels in the Profiles of Soils Used for Corn Production

By D. L. Mokma, B. D. Knezek and L. S. Robertson
Department of Crop and Soil Sciences

INTRODUCTION

Interest in applying municipal and industrial sludges and wastewaters to cropland has increased as a result of amendments to the Federal Water Pollution Control Act (Public Law 92-500) passed by Congress in 1972. These amendments established a goal of zero discharge of pollutants into navigable waters by 1985. Land application of sludges and wastewaters is one treatment alternative being considered by several communities.

Waste materials contain varying amounts of heavy metals, some of which might be toxic to crops and/or might increase the heavy metal concentration in edible crops enough to have harmful effects (2 and 3). Many communities are applying waste materials to the soil with little or no information on heavy metal levels in the soil. By knowing the level in untreated soil and the concentration in waste material, the rate and time of application can be predicted so that toxic levels in soil and runoff do not develop.

Several extraction methods have been used to determine the levels of Cd, (Cadmium), Co (Cobalt), Cr (Chromium), Ni (Nickel) and Pb (Lead) in the soil. The quantity of heavy metals extracted by the different extractions varied considerably.

This report is part of an inventory of the chemical properties of Michigan soils used for corn production. Summaries of soil test levels for pH, P, K, Ca, Mg, S, B, Cu, Fe, Mn, Zn, soil organic matter and cation exchange capacity have already been made (12, 13, 14, 8, 9, and 10). This study determined the current levels of extractable Cd, Co, Cr, Ni and Pb in soils used for field crop production in Michigan.

MATERIALS AND METHODS

Soil profile samples were obtained from corn fields in September and October of 1974 with a 5-ft bucket auger, with two exceptions. The exceptions were soybean fields where corn was grown the previous year.

Samples were collected in the southern 41 counties (Bay-Oceana tier, latitude 44°) where corn is grown most extensively. Each county was represented by a minimum of two sample sites. Since so many soil types are present in the sample area, the soil management concept (7) was used in collecting the samples and presenting the data.

The number of profile samples per soil management group was approximately proportional to the number of acres of corn grown on the soils in each group, but not less than two. Samples were collected only where there had been little or no erosion and the slope was less than 6%.

Sample "A" represented the Ap horizon (plow layer) at all locations, while sample "B" represented the Bt horizon (12 to 30 in.) in most of the profiles. The letter "C" identified the parent material, a lower portion of a thick B horizon or the lower horizon of a two-storied soil.

The heavy metals Cd, Co, Cr, Ni and Pb were determined in each profile sample by extracting separate subsamples with 0.1**N** HCl, 0.1**N** NH_4OAc, and 0.005**M** DTPA. The HCl extraction was made by adding 50 ml of 0.1**N** HCl to 5 g of air dry soil. After shaking for 0.5 hr at a low speed (150 oscillations per minute) the mixture was filtered through Whatman No. 2 filter paper. The filtrate was collected and stored in polyethylene bottles until analyses were made.

The NH_4OAc extraction was made by adding 50 ml of 1**N** NH_4OAc to 5 g of air dry soil. After shaking for 0.5 hrs, the mixture stood for 6 hrs and then was filtered through Whatman No. 2 filter paper. The filtrate was collected and stored in polyethylene bottles under refrigerated conditions until analyses could be completed.

The DTPA extraction was made by adding 50 ml of 0.005**M** DTPA solution containing 0.01**M** $CaCl_2$ and 0.1**M** triethanolamine buffered at pH 7.3 to 12.5 g of air dry soil (6). After shaking for 2 hrs, the mixture was filtered through Whatman No. 2 filter paper, and the filtrate was collected and stored in polyethylene bottles in a refrigerator.

Cd, Co, Cr, Ni and Pb levels were determined in the extracts with a Perkin-Elmer 303 Atomic Absorption Spectrophotometer. Detection limits in the extracts for Cd, Co, Cr, Ni and Pb were 0.1, 1.0, 1.0, 0.5 and 1.0 ppm, respectively. Those extracts which contained levels of metals below the detection limits of this experiment were averaged into the date summaries as zeros.

