# WATER QUALITY OF RUNOFF FROM REVEGETATED MINE SPOIL

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ABSTRACT

Permanent vegetation plots were established on mixed overburden and topsoiled overburden on a lignite test pit in eastern Texas in 1982. Vegetative treatments included two grass-legume treatments {switchgrass (Panicum virgatum) - sideoats grama (Bouteloua curtipendula) - subterranean clover (Trifolium subterranean) and little bluestem (Schizachyrium scoparium) - sideoats grama (Bouteloua curtipendula) - Illinois bundleflower (Desmanthus illinoiensis)} and three monocultures {Coastal bermudagrass (Cynodon dactylon), bahia grass (Paspalum notatum) and yellow Indiangrass (Sorghastrum nutans) }. Water was applied to the $0.5m^2$ plots using a sprinkler-type rainfall simulator and quality of runoff was determined for each plot. Parameters analyzed included: settleable solids, total filterable solids, sediment production, infiltration rate, nitrites, nitrates, total iron and total manganese. Topsoiling significantly increased infiltration and significantly decreased filterable sediments, sediment production and settleable solids. The hydrologic qualities of the switchgrass-sideoats grama-subterranean clover mixture coincided closely with those of the Coastal bermudagrass monoculture.

# INTRODUCTION

Lignite production in Texas has increased greatly since 1970 as demand for an economical fuel for electrical power generation has increased. Surface mining, which is expected to disturb an additional 400,000 hectares (ha) in Texas by the year 2000, is the only economically and technologically feasible means of extracting this near-surface lignite[1]. There is, however, probably no greater man-made impact upon the land than that caused by surface mining. Surface mining involves three basic steps: 1) removal of the overburden or soil and rock lying above the seam of lignite; 2) mining the lignite; and 3) reclaiming the land to a designated post mining land use[2]. Thus, vegetative, edaphic, geologic, and hydrologic systems are severely disrupted resulting in temporary ecological disorder. Reclamation of these lands, therefore, is no easy task. Revegetation and topsoil replacement are major factors determining ultimate reclamation success on surface mined lands.

Successful revegetation of surface mine spoils depends upon quick stabilization of freshly regraded spoils to control erosion and retain moisture[3]. Revegetation strategies in Texas have emphasized the use of Coastal bermudagrass (Cynodon dactylon (L.) Pers.) because of its rapid soil coverage and stabilization, and high production capabilities under heavy nitrogen fertilization. As fertilization rates are decreased, however, forage productivity, quality, and persistance are reduced. Due to its ease of establishment by sprigging and high forage and livestock production under fertilization, Coastal bermudagrass pastures are preferred by many landowners to native grass range. Unfortunately, this decision is usually based on economic and management factors regardless of the long-term ecological implications.

Although annual forage legumes such as arrowleaf clover (*Trifolium vesiculosum* Savi) and crimson clover (*T. incarnatum* L.) are used to supplement Coastal, they often must be reseeded every year thus adding little to long-term plant diversity. Nodulation and nitrogen fixation of some legumes has also been shown to decrease as nitrogen fertilization increases. Therefore, their contribution to the nitrogen balance of spoil under these agronomic management schemes is often diminished.

This revegetation strategy, although adequate when improved pasture is the post mining land use, is incapable of providing the plant diversity and stability necessary for establishment of rangeland or wildlife habitat. Mixtures of compatible, self-perpetuating, adapted species are needed to achieve these land uses.

Due to the inherently poor native soils, current Texas laws allow mining companies to revegetate non-topsoiled mixed overburden provided they can show it to be equal or superior to the productivity of native soils[4]. In most cases, spoil material was found to have a more favorable texture and thus a greater water and nutrient holding potential than unmined surface soils and equal or greater productivity under optimal fertilization[5]. Research also has determined that when spoil is treated properly for revegetation as required by law, the quality of surface water running off the reclaimed site is similar to the water running off undisturbed soils[6]. Yet surface runoff originating from such reclaimed overburden may be contaminated with undesirable constituents, resulting in degradation of receiving waters[4].

Barren spoil areas and decreased infiltration rates tend to increase peak flow rates of runoff from mined areas. Such increased runoff erodes the spoil areas and carries spoil particles that cause sedimentation of waterways and reservoirs[7].

