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A Survey of the Content of Some Heavy Metals in Soil and Corn Grain in the Pond and Lower Green River Bottoms

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A Survey of the Content of Some Heavy Metals in Soil and Corn Grain in the Pond and Lower Green River Bottoms[1]

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Background

Corn is intensively grown along the Green and Pond Rivers in McLean, Hopkins, and Webster Counties, Kentucky, representing a major source of income to producers in those areas. However, producers in McLean County have experienced poorer corn production than expected for many years. This has been observed more on the Pond River bottoms and the Green River bottoms below the confluence of the Pond than upstream on the Green above the Pond. Some producers have speculated that their poor production may be associated with chemical pollution from the Pond River and/or nearby industrial sources. On this basis, an assumption was made that if chemical pollution did occur, it would be most noticeable in fields which commonly overflow with water originating upstream on the Green or Pond Rivers. Further, a second assumption was made that bottomland sites which less frequently overflow, would have lower concentrations of chemical pollutants.

This study was conducted by sampling carefully selected cornfields along these streams to test the hypothesis that accumulation of certain heavy metals, cadmium (Cd), chromium (Cr), lead (Pb), and nickel (Ni), which may possibly originate from extensive stripmining upstream along the Pond River or from industrial sources along the lower Green River, may be associated with poorer than expected corn yields.

The objectives of the study were: (1) To determine if the heavy metal content of soil from selected fields which overflow from the Green and Pond Rivers and from adjacent areas which do not overflow, differ, and (2) to measure the heavy metal content of corn grain which is grown at each of the soil sites.

Methods

Sixteen fields were selected for sampling in September, 1992, along the Green and Pond Rivers in McLean, and Hopkins Counties, using the criteria that: (1) the fields be planted to corn, (2) the fields be in such locations that floodwaters originate from the rivers rather than from back-up of tributary streams, (3) the fields be in areas not expected to be covered with floodwater except during major floods. No sites were sampled in Webster County because those fields in corn did not meet the criteria for selection. An initial attempt was made to confine sampling sites to Karnak and Karnak overwash phase soils (we initially assumed that only the Karnak overwash phase soils would undergo annual flooding). However there was no relationship between these two soil types and elevation. In several instances we located "high water" lines in fields by talking with owners, but in most instances we made an on-site judgement in locating the "high water" line.

To serve as a control against which to test the part of the hypothesis regarding origin of the heavy metals, we sampled two cornfields on the headwaters of the Pond River in Todd county (upstream on the Pond from

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the extensive strip mining in Muhlenberg County). Table 1 shows site locations and soil types.

Fields were located and sampled when corn was physiologically mature (mid-September), just ahead of farmer harvest of fields. Two sites were located in each field; a "high elevation" site which represented our best judgement of a part of the field which was rarely flooded, and a "low-elevation" site which represented our best judgment of a part of the field which commonly floods. At each of these two locations, we sampled both soil and corn from three areas (replications). The sampling technique used was that outlined in Kentucky Integrated Crop Management Manual For Field Crops (1). This involved measuring a row length equal to a thousandth of an acre, making a stalk count, and then estimating grain yields based on number of rows per ear and number of kernels per row for the second, sixth, and tenth ear within the measured row length. A 0-6 inch soil sample was taken at the base of the stalk from which each ear was sampled. Grain yields were estimated by averaging results from the three areas sampled at each sampling site.

The nine soil cores were composited, air-dried and ground for analysis. All nine corn ears collected from the three sampled areas at each sample site, were air dried. A composite grain sample was then collected by hand shelling (to eliminate metal contamination) two rows from each of the nine ears. This sampling procedure resulted in 16 "high elevation," 16 "low elevation," and two samples from the Pond River headwaters, for a total of 34 soil samples and 34 corn grain samples.

Soils were analyzed for pH, P, K, Ca, Mg, and Zn by the University of Kentucky College of Agriculture's Soil Test Laboratory. Elements were extracted by the Mehlich III procedure, and concentrations determined by inductive coupled plasma emission. For determination of Cadmium (Cd), chromium (Cr), lead (Pb) and nickel (Ni), soil and corn grain samples were sent to the A&L Laboratory in Memphis, TN. Metals were determined by atomic absorption on extracts following digestion with nitric-perchloric acid.

Results

Corn yield and soil test results for pH, P, K, Ca, Mg, and Zn are summarized in Table 2. These data were combined to see if there were yield differences due to either river location or elevation (Table 3). No relationship was found between yield and "elevation". The overall average, in fact, was the same for either "high" or "low" elevations. There was, however, a difference in average yields as related to river location. The lower Green river sites in both counties yielded considerably less corn than the upper Green River sites, and the Pond River sites yielded lower than either the upper Green or lower Green River sites.

