WATER AND SOIL PARAMETERS AFFECTING GROWTH OF CATTAILS; PILOT STUDIES IN WEST VIRGINIA MINES[1]

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Abstract.--Although it has been shown that cattail-dominated wetlands reduce manganese and iron content of acid mine drainage, little is known about the effects water and soil parameters have on the growth of cattails (Typha latifolia). Knowledge of such parameters for vegetation growth is essential for planned construction of wetlands. Three pilot studies were done to: (a) survey water quality where cattails grow naturally, (b) compare water and soil parameters from sites where cattails were found to immediately adjacent spots where no cattails were found, and (c) determine the effects of wetland vegetation on total iron and manganese concentrations and removal in water as compared to an identical site with no vegetation. In June 1986 water quality parameters were measured at 26 sites with cattails and 30 nearby sites without cattails in northern West Virginia Water pH was below 2.5 at six cattail sites and below 2.0 at one site. Only three cattail sites had water with over 100 ppm total iron. Comparison of 10 of the above-mentioned locations, without any vegetative growth, and seven adjacent spots with cattails showed that only total iron in water was significantly lower in cattail versus non-cattail sites. Data also suggest that lower pH and higher aluminum content present problems for cattail survival and germination. To determine the effects of wetland vegetation on iron and manganese removal two watertight boxes (16 ft by 4 ft by 1 ft) were constructed side-by-side in a cattail marsh. Sediment was placed in both boxes and 228 cattails were transplanted to one on June 17, 1986 Water entering each box at a flow of 1 gal/min had total iron concentrations of approximately 20-25 ppm and Mn concentrations of 15-20 ppm. Adult cattails died, but new sucker growth yielded 261 cattails by August 1986. There were 194, 293, and 295 cattails in April, May, and June 1987, respectively. From October 1986 through May 1987, there was an average decrease of 3.14 ppm in total iron in cattails and 0.04 ppm in the control box. During the same period there was no significant decrease in manganese in the cattail box (average decrease of 1.9 ppm), or the control. There were no changes in pH in either box during the study. From the results of these three studies, it appears that cattails, and perhaps any wetland vegetation, play some role in providing an ecological system which functions to remove iron.

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INTRODUCTION

Cattail-dominated wetlands have been shown to reduce manganese (Kleinmann et al. 1985), and iron (Kleinmann 1985, Brodie et al. 1985). Another reason for utilizing cattails in manmade wetlands is because survival is high. Fulton et al. (1983) found that cattail survival after transplanting by various procedures was higher (survival was 78%) than 11 other wetland species.

These pilot studies were precipitated by discussions with consultants building wetlands for industry to improve water quality. Little, if anything, is known about the various water quality or soil chemical properties that may limit the growth of wetland plants, including cattails. This information is needed so that these limitations to growth can be overcome when building wetlands to treat acid mine drainage. While conducting other field studies, we noted other sites where cattails were growing immediately adjacent to, and in the same substrate and seep as, areas where no cattails were growing. Therefore, the following three pilot studies were done to: (a) survey water quality where cattails grow naturally; (b)compare water and soil parameters from sites where cattails were found to immediately adjacent spots where no cattails were found; and (c) determine the effects of wetland vegetation on total iron and manganese concentrations and removal in water as compared to an identical site with no vegetation.

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MATERIALS AND METHODS

Between June 19 and June 26, 1986, water samples were taken at 56 sites near Morgantown. Sites were selected which had cattails growing. If an adjacent site appeared to have the same flow of water and the same substrate, but no cattails growing, then it was sampled. In addition, other isolated sites with no cattails that appeared to have good water flow and a mud substrate were sampled. Water temperature was measured at each site to the nearest 0.5^{o}C. Readings were made within 1 second of removing the thermometer from the water. Water temperature was used in standardizing pH and conductivity meters.

