Soil Sampling for Detection of Acid Overburden on Small Game Management Areas Located on Severely-disturbed Land Bases

Jeanne C. Jones, *Department of Wildlife and Fisheries, Mississippi State University, MS 39762*

Dale H. Arner, *Department of Wildlife and Fisheries, Mississippi State University, MS 39762*

Chris H. Bucciantini, *Department of Wildlife and Fisheries, Mississippi State University, MS 39762*

Abstract: A vegetation and soil study was conducted on upland disposal sites of a 4,425-ha management area in Mississippi. This area comprised disposal sites managed for northern bobwhites (*Colinus virginianus*). The soil and subsoil materials of these disposal areas originated from vertical cuts of geological strata up to 54 m and contained acidic overburden. Soil samples were collected at 0- to 10-cm and >10- to 20-cm depths on 35 disposal areas. Soil pH values in 0- to 10-cm depths were not related to depths to overburden. Soil pH levels in >10- to 20-cm depths were related to overburden depths ($P < 0.0001$). Soil pH levels in 0- to 10-cm depths (range: 5.2–7.7) on vegetated disposal areas were higher ($P < 0.0001$) than pH levels (range: 3.2–7.7) at >10- to 20-cm depths. Soil pH values on sites where overburden was intermixed in the upper 40 cm of substrate ranged from 2.9 to 3.9. Vegetation was generally absent in these areas due to inadequate coverage of overburden and resulting phytotoxic soil conditions. The relationship between depths to acid-producing overburden and pH levels in >10- to 20-cm soil depths indicated a need for collection of soil samples at greater depths on disturbed lands containing acidic overburden than on undisturbed lands that lack such overburden.

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Many state and federal agencies manage wildlife on land that has been disturbed by surface mining and public works projects (U.S. Fish and Wildl Serv. 1981). Although erosion control and revegetation are initial reclamation objectives on these perturbed lands, reestablishment of native plant communities and reforestation with native forage and cover plants are longer-term goals for wildlife habitat restoration. Plant community development on these sites may be related to substrate conditions, interspersion of undisturbed seed sources, patch dynamics of colonizing plants, and dominant plant cover (Bramble and Ashby 1955, Hulst 1978, Game et al. 1982, Gibson et al. 1985, Skousen et al. 1994).

Reclamation and habitat restoration on disturbed lands may present unique challenges to wildlife biologists due to altered soil and vegetation conditions (Byrnes and Miller 1973, Vogel 1980, Ammons et al. 1983, Davidson et al. 1984, Wade et al. 1985, Skousen et al. 1994). Limited reforestation, dominance of seeded legumes and grasses, and lack of native plant diversity are plant community characteristics common to reclaimed mine and disposal sites (Byrnes and Miller 1973, Vogel 1980, Wade et al. 1985, Jones 1995). Edaphic factors, such as sandy or rocky substrates, phytotoxic chemical conditions, slow soil formation, and substrate compaction create unique vegetation management challenges to land managers (Pettry et al. 1980, Vogel 1980, Ammons et al. 1983, Wade et al. 1985).

A possible management scenario often encountered on coal mines and upland disposal sites is a dominance of seeded perennial plants, low native plant diversity, and substrates that contain acid-forming overburden (Ammons and Shelton 1991, Skousen et al. 1994, Johnson and Skousen 1995). A need for greater native plant diversity and increased wildlife food plants may be identified in this landscape. However, habitat management techniques, such as disking and planting food plots, on substrates containing pyrite may produce phytotoxic soil conditions (D. E. Pettry, Dep. Agron., Miss. State Univ., pers. commun.). Overturning substrates with pyrite near the soil's surface generally produces high soil acidity and vegetation die-off (Pugh et al. 1984, Ammons and Shelton 1991). Pyrite, which is comprised of iron sulfide, undergoes oxidation to produce sulfuric acid when exposed to oxygen and water at the substrate's surface (Pugh et al. 1984). Levels of soil acidity recorded for pyrite oxidation sites may reach pH levels of ≤ 4.5. At these pH values, metal and salt toxicities from hydrogen and metal cations become a limiting factor to plant survival (Pugh et al. 1984, Ammons et al. 1983, Skousen 1987, Ammons and Shelton 1991). In many cases, efforts to increase plant diversity may produce soil conditions unsuitable for vegetation.

