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Changes in Soil Manganese Concentrations

A Case Study from an Illinois Coal Strip Mine

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OBJECTIVE

Determine if the concentration of Manganese present in the coal mine retention pond water is the result of inherent concentrations of Mn present in the original soil profiles or that of acid rock drainage.

ABSTRACT

The concentration of manganese in pond water attributed to acid mine drainage is a common problem for many mining operations. A retention pond at the restored Freeman United mine at Industry Illinois had continually tested above acceptable levels for manganese (Mn) concentration even after repeated treatment with gypsum.

It was noted that the NRCS soil profile descriptions of the pre-mined soil series which originally comprised the watershed area of the retention pond had naturally occurring accumulations of Mn. Due to the occurrence of Mn in the undisturbed soil profiles, it is possible that the concentration of Mn in the water is the result of inherent concentrations of Mn from the original soil profiles and not that of acid rock drainage.

Six sample sites were selected from the reclaimed fields that drain into the pond and six corresponding sites, within the same watershed, were selected in undisturbed areas adjacent to the mine location. Six inch soil samples were taken to a depth of 72 inches at each location. Each sample was analyzed in the laboratory for pH and Mn concentration. The data was then plotted by depth and comparisons were made between the values found in the undisturbed sites and those found in the reclaimed sites. Statistical significance was determined within each sample depth and calculated at 95% confidence.

The average pH of the undisturbed samples in each six inch sample range as well as over the entire profile was lower than that of the reclaimed soils. The reclaimed soil profiles contain less total Mn than the profiles of the undisturbed soils from 0-12 inches, 30-72 inches, and through the entire 72 inch profile. When Mn concentrations at each depth were compared between reclaimed and undisturbed locations numerous incidences of statistically higher Mn were identified. Over two-thirds (69.23%) of the samples that contained statistically higher Mn concentrations were found in the undisturbed soil profiles.

The pH of the reclaimed soils was higher than that of the undisturbed soils indicating there was not an increase in acidity due to acid rock. Additionally, no layers of increased acidity (below pH of 4.5) were found through any of the reclaimed soil profiles. The Mn levels found in the undisturbed soils were higher than those found in the reclaimed soils and the undisturbed samples had far more incidences of significantly high Mn concentration than the reclaimed soils. The Mn levels found in the water of the retention pond, which received drainage from the reclaimed soils are most likely due to the naturally occurring Mn levels of the soil material in the region and not due to acid rock drainage.

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INTRODUCTION

A retention pond at the restored Freeman United mine at Industry Illinois had continually tested above acceptable levels for manganese (Mn) concentration even after repeated treatment with gypsum.

Soil Scientists with Key Agricultural Services Inc. were digging soil pits to an approximate depth of 50 inches and noted that Mn concretions are common throughout the soil profile below the surface horizon (see photo below). The presence of the Mn accumulations in the shallow depths of the soil profile raises the question as to whether the Mn levels found in the pond water are elevated due to acid rock drainage, or due to the natural Mn concentrations associated with the parent material and soil forming factors of the undisturbed soils common to the region.

The dominant soil types originally located in the area of the mine that now drain into the pond are Rozetta and Keomah. The NRCS soil profile descriptions for the Rozetta and Keomah soil series note the presence of Mn and iron (Fe) accumulations beginning at 26 inches and the soil surface, respectively. Due to the natural occurrence of accumulated Mn in the undisturbed soil profiles it is possible that the concentration of Mn in the water of the pond is originating from the inherent concentrations of Mn and not that of acid rock drainage.

METHODS

Six sample sites were selected in an undisturbed area adjacent to the mine location. Three of those sites were located in Rozetta and three in Keomah soils. Six corresponding sites were chosen from the reclaimed fields that drain into the pond. Three of the reclaimed sites represent the topographic-position of a Rozetta and three represent that of a Keomah soil.

Six inch soil samples were taken to a depth of 72 inches at each of the 12 locations. Each sample was analyzed in the laboratory for pH, and Mn and Fe concentrations.

pH levels were determined in the laboratory using a 1:1 soil to water extract and measured with a Fischer Accummet pH meter with a universal glass electrode and a single junction reference electrode. Mn concentration is Mehlich III extractable Manganese measured with a single beam atomic absorption spectrophotometer.

The data obtained was then plotted by depth and comparisons were made between the values found in the undisturbed sites versus that of the reclaimed sites. Statistical significance was determined within each sample depth and calculated at 95% confidence.

RESULTS

pH

The pH levels found in the reclaimed soils ranged from 4.91 to 7.02. The pH levels found in the undisturbed soils ranged from 4.42 to 6.87.

The average pH of the undisturbed samples in each six inch sample range as well as over the entire profile was lower than that of the reclaimed soils (Table 1 and Graph 2). The lowest pH readings obtained in each depth increment were all found in the undisturbed samples with the exception of the 60-66 inch range where both the reclaimed and undisturbed soils had a low pH of 5.39.

The lowest pH level found at each sample depth in the reclaimed soil profiles were never lower than the lowest pH level found at the same sample depth of the undisturbed soils.

