OCCURRENCE OF PHYTOPHTHORA ON REFORESTED LOOSE-GRADED SPOILS IN EASTERN KENTUCKY1

Kathryn M. Adank2, Christopher D. Barton, Michael E. French, and Patricia B. de Sá

Abstract. Plant pathogens of the genus *Phytophthora* may pose a threat to trees on reclaimed mine lands. The presence of these pathogens in forest soils of Appalachia has been documented, but their presence and relative distribution in mine spoils is unknown. Soil samples from mine spoils at the Bent Mountain, KY reforestation site were tested for presence of *Phytophthora* spp., and, specifically, *P. cinnamomi*, using a soil-baiting method. Loose-graded mine spoils (brown sandstone, gray sandstone, mixed spoil, and shale) dumped in 2005 and 2007 at the Bent Mountain reforestation site were tested monthly from May to October 2007 for *Phytophthora* at the surface (top 0-10 cm) using a soil baiting method. Soils collected from two non-mined control sites within Robinson Forest and Berea Forest were also tested using the same method. Colonies obtained from the baiting method were isolated in PARP-H V8 *Phytophthora*-selective medium and incubated at 25°C. Colonies with *Phytophthora*-characteristic morphology were tested by PCR. PCR results, confirmed by DNA sequencing, indicate that *P. cinnamomi* was successfully isolated using the baiting method from forest soils. No *Phytophthora* spp. were detected by the baiting method from mine spoils. Future work will involve testing water that has infiltrated through mine spoils for presence of *Phytophthora* spp. Water collected from lysimeters will be filtered to capture mycelial fragments or reproductive structures of *Phytophthora species* through exclusion on the filter membrane and the membrane will be subjected to DNA extraction and PCR. The presence of *Phytophthora* spp. in spoils and water in comparison to media physiochemical characteristics, aqueous geochemistry of infiltrated waters, and tree growth with regards to reforestation efforts on different tailing media will be evaluated.

Additional Key Words: PCR, *P. cinnamomi*

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Abstract. Granular mine waste are generated from the extraction and beneficiation of lead/zinc minerals. The fine gravel waste, commonly known as chat, contains elevated levels of lead, zinc and cadmium which can result in potentially serious human health and ecological concerns. With the use of chat in a variety of applications such as road construction, there is an increased environmental concern due to the potential leachability of lead (Pb), cadmium (Cd) and zinc (Zn) at high concentrations. In this study, we examine the release of these three metals from raw chat and its reuse products, mainly cold-mix asphalt (CMA) and hot-mix asphalt (HMA), to determine the environmental stability of the materials under different environmental conditions.

The leachability of metals was evaluated using extraction tests including the toxicity characteristic leaching procedure (TCLP), synthetic precipitation leaching procedure (SPLP) and deionized water extraction procedure (DWEP). In addition, the relative bioaccessability of the metals was determined by the relative bioaccessability leaching procedure (RBLP) tests. Based on the conducted leaching tests, it was observed that all the three samples failed the TCLP test. The Cd and Pb concentrations in the TCLP extracts were higher than the mandated TCLP limits for leaching from wastes. The TCLP extracts of CMA and HMA samples were found to be less than the limit for Cd, but higher for Pb. The experimental data also showed that the concentrations of Cd and Pb in the SPLP extracts were less than the National Drinking Water Primary Standards of 0.005 mg/L and 0.015 mg/L, respectively. This indicated the suitability of the mine tailing and its reuse products for beneficial applications. The percent bioaccessible metal followed the order: raw chat < HMA < CMA, probably due to its smaller particle size (< 250 µm), compared to the particle sizes of CMA and HMA tested (< 2 mm). The data indicated that while the use of chat in asphalt is environmentally safe, care should be taken as metals could leach in significant concentrations when placed in moist environments for longer duration.

Keywords: Mine waste, Lead, Cadmium, Leaching, Bioaccessability, TCLP, SPLP


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FOREST ESTABLISHMENT AND WATER QUALITY CHARACTERISTICS AS INFLUENCED BY SPOIL TYPE ON A LOOSE-GRADED SURFACE MINE IN EASTERN KENTUCKY

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Abstract: Six research plots were established on a surface mine for the purpose of evaluating the forest productivity potential and hydrological and water quality characteristics of three different loose-graded spoil types. The three spoil types were: (1) predominately brown, weathered sandstone (BROWN); (2) predominately gray, un-weathered sandstone (GRAY); and (3) mixed weathered and un-weathered sandstones and shale material (MIXED). The average area of the six plots was approximately 3,658 m². The physical and chemical soil characteristics that gave the BROWN spoil type a predictably higher productivity potential and natural regeneration than the GRAY and MIXED spoil were its finer soil texture, higher CEC and P concentration, and a pH that was more suitable for native hardwood trees.