This paper describes 1 component of an 11-year study of edaphic conditions and plant succession on reclaimed, upland disposal areas located along the Tennessee-Tombigbee Waterway in Mississippi. Vegetation monitoring on disposal sites from 1982 to 1992 revealed that most disposal areas were dominated by seeded sericea lespedeza (*Lespedeza cuneata*). High coverages (>60%) of sericea limited native plant diversity and coverage. Native plant cover was found to be inversely related to sericea cover over the 11-year period ($P < 0.0001$, $r = 0.79$) (Jones 1995). Native legume cover over the study area averaged <6% from 1982 through 1992. Sites dominated with sericea lespedeza exhibited <1% cover of native legumes over this period (Jones 1995).

Vegetation management for increasing food and cover plant diversity for northern bobwhites was initiated by the U.S. Army Corps of Engineers (USACE) and Mississippi Department of Wildlife, Fisheries, and Parks (MDWFP) in 1984. Annual food plot establishment and disking were implemented to enhance quail habitat; however, failure of food plot plantings and an increase in bare soil exposure were noted on selected sites where soil was disturbed annually. Data collection for measuring soil acidity and depth to overburden were initiated in 1991 due to these planting failures.

The primary purpose of the paper is to illustrate the importance of soil sample collection and testing for detection of high soil acidities and acid-forming complexes near the surface of substrate on disturbed lands managed for wildlife. The major objectives of the study were to measure the relationship between substrate pH levels and depths to acid-forming overburden material on disposal areas, to evaluate the effects of soil acidification on plant biomass production, and to recommend an approach for collecting soil samples for the detection of acid-producing materials near the soil's surface.

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Methods

Study Area

The study area was located on the Divide Section Wildlife Management Area (DSWMA) in Tishomingo, Mississippi. The 4,425-ha management area is managed by the MDWFP for small game species with an emphasis on northern bobwhites (*Colinus virginianus*). The DSWMA is comprised primarily of upland disposal sites which were created by the USACE during construction of the Tennessee-Tombigbee Waterway. Approximately 156 million m^3 of substrate were removed from a 64.4-km section, where vertical cuts of ≤ 54 meters in depth were required to join the Tennessee and Tombigbee River drainage systems. Excavated material was placed adjacent to the waterway canal in forested ravines. Preproject core sampling revealed that material excavated from the canal contained pyrite overburden. Overburden was covered with sandy-loam soils at depths ranging from 0.9 to 1.2 m. Following overburden deposition and resurfacing, disposal areas were reclaimed by applying lime and fertilizer and seeding perennial grasses and legumes. Lime was applied at rates ranging from 18 to 43 metric tons/ha and incorporated into substrate to ameliorate high potential soil acidities. Disposal area reclamation was completed by the USACE in 1981. Site monitoring and amelioration are conducted annually by the USACE.

Soil and Vegetation Sampling

Thirty-five disposal areas were selected and categorized through stratified random sampling based on plant cover occurring along line intercepts during 1988 and 1989. Disposal areas were grouped into 5 cover types based on dominant ground cover (>60% ground cover) as follows: seeded legume ($N = 10$), seeded grasses ($N = 5$), native herbaceous plants ($N = 10$), bare, pyritic sites ($N = 5$), and planted shrubs ($N = 5$).

Vegetation biomass and edaphic conditions were monitored on the 35 disposal sites during 1991 and 1992. Herbaceous biomass was collected on each study site within randomly-located 1-m^2 plots. Sampling intensity for plant biomass was based on maintaining a coefficient of variation equaling $\leq$30%. The number of clipped plots on each study site ranged from 15–20/site. All vegetation within each plot was clipped within 2.54 cm above ground level, separated into seeded and unseeded categories, and oven-dried at 60 C for 72 hours. Dry weight biomass is reported in kg/ha.

One 20-cm soil sample was collected on each disposal area along permanent line intercepts during February–March 1991 and 1992. Each soil sample was divided into 2 depth categories: 0–10 cm and >10–20 cm. Subsamples were stored in plastic ziploc bags in the field. In the laboratory, samples were air-dried and sieved with a 2-mm mesh sieve to remove rock fragments. Active acidity was measured in a 1:1 soil/water ratio mixture using a Coleman pH meter (Peech 1965). The depth to pyrite overburden was measured on each study site with a 2-m manual auger in March 1992. Auger samples were taken within 0.33 m from the soil sample collection point on each study site. Overburden was distinguished from soil by the presence of rock fragments, low chroma colors of unweathered material, and the presence of carbolithic and grey-colored materials (Ammons et al. 1983).