The Surface Mining Control and Reclamation Act of 1977 requires that the mining company shall make a 'determination of the probable hydrologic consequences of the mining and reclamation operations, both on and off the mine site, with respect to the hydrologic regime.' The law states that if there is not enough information to make this determination, no mining permit will be granted[7].

Many yield comparisons of vegetative growth on mine spoil in Texas were made either under high fertilization regimes, under artificial greenhouse conditions, or in relation to native soil, not topsoiled mine spoil.

The exclusive use of mixed overburden as a revegetation substrate may be questionable due to: a low nutrient status under low or no fertilization, low infiltration rates; and the length of time required to build up the organic matter component and re-establish nutrient cycling. The suitability of spoil as compared to topsoil, especially under a low-maintenance reclamation regime, needs closer scrutiny to determine not only its short-term but its long-term potential for sustaining plant growth.

The objective of this study was to determine water quality of runoff from artificial rainfall from revegetated mixed overburden and topsoiled spoil material.

# MATERIALS AND METHODS

## Study Site Description and Treatment

The study site is a continuing project located on a lignite test pit south of Dew, Texas. Dew is located approximately 180 km southeast of Dallas. The resource area is the Post Oak Savannah with an average annual precipitation of 97 cm, bimodally distributed with April-May and Oct-Nov peaks.

The test pit was filled with mixed overburden and sloped to 2%. Approximately 15 cm of topsoil was applied to 1/2 of the pit and graded to a 2% slope. The spoil is a stratified clay, silty clay and silty clay loam with the surface being a massive, heavy silty clay loam. The topsoil is a fine sandy loam resembling the Crockett series. Crockett soils are members of the fine, montmorillonitic, thermic family of Udertic, Paleustalfs.

Two revegetative treatments, 3 monocultures and 2 mixtures, were planted in 6 x 9 meter plots in a split-plot design with 3 replications per treatment. The monocultures consisted of Pensacola bahiagrass (*Paspalum notatum*), Coastal bermudagrass (*Cynodon dactylon*), and Lometa Indiangrass (*Sorghastrum nutans*). The mixtures consist of Haskell sideoats grama (*Bouteloua curtipendula*), Alamo switchgrass (*Panicum virgatum*) and Mt. Barker subterranean clover (*Trifolium subterranean*); and of little bluestem (*Schizachyrium scoparium*), Haskell sideoats grama, and Sabine Illinois bundleflower (*Desmanthus illinoensis*).

## Methods

Two 0.5$m^2$ permanent rainfall simulator test plots were located on each replication, giving 60 plots per collection date. A rainfall simulator similar to that described by Meyer and Harmon[8] was used to determine infiltration rates on the plots within each treatment. The plots were prewet with approximately 115 l of water using a sprinkler system to remove antecedent soil-water content differences. After prewetting, the plots were covered with plastic to retain uniform soil moisture conditions for approximately 18-24 hours. Simulated rainfall was applied at the rate of 18.8 cm per hour for 30 minutes to represent a 75 year storm and to insure runoff from every plot. Runoff was collected at 5 minute intervals for 30 minutes. Infiltration rates were calculated as the difference in rainfall applied and water collected as runoff.

Sediment production, settleable solids and filterable sediment were determined using a one-liter subsample of thoroughly mixed runoff collected after completion of each simulated rainfall period. Settleable solids were determined by allowing the one-liter subsamples to settle for one hour in a one-liter setting cone according to the technique described by the American Public Health Association[9]. Filterable sediment was determined by filtering the entire subsample through .45 micron filter paper and weighing the oven-dried filter and sediment. Sediment production was determined on a per ha basis from the filterable sediment. Two 400 ml subsamples of thoroughly mixed runoff were collected, one of which was treated with 1:1 mixture of nitric acid ($HNO_3$) and the other was frozen. The acid-treated subsample was digested and analyzed for iron (Fe) and manganese (Mn) using an atomic adsorption spectophotometer following standard methods. The frozen samples were thawed, filtered and analyzed for nitrate and nitrite using standard procedures on an auto-analyzer.

Percent cover estimates were visually estimated in each plot by plant species, bare ground, litter and rock. Soil moisture and bulk density were determined prior to each simulated rainfall event. Two samples were collected at 0-3 cm depths on areas adjacent to each plot. Soil moisture was estimated using the gravimetric method and the core method was used to determine bulk density[10]. Data were collected in April, June and October, 1983.