RESULTS AND DISCUSSION

The three extractants, as expected, removed different quantities of the heavy metals from the samples. Because the extractants have different properties, it was assumed that they removed, in part, specific fractions from the soil and that there may be some that are common to two if not all of the extractants. Although the solubility of heavy metals is frequently closely related to pH, no attempt was made to relate extractable levels with soil reaction.

Cadmium

Mean extractable Cd levels ranged from 0 to 0.94 ppm (Table 1). The range of extractable Cd levels was 0-1.08 ppm for HCl, 0 to 3.86 ppm for NH_4OAc and 0 to 1.34 ppm for DTPA (Table 2). HCl extracted a mean of 0.11 ppm from all samples, NH_4OAc extracted a mean of 0.10 ppm from all samples and DTPA extracted a mean of 0.05 ppm from all samples. For the muck soils, DTPA extracted the most, mean of 0.42 ppm, while HCl extracted a mean of 0.27 and NH_4OAc extracted a mean of 0.19 ppm. The NH_4OAc and DTPA extractable levels of Cd were below detection limits for the procedures and equipment used.

Mean HCl extractable Cd levels tended to be greater in the poorly drained soils than in the well and somewhat poorly drained soils (Table 1). Mean Cd levels in the NH_4OAc and DTPA extracts did not tend to vary with natural drainage class.

Mean extractable Cd levels tended to be greater in A horizons than in B and C horizons. This resulted primarily from Cd being precipitated from the atmosphere (5).

Mean extractable Cd levels tended to be lower in sand and loamy sand soils than in finer textured soils.

Table 1. Mean extractable cadmium levels (ppm) in profiles of soil management groups.

Dominant Profile Texture	Horizon	Natural Drainage: Well (a) HCl	Well (a) NH_4OAc	Well (a) DTPA	Somewhat poorly (b) HCl	Somewhat poorly (b) NH_4OAc	Somewhat poorly (b) DTPA	Poorly (c) HCl	Poorly (c) NH_4OAc	Poorly (c) DTPA
Clay (1)	A	.16	0	.45	.05	.79	.12	.19	0	0
	B	.11	0	0	.11	0	0	0	0	0
	C	.14	0	0	0	0	.01	0	0	0
Clay Loam (1.5)	A	.14	.61	.05	.17	.28	.11	.43	.11	.07
	B	.12	0	0	.06	0	0	.13	.05	0
	C	.14	.06	.11	.07	0	0	.14	.09	.08
Loam (2.5)	A	.09	.14	.06	.13	.02	.09	.13	.08	.07
	B	.05	.08	.01	.05	.31	.01	.11	0	.02
	C	.12	.08	0	.06	.04	.04	.09	.05	.02
Sandy Loam (3)	A	.17	.20	.02	0	.44	.06	.41	0	.32
	B	.06	.05	.04	.03	.04	.37	.12	0	0
	C	.10	.17	0	.08	0	0	.18	.13	0
Loamy Sand (4)	A	.08	.14	0	.22	.37	.10	.11	0	.07
	B	.10	.05	0	.18	0	.04	.05	0	0
	C	.11	0	0	.31	0	0	.08	0	0
Sand (5)	A	.08	0	0	.04	0	.05	.34	0	.19
	B	0	0	0	.02	.43	0	.06	0	.03
	C	.04	0	0	.04	.19	0	.04	0	.06
Sandy Loam over Loam (3/2)	A				.08	.27	.18			
	B				0	0	0			
	C				.20	0	0			
Loamy Sand over Loam to Clay (4/1, 4/2)	A	.14	0	0	.18	0	0			
	B	.10	0	0	.06	0	0			
	C	.14	0	0	.03	0	.03			
Sand over Loam to Clay Loam (5/2)	A	.08	0	0						
	B	0	0	0						
	C	.05	0	0						
Muck (M, M/m, M/3, M/4)	1							.45	.26	.94
	2							.15	.18	.25
	3							.21	.13	.07

Table 2. Ranges of HCl, NH_4OAc and DTPA extractable cadmium levels (ppm) in profiles of soil management groups.