Four species of tree seedlings were planted into the spoils. Growth and survival of the planted trees were evaluated for three years. As an indicator of natural succession potential, percentage ground cover of volunteer vegetation on the three spoil types was also evaluated. By the third year (2007) after planting, the BROWN spoil type had a significantly higher average tree volume index than the MIXED spoil and MIXED was significantly higher than GRAY. Ground cover from natural regeneration was found to be 66.4% on the BROWN spoil (61 different species), 5.8% on the MIXED spoil (35 different species), and less than 2.0% on the GRAY spoil (12 different species).

Results showed that the loose-graded spoil in this experiment was characterized by low discharge volumes, small peak discharges, and long durations of discharge and had hydrologic characteristics of a forested watershed, even at this early stage of development. Generally, concentrations of Ca, Mg, and SO₄²⁻ decreased over time in GRAY and MIXED and increased in BROWN. The pH of the water discharge from all three spoil types has increased from about 7.5 to 8.5. Although the average electrical conductivity (EC) in water discharged from the BROWN spoil remained relatively level during the study period, the GRAY and MIXED appears to be on a downward trajectory from about 1500 S cm⁻¹ to about 500 S cm⁻¹. The latter value of EC has been reported as the apparent threshold at which the benthic invertebrate community returns to drastically disturbed headwater streams of eastern Kentucky and adjacent coal-producing Appalachian states.

Additional Key Words: tree performance, compacted spoil, infiltration, coal, stream.

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WHERE DID ALL THE WATER GO\textsuperscript{1}

Randall Drake Asberry\textsuperscript{2}

\textbf{Abstract:} The Friends of the Cheat (FOC) is a 501 (c) 3 watershed organization in northern West Virginia. FOC formed in 1994 to respond to the impact of acid mine drainage on tributary streams and the mainstem of the Cheat River. Since then, millions of dollars in water monitoring, assessment and treatment has been invested within the watershed.

In 2006, FOC received an EPA Targeted Watershed Grant to address 27 miles of impaired water on Muddy Creek, a major contributor of acid mine drainage to the Cheat River. Over the past eighteen months, monitoring has taken place on Muddy Creek and the data collected has brought to light some interesting results that otherwise would have went unnoticed without continual sampling. Water monitoring consisted of walking streams with GPS unit to determine locations of all acid mine drainage sources. Data collected while monitoring also included the pH, conductivity, and flow rates, which were then mapped using ArcGIS to produce a spatial picture of water quality in the Muddy Creek drainage area.

With this database and the GIS map, FOC consulted with WVU geologist Dr. Joe Donovan, who has conducted research on mine pools in the Freeport coal seam. After reviewing the data we had collected, Donovan realized that several surrounding mines were not discharging where they should be according to existing mine maps. In addition, he noticed an unusually high flow coming from an abandoned deep mine, which contributes about twenty percent of the acid load on Muddy Creek.

This proposed presentation will show field research and technical analysis that is currently ongoing and is expected to be completed by the spring of 2008. Research will involve geo-spatial assessment of mine maps, continued monitoring, investigation into mining permits as well as the local history. In addition, drilling may occur to help in determining mine pool locations. The utilization of water monitoring, GIS mapping, and assessment will have a direct influence on the level of restoration this project achieves for the Cheat watershed. The determination of the source of this discharge from the abandoned deep mine could determine how hundreds of thousands of dollars in reclamation expense will be funded.

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COAL MINE RECLAMATION IN THE SOUTHERN APPALACHAINS: COSTS OF FORESTRY VERSUS HAYLAND/PASTURE


Abstract. The two most common options for post-mining land uses in the southern Appalachians are hayland/pasture or forestry. Hayland/pasture has become the predominant reclamation type due to strict regulation standards requiring quick and dense erosion control by herbaceous cover. Recently, more landowners have become interested in returning mined land to an economically valuable post-mining land use. Current research has provided the biological and technical information needed to reclaim mine lands to productive forest stands and achieve bond release. Cost information though has been lacking or variable at best. The purpose of this study was to understand the processes of reclamation for both forestry and hayland/pasture, and calculate detailed cost estimates for both reclamation types. Total costs of reclamation were determined using a cost-engineering method in conjunction with Office of Surface Mining Regulation and Enforcement bond-calculation worksheets. In all states analyzed, pasture reclamation was more costly on a per acre basis. In Ohio, reclamation costs differed by only $50 per acre between pasture and forestry reclamation. On the high end, reclamation costs differed by nearly $500 per acre for pasture versus forestry in West Virginia. Grading costs have the greatest impact on the difference between forestry and pasture reclamation. Forestry reclamation should involve only grading the site with one dozer pass to prevent compaction of minesoils which inhibits tree growth. Pasture reclamation requires more grading passes to prepare the seedbed, requiring four passes. Herbaceous seeding costs were higher for pasture reclamation due to higher application rates, but differences were not as substantial as the cost of grading. Fertilizer and lime costs were not substantively different between forestry and pasture reclamation. These cost estimates provide useful tools for mine operators and landowners to determine the most economical and suitable post-mining land use for their individual property.

