CHEMICAL AND PHYSICAL CHARACTERISTICS OF ANTHROPOGENIC HYDRIC SOILS ON MINE TAILINGS IN THE COPPER BASIN, TENNESSEE[1]

by

V.C. Stevens[2], J.T. Ammons[2], J.L. Branson[2], T.E. Cook[2], and D.J. Inman[2]

Abstract. Hydric soils are one criteria in delineating wetlands. The formation of a tailings pond related to copper and pyrite milling near Ducktown, Tennessee, presented an opportunity to study hydric soils which have formed on wetlands of anthropogenic origin. Objectives of this study were to: 1) perform complete soil chemical, morphological, and physical characterization; 2) classify soils to the family level of Soil Taxonomy; and 3) use soil chemical, morphological, and physical characterization to identify hydric soils and delineate the hydric soil fringe. Three hydric soil profiles were described and sampled. Depth to the gleyed layer ranged from 8 to 17 cm, which fit hydric soil criteria. Depth to the water table ranged from 28 to 42 cm. Substantial hydrophytic vegetation such as cattails, rushes, and sedges were present. Laboratory analysis included standard soil survey methods. Profile 1 had a soil drainage class of very poorly drained while profiles 2 and 3 had a soil drainage class of poorly drained. Profiles 1 and 3 were classified as sandy, mixed, mesic Typic Endoaquents. Profile 2 was classified as a mixed, mesic Typic Psammaquent. Soil chemical, morphological, and physical characterization were successful in identifying anthropogenic hydric soils to delineate the hydric soil fringe for future land use.

Additional Key Words: hydric soil, minesoil, wetland, disturbed, anthropogenic.

Introduction

One criteria critical for wetland determination is the presence of hydric soils. Hydric soils are defined as "soils formed under conditions of saturation, flooding, or ponding long enough during the growing season to develop anaerobic conditions in the upper part" (USDA, NRCS, 1998). Characteristics used to identify hydric soils include the presence of a gleyed layer (50% with chroma ≤ 2), redoximorphic features, and/or a surface horizon high in organic matter (Megonigal, et al., 1993).

Formation of anthropogenic hydric soils on a mine tailings pond which formed as a result of copper mining processes presented an opportunity to study these soils. Anthropogenic or disturbed soils are unique and have to be studied in detail to achieve valid

interpretations (Ammons and Sencindiver, 1990). Defining, classifying, mapping, and characterizing these soils are difficult. Only recently has there been a demand for soil maps on anthropogenic soils. Pedologists have been slow to separate and define different soils in disturbed areas due to high variability (Indorante and Jansen, 1984).

Anthropogenic soils vary because there are many different types of disturbances affecting the soil in different ways. For example, soils disturbed by mining practices will differ from those soils disturbed by landfilling. Currently, *Keys to Soil Taxonomy* offers no classification scheme to account for disturbed soils. The dissimilarities inherent in disturbed soils presents the problem when classifying (Indorante and Jansen, 1984).

The same criteria used to identify disturbed hydric soils is used to identify undisturbed hydric soils. Boundaries marked by hydric soils are used to estimate wetland acreage. Wetland delineation becomes important in land management issues such as construction, future land development, habitat management, and agriculture. Fluctuating water tables and flooding potential common where hydric soils are located could be problematic to builders, farmers, and engineers. In addition, wetland delineation has become an increasingly important topic, especially with wetland trading issues, wetland drainage,

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and controversies over wetland laws which are constantly being changed.

During the 1970s, tailings were released into a mine tailings pond. Tailings are waste materials generated by the mining and processing of ores (Hossner and Hons, 1992). Water in the tailings pond eventually evaporated and/or drained. Wetlands began to form when water naturally collected and impounded in lower landscape positions. Water level in the wetlands is not artificially controlled, but controlled by seasonal fluctuations and changes in the water table. These wetlands have not been altered or dredged since their formation. Future plans include building a dam and flooding the lower landscape to expand the wetland area to continue to support wetland species while reclaiming the upper areas of the mine tailings pond.