Dominant Profile Texture	Horizon	HCl Well (a)	HCl Somewhat Poorly (b)	HCl Poorly (c)	NH_4OAc Well (a)	NH_4OAc Somewhat Poorly (b)	NH_4OAc Poorly (c)	DTPA Well (a)	DTPA Somewhat Poorly (b)	DTPA Poorly (c)
Clay (1)	A	0 - 0.33	0 - .16	0 - .58	0	.53 - 1.32	0	0 - 1.34	0 .35	0
	B	0 - .33	0 - .33	0	0	0	0	0	0	0
	C	0 - .25	0	0	0	0	0	0	0 - .04	0
Clay Loam (1.5)	A	0 - .33	0 - .38	0 - 1.08	0 - 1.72	0 - 1.05	0 - .79	0 - .18	0 - .18	0 - .31
	B	0 - .33	0 - .25	0 - .50	0	0	0 - .39	0	0	0
	C	0 - .33	0 - .28	0 - .50	0 - .39	0	0 - .66	0 - .40	0	0 - .44
Loam (2.5)	A	0 - .47	0 - .50	0 - .38	0 - .79	0 - .26	0 - .53	0 - .40	0 - .44	0 - .44
	B	0 - .33	0 - .41	0 - .47	0 - 1.32	0 - 3.86	0	0 - .09	0 - .09	0 - .18
	C	0 - .41	0 - .25	0 - .47	0 - 1.05	0 - .26	0 - .39	0	0 - .22	0 - .18
Sandy Loam (3)	A	0 - .66	0	0 - .66	0 - .92	0 - 1.32	0	0 - .27	0 - .18	0 - .66
	B	0 - .33	0 - .08	0 - .19	0 - .66	0 - .13	0	0 - .27	0 - 1.12	0
	C	0 - .50	0 - .25	0 - .28	0 - 1.32	0	0 - .39	0	0	0
Loamy Sand (4)	A	0 - .28	0 - .50	0 - .25	0 - 1.19	0 - 1.85	0	0 - .04	0 - .49	0 - .22
	B	0 - .33	0 - .50	0 - .16	0 - .53	0	0	0	0 - .18	0
	C	0 - .28	0 - .99	0 - .25	0	0	0	0	0	0
Sand (5)	A	0 - .33	0 - .16	.25 - .58	0	0	0	0	0 - .18	0 - .44
	B	0	0 - .08	0 - .16	0	0 - 1.72	0	0	0	0 - .13
	C	0 - .16	0 - .16	0 - .16	0	0 - .79	0	0	0	0 - .22
Sandy Loam over Loam (3/2)	A		0 - .16			0 - .53			0 - .35	
	B		0			0			0	
	C		0 - .41			0			0	
Loamy Sand over Loam to Clay (4/1, 4/2)	A	0 - .28	0 - .38		0	0		0	0	
	B	0 - .19	0 - .19		0	0		0	0	
	C	0 - .28	0 - .08		0	0		0	0 - .09	
Sand over Loam to Clay Loam (5/2)	A	0 - .16			0			0		
	B	0			0			0		
	C	0 - .09			0			0		
Muck (M, M/m, M/3, M/4)	1			0 - .76			0 - .79			.67 - 1.34
	2			0 - .33			0 - .53			0 - .44
	3			0 - .50			0 - .39			0 - .13

Chromium

Cr levels in all three extractants were too low to detect (below 1 ppm). This result was somewhat unexpected because Cr has been reported to be widely distributed in soils, waters and biological materials (11). However, attempts to measure available Cr were unsuccessful with the techniques used in this investigation.

Cobalt

Mean extractable Co levels ranged from 0 to 5.88 ppm (Table 3). The range of extractable Co levels was 0 to 10.74 ppm in HCl extracts, 0 to 7.68 ppm in NH_4OAc extracts and 0 to 8.39 ppm in DTPA extracts (Table 4). Many profiles had no detectable Co. Only 19 of the 135 profiles sampled had Co extracted by HCl. Twenty-seven profiles had Co extracted by NH_4OAc, while 63 profiles had Co extracted by DTPA.