RESULTS (continued)

Comparison of pH Data

Table 1	Undisturbed Samples		Reclaimed Samples	
Sample Depth (inches)	Average pH	Lowest pH	Average pH	Lowest pH
0-6	5.75	5.23	6.19	5.31
6-12	5.28	4.52	5.95	5.04
12-18	4.83	4.59	5.55	4.98
18-24	4.75	4.42	5.49	5.01
24-30	4.80	4.47	5.67	4.91
30-36	4.96	4.49	5.60	4.97
36-42	5.16	4.65	5.61	4.99
42-48	5.14	4.73	5.78	5.02
48-54	5.39	4.92	6.06	5.08
54-60	5.63	5.20	6.10	5.38
60-66	5.79	5.39	5.96	5.39
66-72	5.87	5.29	5.83	5.40

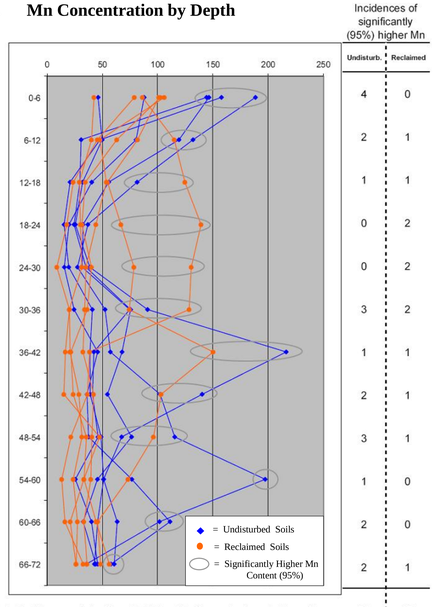
= the lowest value for that depth when comparing Undisturbed and Reclaimed sites.

Manganese

In all but one of the 12 soil profiles collected the Mn concentrations decreased from the surface sample down to 18 inches. The Mn content in most samples remained at relatively minimal levels from 12 to 72 inches, ranging from 8.9 to 67.8 ppm. At each sample depth one to five samples were found to be significantly higher in Mn than the rest of the samples at that same depth (Graph 1).

The reclaimed soil profiles contain less total Mn than the undisturbed soils from 0-12 inches, 30-72 inches, and through the entire 72 inch profile (Graph 2). The reclaimed soils contained more Mn than the undisturbed soils only through the 12-30 inch range.

Graph 1. Mn Concentration by Depth

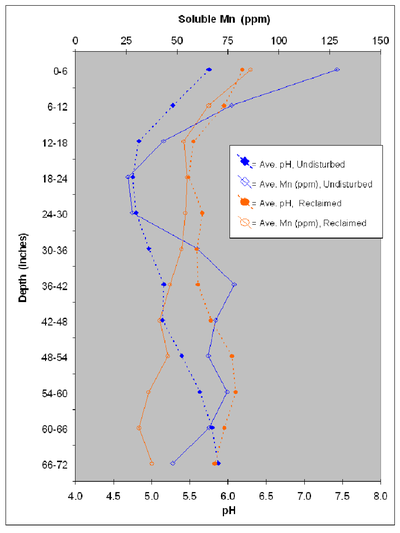


RESULTS (continued)

In the surface 12 inches of all profiles 6 of the 7 (85.71%) Mn levels that were significantly higher were from the undisturbed soil profiles. In the upper 36 inches 10 of the 18 (55.56%) samples with high Mn concentrations were from the undisturbed soils. From 36 to 72 inches 11 of the 14 (73.33%) samples with significantly greater Mn concentrations were from the undisturbed soil profiles.

In the 12 sample depths tested 2 (16.67%) had more reclaimed samples with significantly high Mn levels than undisturbed samples, 2 (16.67%) depths had equal incidences of significantly high Mn levels between the undisturbed and reclaimed samples, and 8 (66.67%) had more undisturbed samples with significantly high Mn concentrations than reclaimed samples (Graph 1).

Graph 2. Average Mn Concentration and Average pH with Depth



CONCLUSIONS

Although all twelve soil profiles tested have lower pH levels than typically recommended for the row crops planted in the region, the pH of the reclaimed soils is higher than that of the undisturbed soils indicating there is not increased acidity due to acid rock. Additionally, no layers of increased acidity (below pH of 4.5) were found through any of the reclaimed soil profiles.

The Mn levels found in both the surface and sub-surface of the undisturbed soil types are higher than those found in the reclaimed soils and the undisturbed samples have far more incidences of significantly high Mn concentration than the reclaimed soils.

Therefore the Mn levels found in water of the retention pond which received drainage from the reclaimed soils of the Freeman United Mine in Illinois are most likely due to the naturally occurring Mn levels of the soil material in the region and not due to acid rock drainage.

Additional research could be conducted to further test the conclusions of this study. To further substantiate these results samples could be collected to compare the Mn content and pH from water samples taken from ponds that receive drainage from the undisturbed field locations to samples taken from the pond identified in this study.