Additional Key Words: Reforestation, Bond Calculation

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INNOVATIONS IN EROSION CONTROL, LANDSLIDE REMEDIATION AND DESIGN AND CONSTRUCTION OF RETAINING WALLS, BOX CULVERTS AND BRIDGES: ONE TECHNOLOGY; MULTIPLE APPLICATIONS¹

Robert K. Barrett², Cameron A. Lobato, and Colby E. Barrett

Geosynthetically Confined Soil research and demonstrations over the last 40 years by the United States Department of Agriculture, Forest Service, (USFS), the Federal Highway Administration (FHWA), the Colorado Department of Transportation (CDOT), the University of Colorado/Denver (UC/D), the National Cooperative Highway Research Program (NCHRP) and a host of researchers and institutions around the world has resulted in more efficient, expedient and cost effective tools and methods to control landslides and erosion, and to build retaining walls, box culverts and bridges. It is a case of one basic technology that can be adapted to multiple uses.

Before about 1970, the choices for retaining walls were limited to cantilever and crib-type gravity systems. Researchers in France developed a novel and counterintuitive system whereby soils were modified with tensile inclusions. The result was the ability to build retaining walls with vertical faces where most of the forces and loads were accommodated by the backfill soil, and not the external containments as with traditional walls.

The first tensile inclusions were metallic. It has been demonstrated that geosynthetic sheets and grids can also serve as the tensile or confining element. The most recent research and demonstrations show that composites constructed with soil and geosynthetics have bearing capacities that lend to building abutments and piers. Soil Nailing and Micropile Foundations are also benefiting from new design approaches based on closer spacing with much smaller elements.

State of the Art has advanced well beyond Practice. The Poster will show a number of case histories of innovative applications of seismic-resistant soil nails, micropiles, retaining walls, bridges and more that can now be implemented to advantage in new construction and in maintenance of existing facilities.

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EVALUATING SPOIL AMENDMENT USE AND MYCORRHIZAL INOCULATION ON REFORESTATION SUCCESS IN THE EASTERN AND WESTERN KENTUCKY COALFIELDS

Christopher D. Barton, Rick J. Sweigard, Donald Marx, and Will Barton

Abstract: A factorial experiment using inoculated vs. non-inoculated forest species in non-fertilized, fertilized only, amended (organic mulch) only, and fertilized + amended plots was established in 2004 on two mined lands in the Eastern (EKY) and Western (WKY) Kentucky coalfields. Fifty-four 15 x 15 meter plots were delineated on each site. Half of the plots received an application of 40 tons per acre of a wood chip/manure compost mixture. All plots were subsequently ripped to a depth of approximately 2-meters using a dozer. Two tree species; Loblolly Pine (LP) (Pinus taeda) and Northern Red Oak (NRO) (Quercus rubra), were planted in the plots. Each plot received 100 seedlings spaced at 1.5 meter centers. The mycorrhizal trees were inoculated with Pisolithus tinctorius (Pt) and Scleroderma cepa (Sc) in the nursery beds. Additional spores were applied in the field after they were transplanted. The non-mycorrhizal plots received an application of fungicide on an annual basis (Bayleton; 1 kg per plot) to suppress natural inoculation. Fertilized plots received 150 pounds of 20-20-20 fertilizer per acre (168 kg per ha) on an annual basis. Each treatment was examined in triplicate for each species. Ripping of the sites reduced in-situ bulk density at both locations. Application and incorporation of the compost resulted in a further decrease in bulk density both at the surface and through the entire 30.5-cm depth examined. Although the effect was similar between the two sites, the WKY site exhibited a higher final bulk density than that observed in EKY. After four years, growth and survival of planted seedlings differed with respect to species, site and treatments. LP exhibited almost a doubling in growth at the EKY mine as compared to the WKY mine. Amendments had no effect on LP growth at the WKY site. All amendments had a positive effect on LP growth over that of the control in the EKY site. Use of compost and mycorrhizal fungi yielded the highest survival for LP at both sites. NRO growth was very low compared to LP and did not differ drastically between the two sites. Treatment effects were observed on both sites and results varied. Compost and fertilizer without mycorrhizae exhibited the highest NRO survival at both sites. Fertilizer addition improved NRO survival at the EKY mine and the use of compost without fertilizer appeared to increase mortality. The use of compost with mycorrhizae may have also had an inhibitory effect on NRO survival in WKY, or fungicide application may have provided a positive effect at this site. Herbaceous biomass was much higher on the EKY mine, but no correlations between herbaceous biomass and tree growth or survival were observed for either site.