Three anthropogenic hydric soils were compared on a mine tailings pond in the Copper Basin, Tennessee. The objectives of this study were to: 1) perform complete soil chemical, morphological, and physical characterization; 2) classify soils to the family level of Soil Taxonomy; and 3) use soil chemical, morphological, and physical characterization to identify hydric soils and delineate the hydric soil fringe.

Materials and Methods

Site Selection

The study sites were located near Ducktown in Polk County, Tennessee. An initial site investigation was performed using USGS topographic maps (Isabella Quadrangle, USGS, 1978). Aerial photographs were used to identify the hydric soil fringe.

After the initial site investigation, an onsite physical investigation was performed using a soil probe to locate the hydric soil fringe. Three soil profiles were selected based on where the hydric soil fringe might be located on the aerial map, observations from the onsite physical investigation, and areas that had characteristics of wetlands as described by the Wetland Training Institute Manual, Inc., (1995).

Field Methods

Three hydric soil profiles were excavated with shovels to the water table. All three profiles were described and sampled according to National Cooperative Soil Survey Standards (Soil Survey Staff, 1998). Profile 1 was located N 35°02'59.4" and W 84°21'25.6", west on

the mine tailings pond close to a wetland. Profile 2 was located N 35°02'58.6" and W 84°20'42.8", east on the mine tailings pond. Profile 3 was located N 35°03'03.2" and W 84°21'06.0", east on the mine tailings pond (Fig. 1). Profiles 2 and 3 were located at lower landscape positions.

Field descriptions included soil color, depth to the gleyed layer, presence of redoximorphic features, and reaction to alpha, alpha,-dipyridyl (Childs, 1981). Other characteristics noted included depth to the water table, types of hydrophytic vegetation, and soil drainage class. Each soil profile was classified to the family level using the *Keys to Soil Taxonomy* (Soil Survey Staff, 1998).

Laboratory Methods

Particle size distribution was determined using the pipette method (Kilmer and Alexander, 1949). Textures were determined using the USDA textural classification system. pH was determined using a 1:1 soil-water suspension (Olsen and Ellis, 1982a) and a 2:1 soil suspension in 0.02 N calcium chloride.

A fizz test was performed initially to determine if free carbonates were present. Neutralization potential (Sobek et al., 1978), a part of acid-base accounting, was used to determine the amount of neutralizing bases (free carbonates) in the soil.

Exchangeable bases were extracted by saturation with 1 N ammonium acetate at pH 7 (Hammer and Lewis, 1987). Cation exchange capacity was determined using an acidified sodium chloride solution (Chapman, 1965).

Manganese oxides were extracted using an acidified hydroxylamine hydrochloride method (Chao, 1972; Gambrell and Patrick, 1982). Free iron oxides were extracted using the citrate-dithionite method (Olsen and Ellis, 1982b). Alpha, alpha,-dipyridyl (Childs, 1981),
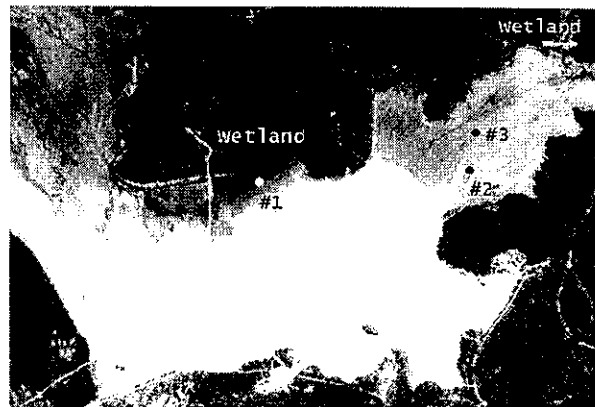

Figure 1. Aerial map of mine tailings pond.

was used to determine the presence of ferrous iron (Fe^{2+}).