Electrical conductivity was measured with an 18-volt Fisher conductivity meter, Model No. 152. A Fisher mini pH meter, Model No. 640, was used to measure water pH. Prior to each pH measurement the meter was standardized to Ph 4 and pH 7 buffers which had been allowed to equilibrate at water temperature. The combination electrode was cleaned with distilled water between each buffer and each water measurement. Water flow velocity and depth were measured for flow rate calculations to be made at a later time.

Two water samples were collected in 250-mL nalgene bottles at each sampling point. One of these samples was filtered through pre-weighted metrical membrane filters, pore size 0.45 um. Both samples were treated with 1 mL of 50% nitric acid to fix metals. A third unfiltered, unacidified water sample was collected in 1-L plastic cubitainers.

In the laboratory, unfiltered, acidified water samples were used to determine concentrations of total iron and manganese cations, and of Ca^{+2}, Mg^{+2}, Na^{+1}, and K^{+1}. Filtered, acidified samples were used to determine dissolved iron and manganese levels. Cation concentrations were determined by atomic absorption spectro-photometry by ASTM Method D2576 (ASTM 1976a).

In the course of collecting information for the first objective of this study, four sites of interest were noted. These sites had dense stand of cattails growing naturally, but there were small spots, either adjacent to or within the wetlands, that had no cattails. On September 3, 1986, soil and water samples were taken at 17 locations within these four sites. Methods of water analysis were identical to those outlined above. Sediment samples were taken from the same points as water samples, usually in the middle of the cattails wetland or in the nonvegetated areas. Sediment samples were collected with an auger to a depth of 10 cm from the soil-water interface and transferred to plastic bags. In the laboratory, cations were extracted by the double-acid method of Baker and Amacher (1982) and determined by atomic absorption spectrophotometry. Phosphorous was extracted by the method of Boltz and Howell (1978) and measured on a UV-VIS spectrophotometer.

To study the effects of wetland vegetation on iron and manganese removal, two plywood boxes were constructed in the middle of a cattail marsh in Greene County, PA on June 17, 1986. The marsh is approximately 4 acres in size and had an average water pH of 2.85, total iron of 25 ppm, and total manganese of 16 ppm (based on samples taken, three locations in three seasons).

The boxes were 16 ft by 4 ft by 1 ft in size, and were imbedded 1 ft deep in the marsh, adjacent to each other. They were placed so that there was a slight flow of water from one end to the other. Inflow pipes allowed flow of about 1 gal/min. Sediment from the marsh was placed into the

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boxes as substrate. In one box adult cattail plants were carefully transplanted at the same density found in the marsh (3.5/ ft^2) making a total of 228 cattails. The other box remained devoid of all vegetation. Water samples were taken at the inflow and outlfow of each box on June 20 and approximately every month thereafter for a year (sampling in December 1986 and February 1987 was not possible due to weather conditions). Counts of cattail density were made periodically as well. Sediment samples were taken in July 1987.

RESULTS AND DISCUSSION

Where cattails grow.--Water at cattail sites had a wider range of pH than water at non-cattail sites (fig. 1).