Additional Key Words: forest reclamation approach, soil amendments, topsoil replacement.

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PLANT GROWTH EFFECTS OF COAL COMBUSTION PRODUCT AMENDMENT TO MINE SPOILS AND ASSOCIATED LEACHING POTENTIALS¹

Michel A. Beck², W. Lee Daniels and Matt J. Eick

Abstract: Research on the beneficial utilization of coal combustion products (CCPs) as surface amendments in mining environments has focused upon bulk acid-base balances and heavy metal (Cu, Zn, Fe, Al, Mn, etc.) mobility to local groundwater. Currently, the public and regulatory communities are placing greater focus on the potential of As, B and Se mobility from CCP utilization. Five CCPs were selected from a regional set of 28 materials following complete chemical characterization for greenhouse bioassay trials. Acidic sandstone mine spoil was amended at 0, 10, and 20% (v:v) with the CCPs. The bioassay trial was designed to test the presumed effectiveness of CCPs as surface-applied amendments to mine soils for improving pH and water holding capacity. The procedures were modified to include a “pour-through” protocol where we leached greenhouse pots with excess water starting one month after establishment of the trial, and then collected leachates for analyses of pH, EC, As, B, Se and other parameters. The trial was conducted using soybean (Glycine max) as an indicator plant sensitive to substrate chemical conditions (EC, pH, elemental toxicity) and tall fescue (Festuca arundinaceae) as a species exhibiting relative tolerance to low pH, metals, and salts. Tall fescue dry matter yield tended to increase with increasing CCP rate as long as the bulk soil pH remained at pH 8.0 or less. Depending on the liming capacity (as measured by calcium carbonate equivalence - CCE) of the CCP applied, the 20% application had the greatest positive effect on plant yield (e.g. at CCE = 7.7). However, in case of a CCP with a high liming potential (CCE = 47.7), a 5% application was most beneficial to dry matter yield. The EC and pH from various mixes related well to CCE of the respective CCP and the loading rate. Leaching of oxyanion forming elements (As, Mo, Se) under these soil conditions and loading rates does not appear to be a concern, although some Se was observed in the first leachates. As expected, B along with S (as SO₄²⁻) were the two elements at highest concentration in the leachates. However, correlation and stepwise regression analysis of yield data with the elemental concentrations from the pour-through solutions indicated these two elements did not negatively affect fescue yield. However, stepwise regression analysis did show that fescue yield was affected by pH (p > 0.0034). Our combined results indicate that a few relatively simple lab measurements (pH, EC, CCE) coupled with a simple soybean bioassay such as reported here can readily predict both the relative effectiveness and potential toxicity of a given CCP when used as either a bulk mine soil amendment or an alkaline additive for mine soil acidity control.

Additional Key Words: Fly ash, flue gas desulfurization sludge, beneficial use, phytotoxicity.

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PASSIVE TREATMENT OF ACID MINE DRAINAGE – THE ENOS RECLAMATION PROJECT, INDIANA: PRELIMINARY RESULTS

Paul T. Behum, Dan R. Hause, Mark A. Stacy and Tracy D. Branam

Abstract: The Enos Gob Pile, located in Pike County, Indiana, is a 250-acre refuse disposal area emplaced prior to the August 3, 1977 enactment of the Surface Mining Control and Reclamation Act (SMCRA). Two passive treatment systems totaling approximately 64-acres were constructed in 2005 by the Indiana Department of Natural Resources, Division of Reclamation (IDOR) to treat AMD discharging from the refuse disposal area. IDOR, with the assistance of the OSM, Mid-Continent Regional Office (OSM-MCR) designed the passive treatment system at the site that includes: 1) addition of alkaline water (alkalinity = 242 mg/L) from adjacent pre-SMCRA mine impoundments, 2) construction of two vertical flow ponds (VFP) for additional alkalinity enhancement, and 3) excavation of a series of oxidation ponds and aerobic wetlands for metal precipitation. The system was designed to handle a large amount of acidic runoff during storm events (1.5 to 2.0 CFS). Underlying and surrounding the refuse pile is mine spoil with a generally favorable neutralization potential. As a result of that neutralization the water entering each VFP is relatively low in iron (19.2 mg/L) and total acidity (92 mg/L). However, the designers were required to consider the impact of a significant amount of Al (5.2 mg/L) on the life expectancy of the VFP. Post-construction evaluations are being assisted by the Indiana Geological Survey (IGS). These studies indicate nearly complete Fe removal by the system (total iron = 0.25 mg/L) and a net alkaline discharge (alkalinity exceeds acidity by about 65 mg/L). Although no specific structures were incorporated in the design for Mn removal, Mn is also being removed by the wetland system (3.7 mg/L in the VFP inlet, 0.23 mg/L at the system outlet). Improvements in metal removal occurred when aquatic vegetation developed. Additional studies will evaluate the reduction in system efficiency during winter months and a comparison of the alkalinity generated by the two parallel VFPs one with dolomitic limestone and one with high-calcium limestone, as an alkalinity source.

