

CONCEPTS AND CRITERIA FOR EVALUATING TOPSOIL SUBSTITUTES: THE TEXAS EXPERIENCE¹

by

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Abstract. Presented in this paper are: (1) historical background, (2) Federal and State regulatory basis and authority, and (3) justification for selected criteria and parameters which are currently used to evaluate the quality of topsoil-substitute materials and postmine soils in Texas. The specific parameters and concepts discussed include (1) acid- and toxic-forming materials (AFM and TFM), (2) quantification procedures for AFM and TFM, (3) procedures used to identify topsoil substitutes that are "equal to or more suitable than" existing premine native soils, and (4) current interpretations of what is meant by "the best available material to support revegetation" of surface-mined areas. To support these interpretations, reference is made throughout the paper to relevant sections of the (1) Texas Coal Mining Regulations (TCMR), (2) Surface Mining Control and Reclamation Act (SMCRA), and (3) Federal regulations promulgated by the Office of Surface Mining (OSM) to implement SMCRA. The success of the Texas reclamation program, as indicated by the quality of the reclaimed soils is also discussed. This success is partly attributed to the rigorous application of the quantification concepts and parameters discussed in this paper.

Additional Key Words: Reclamation, acid-forming materials, toxic-forming materials, minesoils, overburden.

Introduction

The Texas Coal Mining Regulations are codified in Title 16 of the Texas Administrative Code (TAC), Chapter 12. The regulations were adopted by the Railroad Commission of Texas, effective April 7, 1997 (RCT, 1997). According to Section 12.335(e) of the TAC, selected overburden materials may be substituted for or used as a supplement to topsoil if the Railroad Commission of Texas determines that (1) the resulting soil medium is equal to or more suitable for sustaining revegetation than is the available topsoil, and (2) the

substitute material is the best available material to support revegetation. The objectives of this paper are to provide (1) historical background information, (2) regulatory basis and authority, and (3) justification for the procedures and parameters that are currently used to evaluate the suitability of selected overburden materials for topsoil substitution. Specifically, the following parameters are discussed:

- Acid-forming materials (TAC, Section 12.3)
- Toxic-forming materials (TAC, Section 12.3)
- Topsoil substitutes that are "...equal to or more suitable than is the available topsoil..." (TAC, Section 12.335(e)(2)(A)).
- Concept of "...best available material to support vegetation..." (TAC, Section 12.335(e)(2)(B))

The experience gained by applying these concepts to the characterization of topsoil substitutes and monitoring of the postmine soils is also described in the paper. In general, replacement of native soil horizons by selected oxidized overburden

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material has successfully been implemented, particularly in Central and Northeast Texas.

Acid-Forming Materials

Acid-forming materials (AFM) means earth materials that contain sulfide minerals or other materials which, if exposed to air, water, or weathering processes, form acids that may create acid drainage (TAC, Section 12.3). Determining whether topsoil substitutes contain AFM involves a determination of the difference between acid neutralizers and acid producers present in the material. This is the basis of the acid/base accounting procedure.

Prior to 1984, the method used to determine the acid/base accounting of topsoil substitutes in Texas was the method described in EPA Publication No. 600/2-78-054 (EPA 1978). According to this method, the acid/base account value is calculated by subtracting the potential acidity value from the neutralization potential value. The difference between the neutralization potential and the potential acidity is expressed in tons of calcium carbonate equivalents per 1000 tons of material, or parts per thousand (ppt). Materials that have negative acid/base account values of less than or equal to -5 ppt and/or pH values of less than 4.0 are considered to be AFM.

However, experience showed that many native soils in east Texas and north of the Colorado River are characterized by low pH and negative acid/base account values, due to the significant amounts of exchangeable acidity in these soils. For example, many of the native soil series found at the Texas Municipal Power Agency (TMPA) Gibbons Creek Lignite Mine, Northwestern Resources (NWR) Company Jewett Mine, and Texas Utilities Mining Company (TUMCO) mine at Oak Hill are characterized by low pH and negative acid/base account values (TMPA, 1995; NWR, 1994, and TUMCO, 1992). Based on the information submitted to the RCT-SMRD by TUMCO, the Cuthbert soil series at Oak Hill Mine has an average pH of 5.1 and an average acid/base account value of -2 ppt in the surface horizon. The average pH and acid/base account (ppt) values of the subsurface horizons are 4.8 and -4, respectively. The exchangeable aluminum in the subsurface horizons of the Cuthbert soil series is as high as 10 meq/100. Therefore, the concept of acid/base accounting was redefined to include exchangeable acidity in the definition of AFM. This work was conducted between 1984 and 1991, with the cooperation of a Technical Advisory Committee, which was set up to advise the Surface Mining and