All statistics were run using the SAS procedure[11] on the Texas A&M Amdahl 470V6 Computer. Data normality was determined by tests for skewness and kurtosis. Differences due to treatment were determined by data analysis techniques and, when appropriate, Duncan's multiple range test was used to separate means.

## RESULTS AND DISCUSSION

### Soil Treatments

Vegetation and litter cover on the topsoil were significantly greater than that on the overburden (Table 1). This can be partially attributed to the seedbank present within the topsoil and to more rapid establishment of vegetation on the topsoil. Bare ground was comparably lower on topsoiled plots.

Infiltration rates were significantly greater on topsoil than on overburden (Table 1). Infiltration was enhanced by soil texture and by vegetative cover present on the plots.

Sediment production was significantly greater on the overburden plots than on topsoiled plots (Table 1). There was a greater potential for erosion on the overburden due to the lack of vegetation or litter cover. The topsoil had a greater vegetation and litter cover throughout the sampling period. This greater cover, plus the sandy soil texture accounted for more retention of soil, thus, less sediment production per hectare. The lower filterable sediment combined with the lower runoff from the topsoil plots accounted for the very low sediment production.

Settleable solids were significantly greater on overburden samples than on topsoil samples (Table 1). This corresponds to the greater amount of sediment in the overburden runoff samples. This occurs despite the clay texture of the overburden, which allows for the sediment to stay in suspension longer. Although the topsoil was of a sandy texture, there was less sediment in the runoff; therefore, there was less to settle out.

Filterable sediment was significantly greater on overburden plots than on topsoil plots (Table 1). The high percentage of bareground and

Table 1. Mean averages of physical and vegetational parameters on topsoil and overburden plots in Dew, Texas 1983.

| Variables | Topsoil | Overburden |
|---|---|---|
| Vegetation cover (%) | 74.68 a[1/] | 62.01 b |
| Bare ground (%) | 9.64 b | 29.90 a |
| Litter cover (%) | 15.44 a | 7.76 b |
| Infiltration rate (cm/hr) | 15.1 a | 13.2 b |
| Sediment production (kg/ha) | 25 b | 610 a |
| Settleable solids (ml/l/hr) | 0.4 b | 3.1 a |
| Filterable sediment (g/l) | 0.126 b | 1.688 a |

1/ Numbers within rows followed by the same letter are not significantly different at the 95% probability level (p = .05) low percentage of litter cover present on the April collection date were significant factors in the overall overburden production of filterable sediment from overburden. The increase in litter production and decrease in bareground in June and October somewhat compensate for the initial high sediment readings in April. Bareground on topsoil plots was never great enough on any collection date to be a significant factor, and litter cover was greater than that on overburden due to the greater plant cover. A considerable amount of initial cover can be attributed to forbs produced from the seedbank within the topsoil.

Nitrite and nitrate levels were significantly greater on overburden than on topsoil (Table 2). This could be attributed to greater bareground and greater sediment production. Levels of nitrite and nitrate in the simulated rainfall were 46 and 47 µg/l, respectively.

Iron and manganese were significantly greater in the samples taken from the overburden runoff than from the topsoil runoff. Manganese was undetected in the precipitation water, and iron was detected at 2.5 mg/l in the precipitation water.

Revegetation Treatment

On the mixed overburden, plant cover was significantly greater on the Coastal bermudagrass monoculture than any other revegetation treatment (Table 3). The two grass-legume mixtures provided more plant cover than the bahiagrass and Indiangrass monocultures. On the topsoiled area, greatest plant cover was observed on Coastal bermudagrass monocultures, and the little bluestem-sideoats grama-Illinois bundleflower and sideoats grama-switchgrass-subterranean clover mixtures.

Litter cover was significantly greater on the sideoats grama-Alamo switchgrass-subterranean clover mixture from the overburden treatment

Table 2. Chemical properties of runoff from topsoil and overburden plots from Dew, Texas in 1983.

| Treatments | Nitrate (μg/l) | Nitrite (μg/l) | Manganese (mg/l) | Iron (mg/l) |
|---|---|---|---|---|
| overburden | 63 a[1/] | 49 a | .86 a | 57.4 a |
| topsoil | 49 b | 36 b | .23 b | 8.5 b |

[1/] Numbers within columns followed by the same letter are not significantly different at the 95% probability level (p = .05)

Table 3. First year plant cover on topsoil and overburden plots according to revegetation treatments.