HCl extracted a mean of 0.69 ppm Co from all samples, while DTPA and NH_4OAc extracted a mean of 0.43 and 0.27 ppm Co, respectively, from all samples. Vanselow (15) also reported HCl extracted more Co from soils than NH_4OAc. DTPA extracted a mean of 2.28 ppm Co from muck soils, while HCl and NH_4OAc extracted 0.78 and 0.77 ppm Co from the same samples.

No apparent relationship was observed between mean extractable Co levels and natural drainage.

A horizons tended to have higher mean levels of extractable Co than B horizons which tended to have higher mean levels than the C horizons. There were many exceptions to this general trend.

No relationship between mean extractable Co and profile texture was apparent. The sand and loamy sand soils tended to have low levels of extractable Co, but there were several exceptions. This was in partial agreement with the findings of Vanselow (15) that sandy soils had the lowest levels of HCl extractable Co and the heavy soil (finer textured) had the highest levels. Kubota and Allaway (4) found that Co deficiency occurred on sandy soils.

Lead

Pb levels in all NH_4OAc extracts were below detection limits of 1.0 ppm in solution. Pb was detected in the HCl extracts of only four samples: three A horizons and one B horizon. Mean extractable Pb levels ranged from 0 to 4.15 ppm, while the range of all samples was 0 to 6.49 ppm (Table 5).

For A and B horizons mean DTPA extractable Pb were higher in the somewhat poorly drained soils than in the well drained and poorly drained soils. For the C horizons there was no apparent relationship between Pb levels and natural drainage conditions.

Mean DTPA extractable Pb levels decreased with depth in the profile. This agreed with the findings of Lagerwerff (5) and Brewer (1) that Pb levels were much higher in surface soils than in subsoils. This might result from Pb being added to the soil from the atmosphere and as a pesticide. Because most samples were collected relatively close to roads, some of the Pb in the surface horizons theoretically might be from auto emissions.

Sand and loamy sand soils had lower extractable PB levels than the finer textured soils, sandy loam to clay. Mean extractable Pb level in muck soils was greater than the mean Pb level in poorly drained, mineral soils.

Nickel

Ni levels in the NH_4OAc extracts of all soils were below detection limits (0.5 ppm). Ni was detected in the HCl and DTPA extracts of the muck soils but not in those of the mineral soils. HCl extracted more Ni from the muck soils than did DTPA (Table 6). Mean extractable Ni levels decreased with depth in the muck soils.

Table 3. Mean extractable cobalt levels (ppm) in profiles of soil management groups.

Dominant Profile Texture	Horizon	Well (a)			Somewhat poorly (b)			Poorly (c)		
		HCl	NH_4OAc	DTPA	HCl	NH_4OAc	DTPA	HCl	NH_4OAc	DTPA
Clay (1)	A	1.53	0	.46	3.07	2.81	1.16	0	0	0
	B	0	0	1.39	0	0	.23	0	0	0
	C	2.55	0	0	1.53	0	0	0	0	0
Clay Loam (1.5)	A	1.02	1.40	.58	0	.89	0	.71	.32	.70
	B	1.79	.25	1.04	0	0	0	0	.43	.30
	C	1.02	.51	.70	0	0	0	0	.32	0
Loam (2.5)	A	.64	.25	.25	1.63	.47	.27	1.38	0	.81
	B	.53	.10	.30	.13	0	.06	.83	0	.47
	C	1.00	0	.20	1.38	0	.16	1.25	0	.64
Sandy Loam (3)	A	.27	.76	.45	1.02	.51	1.16	0	0	1.63
	B	.27	0	.45	.51	.51	1.86	0	0	.47
	C	0	.27	.17	0	0	.70	0	0	.23
Loamy Sand (4)	A	.31	.45	.35	1.53	.92	.56	3.70	.77	.93
	B	0	0	.14	.61	0	0	1.66	0	0
	C	0	0	0	.92	.46	0	5.88	0	0
Sand (5)	A	0	0	0	1.15	0	1.05	.77	0	.87
	B	0	0	.52	0	.77	2.09	0	0	0
	C	0	0	.18	0	.58	.52	0	0	.18
Sandy Loam over Loam (3/2)	A				0	1.53	.70			
	B				0	0	0			
	C				0	0	0			
Loamy Sand over Loam to Clay (4/1,4/2)	A	2.30	0	0	3.15	0	.23			
	B	0	0	0	.51	0	0			
	C	2.30	0	0	1.53	0	0			
Sand over Loam to Clay Loam (5/2)	A	0	0	0						
	B	0	0	0						
	C	0	0	0						
Muck (M, M/m, M/3, M/4)	1							1.00	.92	3.49
	2							.66	.92	1.67
	3							.66	.46	1.67