Results

Soil Profile 1

All the soils were hydric because at least 50% of the matrix had a chroma ≤ 2 at a depth of 25 cm (10 in). Soil profile 1 showed evidence of gleying at 8 cm. This site had hydrophytic vegetation dominated by scarce brown sedges and cattails. The soil drainage class was very poorly drained and depth to the water table was 42 cm. Surface water was apparent from the adjacent wetland. Soil samples were collected and morphology was described to a depth of 55 cm.

Redoximorphic features were present in the C, Cg1, and Cg3 horizons. Horizons above the gleyed layers tested positive for alpha, alpha-dipyridyl. Gleyed layers showed no reaction to alpha, alpha-dipyridyl (Table 1).

Manganese concentrations (hydroxylamine manganese which accounts for Mn^{2+} a reducible form) were lowest in the horizon preceding the gleyed layers. Manganese concentrations were highest in the gleyed layers (Table 2).

Free iron (%) was lower in the C horizon compared to Cg1 in which the free iron was slightly higher, but compared to the other gleyed layers, decreased. Free iron decreased in Cg2 and at lower depths (Table 2).

Cation exchange capacity (CEC) was highest in the surface horizon, decreased in Cg1, increased again in Cg2, and then steadily decreased with depth (Table 2).

High base saturation was observed in all horizons (Table 2). Calcium carbonate equivalent (CCE) remained nearly constant throughout the profile regardless of pH, with a slight increase in Cg5 (Table 2). In this horizon, the high CCE corresponded to the high pH. A violent effervescent reaction to 10% HCl was noted in each horizon (Table 1).

Calcium concentrations were greater in the horizon above the gleyed layers and lower in the gleyed layers. Magnesium and potassium concentrations were greater in the gleyed layers. Sodium concentrations were slightly lower in the gleyed layers (Table 2).

Profile 1 was the closest profile to the wetland. In addition, the water table was slightly deeper than profiles 2 and 3. Also, manganese concentrations were lower in the horizon preceding the gleyed layers and higher in the gleyed layers.

Soil Profile 2

Soil profile 2 showed evidence of gleying at 17 cm. This site had scarce hydrophytic vegetation such as sedges, rushes, and reeds. The soil drainage class was poorly drained and depth to the water table was 30 cm. No surface water was apparent. Soil samples were collected and morphology was described to 43 cm.

Redoximorphic features were present in all

Table 1. Morphology of Hydric Soil Profile 1

Horizon	Lower Depth (cm)	Color Moist	Color Dry	Texture*	Structure*	Boundary Distinctness	Reaction 10% HCl	Redoximorphic Features	alpha,alpha dipyridyl
C	8	5G 4/1 5YR 5/8 5GY 5/1	10YR 4/6 10YR 4/4	fS	sls sg	abrupt	Violent	Fe and Mn Concentrations	Positive
Cg1	20	5Y 4/2	10YR 4/4 2.5Y 4/4 5GY 4/1 N4	fS	sls sg	clear	Violent	Fe Depletions	Negative
Cg2	27	5GY 4/1	5Y 4/3 2.5 Y 4/4	fS	sls sg	clear	Violent		Negative
Cg3	42	5GY 4/1	2.5Y 4/4 5Y 4/3	fS	sls sg	clear	Violent	Fe Depletions	Negative
Cg4	50	N3	N4	fS	sls sg	clear	Violent		Negative
Cg5	55+		N4	fS	sls sg	-	Violent		Negative

*fS fine sand; sls structureless; sg single grain

Table 2. Chemical Characterization for Hydric Soil Profile 1

Horizon	Lower Depth (cm)	CaCO$_3$ Equivalent (%)	pH (1:1 H$_2$O)	Free Iron (%)	Mn g kg^{-1}	CEC cmol+ kg^{-1}
C	8	20.8	6.6	2.1	0.2448	1.20
Cg1	20	19.8	6.2	2.7	0.2844	0.85
Cg2	27	20.9	6.3	1.9	0.3152	1.07
Cg3	42	20.6	6.0	1.6	0.3244	0.67
Cg4	50	20.5	6.8	0.8	0.3457	0.62
Cg5	55+	22.5	6.9	0.9	0.3237	0.49