| Treatments | Overburden | | | Topsoil | | |
|---|---|---|---|---|---|---|
| | Plant cover (%) | Bare ground (%) | Litter cover (%) | Plant cover (%) | Bare ground (%) | Litter cover (%) |
| bahiagrass | 51.11 c[1/] | 42.44 a | 5.67 b | 67.00 b | 15.67 a | 17.53 a |
| Indiangrass | 54.17 c | 38.39 a | 6.89 b | 64.50 b | 17.78 a | 17.80 a |
| sideoats grama - switchgrass- subterranean clover | 66.11 b | 22.17 bc | 11.89 a | 78.33 a | 5.67 bc | 16.23 a |
| little bluestem - sideoats grama - Illinois bundleflower | 63.44 b | 29.61 b | 6.89 b | 79.40 a | 8.05 b | 12.50 a |
| Coastal bermudagrass | 75.22 a | 16.89 c | 7.44 b | 82.73 a | 1.66 c | 15.83 a |

1/ Numbers within columns followed by the same letter are not significantly different at the 95% probability level (p = .05).

(Table 3). There was no significant difference in litter cover between the revegetation treatments on the topsoiled plots.

Infiltration rates were significantly greater on Coastal bermuda treatments than all other revegetation treatments on overburden (Table 4). Indiangrass had more runoff and less infiltration, yet not a significantly higher rate of filterable sediment than the bahiagrass or little bluestem-sideoats grama-Illinois bundleflower plots. On topsoiled plots, Coastal bermudagrass had significantly greater infiltration rates than did Indiangrass. All other vegetation treatments were intermediate.

Sediment production from the overburden plots was significantly less on the Coastal bermudagrass and the sideoats grama-switchgrass-subterranean clover treatments than other vegetation treatments (Table 4). Sediment production from the topsoiled area was significantly higher on bahiagrass and Indiangrass treatments than on other treatments. The rapid establishment of vegetation cover throughout the initial growing season accounted for the decrease in sediment found in the runoff. The little bluestem-sideoats grama-Illinois bundleflower mixture had a lower percentage of bareground and higher plant cover on the topsoil plots which caused it to have significantly less sediment loss than the bahiagrass and Indiangrass treatments when compared to the overburden plots.

There was no significant difference in settleable solids between the revegetation treatments on either soil type (Table 4) although, as already mentioned, there was a significant difference between soil types (Table 1). This could be attributed to the soil types, which allowed for differential settling, and to the vegetation established on these soils. The high variation in readings from early samples to later samples tended to mask apparent differences between treatments.

Table 4. Physical properties of runoff from five revegetation treatments on topsoil and overburden plots in Dew, Texas 1983.

| Treatments | OVERBURDEN | | | | TOPSOIL | | | |
|---|---|---|---|---|---|---|---|---|
| | Settleable Solids (ml/l/hr) | Filterable Sediment (g/l) | Sediment Production (kg/ha) | Infiltr. rate (cm/hr) | Settleable Solids (ml/l/hr) | Filterable Sediment (g/l) | Sediment Production (kg/ha) | Infiltr. Rate (cm/hr) |
| bahiagrass | 4.4 a[1/] | 2.428 a | 957 a | 13.4 b | 0.4 a | 0.177 a | 36 a | 15.3 ab |
| Indiangrass | 4.5 a | 2.22 a | 913 a | 12.3 b | 0.3 a | 0.150 a | 46 a | 13.7 b |
| sideoats grama - switchgrass - Subterranean clover | 1.7 a | 0.836 b | 102 b | 12.8 b | 0.4 a | 0.096 a | 17 b | 15.1 ab |
| little bluestem - sideoats grama - Illinois bundle-flower | 3.9 a | 2.502 a | 941 a | 12.9 b | 0.4 a | 0.096 a | 15 b | 15.4 ab |
| Coastal bermudagrass | 0.8 a | 0.446 b | 135 b | 14.7 a | 0.3 a | 0.110 a | 14 b | 16.0 a |

[1/] Numbers within columns followed by the same letter are not significantly different at the 95% probability level (p = .05)

Filterable sediment from overburden plots was significantly greater on bahiagrass and Indiangrass monocultures, and the little bluestem-sideoats grama-Illinois bundleflower mixture than on other treatments (Table 4). The significant reduction in filterable sediment on overburden plots of the sideoats grama-switchgrass-subterranean clover mixture and Coastal bermudagrass treatments can be attributed to their rapid establishment after planting and their vigorous growth throughout the year. There were no differences between revegetation treatments on the topsoiled plots (Table 4), but filterable sediment values were significantly lower compared to the overburden plots (Table 1).