Table 4. Ranges of HCl, NH_4OAc and DTPA extractable cobalt levels (ppm) in profiles of soil management groups.

Dominant Profile Texture	Horizon	HCl			NH_4OAc			DTPA		
		Well (a)	Somewhat Poorly (b)	Poorly (c)	Well (a)	Somewhat Poorly (b)	Poorly (c)	Well (a)	Somewhat Poorly (b)	Poorly (c)
Clay (1)	A	0 - 4.59	0 - 9.20	0	0	0 - 5.37	0	0 - 1.39	0 - 3.48	0
	B	0	0	0	0	0	0	0 - 2.79	0 - .69	0
	C	0 - 7.66	0 - 4.59	0	0	0	0	0	0	0
Clay Loam (1.5)	A	0 - 6.13	0	0 - 4.98	0 - 5.37	0 - 3.06	0 - 2.30	0 - 3.48	0	0 - 2.09
	B	0 - 10.74	0	0	0 - 1.53	0	0 - 2.30	0 - 4.18	0	0 - 1.39
	C	0 - 6.13	0	0	0 - 3.06	0	0 - 2.30	0 - 4.18	0	0
Loam (2.5)	A	0 - 4.98	0 - 6.64	0 - 9.97	0 - 3.83	0 - 3.06	0 - .53	0 - 1.39	0 - 2.09	0 - 2.79
	B	0 - 4.59	0 - 1.66	0 - 4.98	0 - 1.53	0 - 3.86	0	0 - 1.39	0 - .70	0 - 2.09
	C	0 - 8.30	0 - 4.98	0 - 9.97	0	0 - .26	0	0 - 2.79	0 - 2.09	0 - 4.18
Sandy Loam (3)	A	0 - 4.59	0 - 3.06	0	0 - 7.68	0 - 1.53	0	0 - 2.79	.70 - 1.39	0 - 2.79
	B	0 - 4.59	0 - 1.53	0	0	0 - 1.53	0	0 - 2.09	0 - 4.88	0 - .70
	C	0	0	0	0 - 4.60	0	0	0 - 1.39	0 - 2.09	0 - .70
Loamy Sand (4)	A	0 - 3.06	0 - 6.13	0 - 6.13	0 - 3.06	0 - 4.60	0 - 2.30	0 - 2.09	0 - 2.79	0 - 2.09
	B	0	0 - 3.06	0 - 4.98	0	0	0	0 - 1.39	0	0
	C	0	0 - 4.59	0 - 9.97	0	0 - 2.30	0	0	0	0
Sand (5)	A	0	0 - 4.59	0 - 3.06	0	0	0	0	0 - 2.79	0 - 2.09
	B	0	0	0	0	0 - 3.06	0	0 - 2.09	0 - 8.39	0
	C	0	0	0	0	0 - 2.30	0	0 - .70	0 - 2.09	0 - .70
Sandy Loam over Loam (3/2)	A		0			0 - 3.06			0 - 1.39	
	B		0			0			0	
	C		0			0			0	
Loamy Sand over Loam to Clay (4/1, 4/2)	A	0 - 4.59	0 - 6.13		0	0		0	0 - .70	
	B	0	0 - 1.53		0	0		0	0	
	C	0 - 4.59	0 - 4.59		0	0		0	0	
Sand over Loam to Clay Loam (5/2)	A	0			0			0 - 1.39		
	B	0			0			0		
	C	0			0			0		
Muck (M, M/m, M/3, M/4)	1			0 - 4.98			0 - 4.60			0 - 4.88
	2			0 - 3.32			0 - 3.06			0 - 3.48
	3			0 - 3.32			0 - 2.30			0 - 6.28

These low levels were not entirely unexpected because Vanselow (16) reported that exchangeable Ni levels were almost always much lower than 1 ppm. The zero extractable levels in all mineral soils were somewhat surprising because Ni has been reported in many soils.