Relationships between overburden depths and pH levels in soil samples were tested using correlation and linear regression analysis. The Wilcoxon Signed Rank test was used for comparisons of pH levels between sample depths and study years. Correlation analysis was used to examine the relationship between vegetative biomass and soil pH (Daniel 1990, Myers 1990).

Results and Discussion

Soil pH at the 2 depths did not differ across study sites from 1991 to 1992 ($P >$ 0.10). The pH levels on vegetated disposal areas ($N = 30$) at 0- to 10-cm depths ranged from 5.2 to 7.9 in 1991 and 5.3 to 7.9 in 1992 (Table 1). Soil pH levels were lower in the >10 to 20-cm samples, ranging from 3.3 to 7.7 in 1991 and 3.2 to 7.9 in 1992 ($P < 0.0001$) (Table 1).

Depths to overburden exhibited variation among disposal sites, ranging from 2.54 cm to 152.40 cm. Soil pH levels in the 0- to 10-cm samples were not related to overburden depth. However, pH levels in the >10 to 20-cm samples exhibited a direct relationship to overburden depths across all study sites (Y[pH] = 3.4397 + 0.1636X [cm to overburden], $r^2 = 0.66$, 31 dF, $P < 0.0001$; Figure 1).

Soil pH levels were lowest on sites where overburden layers were found in the upper 36 cm and subsurface pockets of overburden were found within the upper 10 cm of soil. Soil pH levels on these sites ranged from 2.9 to 3.9. Depths to overburden layers ranged from 2.54 cm to 35.6 cm. Vegetation was generally absent throughout the study period, with 1 site supporting sparse cover (2.0%) and biomass (6.3 kg/ha) of common broomsedge (*Andropogon virginicus*) and rabbit tobacco (*Gnaphalium spp.*) in summer 1991 (Table 2).

Vegetative biomass was related to soil pH levels in both sample depths ($r = 0.71$; $P = 0.0001$), with the lowest biomass being recorded on highly acid sites. Separate

Table 1. Mean (± SE) seeded and native herbaceous biomass (kg/ha) and pH levels at 2 soil depths on 5 cover types on 35 reclaimed disposal areas of the Divide Section Wildlife Management Area in Tishomingo County, Mississippi, during 1991–1992.

			pH level	
Cover Type	*N*	Plant biomass	0–10 cm	>10–20 cm
1991				
Seeded legume	10	3256.6 (± 555.5)	6.7 (±0.3)	6.0 (±0.3)
Seeded grasses	5	3170.0 (±1853.4)	7.4 (±0.1)	5.9 (±0.5)
Native herbaceous	10	3459.7 (± 493.8)	6.5 (±0.2)	5.0 (±0.4)
Planted shrubs[a]	5		6.9 (±0.5)	5.9 (±0.5)
Pyritic sites	5	0.6 (± 0.6)	3.6 (±0.1)	3.3 (±0.1)
1992				
Seeded legume	10	1927.2 (± 624.5)	6.7 (±0.3)	5.8 (±0.5)
Seeded grasses	5	3372.0 (±1131.1)	7.2 (±0.3)	5.8 (±0.7)
Native herbaceous	10	4913.1 (± 566.4)	6.3 (±0.3)	5.1 (±0.4)
Planted shrubs[a]	5		7.3 (±0.3)	5.8 (±0.5)
Pyritic sites	5	0.0	3.6 (±0.2)	3.2 (±0.2)

[a] No vegetative biomass collected under planted shrubs. Shading by shrubs limited plant cover.