Additional Key Words: passive treatment, vertical flow ponds, SAPS, AMD, water sampling.

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DESIGNING A BIOCHEMICAL REACTOR FOR SELENIUM AND THALLIUM REMOVAL, FROM BENCH SCALE TESTING THROUGH PILOT CONSTRUCTION

E.P. Blumenstein, J. Volberding, and J.J. Gusek

Abstract: Water treatment is often required at active and inactive mine sites to remove heavy metals and other contaminants of concern (COCs) prior to discharging water. Traditional water treatment can be expensive and impractical at some sites due to excessive energy, manual labor, and operations and maintenance (O&M) requirements. Passive treatment has emerged as a way to treat such waters inexpensively by requiring minimal amounts of O&M and little to no external energy. One form of passive treatment technology that has been developed over the last twenty years is the biochemical reactor (BCR), also known as a sulfate reducing bioreactor (SRBR). As its name would suggest, a BCR treats water by way of biological and chemical reactions. A BCR uses a combination of organic substrate materials and microbial activity to remove heavy metals, remove other COCs, and stabilize pH in mining influenced water (MIW). Additionally, a BCR adds hardness, alkalinity, and organic matter to the MIW, all of which are beneficial to overall water quality and aquatic life.

A historic gold mine in Montana is using passive treatment in the form of a BCR to remove selenium (Se), thallium (Tl), and nitrate (NO₃⁻) from its MIW. Selenium is a metal common to MIW and can be difficult to remove with traditional technologies, while Tl is a metal of which very little is known, but has extremely low discharge standards throughout the United States. The first step in this process was designing and conducting a three-month bench-scale test using a variety of different organic substrate mixtures. After steady state conditions were reached in the BCR, bench-scale testing demonstrated ≥ 99% removal of Tl and Se as well as for traditional heavy metals (Zn, Cu, Fe, etc.). Average influent Tl concentrations of 1.40 mg/L were removed to an average concentration of 0.008 mg/L; concurrently, average influent Se concentrations of 0.011 mg/L were removed to below the detection limit at 0.0025 mg/L. Using the bench-scale testing results; design began on a demonstration-scale passive treatment system which is half of the size of a full-scale system. Design and construction of the demonstration-scale passive treatment system was performed so that scaling up to a full-scale system will be easy in the future.

Additional Key Words: biochemical reactors, passive treatment, heavy metals, mining influenced water, design and construction

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EARLY TREE AND GROUND COVER ESTABLISHMENT AS AFFECTED BY SEEDING AND FERTILIZATION RATES IN TENNESSEE

D. S. Buckley and J. A. Franklin

Abstract: Planted ground covers can compete strongly with planted tree seedlings, hindering reforestation efforts. Fertilization increases the growth of ground cover, but its effects on hardwood tree seedlings and competitive interactions between trees and ground cover species are unclear. A 3x3 factorial experiment with 3 levels of broadcast water-soluble fertilizer and 3 seeding rates was established in 2006 to test for differences in tree seedling growth and survival, and for differences in ground cover establishment and composition. The ground cover was applied by hydroseeding a mixture of native warm-season grasses, annual rye and Korean lespedeza, along with lime, mulch and tackifier. Bare-root, 1-0 tree seedlings of scarlet oak, white oak, black walnut and mockernut hickory, along with mockernut hickory seed were planted on an 2.4 x 2.4m spacing. Tree growth and survival, and ground cover establishment have been monitored, and the effect of seeding and fertilization rate evaluated. Generally, seeding rate had little effect, while increased fertilization rate was associated with increased percent cover of forbs. However, there was high variability between blocks, with substantially greater ground cover on the block immediately below intact forest. At the highest seeding rate, fertilization significantly increased cover of legumes. First year survival of white and scarlet oak was greater than 90%. Survival of direct seeded and planted 1-0 mockernut hickory seedlings was similar after one year. Continued monitoring of longer term survival and growth of trees is planned.