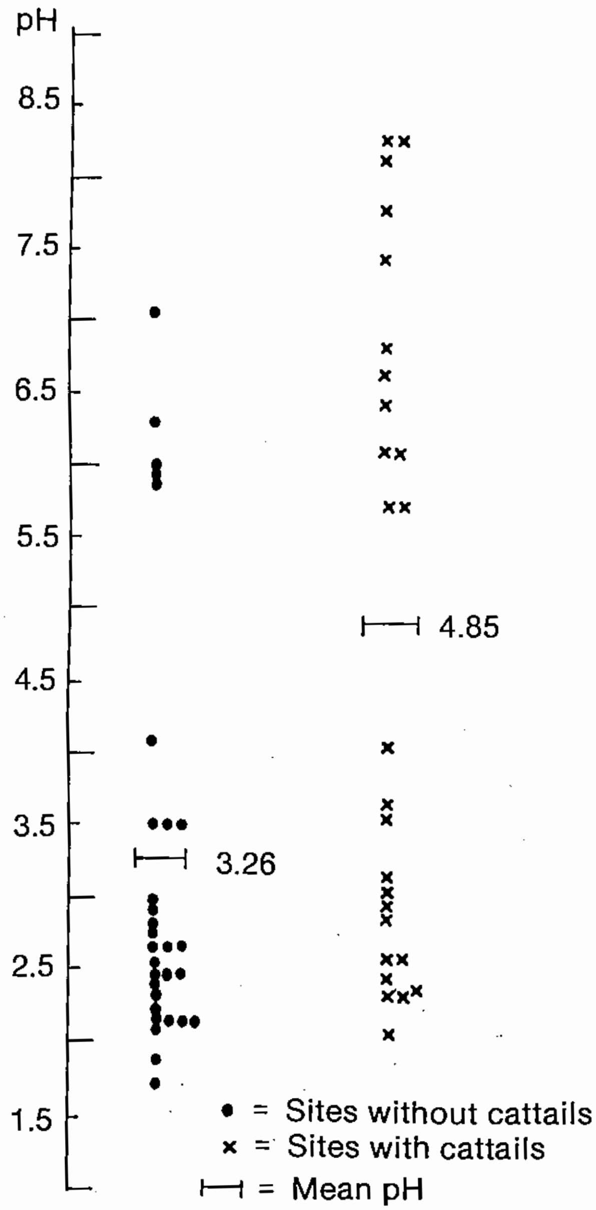

Figure 1.--pH levels of water samples taken at 56 sites in northern West Virginia.

Cattail sites had a mean pH of 4.85, while non-cattail sites had a mean pH of 3.26. A wetland consultant (B. Pesavento, personal communication) indicated that only rarely were cattails found in water with pH below 2.5 or an iron concentration above 100 ppm. Forty-two percent (11/26) of the cattail sites in this study had a water pH below the 3.26 mean, with six sites below pH 2.5 and one below 2.0. This suggests that cattails will tolerate lower pH, and pH alone may not be a limiting factor for the establishment of this plant.

There appears to be a relationship between iron concentrations and the presence or absence of cattails (fig. 2). More often sites with lower concentrations of total iron in water had cattails; 57% (15/26) of the cattail sites had iron levels below 25 ppm, as compred with 13% (4/30) of the non-cattail sites. In contrast 36.7% (11/30) of the non-cattail sites had iron concentrations over 101 ppm (table 1).

There were only three cattail sites with iron concentrations of over 100 ppm, with the highest being 144 ppm (table 1). On that site only scattered cattails were found. A second site with 113 ppm iron had only four scattered cattail plants while another site with 113 ppm iron had a dense stand of cattails.

There may well be a combination of factors that affect cattail growth. When the sites without cattails were ranked by increasing water pH (table 2), there was higher total iron at the lower pH levels. There were nine sites with pH less than 2.3 (fig. 1). The average total iron for the eight non-cattail sites with pH below 2.30 was 233.7 ppm while average total iron for eight non-cattail sites with pH above 3.51 was 73.5 ppm (table 2). Iron levels of sites with pH between 2.30 and 3.51 were highly variable (table 2). When the low pH sites with no cattails were compared to the low pH sites with cattails, it was noted that iron levels were lower in the cattail sites (table 2). Seventeen of 26 sites with cattails had pH above 3.00, and only three of those had iron levels of 73 ppm or above (table 2). Average total iron for the 12 cattail sites with pH above 4.02 was only 27.9 ppm (table 2).

No other measured water quality parameters (Mn, K, Na, Ca, Mg) showed any notable trends between sites with and without cattails.

PAIRED SITES

Water and soil samples were taken on a paired basis when possible (i.e., one sample from a cattail site and another sample from an adjacent spot without cattails) to test for additional differences associated with cattails. Only total iron in water samples was significantly different (Wilcoxon's sign rank $p < 0.055$) between sites with

Table 1.--Sites with and without cattails ranked by Fe concentration in water. All values are in ppm units except for pH.