Horizon	Lower Depth (cm)	Bases Ca^{2+} cmol+ kg^{-1}	Mg^{2+} cmol+ kg^{-1}	K$^+$ cmol+ kg^{-1}	Na$^+$ cmol+ kg^{-1}	Base Saturation (%)
C	8	113.3	0.53	0.05	0.08	>100
Cg1	20	69.6	0.91	0.09	0.05	>100
Cg2	27	85.1	1.17	0.22	0.05	>100
Cg3	42	37.8	1.20	0.15	0.04	>100
Cg4	50	19.0	1.18	0.12	0.03	>100
Cg5	55+	18.3	1.09	0.09	0.03	>100

horizons. Horizons above the gleyed layers tested positive for alpha, alpha-dipyridyl, while, the gleyed layers showed no reaction to alpha, alpha-dipyridyl (Table 3).

Manganese concentrations were substantially higher in the horizons preceding the gleyed layers. Lower manganese concentrations were noted in the gleyed layers (Table 4). The highest concentration of free iron was in C1. The lowest concentration of free iron was in Cg2A. Free iron concentrations decreased with depth throughout the soil profile (Table 4).

Cation exchange capacity decreased steadily with depth, except for Cg2B in which it increased. CEC was highest in the surface horizon (Table 4).

High base saturation was observed in all horizons (Table 4). Calcium carbonate equivalent (CCE) increased with increasing pH, except for Cg2A which had the highest CCE corresponding to the lowest pH (Table 4). The surface horizon had the lowest CCE and a low pH. In addition, the surface horizon had a slight reaction to 10% HCl, while the other horizons reacted violently (Table 3).

Calcium concentrations were greater in the horizons above the gleyed layers, however, the Cg1 horizon also showed a high calcium concentration. Both Cg2A and Cg2B showed low calcium concentrations. Magnesium and potassium concentrations were greater in the gleyed layers. Sodium concentrations were consistent throughout the soil profile except for Cg2A in which it

Table 3. Morphology of Hydric Soil Profile 2

Horizon	Lower Depth (cm)	Color Moist	Color Dry	Texture*	Structure*	Boundary Distinctness	Reaction 10% HCl	Redoximorphic Features	alpha,alpha dipyridyl
C1	8	5YR 4/4	10YR 4/6 7.5YR 4/4	fS	sls sg	clear	Slight	Fe and Mn Concentrations	Positive
C2	17	7.5YR 4/4 10YR 4/4	2.5Y 5/6	fS	sls sg	abrupt	Violent	Fe and Mn Concentrations Fe Depletions	Positive
Cg1	33	10YR 4/2 2.5Y 4/2	2.5Y 6/4	LfS	sls sg	clear	Violent	Fe Depletions & Concentrations	Negative
Cg2	43+	5GY 4/1 N3	5Y 4/4 N5	S/LfS/VfSL	sls sg	-	Violent	Fe Depletions & Concentrations	Negative

*fS fine sand; LfS loamy fine sand; S Sand; VfSL very fine sandy loam; sls structureless; sg single grain

Table 4. Chemical Characterization for Hydric Soil Profile 2

Horizon	Lower Depth (cm)	CaCO$_3$ Equivalent (%)	pH (1:1 H$_2$O)	Free Iron (%)	Mn g kg^{-1}	CEC cmol+ kg^{-1}
C1	8	6.5	6.5	5.8	0.5241	1.68
C2	17	10.1	6.8	4.7	0.4596	1.20
Cg1	33	13.7	6.8	3.4	0.3368	1.22
Cg2A	43+	21.6	6.4	2.2	0.3643	0.73
Cg2B	43+	17.6	6.8	2.9	0.3877	1.08