Additional Key Words: hardwoods, warm-season grass, forestry, native species

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**HARDWOOD REFORESTATION FOR PHASE III BOND RELEASE: NEED FOR REDUCED GROUND COVER**

J. A. Burger², D. O. Mitchem, C. E. Zipper, and R. Williams

**Abstract:** During the past five years, a forestry reclamation approach has been adopted by some coal companies. To ensure adequate tree survival and growth, competition from erosion control groundcovers must be reduced. The purpose of this study was to test the effect of herbaceous groundcover on reforestation success after five years for Phase III bond release. An herbaceous ground cover mix consisting of orchard grass, redtop, birdsfoot trefoil, and red clover was hydaseeded on reclaimed mined land in Wise County, Virginia. The mine soil was a mix of weathered sandstone and unweathered siltstone that was lightly graded and left uncompacted. The following winter, 100 each of white oak, red oak, sugar maple, white ash, and tulip poplar (“crop trees”) were mixed and planted per acre. An additional wildlife mix of crab apple, dogwood, white pine, and bristly locust was planted at a combined rate of 100 trees/ac. Three half-acre treatment plots were spot-sprayed with Roundup herbicide (3-ft circle around each tree, achieving 70% groundcover (reduced cover) for three years, and three half-acre treatments were left untreated (full cover). After five years, average crop-tree survival rates were 58% and 69% on the untreated plots (full cover) and sprayed (reduced cover) plots, respectively. The actual numbers of trees planted by the professional tree planting crew were 687 and 663 per acre for the full cover and reduced cover plots, respectively. After five years, 415 and 419 surviving trees per acre remained which exceeded the minimum number needed for bond release in Virginia. Tree growth on the full cover plots was suppressed, but growth was excellent on reduced cover plots compared to that expected for these species on undisturbed sites. Reduced cover doubled the growth rate for most species except for red oak, which grew three times faster, and white ash, which grew four times faster when released from some of the ground cover competition. All species in this mix appeared to be compatible and should grow into a valuable tree stand. This study shows that this reforestation approach is quite viable for restoring native hardwoods, except that commonly used ground cover could compromise reforestation success.

Additional Key Words: reforestation, tree planting, herbicides, reclamation.

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PRELIMINARY RESULTS: RELEASE OF METALS FROM ACID-MINE DRAINAGE CONTAMINATED STREAMBED SEDIMENTS UNDER ANAEROBIC CONDITIONS

Barbara A. Butler2 and David J. Reisman

Abstract. Many miles of streams in the western U.S are contaminated with acid-mine drainage (AMD) from abandoned metal mines. Treatment of these streams may include removal of the existing sediments, with subsequent burial (e.g. in a repository). Burial of previously aerobic sediments may result in release of metals through multiple processes, including reductive-dissolution of metal oxyhydroxides, with concurrent release of previously sorbed metals. This paper discusses preliminary results from a laboratory study examining the release of Cd, Cu, Fe, Mn, and Zn from aerobic streambed sediments collected from an AMD-impacted stream (North Fork Clear Creek, CO). The pH, Eh, and metal release were monitored over twenty-eight days in an anaerobic chamber from sediment slurries prepared using filtered stream water. Additionally, the effect of sediment size was examined by using two size fractions: 2 mm to 63 μm and less than 63 μm. Dissolved Cd, Cu, Fe, and Mn were released and re-sequestered over time from both sediment size fractions. Dissolved Zn, however, demonstrated a continual decrease in concentration over time, relative to the concentration present in the stream water used to prepare the slurries. Releases of Cd, Cu, Fe, and Mn varied for each of the size fractions over time. In the case of Cd and Cu, no further release was observed in either size fraction after one week. Releases of Fe and Mn declined after the first week in the smaller size fraction and after the second week in the larger size fraction. Because of the presence of SO42- in the stream water, it is hypothesized that the metals were re-sequestered as sulfide precipitates. Future studies will include replication, measurement of sulfur species, and the use of surface chemical techniques to examine the solids for the presence of metal oxides and sulfides.