Without Cattails			With Cattails		
Fe	pH	Mn	Fe	pH	Mn
747.00	2.07	34.00	144.00	5.70	7.30
537.00	1.84	11.30	113.00	2.85	3.56
211.30	2.91	9.30	113.00	2.85	3.56
169.00	2.36	2.85	91.77	2.05	10.08
152.00	3.51	3.78	91.00	2.30	15.10
153.70	2.15	9.12	90.00	5.70	6.90
133.00	2.14	3.03	73.00	6.78	10.30
123.00	5.90	5.50	70.00	2.30	3.55
122.00	2.98	1.11	59.10	2.36	6.60
116.60	3.57	13.09	32.00	4.02	14.50
103.00	2.45	2.28	28.16	2.42	16.94
93.00	1.70	7.40	14.90	3.67	4.10
89.67	2.13	14.63	12.06	2.54	18.92
88.62	2.20	9.90	10.60	3.12	51.80
86.00	5.87	5.56	9.80	6.10	2.30
85.00	4.11	15.10	8.10	6.41	1.46
78.00	3.54	4.22	7.06	2.55	
63.50	2.79	7.70	4.98	3.56	15.80
63.00	6.32	1.76	4.43	8.25	0.42
60.00	2.33	6.30	3.45	3.03	5.40
47.63	2.66	6.36	2.14	8.10	0.24
39.00	5.99	7.80	1.44	6.10	0.34
38.60	2.54	11.10	1.05	7.40	0.12
30.80	2.43	4.19	0.39	6.63	2.41
27.94	2.19	17.05	0.14	8.25	0.01
25.20	2.47	7.40			
24.40	2.66	15.20			
23.00	2.81	21.90	0.02	7.78	0.04
23.00	2.65	24.90			
0.38	7.06	2.41			

cattails (53.8 ppm mean iron) and adjacent sites without cattails (98.2 ppm mean iron) (table 3). For soil samples, significant differences occurred for Ca (p 0.062) and Mn (p 0.062), with higher levels of both elements present in sites with cattails (table 3). These differences were affected by the small sample sizes and great variation in samples. For example, the high soil Mn level found in cattail sites was due to one site's having 184 ppm and a second having 57.6 ppm of Mn. No other cattail site soil samples contained more than 12.2 ppm Mn. One cattail site had 228 ppm K, but no other sites were higher than 21.2 ppm. Ca levels in soil samples from cattail sites seemed inflated as well, due to two samples of 1074 and 752.

B. Pesavento (personal communication) suggested that aluminum may be toxic to cattails with low water pH. Aluminum was not measured in water samples, but it was in soil samples. The ratio of the average pH/Al for 10 soil samples from non-cattail sites was .143, while the same ratio from 7 cattail sites was .240. Thus, it appears that lower pH and higher Al of the soil may present problems for cattail germination or survival.

It is obvious from table 3 that no one soil or water parameter exhibits low or high levels when cattails are present compared to when they are absent in the adjacent sites. At several adjacent sites (one with and one without cattails), it was noted that both had high pH and low iron concentrations in both soil and water samples. Other parameters such as soil Al were similar. One pair of samples showed low water pH (2.8-3.0), and high iron (120-150 ppm) in the water, and similarly had low soil pH and high soil iron levels. Yet cattails thrived in one place and were totally absent -- as was all vegetation -- immediately adjacent. In fact, there was a distinct demarcation between the area with