Horizon	Lower Depth (cm)	Ca^{2+} cmol+ kg^{-1}	Mg^{2+} cmol+ kg^{-1}	Bases K$^+$ cmol+ kg^{-1}	Na$^+$ cmol+ kg^{-1}	Base Saturation (%)
C1	8	177.1	0.26	0.03	0.04	>100
C2	17	138.9	0.32	0.02	0.04	>100
Cg1	33	121.4	1.05	0.04	0.04	>100
Cg2A	43+	44.5	1.31	0.08	1.26	>100
Cg2B	43+	38.8	2.25	0.13	0.04	>100

increased (Table 4).

Unlike profile 1, the soil drainage class was poorly drained. This profile also had a shallower water table, but there was not any surface water present and it was not located near the wetland. This site was located at a lower landscape position than profile 1. In addition, manganese and free iron concentrations were higher in the horizons preceding the gleyed layers and lower in the gleyed layers. A lower CCE and pH were noted in the surface horizon. Also, the surface horizon had a slight reaction to 10% Hcl (Table 3).

Like profile 1, horizons above the gleyed layers tested positive for alpha, alpha-dipyridyl. Gleyed layers showed no reaction to alpha, alpha-dipyridyl. Cation exchange capacity was highest in the surface horizon. High base saturation was noted in all horizons. Horizons above the gleyed layers showed higher calcium concentrations, except for Cg1, which also had a high calcium concentration. Magnesium and potassium concentrations were greater in the gleyed layers.

Soil Profile 3

Profile 3 showed evidence of gleying at 10 cm. This site was sparsely vegetated with hydrophytes such as sedges and rushes. The soil drainage class was poorly drained with depth to the water table at 28 cm. No surface water was evident. Soil samples were collected and morphology was described to 33 cm.

Redoximorphic features were noted in the C and Cg1 horizon. The horizon above the gleyed layers tested positive for alpha, alpha-dipyridyl. In addition, the gleyed layers showed no reaction to alpha, alpha-dipyridyl (Table 5).

Manganese concentrations were higher in the horizon preceding the gleyed layers. Lower manganese concentrations noted in the gleyed layers (Table 6). The highest concentration of free iron was in the horizon preceding the gleyed layers. Free iron concentrations decreased with depth to 33 cm. Cation exchange capacity also decreased with depth but slightly increased in Cg2

Table 5. Morphology of Hydric Soil Profile 3

Horizon	Lower Depth (cm)	Color Moist	Color Dry	Texture*	Structure*	Boundary Distinctness	Reaction 10% HCl	Redoximorphic Features	alpha,alpha dipyridyl
C	10	7.5YR 4/4 5YR 3/4	5YR 3/4 10YR 4/6	LfS	sls sg	abrupt	None	Fe Concentrations & Depletions	Positive
Cg1	15	5GY 4/1	N4 2.5Y 5/4	fS	sls sg	clear	Violent	Fe Depletions	Negative
Cg2	33+	N3	N5	LvfS	sls sg	-	Violent		Negative

*fS fine sand; LfS loamy fine sand; sls structureless; sg single grain

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Table 6. Chemical Characterization for Hydric Soil Profile 3

Horizon	Lower Depth (cm)	CaCO₃ Equivalent (%)	pH (1:1 H₂O)	Free Iron (%)	Mn g kg⁻¹	CEC cmol+ kg⁻¹
C	10	3.7	5.7	7.0	0.4741	2.30
Cg1	15	18.7	6.6	2.1	0.3108	0.60
Cg2	33+	20.2	7.0	1.3	0.3354	0.66

Horizon	Lower Depth (cm)	Ca^{2+} cmol+ kg⁻¹	Mg^{2+} cmol+ kg⁻¹	Bases K^+ cmol+ kg⁻¹	Na^+ cmol+ kg⁻¹	Base Saturation (%)
C	10	170.1	0.80	0.09	0.06	>100
Cg1	15	42.9	2.91	0.21	1.59	>100
Cg2	33+	17.4	2.57	0.19	0.80	>100

(Table 6).