Heavy Metals In C Horizons

Mean extractable Cd, Co and Pb levels in the C horizons (Table 7) were determined for the three glacial lobes in the study area (Fig. 1). Mean Cd levels in the three extractants were 0.09 ppm for the Saginaw lobe, 0.08 ppm for the Huron-Erie lobe and 0.02 ppm for the Lake Michigan lobe. Mean levels in each extractant differed slightly from this trend.

Mean Co levels in the three extractants were 0.55 ppm for the Lake Michigan lobe, 0.31 ppm for the Saginaw lobe and 0.14 ppm for the Huron-Erie lobe. This trend existed for the HCl and DTPA extracts but not for the NH_4OAc extract.

Mean Pb levels in the DTPA extract were 0.89 ppm for the Lake Michigan lobe, 0.59 ppm for the Saginaw lobe and 0.48 ppm for the Huron-Erie lobe. Pb was not detected in the HCl and NH_4OAc extracts.

While the means of the levels of the three heavy metals vary with the glacial lobe, the significance of these differences might not be great because the ranges were quite large and overlap that from lobe to lobe.

CONCLUSIONS

The three extractants 0.1**N** HCl, 1**N** NH_4OAc and 0.005 **M** DTPA extracted different amounts of Cd, Co, Pb and Ni from the samples. HCl extractable Cd levels tended to be higher in the poorly drained soils than in the well drained and somewhat poorly drained soils. Extractable Cd levels tended to be greater in the A horizons than in the B and C horizons and lower in the sandy soils than in the finer textured soils. Cr levels in all three extractants were too low to detect with the procedures used.

Table 5. **Mean and ranges of DTPA extractable lead levels (ppm) in profiles of soil management groups.**

Dominant Profile Texture	Horizon	Well (a)	Somewhat poorly (b)	Poorly (c)
Clay (1)	A	4.02 (1.64 - 6.59)	3.47 (2.18 - 4.39)	2.01 (0 - 4.94)
	B	2.01 (1.64 - 2.19)	1.09 (0 - 2.19)	.73 (0 - 2.19)
	C	.91 (0 - 1.64)	.36 (0 - 1.09)	.91 (0 - 2.74)
Clay Loam (1.5)	A	2.74 (1.09 - 5.49)	3.66 (2.74 - 5.49)	2.11 (1.09 - 3.84)
	B	1.28 (0 - 2.19)	1.46 (1.09 - 2.19)	1.25 (.55 - 2.74)
	C	.73 (0 - 1.09)	.18 (0 - 1.09)	.78 (0 - 1.09)
Loam (2.5)	A	1.80 (0 - 3.29)	2.23 (0 - 4.39)	1.78 (.55 - 3.29)
	B	1.25 (0 - 2.74)	1.83 (0 - 5.49)	.72 (0 - 2.19)
	C	.62 (0 - 1.64)	1.35 (0 - 3.84)	.32 (0 - 1.09)
Sandy Loam (3)	A	3.13 (1.09 - 4.94)	2.56 (1.09 - 5.49)	2.01 (1.09 - 3.84)
	B	1.48 (0 - 4.94)	1.82 (1.09 - 2.19)	.73 (0 - 1.64)
	C	.82 (0 - 3.84)	.37 (0 - .55)	.18 (0 - .55)
Loamy Sand (4)	A	1.64 (0 - 6.04)	1.86 (0 - 3.29)	1.64 (1.09 - 2.74)
	B	.65 (0 - 2.19)	1.20 (.55 - 1.64)	.55 (0 - 1.09)
	C	.22 (0 - 1.09)	0 (0)	0 (0)
Sand (5)	A	1.51 (0 - 3.29)	1.78 (0 - 3.29)	1.64 (0 - 3.84)
	B	.55 (0 - 1.09)	.96 (0 - 2.19)	.27 (0 - 1.09)
	C	0 (0)	.41 (0 - 1.09)	.27 (0 - 1.09)
Sandy Loam over Loam (3/2)	A		.55 (0 - 1.09)	
	B		0 (0)	
	C		0 (0)	
Loamy Sand over Loam to Clay (4/1, 4/2)	A	2.20 (1.64 - 2.74)	1.82 (1.09 - 3.29)	
	B	.82 (0 - 1.64)	.73 (0 - 2.19)	
	C	.28 (0 - .55)	0 (0)	
Sand over Loam to Clay Loam (5/2)	A	3.29 (2.19 - 4.39)		
	B	1.10 (.55 - 1.64)		
	C	0 (0)		
Muck (M, M/m, M/3, M/4)	1			2.74 (1.09 - 5.49)
	2			2.19 (.55 - 4.39)
	3			1.42 (0 - 3.84)