Additional Key Words: Iron oxyhydroxides, manganese oxyhydroxides, and metal sulfides, AMD

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QUANTITY AND QUALITY OF STREAM WATER DRAINING MINED AREAS OF THE UPPER SCHUYLKILL RIVER BASIN, SCHUYLKILL COUNTY, PENNSYLVANIA, USA, 2005-2007

Charles A. Cravotta III and John M. Nantz

Abstract: Hydrologic effects of abandoned anthracite mines were documented by continuous streamflow gaging coupled with synoptic streamflow and water-quality monitoring in headwater reaches and at the mouths of major tributaries in the upper Schuylkill River Basin, Pa., during 2005-2007. Hydrograph separation of the daily average streamflow for 10 streamflow-gaging stations was used to evaluate the annual streamflow characteristics for October 2005 through September 2006. Maps showing stream locations and areas underlain by underground mines were used to explain the differences in total annual runoff, base flow, and streamflow yields (streamflow/drainage area) for the gaged watersheds. For example, one stream that had the lowest yield (59.2 cm/yr) could have lost water to an underground mine that extended beneath the topographic watershed divide, whereas the neighboring stream that had the highest yield (97.3 cm/yr) gained that water as abandoned mine drainage (AMD). Although the stream-water chemistry and fish abundance were poor downstream of this site and others where AMD was a major source of streamflow, the neighboring stream that had diminished streamflow met relevant in-stream water-quality criteria and supported a diverse fish community. If streamflow losses could be reduced, natural streamflow and water quality could be maintained in the watersheds with lower than normal yields. Likewise, stream restoration could lead to decreases in discharges of AMD from underground mines, with potential for decreased metal loading and corresponding improvements in downstream conditions. Additional streamflow measurements and geophysical surveys along the stream segments identified as probable losing reaches could indicate where streambed sealing or stream rerouting may be appropriate restoration strategies. Longer-term streamflow data and investigation of the surface-water/ground-water interactions would be needed to evaluate possible consequences of streamflow restoration on flooding and water quality.

Additional Key Words: Streamflow; hydrograph; hydrologic budget; water quality.

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ILLINOIS RIVER DREDGED SEDIMENT: CHARACTERIZATION AND UTILITY FOR BROWNFIELD RECLAMATION

Robert Darmody, and John Marlin

Abstract. Brownfield reclamation in some ways is similar to surface mine reclamation. The similarities are that in both cases there is a large area of once productive ground that was severely impacted as part of a no-longer active resource extraction or augmentation industry. The differences include possible toxic soils or substrate and generally a lack of nearby quality soil for the brownfields given their typically urban settings. In contrast, reclamation is now part of a surface mining permit, soils are stockpiled to be replaced after mining, or topsoil substitutes are located and approved to serve as a final cover at a mine site. Brownfields, however, are usually located in urban areas where topsoils are difficult to obtain and transport. We conducted a large field demonstration project involving a brownfield in Chicago that was reclaimed with dredged spoils from the Illinois River. Disposal of dredged spoil often presents a problem in and of itself, and utilization as a topsoil substitute presents several advantages. In the case of the Peoria River sediments, the chemical and physical attributes are generally favorable as a topsoil substitute. These sediments tend to be fine textured, Silty Loams and Silts with about 3–5% organic matter content. Metal content is typically elevated above reference soils, but is generally not a problem. This paper presents our experience with this reclamation approach.

Additional Key Words: Illinois River, Chicago, topsoil substitute, remediation, restoration, mitigation.

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ASSESSMENT OF ABANDONED QUARRIES FOR REVEGETATION AND WATER HARVESTING IN LEBANON, EAST MEDITERRANEAN

T. M. DARWISH¹, R. STEHOUWER², D. MILLER³, J., SLOAN³, I. JOMAA¹, A. SHABAN¹, C. KHATER¹, and M. HAMZÉ⁴

Abstract. Negative impacts of abandoned quarries in Lebanon include degraded scenery, landscape fragmentation, loss of biodiversity and decreased quantity and quality of water resources. Between 1996 and 2005 the number of quarries increased from 711 to 1278 and the quarried land area increased from 2875 to 5283 ha. Recent remote sensing data (2005) showed that 21.5% were distributed on forested land and arable land while 32.4% of quarries were detected on scrubland and grassland and 3.2% of quarries were distributed inside urban zones. Due to institutional weakness and the absence of national policy, most Lebanese quarries have not been developed using environmental concepts and in preparation for post operation reclamation or restoration. Limited national resources available for reclamation must be targeted toward those quarries where the likelihood of successful reclamation, and thus the likelihood for mitigation of negative environmental impacts, is the greatest. To facilitate such decision making we developed a GIS based model that utilizes geomorphological and pedoclimatic characteristics of the site, including precipitation, slope gradient, slope aspect, rock infiltration, catchment area, the availability of soil material and soil texture to assess probability of reclamation success. Each abandoned quarry was categorized into specific classes with respect to surrounding native vegetation, rainfall and slope gradient. Deserted quarries were assessed for suitability for vegetation establishment and/or water harvesting. Potential revegetation success is strongly linked to slope aspect where southern facing slopes especially in semi-arid areas with annual rainfall below 600mm, were given lower prospects of success in relation to spontaneous revegetation processes. The quantity and quality of soil material adjacent to quarries was included in the vegetation model to evaluate the possibility of providing sufficient mineral substrate from neighboring areas with deep soils possessing good physico-chemical properties for plant establishment and survival. All attributes in the vegetation recovery model were assigned a weighted numeric score which were summed to provide a relative ranking of all quarries. These were then separated into four classes of likely revegetation success. In addition, water harvesting potential was assessed based on catchment area above the quarry and rock permeability in the quarry. The priority for reclamation was based on the comparison of vegetation success and suitability for water harvesting. The results of this model can be used to facilitate decision making concerning priority selection of sites for reclamation efforts, reclamation strategies to be attempted and possible alternative post-reclamation land use.