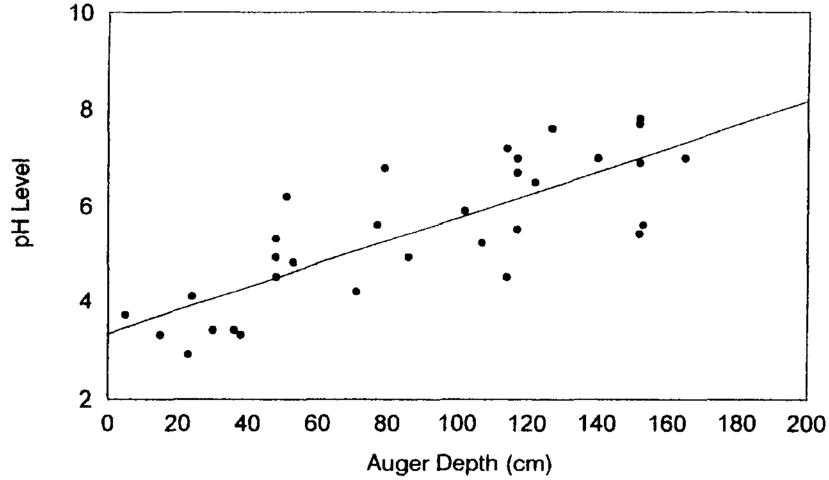

Figure 1. Linear relationship of auger depth to overburden material and soil pH levels in >10- to 20-cm sample depths on reclaimed disposal areas of the Divide Section Wildlife Management Area in Tishomingo County, Mississippi ($r^2 = 0.67$, 31 dF, $P < 0.0001$).

analysis of seeded and naturally-colonizing biomass revealed that seeded plant biomass showed a stronger direct relationship ($r = 0.74$; $P = 0.0001$) with soil pH levels than did native plant biomass ($P > 0.10$). The differences in these relationships may be due, in part, to broader ranges of soil acidity tolerance exhibited by selected native species. Naturally-colonizing plants that were found on disposal areas where pH levels were <5.0 included common broomsedge, goldenrod (*Solidago spp.*), erigeron

Table 2. Range of soil pH levels, depth to overburden, and vegetative characteristics of five pyritic sites on reclaimed disposal areas of the Divide Section Wildlife Management Area in Tishomingo County, Mississippi, during 1992.

Parameter	Range of Values
pH level	
10 cm	3.3–3.9
>10–20 cm	2.9–3.4
Depth to overburden	2.5–35.6 cm
Vegetative coverage	0.0–0.2%
Vegetative biomass	0.0–6.4 kg/ha

(*Erigeron canadensis*), panic grasses (*Panicum spp.*), rabbit tobacco, eupatorium (*Eupatorium album*), and common lespedeza (*Lespedeza striata*).

Lower pH levels in >10 to 20-cm soil samples indicated that active soil acidity was higher in deeper substrates. Proximity to acidic overburden and the vertical movement of acid-forming complexes upward from the overburden through capillary action resulted in low soil pH at these depths. Metal cations, anions, and salts that may be produced from oxidation of pyrite include hydrogen, iron, aluminum, manganese, and sulfates (Pugh et al. 1984, Skousen 1987). At pH levels of ≤4.5, concentrations of these complexes are generally phytotoxic. Soil pH levels at 0–10 cm were less influenced by overburden depth unless pyrite occurred as a layer or was intermixed in the substrate within the upper 36 cm of the soil's surface. Coverage of overburden at depths of ≤36 cm or the presence of subsurface pockets of pyrite mixed within the upper 36 cm of soil resulted in high active soil acidity (pH ≤ 4.0) and limited vegetation cover. Coverage depths of >101.6 cm appeared to be adequate for limiting pyrite oxidation and slowing soil acidification. Of the 25 monitored disposal sites dominated by herbaceous cover, 19 disposal areas exhibited pH levels of ≥5.5 in >10- to 20-cm soil depths and ≥6.0 in 0- to 10-cm soil depths. Fifteen of these 25 sites exhibited soil coverages of pyrite overburden at depths of ≥101.6 cm. These soil coverage amounts and pH levels were adequate for establishment and maintenance of vegetation. Sites that were characterized by these soil conditions supported ≥98% plant cover and >3000 kg/ha of plant biomass in the summers of 1991 and 1992 (Jones 1995).

Six vegetated disposal sites had soil coverage of the overburden layer ranging from 24.1 to 53.3 cm in depth. No subsurface pockets of overburden were detected on these sites. These disposal sites typically supported vegetation. However, bare soil areas ranged from 3% to 10% along line intercepts. Soil analysis on these sites revealed that pH levels ranged from 5.3 to 6.9 in 0- to 10-cm samples, and from 3.3 to 4.40 in >10- to 20-cm soil samples. Lower soil pH levels recorded in deeper soil layers and shallower overburden coverage led to reduced plant cover (≤90%) and herbaceous biomass (≤2700 kg/ha). Common plants inhabiting these disposal areas were common lespedaza, common broomsedge, bromes (*Bromus* spp.), panic grasses, partridge pea (*Chameacrista fasciculata*), erigeron, aster (*Aster pilosus*), and eupatorium. Although plant cover on these sites was considered adequate for erosion control, low pH levels in deeper soil samples and proximity of overburden to soil surface could produce phytotoxic conditions if the soil surface is disrupted or overturned. Edaphic conditions on these sites are conducive to maintenance of naturally-colonizing plants through management practices that do not disrupt the soil surface.