High base saturation (>100%) was observed in all horizons (Table 6). Calcium carbonate equivalent (CCE) increased with increasing pH and depth throughout the soil profile. Calcium carbonate equivalent in Cg2 corresponded to the highest pH. The lowest CCE in C corresponded to the lowest pH (Table 6). The surface horizon had no reaction to 10% HCl, while the other horizons reacted violently (Table 5).

The C horizon above the gleyed layers showed higher calcium concentrations while the gleyed layers showed lower calcium concentrations. Magnesium, sodium, and potassium concentrations were all greater in the gleyed layers (Table 6).

Like profile 2, this site was located at a lower landscape position. The soil drainage class was also poorly drained. In addition, depth to the water table was shallower than profile 1. As in profiles 1 and 2, horizons above the gleyed layers tested positive for alpha, alpha-dipyridyl and gleyed layers showed no reaction to alpha, alpha-dipyridyl. As in profile 2, manganese and free iron concentrations were higher in the horizon preceding the gleyed layers and lower in the gleyed layers. CEC was highest in the surface horizon. A high base saturation was noted in all horizons. A lower CCE and pH were noted in the surface horizon. But, unlike profiles 1 and 2, no reaction to 10% HCl was noted. Finally, as in profiles 1 and 2, higher calcium concentrations were noted in the horizon above the gleyed layers. Magnesium and potassium concentrations were also greater in the gleyed layers.

Discussion

All three profiles were hydric because at least 50% of the matrix had a chroma ≤2 at a depth of 25 cm (10 in). Redoximorphic features were evident in all soil profiles, especially in the horizons above the gleyed layers and indicated anoxic conditions, a fluctuating water table, and repeated soil saturation were apparent. Water drives the development of redoximorphic features by assisting in additions, removals, transfers, and transformations of substances in the soil (Mausbach and Richardson, 1994).

In all three profiles, horizons above the gleyed layers tested positive for alpha,alpha-dipyridyl indicating there was enough ferrous iron to react with the dye. The gleyed layers showed no reaction to the alpha,alpha-dipyridyl. Consequently, the ferrous iron was removed from these horizons. These soils were subjected to constant saturation and have been waterlogged for some time, not only due to seasonal differences, but also due to a constant high water table.

In profile 1, higher manganese concentrations in the gleyed layers can be attributed to the increased ability of anaerobic microorganisms to actively reduce manganese to a more usable form. As oxygen becomes limited, anaerobic organisms use manganese oxides and iron oxides and convert them to reduced forms (Mausbach and Richardson, 1994). This is important, especially in hydric soil development.

In profile 1, it is likely that the high concentration of iron in Cg1 indicates anaerobic microorganisms were actively converting Fe^{3+} to Fe^{2+}. As iron is reduced, the gray color of the hydric soil develops. Ferrous iron decreased because it leaches easily in sandy textures and in this form, is very mobile moving with the fluctuating water table.

In profiles 2 and 3, the lower manganese and

free iron concentrations in gleyed layers could be attributed to the shallower water table leaching the manganese and free iron from the soil profile. Profiles had a low cation exchange capacity and sandy textures which did not allow the manganese or free iron to attach to exchange sites. Therefore, they leached more easily and apparently moved with the shallower water table.

The low cation exchange capacity can be attributed to the sandy textures and low clay percent. Clays have the exchange sites which are responsible for cations (Ca^{2+}, K^+, Na^+, Mg^{2+}) to be held or exchanged on a site (Miller and Donahue, 1990). Because of the low clay percentage, there is little to no exchange. In profile 2, a slight increase in CEC in the bottom horizon could be related to an increase in total clay percentage and a decrease in total sand percentage.