Reclamation Division on technical issues concerning surface mining in Texas. The Technical Advisory Committee consisted of seven representatives: four representatives from academia, and one representative from each of the following entities: (1) Soil Conservation Service, now known as the Natural Resources Conservation Service, (2) the Texas Mining and Reclamation Association (TMRA), and (3) the Railroad Commission of Texas. Representatives of the Office of Surface Mining (OSM) also participated in the work of this committee. In 1985, the Railroad Commission of Texas, under OSM oversight, directed mine operators who were using topsoil substitutes to further justify this mode of minesoil reconstruction. As a result of this directive and with the recommendation of the Technical Advisory Committee, technical guidelines (called Technical Releases) were produced to provide guidance to the regulated community on procedures for quantitatively determining the presence of AFM in the proposed topsoil substitutes. The RCT-SMRD officially released Technical Release (TR) SA-1 to industry in October of 1988. This guidance document contains the definition of AFM, which was defined by using a combination of two parameters, pH and acid/base balance or acid/base accounting as illustrated in the following equations:

$$(1) \text{ ABB} = [(0.2 \times \text{CEC}) + \text{IC}] - [\text{PA} + \text{EA}]$$

$$(2) \text{ ABA} = \text{NP} - [\text{PA} + \text{EA}]$$

Where:

ABB = Acid/base balance (ppt)

ABA = Acid/base accounting (ppt)

CEC = Cation exchange capacity (ppt)

PA = Potential acidity (ppt)

EA = Exchangeable acidity (ppt)

NP = Neutralization potential (ppt)

IC = Inorganic Carbonates (ppt)

Presence of AFM in postmine soils is indicated by soil pH values that are less than 5.0 or pH values that are lower than those of the premine native soils. Presence of AFM in potential topsoil

substitutes is also indicated by negative ABB or ABA values that are lower than those of premine soils.

Toxic-Forming Materials

Toxic-forming materials (TFM) means "earth materials or wastes which, if acted upon by air, water, weathering, or microbiological processes, are likely to produce chemical or physical conditions in soils or water that are detrimental to biota or uses of water" (TAC, Section 12.3). Weathering of topsoil-substitute materials may result in high concentrations of certain substances that may be detrimental to the vegetation established on postmine soils. For example, weathering of topsoil substitutes may result in (1) high salt conditions, and (2) high levels of trace elements.

Technical Release SA-2, dated October 1988, contains critical levels for several parameters, including electrical conductivity (EC), sodium adsorption ratio (SAR), and trace-elements. Topsoil-substitute materials and minesoils with EC, SAR, and trace element concentrations that exceed the critical levels specified in TR SA-2 are considered to be TFM.

Section 12.386 of the TAC specifies that (1) all TFM produced during surface-mining activities must be covered with a minimum of 4 feet of the best available nontoxic and noncombustible materials, and (2) AFM or TFM should not be buried or stored in proximity to a drainage course so as to cause or pose a threat due to water pollution. Technical Releases SA-1 and SA-2 provide guidance on criteria for defining material that is free from AFM and TFM. Such materials should be placed in the upper four feet of the regraded area.

Suitability of Topsoil Substitute

Section 12.145(b)(4) of the TAC requires that "a demonstration of the suitability of topsoil substitutes and supplements...be based upon analysis of the thickness of soil horizons, total depth, texture, percent coarse fragments, pH, and areal extent" of the native soil series present in the premine area. However, "the Commission may require other chemical and physical analyses, field-site trials, or greenhouse tests if determined to be necessary or desirable to demonstrate the suitability of topsoil substitutes or supplements."

Title 30, Part 780.18(b)(4) of the Code of Federal Regulations (CFR) also requires the same,

indicating that the determination of suitability, that is, whether or not the supplement or substitute material is equal to or more suitable and is the best available for sustaining revegetation, compared to the available topsoil, be based, at a minimum, on the results of physical and chemical tests.

According to Section 12.335(e) of the Texas Administrative Code, "selected overburden materials may be substituted for or used as a supplement to topsoil, if the Commission determines that the resulting soil medium is equal to or more suitable for sustaining revegetation than is the available topsoil...", and that the "...substitute material is the best available to support revegetation". As specified in 30 CFR 816.22(b), topsoil substitutes and supplements must be "the best available in the permit area to support vegetation".