Soil test data from the "high elevation" and low elevation" sites were also examined to determine if there were any differences which might be related to yield differences. Except for two sites in McLean County, it did not seem likely that differences in soil test levels would have affected yields. At McLean County site number 1, lower pH, P, K, and Zn levels on the "high elevation" location in the field could possibly explain why yields were lower than those from the "low elevation" location. Also, at site number 4 in McLean County, lower levels of Mg and lower pH on the "high elevation" could possibly explain why yields were lower than from the "low elevation" location. The only other observation of note regarding soil test levels was the exceptionally high (by Kentucky standards) Mg soil test levels at sites 3, 5, 6, 8, 9 in McLean County and sites 3, 5, 6, 7 in Hopkins. In all instances, these high Mg levels are from Karnak soils, which have high clay contents with a clay mineralogy predominantly montmorillonitic. These soils have much higher cation exchange capacities than those of typical Kentucky soils.

Heavy metal content of soils and corn grain, soil pH, and yield of corn for all sites are summarized in Table 4. There was no relationship between heavy metal content of soil or grain between "high elevation" and "low elevation" locations except at site 1 in McLean County, where Cd content of corn was twice as high from the "low" site as from the "high" site. However, there was little difference between the two sites in soil Cd. Soil type at both locations was Melvin silt loam. Corn Cd levels at sites 1 and 2 in McLean County, were largely responsible for the higher averages in grain Cd in the lower Green River samples than in grain from the other river locations (Table 5). Most of the highest levels of soil Cd were from Karnak soils and most sites had Cd values near or above the upper end of the normal range of soil Cd for U.S. soils. Content of soil Cd from the upper Pond River control sites in Todd County was lower than that of the Karnak soils, but about the same as that for other soils. Even so, the upper Pond soil Cd values are in the upper end of the normal range. There was no relationship between content of Cd in the soil and content of Cd in corn grain. And, neither content of soil Cd nor content of corn grain Cd was related to soil pH.

Soil contents of Cr, Pb, and Ni were well within the normal range of contents for U.S. soils (Table 5). Content of soil Pb had no influence on corn content of Pb (Table 4). And, soil content of Cr and Ni also had no effect on corn grain content.

Discussion

The data collected do not support our initial hypothesis that there would be higher heavy metal content in soils from areas which frequently overflow as compared to sites which rarely overflow. This probably indicates that strip mining along the Pond River upstream from McLean and Hopkins Counties has not influenced heavy metal content of fields which commonly flood. Except for Cd, soil contents of Cr, Pb, and Ni were well within the normal range for U.S. soils (2).

In general, soil Cd was near or exceeded the upper end of the normal range for soils. This was also true for the two Todd County sites on the headwaters of the Pond River. We do not know what implication this has, but based on our limited data, we assume that the "natural content" of Cd is in the range of 10 to 12 ppm on the Karnak soils and 5 to 9 ppm on the other soils we sampled. Despite the fact that these soil Cd levels are near or above the normal range reported by Allaway (2), there was no relationship between level of soil Cd and Cd content in corn grain. As a matter of fact, the highest corn grain Cd levels measured (samples M-1, M-2, M-3, and M-4), came from soils measuring lower in Cd than that from several other sites. Based on the scant Cd information contained in two references (3) (4), we do not feel Cd content of corn grain grown in these areas poses any threat to human or animal health.

Summary

While our results do support the local observation that lower than expected corn yields occur along the Pond and lower Green Rivers, they do not provide the reason for this. There was a tendency for the Karnak soils to yield less than other soils, but due to the nature of this study, no conclusions can be drawn in this regard. We would note, however, that due to the physical characteristics of Karnak soils, they are more difficult to manage in terms of tillage, timely planting, and nitrogen fertilization than many of the other soils in the area.