Each profile had a high base saturation (>100%). This can be attributed to the high calcium concentrations in each horizon. Calcium concentrations decreased in the gleyed layers because calcium is very mobile in water. High calcium concentrations were a result of high amounts of calcium carbonate ($CaCO_3$, a type of lime) used during the mining process to raise the pH before releasing the tailings into the mine tailings pond.

Calcium carbonate equivalent (CCE%) determines the amount of readily available neutralizing bases in the soil (Jackson, 1958). pH is depended on CCE. As CCE increases, pH should also increase, because this increases the potential for base cations to form. This is related to the buffering capacity of the soil. Buffering capacity is the ability of a soil to resist changes in pH (Miller and Donahue, 1990). An increase in buffering capacity can be attributed to an increase in CEC which is related to an increase in clay. As the buffering capacity increases, it is more difficult to change the pH. Sandy textures of these soils lowered the buffering capacity, therefore, high amounts of calcium carbonate were added to neutralize the soil and raise the pH. By adding calcium carbonate, neutralization occurs, and the pH increases. The added calcium carbonate removes the acid formers. Once soils highly buffered with calcium carbonate come in contact with acid, hydrogen ions are not produced, therefore, pH will not decrease (Miller and Donahue, 1990). The highest CCE should be in the surface horizon corresponding to the high calcium concentrations. Lower pH values in the surface horizon for soil profiles 2 and 3 corresponded to the lower CCE. This could be attributed to the acid soils and runoff from the upland to the lower landscape positions.

A violent effervescent reaction to 10% HCl indicated that calcium carbonate was abundant. In profile 2 and 3, the non to slight reaction to 10% HCl in the surface corresponded to the lower pH and lower CCE combined. Profiles 2 and 3 were in a lower landscape position than profile 1.

Hydric soils compose approximately 55 acres (23 ha) of the total 212 acre (86 ha) mine tailings pond. The wetlands have the criteria critical for wetland identification such as the ability to support hydrophytic vegetation including cattails, rushes, and sedges. In addition, they have hydric soils, hydrology, and provide a unique natural habitat for migratory waterfowl, aquatic species, and other wildlife.

Hydric soils which are anthropogenic in origin are unique because they have formed naturally on man-made materials, yet they exhibit the same processes inherent in the development of natural hydric soils. These oxidation-reduction processes are essential in the development of chemical and physical characteristics of hydric soils, even if they are anthropogenic. When oxygen becomes limited, microorganisms use other forms of energy. Organisms carry on respiration by passing electrons to alternate electron acceptors, unlike passing electrons to oxygen as in aerobic conditions. Once oxygen is depleted, other oxidants are used in order of their ease of reduction. The order is as follows: NO_3^-, Mn^{4+}, Fe^{3+}, SO_4^{2-}, and reducible carbon (McKee and McKelvin, 1993). The formation of these oxidants, how they are reduced, anaerobic conditions, and water table fluctuations are all important in the development and the identification of hydric soils, especially to delineate hydric soil and wetland boundaries which is essential for future land management.

Conclusions

1. Profile 1 was classified as a Sandy, mixed, mesic Typic Endoaquent. Profile 2 was classified as a mixed, mesic Typic Psammaquent. Profile 3 was classified as a sandy, mixed, mesic Typic Endoaquent.

2. In profiles 2 and 3, located on the east side of the mine tailings pond, concentrations of manganese and free iron were higher in the horizons preceding the gleyed layers. In profile 1, located on the west side of the mine tailings pond, manganese was lower in the horizon preceding the gleyed layers.

3. In all profiles, tests for alpha,alpha-dipyridyl were positive in the horizons above the gleyed layers indicating that ferrous iron was present and negative in the gleyed layers indicating ferrous iron was low or removed from the profile.

4. From the identification of soil physical, chemical, and morphological characteristics, it was possible to identify the hydric soils and delineate the hydric soil fringe around wetlands of anthropogenic origin for future land management.

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