Nitrate was significantly less on Coastal bermudagrass topsoiled plots as compared to the other vegetated topsoiled plots (Table 5). This could be partially attributed to the amount of cover on the plots. Coastal bermudagrass, overburden plots were significantly lower in nitrates than the bahiagrass plots yet not significantly lower than the other three vegetated plots.

Nitrite was lowest in the Coastal bermudagrass, topsoiled plots, yet not significantly different from the bahiagrass plots (Table 5). The sideoats grama-switchgrass-subterranean clover mixture on topsoiled plots was significantly highest in nitrite levels. There were no significant differences in the five revegetation treatments on the overburden.

There were no significant differences in manganese levels found in the runoff from vegetated topsoil plots (Table 5). There was a greater amount of manganese from the bahiagrass and less manganese in the Coastal bermudagrass overburden plots although not significantly so. Manganese levels were below the maximum acceptable level in all cases.

Levels of iron were not significantly different in vegetation from the

Table 5. Chemical properties of runoff from five revegetation treatments on topsoil and overburden plots in Dew, Texas 1983.

| Vegetation Treatments | OVERBURDEN Nitrates µg/l | OVERBURDEN Nitrites µg/l | OVERBURDEN Manganese mg/l | OVERBURDEN Iron mg/l | TOPSOIL Nitrate g/l | TOPSOIL Nitrite g/l | TOPSOIL Manganese mg/l | TOPSOIL Iron mg/l |
|---|---|---|---|---|---|---|---|---|
| bahiagrass | 75 a [1/] | 44 a | 1.39 a | 93.1 a | 49 a | 30 bc | .31 a | 9.4 a |
| Indiangrass | 61 ab | 48 a | 1.02 ab | 69.0 a | 51 a | 45 ab | .27 a | 9.4 a |
| sideoats grama-switchgrass-subterranean clover | 59 ab | 54 a | .63 bc | 30.9 b | 61 a | 53 a | .18 a | 8.9 a |
| little bluestem-sideoats grama-Illinois bundle-flower | 69 ab | 44 a | .87 b | 69.3 a | 58.0 a | 35.1 b | .15 a | 6.4 a |
| Coastal bermudagrass | 53 b | 55 a | .35 c | 23.0 b | 28.0 b | 17.3 c | .21 a | 8.0 a |

[1/] Numbers within columns followed by the same letter are not significantly different at the 95% probability level ($p = .05$)

topsoil plots (Table 5). Bahiagrass, Indiangrass and little bluestem-sideoats grama-Illinois bundleflower overburden plots were significantly higher than the sideoats grama-switchgrass-subterranean clover plots or the Coastal bermudagrass plots.

# CONCLUSIONS

Topsoiling significantly improved the hydrologic parameters that were evaluated in this study. Therefore, topsoil seems to be a more viable medium than overburden on which to establish vegetation in order to meet Federal Surface Mining Reclamation Water Quality Standards.

Under the current regulations, neither the topsoil nor the overburden fall within the 10 year - 24 hour storm filterable solids production of between .035 g/l and .070 g/l. New proposed regulations are to consider the settleable solids of runoff as opposed to filterable solids. Proposed maximum levels of settleable solids are .5 mg/l/hr. Under the proposed settleable solids regulations, the topsoil would fit the criteria. It must be remembered that these represent levels from small plots, which generally have higher sediment production levels than larger areas.

Chemical qualities of the topsoil runoff met current regulations whereas overburden runoff exceeded iron levels, and was significantly greater than topsoil in nitrite and nitrate levels. Manganese levels were less than the maximum 3.5 mg/l standard for both topsoil and overburden.

All vegetation treatments exceeded the current 10 year - 24 hour filterable solids regulations of .035 g/l to .070 g/l. Using the proposed settleable solids standard of .5 ml/l/hr, all vegetative treatments on the topsoil plots meet the standard and all vegetative treatments on the overburden plots exceed the standard.

Chemically, iron quantities exceeded the maximum of 7 mg/l across all vegetative treatments on overburden plots. Discounting the 2.5 mg/l levels of iron found in the precipitation water, all vegetative treatments on topsoiled plots met the standards of 7 mg/l. Manganese was found at acceptable levels in both topsoiled and overburden plots across all vegetative treatments.

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