Section 134.095(b) of the Texas Coal Mining and Reclamation Act indicates that if "topsoil is of insufficient quantity or of poor quality for sustaining vegetation,...or if other strata can be shown to be more suitable for vegetation requirements,...the operator shall remove, segregate, and preserve ..." in a like manner such other strata which is best able to support vegetation. Section 515(b)(5) of SMCRA contains equivalent language.

Subsoil Segregation and Reconstruction

The preamble to Title 30 of CFR contains the concept that most soil systems need to have more than just the topsoil replaced in order to reclaim its capability and productivity. Thus, 30 CFR 816.22(e) allows the regulatory authority (RA) to require the removal of and reconstruction of a subsoil system. This regulation was challenged by industry (National Coal Association) in a District Court. The industry had claimed, during the development of this rule, that the only subsoil system that was mandated by SMCRA to be reconstructed was for prime farmland. OSM's position was that, if needed to restore the productivity as mandated by SMCRA, the RA should have the authority to require the removal and reconstruction of subsoil horizons. OSM's position prevailed.

Concept of Best Available/More Suitable Material

The TCMR, OSM regulations, and case law do not clearly specify criteria for defining what is meant by the phrases "...equal to or more suitable for sustaining the vegetation than is the available topsoil..." (TAC, Section 12.335(e)(2)(A)) and "...the best available material to support vegetation..." (TAC, Section 12.335(e)(2)(B)). However, all three authorities require that the proposed topsoil substitute material (1) be located within the permit boundary, (2) be free of AFM and TFM, (3) have textural characteristics that are equivalent to those of the native soils within the permit boundary, and (4) be evaluated by using physical and chemical tests or any other criteria specified by the regulatory authority.

The Texas Experience

Texas obtained primacy on February 16, 1980, that is, the state, through the Railroad Commission of Texas, assumed the primary responsibility to administer and enforce the permanent regulatory program. In its efforts to implement the permanent regulatory program, the RCT-SMRD developed quantifiable criteria to define what constitutes topsoil-substitute material that is "equal to or more suitable for sustaining the vegetation than is the available topsoil" (TAC, Section 12.335(e)(2)(A)). These criteria were developed through a cooperative effort among the Commission, OSM, industry, academia, and the Soil Conservation Service. The criteria were developed as an element of the 1985 Texas Action Plan (Starr and Brown 1986). The quantification criteria are described in Technical Releases (TR) SA-1 and SA-2. These documents provide general guidance to the regulated industry. According to these criteria, the phrase "... equal to or more suitable ..." describes any material with characteristics that would be no more limiting than the criteria described in TR SA-2. For example, a minesoil with a pH value of 3.2 is more limiting to plant growth than a minesoil with a pH value of 6.6.

To determine whether or not the reclaimed minesoil is equal to or better than the premine soil, the concept of acreage banking was introduced. The banking method consists of initially determining the premine native-soil acreage which falls within a particular parameter range. This acreage then becomes the "initial bank acreage" for this parameter range. Once this acreage is determined, any reclaimed acreage which falls within the same pH range is subtracted from the "initial bank acreage". If the reclaimed minesoil

acreage does not exceed the "initial bank acreage" during the permit term, then the reclaimed minesoil is equal to or more suitable than the premine native soil. However, if the postmine acreage in this particular pH range exceeds the "initial bank acreage", then the reclaimed minesoil is no longer equal to or better than the premine soils. The banking method is used to continually evaluate the quality of the reclaimed soils by using minesoil-monitoring parameters of pH, acid/base accounting, electrical conductivity, sodium adsorption ratio, sand and clay contents, and trace-element contents of the reclaimed minesoils.

The phrase "... best available to support vegetation..." is used to describe any topsoil-substitute material that is located within the permit boundary and meets the suitability criteria described in TR SA-2.

The Technical Releases SA-1 and SA-2 contain quantifiable performance standards that are simple to apply. The use of these performance standards has resulted in postmine soils with equal or better physical and chemical characteristics than the premine native soils. By using these criteria, the RCT has been able to (1) identify minesoils with AFM/TFM problems at several mining companies, and (2) initiate enforcement actions to force the companies to address these problems. About 5.6 percent of the estimated 54,000 acres that were mined between 1980 and 1996 have been treated with lime to neutralize AFM. Most of the reclaimed acreage (over 95 percent) was found to be free of AFM and TFM, based on postmine-monitoring data. Postmine-monitoring data also indicated that the physical and chemical characteristics of the minesoils are equal or better than those of the premine native soils, particularly in Northeast Texas.