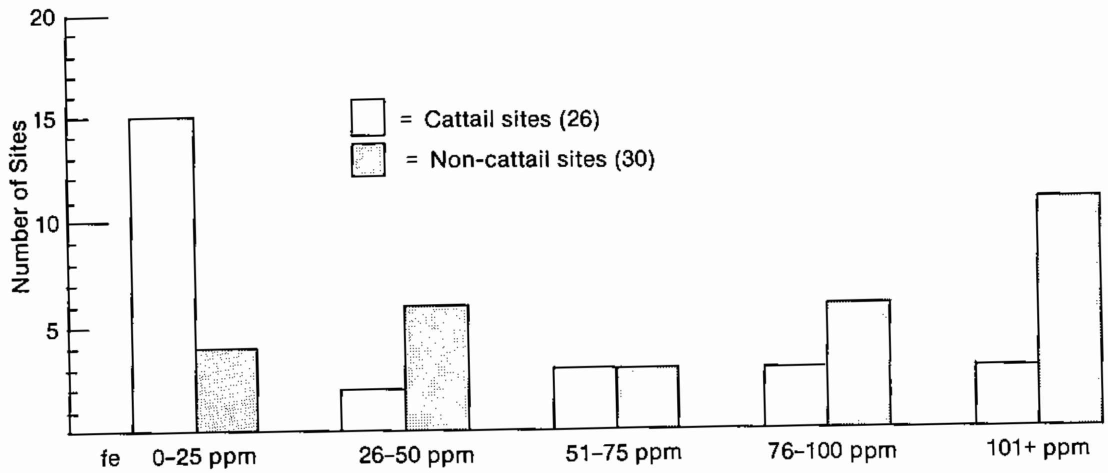

Figure 2.--Iron concentrations in water samples taken at 56 sites in northern West Virginia.

Table 2.--Sites with and without cattails ranked by pH value. All values are in ppm units except for pH.

Without Cattails			With Cattails		
pH	Fe	Mn	pH	Fe	Mn
1.70	93.00	7.40	2.05	91.77	10.08
1.84	537.00	11.30	2.30	91.00	15.10
2.07	747.00	34.00	2.30	70.00	3.55
2.13	89.67	14.63	2.36	59.10	6.60
2.14	133.00	3.03	2.42	28.16	16.94
2.15	153.70	9.12	2.54	12.06	18.92
2.19	27.94	17.05	2.55	7.06	
2.20	88.62	9.90	2.85	113.00	3.56
2.33	60.00	6.30	2.93	113.00	4.92
2.36	169.00	2.86	3.03	3.45	5.40
2.43	30.80	4.19	3.12	110.60	51.80
2.45	103.00	2.28	3.56	4.98	15.80
2.47	25.20	7.40	3.67	14.90	4.10
2.54	38.60	11.10	4.02	32.00	14.50
2.65	23.00	24.90	5.70	144.00	7.30
2.66	47.63	6.36	5.70	90.00	6.90
2.66	24.40	15.20	6.10	9.80	2.30
2.79	63.50	7.70	6.10	1.44	0.34
2.81	23.00	21.90	6.41	8.10	1.46
2.91	211.30	9.30	6.63	0.39	2.41
2.98	122.00	1.11	6.78	73.00	10.30
3.51	152.00	3.78	7.40	1.05	0.12
3.54	78.00	4.22	7.78	0.02	0.04
3.57	116.60	13.09	8.10	2.14	0.24
4.11	85.00	15.10	8.25	4.43	0.42
5.87	68.00	5.56	8.25	0.14	0.01
5.90	123.00	5.50			
5.99	39.00	7.80			
6.32	63.00	1.76			
7.06	0.38	2.41			

Table 3. Mean water and soil quality parameters (ppm) for ten sites without cattails and seven adjacent sites with cattails.

	Water Analysis		Soil Analysis	
	Cattail Sites	Non-cattail Sites	Cattail Sites	Non-cattail sites
pH	3.94	3.87	4.54	3.87
Fe	53.8	98.2	133.6	93.0
Mn	6.3	6.2	43.6	4.4
K	8.7	7.7	49.0	8.9
Na	18.4	15.8	NS	NS
Ca	201.5	190.1	439.1	123.0
Mg	76.2	68.1	17.5	10.0
Al	NS	NS	17.9	25.7
Po	NS	NS	5.9	3.8
Zn	NS	NS	19.8	1.6
Cu	NS	NS	0.5	0.4

NS — Not sampled.

cattails and that with none, within the same seep. This was found at several locations even though no individual paired water or soil parameters were significantly different.