The effect of shallow soil coverage over overburden was most evident on five pyrite oxidation sites monitored in this study. Vegetation was limited or absent on these sites throughout the study period (Tables 1, 2). Concentrations of hydrogen, aluminum, and metal cations yielded phytotoxic conditions where application of lime and topsoiling may be necessary for establishment of plant cover (Skousen 1987, Ammons and Shelton 1991). Soil pH and lack of vegetation on acid sites illustrate the restoration problems that may be inadvertently produced by exposure of acid-forming overburden through shallow soil coverage or disturbance.

Management Implications

High soil acidities within the upper 10 cm of the soil surface and shallow soil coverage of overburden may create phytotoxic soil conditions for plant cover. Many sites may exhibit pH levels of ≥5.0 in the 0–10 cm of soil, but pH levels in deeper soil layers may be <5.0. These substrates may become increasingly acidic over time due to oxidation of pyrite overburden. Tenuous conditions exist on these sites for maintenance of vegetation.

Habitat management programs for areas containing acid overburden should consider the following recommendations. Soil samples should be collected on all sites that are targeted for food plot site preparation or disking. Soil samples should be collected at the surface (0–10 cm) and deeper depths (>10–20 cm). Samples from the 2 depths should not be mixed for analysis. Each soil sample should be analyzed for active soil acidity (pH) and lime requirements as described by Skousen (1987). Most soil testing laboratories perform these analyses and results are easily interpreted by wildlife managers. Lime should be applied at recommended rates and should be incorporated into the top 15.24 cm of soil on sites where pH is low and large amounts of lime are needed (Skousen 1987). The highest rate recommended for surface application of lime with no incorporation is 11.2 Mg/ha (Skousen 1987). If higher liming rates are recommended for neutralizing potential acidity, managers should seek technical assistance from soil scientists.

In substrates containing unweathered parent material and overburden, more extensive soil tests may be needed to measure exchangeable and nonexchangeable acidity. These measurements determine the presence of unweathered acid-forming complexes and the acid-production potential of a substrate over time. Techniques for measuring these parameters include acid-base accounting, potassium chloride extraction, and the barium-chloride-triethanolamine method (Skousen 1987). Annual wildlife food plantings are not recommended on sites containing acid overburden within the upper 100 cm. Instead, native plant maintenance through liming, fertilization, limited prescribed fire, or mowing should be considered. Liming should be conducted regardless of other implemented management practices. Seeding with perennial or reseeding food plants without disking is recommended for these sites. Food and cover plants that colonized soils with pH levels of <5.0 were annual lespedeza, panic grasses, partridge pea, and broomsedge. If plantings are desired for increasing diversity, perennial or reseeding wildlife plants that do not require soil disturbance or annual planting are recommended.

Activities that regularly disturb the soil surface and expose acid-forming substrates should be monitored and limited on many upland disposal and mine sites. These activities include access by horses, tracked vehicles, wheeled vehicles, and habitat management practices, such as disking and food plot site preparation. Disking or any soil disturbance in substrates with soil pH levels of ≤4.5 should be avoided. If substrates contain unweathered parent material or metal sulfides, disking may expose these complexes to weathering conditions. With exposure, the oxidation of these minerals can release acidifying complexes of hydrogen, aluminum, iron, manganese, and sulfates. Amelioration of these sites is generally expensive and involves application of lime and topsoil coverage of acid-producing substrates (Skousen 1987, Ammons and Shelton 1991). Recommended lime rates for pyrite oxidation sites on DS-WMA disposal areas were as high as 27 mg/ha for temporary revegetation and 44 mg/ha for long-term stabilization (Ammons and Shelton 1991). Application of lime at these rates should be combined with topsoil application and resurfacing to establish vegetation (D. E. Pettry, pers. commun.)

Wildlife biologists who manage habitats on disturbed lands that contain acid-producing overburden should understand existing soil chemistry conditions and associated vegetation failures. Management efforts intended to diversify plant communities may produce soil conditions where vegetation does not survive. Collection and analysis of soil samples to detect acid-forming complexes and application of lime at recommended rates are important management strategies that can maintain vegetative cover and wildlife habitat on disturbed lands.

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