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Table 1. Location and Soil Types of Sampling Sites

Sample No	County	River	Elevation[1/]	Soil Type[2/]
M-1	McLean	Lower Green	Lo	Melvin sil
M-2	McLean	Lower Green	Hi	Melvin sil
M-3	McLean	Lower Green	Hi	Elk sil
M-4	McLean	Lower Green	Lo	Melvin sil
M-5	McLean	Lower Green	Lo	Karnak sic
M-6	McLean	Lower Green	Hi	Karnak sil, overwash
M-7	McLean	Upper Green	Lo	Melvin sil
M-8	McLean	Upper Green	Hi	Otwell sil
M-9	McLean	Upper Green	Hi	Karnak sil, overwash
M-10	McLean	Upper Green	Lo	Karnak sic
M-11	McLean	Upper Green	Hi	Karnak sic
M-12	McLean	Upper Green	Lo	Karnak sil, overwash
M-13	McLean	Pond	Lo	Melvin sil
M-14	McLean	Pond	Hi	Otwell sil
M-15	McLean	Pond	Lo	Karnak sic
M-16	McLean	Pond	Hi	Karnak sic
M-17	McLean	Pond	Hi	Karnak sic
M-18	McLean	Pond	Lo	Karnak sic
H-1	Hopkins	Lower Green	Hi	Steff sil
H-2	Hopkins	Lower Green	Lo	Cuba sil
H-3	Hopkins	Lower Green	Hi	Otwell sil
H-4	Hopkins	Lower Green	Lo	Stendal sil
H-5	Hopkins	Pond	Hi	Otwell sil
H-6	Hopkins	Pond	Lo	Karnak sil, overwash
H-7	Hopkins	Pond	Hi	Karnak sic
H-8	Hopkins	Pond	Lo	Karnak sic
H-9	Hopkins	Pond	Lo	Karnak sic
H-10	Hopkins	Pond	Hi	Karnak sil, overwash
H-11	Hopkins	Pond	Hi	Karnak sic
H-12	Hopkins	Pond	Lo	Karnak sic
H-13	Hopkins	Pond	Lo	Karnak sic
H-14	Hopkins	Pond	Hi	Karnak sic
T-1	Todd	Upper Pond	Lo	Newark sil
T-2	Todd	Upper Pond	Lo	Newark sil

[1/] Lo is area in field which was assumed to frequently overflow; Hi is area in field assumed to be above high water line except during unusual floods.

[2/] As identified in USDA-SCS published Soil Survey Reports for these 3 counties.

Table 2. Soil Test Levels For Corn Sampling Sites in The Green and Pond River Bottoms in 1992

Sample No	Soil pH	P	K	Ca	Mg	Zn	Corn Yield (bu/A)
		lbs/A					
M-1	6.4	83	313	3390	210	5.1	159
M-2	5.2	33	167	2930	311	1.9	134
M-3	6.8	46	139	3620	170	2.5	134
M-4	6.0	41	196	4090	434	2.3	118
M-5	6.3	125	500+	6990	899	3.2	156
M-6	6.3	85	477	7210	992	2.5	141
M-7	5.2	121	151	1980	280	3.3	160
M-8	4.8	71	223	1050	88	2.3	148
M-9	5.9	127	279	3060	437	2.5	174
M-10	6.1	117	304	4090	683	4.1	160
M-11	6.7	150	305	4030	481	3.3	144
M-12	6.5	111	276	3350	347	3.4	150
M-13	6.0	73	152	2390	241	2.1	131
M-14	5.8	63	219	2550	309	2.9	124
M-15	6.2	106	321	4610	783	2.9	150
M-16	6.7	91	391	5530	1018	3.2	150
M-17	6.8	63	335	5690	1140	3.7	126
M-18	6.8	54	364	6180	1261	2.9	139
H-1	6.9	50	200	3450	109	2.2	160
H-2	6.6	57	203	2820	154	3.8	157
H-3	6.6	113	247	3300	173	1.3	132
H-4	6.7	90	234	2890	195	1.6	139
H-5	5.4	93	282	1900	127	2.7	135
H-6	6.0	37	231	3660	536	2.9	110
H-7	5.2	75	341	2340	299	3.0	107
H-8	5.1	66	309	2090	332	3.6	135
H-9	6.6	67	329	5820	1157	3.3	123
H-10	6.4	50	318	4370	591	3.0	131
H-11	5.8	67	383	2900	303	6.1	152
H-12	6.7	42	234	4400	525	3.6	127
H-13	6.0	97	427	4300	745	4.0	109
H-14	6.0	115	379	4200	656	4.1	134
T-1	5.9	18	175	3930	225	2.3	120
T-2	7.3	45	181	4390	241	4.3	102

Table 3. McLean and Hopkins Co. Survey, 1992

Av. Corn Yields (bu/A) By River Site and By Elevation

River Site	"High" Elevation	"Low" Elevation	Av/River Site
Upper Green (3 sites)	157	155	156
Pond (8 sites)	132	128	130
Lower Green (5 sites)	140	146	143
Av. by "Elevation"	139	139	

Table 5. Summary Of Heavy Metal Content Of Soils And Corn Grain Samples Taken In Hopkins, McLean, And Todd Cos. 1992