Table 6. Mean and ranges of HC1 and DTPA extractable nickel levels (ppm) in profiles of organic soil.

Horizon	NC1	DTPA
1	1.93 (0 - 9.64)	0.42 (0 - 2.1)
2	1.39 (0 - 6.94)	.36 (0 - 1.8)
3	0 (0)	.24 (0 - 1.2)

Table 7. Mean extractable cadmium, cobalt and lead levels (ppm) and ranges for C horizons of soils in the Lake Michigan, Saginaw, and Huron — Erie glacial lobes (Fig. 1).

Heavy Metal	Extractant	Glacial Lobe: Lake Michigan	Saginaw	Huron - Erie
Cd	HC1	0.03 (0 - 0.25)	.19 (0 - .99)	.12 (0 - .50)
	NH_4OAc	.02 (0 - .39)	.07 (0 - 1.32)	.07 (0 - 1.05)
	DTPA	.02 (0 - .40)	.01 (0 - .22)	.04 (0 - .44)
Co	HC1	1.17 (0 - 7.66)	.81 (0 - 9.97)	.25 (0 - 6.13)
	NH_4OAc	.15 (0 - 3.06)	.08 (0 - 4.60)	.18 (0 - 2.30)
	DTPA	.33 (0 - 4.18)	.23 (0 - 4.18)	0 (0)
Pb	HC1	0 (0)	0 (0)	0 (0)
	NH_4OAc	0 (0)	0 (0)	0 (0)
	DTPA	.89 (0 - 1.64)	.59 (0 - 3.84)	.48 (0 - 1.64)

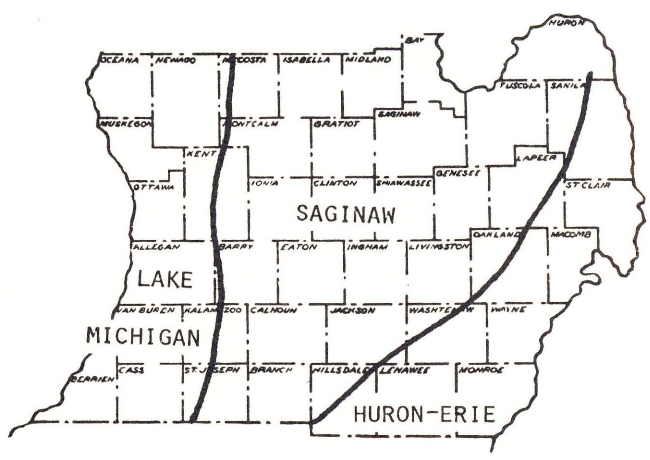

Fig. 1. Boundaries of the three glacial lobes in Southern Michigan.