CATTAIL AND CONTROL BOXES

There has been speculation both in academic settings and in the literature, about the role of wetland plants in the complex process of removing iron and manganese from acid mine drainage. Cattail plants remove some iron from the environment (Snyder and Aharrah 1984), and it is known that complex bacterial reactions also lead to removal of certain metals from water. Some (e.g., B. Pesavento, personal communication) believe that the species of wetland plants is of little consequence in improving water quality and that the entire wetland ecosystem provides the ecological basis for removal of iron and manganese. Thus, the plants and the soil provide the environment for algae and bacteria to remove metals through complex oxidation and reduction reactions.

There were 228 cattails initially planted in the 64-ft^2 box on June 17, 1986. Three months later, many of the adult plants had died, but new sucker growth resulted in 261 cattail plants present. Counts were also made the first week of April, May, and June 1987, yielding 194, 293, and 295 cattails, respectively. There was an increase in plant density from 3.56 cattails ft^2 to 4.61 cattails ft^2 in one year.

Monthly water samples were compared for two periods. The first sample was taken two days after construction of the boxes and placement of substrate and cattails. Other samples in this first period were taken in July, August, and September 1986. In late September, an abandoned surface mine located above the wetland was opened and water was treated. This caused an increase in pH, and a decrease in iron and manganese entering the inflow of the cattail and control box. Thus, a second period was established for data analysis beginning in early October 1986, and running until May 1987. There was no significant change in iron or manganese during the first period (June-September 1986) for either the cattail box or the control box (table 4).

For the second period (October 1986-May 1987), there was no significant average decrease in the difference ($p > 0.05$) between the inflow and outflow for iron in the cattail box (decrease of 3.14 ppm iron) or the control box (decrease of 0.04 ppm iron).

Excluding the first sample, which was taken two days after the wetland was constructed, the cattail site showed a reduction in iron from inflow to outflow in eight of nine samples taken (average monthly decrease of 3.46 ppm). Excluding the first

Table 4. Average inflow and outflow levels (ppm) of iron and manganese in a 16-ft by 4-ft system with a flow of 1 gal/min. One system had cattails and one had no cattails. In analysis, there were two periods*: first, June 20-Sept. 16, 1986 (four samples**); second, Oct. 6, 1986-May 21, 1987 (six samples).

	IRON		MANGANESE	
First Period:	Inflow	Outflow	Inflow	Outflow
Cattails	19.53	17.70	19.15	20.23
No Cattails	20.67	18.90	18.57	20.37
Second Period:				
Cattails	7.77	4.63	12.98	11.08
No Cattails	5.42	5.38	12.08	12.32

* In late September a mine became active above this wetland, and water was treated, which raised the pH and lowered the iron and manganese. Thus, data are separated.

**First sample in this period was taken two days after the wetland was constructed.

sample, the control site showed a reduction in iron from inflow to outflow in four of nine samples (average decrease of 1.43 ppm).

During the first period, manganese increased an average of 1.08 ppm for the cattail wetland and 1.80 ppm for the control from inflow to outflow. During the second period (six samples taken) manganese increased at the outflow (average of 0.24 ppm) in the control but decreased (insignificant average of 1.90 ppm at .05 level) at the outflow of the cattail wetland. The pH range at the inflow was 2.85 to 3.26 for the first period and 3.65 to 6.87 for the second, with no significant difference in the average monthly change for the cattail box or the control at the outfall.

Though preliminary, it appears that cattails aid removal of iron. After the cattails had been planted and were growing for 3 months, there was an average monthly decrease in iron from inflow to outflow of 3.14 ppm. Since only 0.04 ppm was removed during this same time in the control, which contained sediment only, the plants must play some role in providing an ecological system which functions to remove iron.