	Soil Samples				Corn Grain Samples			
	- - - - - - - - - - - - - ppm - - - - - - - - - - -							
River	Cd	Cr	Pb	Ni	Cd	Cr	Pb	Ni
Upper Green (6 samples)	6.1	21	32	16	.13	.94	<3	.85
Pond (16 samples)	9.4	25	50	23	.13	.86	<3	.91
Lower Green (10 samples)	7.9	24	48	22	.26	.91	<3	.89
Upper Pond (2 samples)	6.7	22	40	21	.12	.60	<3	1.05
Normal Range for U.S. Soils[1/]	.01 to 7.0	5 to 3000	2 to 200	5 to 500				

[1/]Alloway, W.H. 1968. Agronomic controls over the environmental cycling of trace metals. Adv. in Agron. 20:235-271.

Table 4. Heavy Metal Content of Soil and Corn Grain, Soil pH, and Corn Grain Yields in Samples Taken From The Green and Pond River Bottoms in 1992

Sample No	Cd (ppm) soil	Cd (ppm) grain	Cr (ppm) soil	Cr (ppm) grain	Pb (ppm) soil	Pb (ppm) grain	Ni (ppm) soil	Ni (ppm) grain	Soil pH	Corn Yield (bu/A)
M-1	8.44	.95	25.1	1.5	53	<3	28.7	1.4	6.4	159
M-2	8.89	.46	27.4	1.1	52	<3	16.6	1.3	5.2	134
M-3	6.98	.35	21.3	1.0	36	<3	15.2	1.0	6.8	134
M-4	6.79	.23	24.1	0.9	37	<3	15.1	1.1	6.0	118
M-5	10.90	.18	26.9	0.9	59	<3	29.7	0.9	6.3	156
M-6	10.70	.17	34.9	1.0	58	<3	29.2	1.0	6.3	141
M-7	4.52	.14	17.1	0.9	29	<3	11.8	0.8	5.2	160
M-8	4.88	.14	17.0	0.9	26	<3	18.0	0.8	4.8	148
M-9	5.87	.12	20.9	0.8	28	<3	15.1	0.8	5.9	174
M-10	7.35	.13	24.6	1.2	37	<3	19.4	0.7	6.1	160
M-11	7.24	.14	23.3	0.9	36	<3	17.4	1.0	6.7	144
M-12	6.44	.12	20.6	0.9	33	<3	16.0	1.0	6.5	150
M-13	6.22	.09	19.3	0.8	35	<3	17.3	1.1	6.0	131
M-14	6.26	.11	18.9	1.0	37	<3	17.4	1.0	5.8	124
M-15	10.19	.11	26.6	2.2	48	<3	23.8	1.7	6.2	150
M-16	10.12	.10	31.0	1.0	57	<3	27.2	0.9	6.7	150
M-17	10.15	.08	27.1	0.7	55	<3	26.2	0.7	6.8	126
M-18	11.21	.09	30.9	0.8	60	<3	29.8	0.8	6.8	139
H-1	6.25	.07	20.3	0.7	46	<3	28.4	0.5	6.9	160
H-2	6.18	.06	21.2	0.7	45	<3	26.5	0.6	6.6	157
H-3	7.59	.07	20.9	0.7	44	<3	16.3	0.6	6.6	132
H-4	6.68	.05	20.6	0.7	45	<3	15.5	0.6	6.7	139
H-5	7.19	.04	20.7	0.6	45	<3	16.7	0.7	5.4	135
H-6	8.52	.08	22.8	0.7	48	<3	19.4	0.9	6.0	110
H-7	7.67	.08	21.0	0.7	47	<3	14.6	0.8	5.2	107
H-8	8.16	.29	21.7	1.0	46	<3	15.7	1.2	5.1	135
H-9	11.30	.27	32.8	0.9	64	<3	27.8	0.7	6.6	123
H-10	8.51	.23	24.1	0.7	43	<3	20.7	0.7	6.4	131
H-11	9.95	.16	24.7	0.6	50	<3	25.9	0.9	5.8	152
H-12	10.89	.12	27.3	0.7	52	<3	24.1	0.6	6.7	127
H-13	11.73	.14	28.6	0.7	55	<3	28.5	1.0	6.0	109
H-14	11.03	.10	27.8	0.6	51	<3	27.2	0.8	6.0	134
T-1	7.44	.10	24.5	0.6	45	<3	23.4	0.9	5.9	120
T-2	5.92	.14	20.0	0.6	34	<3	19.1	1.2	7.3	102