Extractable Co levels tended to increase with depth in the soil profile and to be low in the sandy soils. Pb levels in the HCl and NH_4OAc extracts were also below detection limits. DTPA extractable Pb decreased with depth in the soil and was lower in sand soils than in finer textured soils. Ni levels in all three extracts of mineral soils were below detection limits, but HCl and DTPA extracted Ni from muck soils. Extractable Ni levels increased with depth in the muck soils. Extractable Cd, Co and Pb levels varied from glacial lobe to glacial lobe in the study area.

REFERENCES

1. Brewer, R.F. (1973). Lead. **In** H.D. Chapman (ed.) Diagnostic criteria for plants and soils. Quality Printing Co., Inc., Abilene, TX pp. 213-217.
2. Galloway, H.M. and L.W. Jacobs (1977). Sewage sludges — characteristics and management. **In** L.W. Jacobs (ed.) Utilizing municipal sewage wastewaters and sludges on land for agricultural production. N. Centr. Reg. Ext. Pub. No. 52, p. 3-17.
3. Jacobs, L.W. (1977). Sewage wastewaters — characteristics and management. **In** L.W. Jacobs (ed.) Utilizing municipal sewage wastewaters and sludges on land for agricultural production. N. Centr. Reg. Ext. Pub. No. 52, p. 18-29.
4. Kubota, J. and W.H. Allaway (1972). Geographic distribution of trace element problems. **In** J.J. Mortvedt, P.M. Giordano and W.L. Lindsay (eds.) Micronutrients in agriculture. Soil Sci. Soc. Am., Madison, WI pp. 525-554.
5. Lagerwerff, J.V. (1972). Lead, mercury and cadmium as environmental contaminants. **In** J.J. Mortvedt, P.M. Giordano and W.L. Lindsay (eds.) Micronutrients in agriculture. Soil Sci. Soc. Am., Madison, WI pp. 593-636.
6. Lindsay, W.L. and W.A. Norvell (1978). Development of a DTPA test for zinc, iron, manganese, and copper. Soil Sci. Soc. Am. J. 42:421-428.
7. Mokma, D.L. (1978). Soil management units and land use planning. Ext. Bull. E-1262, Michigan State Univ.
8. Mokma, D.L., L.S. Robertson and S. Jantawat (1976). Soil organic matter levels in corn fields as related to soil management groups. Agr. Exp. Sta. Res. Rept. 297, Michigan State Univ.
9. Mokma, D.L., L.S. Robertson and B.D. Knezek (1979). The cation exchange capacity of soils used for corn production in Michigan. Agr. Exp. Sta. Res. Rep. 369, Michigan State Univ.
10. Mokma, D.L., B.D. Knezek and L.S. Robertson (1979). Extractable micronutrient levels in the profiles of soil used for corn production. Agr. Exp. Sta. Res. Rep. 384, Michigan State Univ.
11. Pratt, F.P. (1973). Chromium. **In** H.D. Chapman (ed.) Diagnostic criteria for plants and soils. Quality Printing Co., Inc., Abilene, TX pp. 136-141.
12. Robertson, L.S., D.L. Mokma and D.D. Warncke (1975). Test levels in soil profiles of Michigan corn fields. Agr. Exp. Sta. Res. Rept. 281, Michigan State Univ.
13. Robertson, L.S., D.L. Mokma and D.D. Warncke (1975). Plant-available calcium, magnesium and sulfur levels in soils used for corn production in Michigan. Agr. Exp. Sta. Res. Rept. 286, Michigan State Univ.
14. Robertson, L.S., D.L. Mokma and B.D. Knezek (1975). An inventory of extractable boron in the profile of soils used for corn production in Michigan. Agr. Exp. Sta. Res. Rept. 287, Michigan State Univ.
15. Vanselow, A.P. (1973). Cobalt. **In** H.D. Chapman (ed.) Diagnostic criteria for plants and soils. Quality Printing Co., Inc., Abilene, TX pp. 142-156.
16. Vanselow, A.P. (1973). Nickel. **In** H.D. Chapman (ed.) Diagnostic criteria for plants and soils. Quality Printing Co., Inc., Abilene, TX pp. 302-309.

4—80—5M