Soil samples were taken at the inflow and the outflow of the cattail and control boxes in August 1987 (table 5). Highest levels of soil iron were found at the outflow of the cattail box. Levels of soil iron were considerably higher in soils found in the box with cattails than the box with sediment and no cattails.

CONCLUSIONS

While its true that iron levels on cattail sites might be lower due to the plants removing iron, chances are that the plants germinate and grow better in areas of lower iron and higher pH.

The paired sites were interesting because of the abrupt demarcation within the wetland. Bare spots with no vegetation were found in the middle of heavy growth of cattails. In some of these paired sites the soil and water iron and pH levels were almost identical yet cattails grew in one site and not the other. How the various levels of metals in the soil and water affect plant germination will require an intensive laboratory study. Even then interactions between various parameters might occur that make results difficult to interpret.

The boxes with cattails and no vegetation showed differences in ability to remove iron. A study on the relationship to cattails, and other vegetation, to bacterial production would be most beneficial. These pilot studies will not provide answers, but they do give us some further direction for study.

LITERATURE CITED

ASTM. 1976a. Metals in water and waste water b atomic absorption spectrophotometry. Annual Book of ASTM Standards. Water. Part 31. American Society for Testing and Materials. pp. 350-354.

Table 5. Soil concentrations (ppm) at the inflow and outflow of the cattail box and the control box, sampled August 4, 1987. Two samples were taken in the wetland near the boxes, and averaged.

	Fe	Mg	Al	pH
Cattail Box				
Inflow	71.70	6.52	82.50	3.62
Outflow	201.50	7.92	68.10	3.20
No Cattail Box				
Inflow	52.20	5.26	75.30	3.97
Outflow	81.40	4.81	21.90	3.68
Surrounding Wetland	155.00	15.40	53.80	3.87

Baker, D.E. and M.C. Amacher. 1982. Nickel, copper, zinc and calcium. pp. 323-336 in A.L. Page et al. (eds), 1982. Methods of Soil Analysis. Part 2. Chemical and Microbiological Properties, Second ed. ASA-SSSA. Mallison, WI.

Brodie, G.A., D.A. Hammer, and D.A. Tomljanovich. 1985. Use of manmade wetlands to treat acid seepage from a coal refuse impoundment. Poster Session, in R.P. Brooks, D. E. Samuel, J.B. Hill (eds), Wetlands and water management on mined lands: Proceedings of a conference at Pennsylvania State University, October 23-24, 1985.

Boltz, D.F. and J.A. Howell. 1978. Colorimetric determination of nonmetals. 2nd Ed. John Wiley & Sons, New York, NY, pp. 250-351.

Fulton, G.W., W.T. Barker, and A. Bjugstad. 1983. Rooted aquatic plant revegetation of strip mine impoundments in the northern great plains. pp. 113-117 in M.D. Scott, (ed), Third Biennial Plains Aquatic Research Conference, Montana State University, August 24-25, 1983.

Kleinmann, R.L.P. 1985. Treatment of acid mine water by wetlands. pp. 48-52 in Bureau of Mines, Control of acid mine drainage, Information Circular 9027, Bureau of Mines.

Kleinmann, R.L.P., G.R. Watzlaf, and T.E. Ackman. 1985. Treatment of mine water to remove manganese. pp. 211-217 in D.H. Graves, (ed), Proceedings. 1985 Symposium on Surface Mining, Hydrology, Sedimentology, and Reclamation. University of Kentucky, Lexington, KY. December 9-13, 1985.

Snyder, C.D. and E.C. Aharrah. 1984. The influence of the *Typha* community on mine drainage. pp. 149-153 in D.H. Graves (ed), 1984 Sympoisum on Surface Mining, Hydrology, Sedimentology, and Reclamation, University of Kentucky. Kexington, KY.