In general, replacement of native soils with selected topsoil substitutes has resulted in:

- A general increase in the clay content of the 0 to 1-foot depth increment and a lesser decrease of the clay content in the 1 to 4-foot depth increment of the reclaimed soils, thus increasing the absorptive and retention capacity of the minesoils for water and nutrients (TUMCO, 1996).
- Removal of native soils having paralithic materials close to the surface, thus increasing

the rooting depth of the postmine soils (TMPA, 1995).

- Removal of claypan layers that are common in native soils developed from the Wilcox and Yegua-Jackson parent materials. This has resulted in the removal of the physical and chemical barriers, which restrict rooting depth for plants (ALCOA, 1991).
- Reduction in the slopes of the postmine topography versus premine topography, which results in lower sediment loads to streams (NWR, 1994).

In the semi-arid Southwest Texas, the overburden strata that overlie the Jackson-Yegua lignite are generally less oxidized than the overburden strata that overlie Wilcox lignite and, therefore, may contain AFM and TFM, including high concentrations of soluble salts and trace elements, such as uranium. In this part of Texas, topsoil substitution has the potential to produce minesoils that contain TFM and AFM. Therefore, topsoil replacement is recommended in Southwest Texas.

In Central and Northeast Texas, the physical, chemical, topography, and crop productivity of several minesoils, such as the Big Brown and Grayrock series satisfy the requirements for prime-farmland soils. Therefore, an overall increase in prime-farmland soil acreage has occurred as a result of surface-mining activities. According to DeMent et. al. (1992), the acreage of prime farmland soils at the TUMCO Mine at Monticello has increased by 27 percent. Also, The acreage reclaimed as prime farmland soils has increased by about 55 percent at the TUMCO's Big Brown Mine in Fairfield, Texas (Personal communication with Eddie Bearden, Texas Utilities Service, Dallas, Texas). This increase in the acreage of prime farmland soils in surface-mined areas is evidence that the reclaimed soils are equal to or better than the native premine soils.

Salvaging of bottom-land soil material (fertile flood-plain soils containing a large and diverse seed source) for subsequent replacement over leveled spoils has not been pursued in Texas mines located north of the Colorado River. This is due to the fact that organic matter accumulates rather rapidly in the top layer of the reclaimed minesoils. Within a period of about 3 to 6 years, the organic matter content of the reclaimed minesoils is equivalent to that of the premine soils, based on personal observations. A variety of bottom-

land species planted along reconstructed drainage ways and low-lying areas have been successfully established at the TUMCO mine at Monticello, as was demonstrated in the Phase III Bond Release Application that was approved by Commission Order dated May 21, 1996. Therefore, the reclaimed soils are able to sustain bottom-land vegetation that is equivalent to that of the premine native soils. However, in areas of Texas where the rate of organic matter accumulation in the reclaimed soil is relatively low (such as in mines south of the Colorado River), the premine topsoil is routinely salvaged and redistributed over the leveled spoil.

Summary and Conclusions

Reclamation activities in Texas primarily consist of replacement of native soils with selected overburden materials or topsoil substitutes. Federal and Texas surface-mining regulations require that the selected topsoil substitutes be "equal to or more suitable" than the premine native soils, or be the "best available material to support revegetation." Topsoil substitutes must also be free of TFM and AFM. An attempt is made in this paper to present an overview of the historical development and evolution of the procedures and criteria that are currently used to characterize physical and chemical characteristics, including AFM and TFM, of topsoil substitutes and reclaimed minesoils in Texas. This paper also includes a description of the concepts and criteria used to determine whether topsoil substitutes are (1) "...equal to or more suitable than premine native soils, or (2) are the "...best available material to support revegetation..."

Experience gained during the last 15 years suggests that, in general, reclaimed soils developed from topsoil substitutes are (1) inherently more fertile than the premine native soils, and (2) generally free of TFM and AFM. Therefore, it is concluded that the concepts and criteria used to quantify and predict the presence or absence of AFM and TFM in topsoil substitutes are fairly accurate. However, more precise methods and procedures for quantifying AFM and TFM in topsoil substitutes and minesoils are currently being investigated.

Topsoil substitution has been successful, particularly in Central and Northeast Texas where

adequate quantities of oxidized overburden overlies the Wilcox lignite. Oxidized overburden is generally free of AFM and TFM. However, Topsoil substitution is not recommended in the semi-arid Southwest Texas. Topsoil is generally salvaged and replaced on mined areas at many coal mines located south of the Colorado River.

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