Additional Keywords: Quarry rehabilitation, vegetation recovery, modeling reclamation success, water harvesting

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SUSTAINABLE PASSIVE TREATMENT OF MINE DRAINAGE:
DEMONSTRATION OF MANGANESE RESOURCE RECOVERY
(A Preliminary Case Study) ¹

Clifford Denholm², Timothy Danehy, Shaun Busler, Robert Dolence, Margaret Dunn

Abstract: Passive treatment system components containing limestone are an effective means to decrease manganese concentrations in coal mine drainage. As precipitates, sediment, vegetation, and other materials accumulate in the void spaces, permeability decreases and treatment effectiveness is reduced. Recently, the ability to recover manganese-bearing material for potential economic use while restoring treatment efficiency has been demonstrated at the De Sale Phase 2 passive treatment system, installed at an abandoned surface coal mine in western Pennsylvania. Efforts to date include pre- and post-recovery water monitoring; development of a unique “full-scale” recovery technique; preliminary physical, chemical, and mineralogical analysis; and identification of a potentially economically-viable use of the recovered material. The horizontal flow limestone bed was monitored 3, 24, 64, and 118 days after manganese recovery. Comparing the influent with the effluent indicated decreases in dissolved manganese concentrations from 64 to 30 mg/L, 55 to 10 mg/L, 46 to 9 mg/L, and 20 to 8 mg/L, respectively, essentially doubling treatment effectiveness. Over 40 cubic yards (30 cubic meters) of manganese-bearing material were recovered. Currently, the Mn material is being used by local ceramic artists as a glaze colorant and is being evaluated by other industries including brick manufacturing.

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NUTRIENT FLUXES FROM ABANDONED MINE SOILS RECLAIMED WITH POULTRY MANURE AND PAPER MILL SLUDGE

Ashlee L. Dere, Richard C. Stehouwer, Kirsten E. McDonald

Abstract: In the Mid-Atlantic region of the United States, intensive animal production generates manure nutrients in excess of crop needs, increasing the likelihood of transport to water bodies and degradation of ecosystems and water quality. In this same region, 150 years of extensive coal mining has severely degraded land and impaired streams. Excess manure could be utilized in mine reclamation, but the large application rates required for successful revegetation could result in significant nutrient discharge. A preliminary greenhouse study determined that composting or adding organic carbon to poultry layer manure greatly reduced nutrient leaching. Based on these results, a field reclamation study was established on a surface coal mine in Schuylkill County, Pennsylvania in April 2006. Treatments include a lime and fertilizer control, two rates of composted poultry layer manure (78 and 156 Mg ha\(^{-1}\) dry weight), and two blends of fresh poultry manure (60 Mg ha\(^{-1}\) dry weight) mixed with paper mill sludge (90 and 170 Mg ha\(^{-1}\)) to achieve C:N ratios of 20:1 and 30:1. Leachate was collected after every rain event using pan lysimeters located 30 cm below each treatment. Leachate analysis showed a pulse of NO\(_3^-\)-N from the two rates of poultry manure and paper mill sludge blends (170 and 156 mg N L\(^{-1}\)) occurred three months following application. Compost treatments showed no such pulse. Cumulative N losses were greatest in the manure/paper mill sludge blends, but the control retained the least amount of original added N. An initial pulse of phosphate (5.8 mg P L\(^{-1}\)) from the control treatment was observed within the first month after application. Subsequently, all treatments show minimal leaching of P (less than 1.0 mg P L\(^{-1}\)). This research supports that amending mine soils with either composted poultry layer manure or fresh manure mixed with paper mill sludge are effective strategies to facilitate establishment of sustained vegetative cover on mined lands. Composted poultry manure is superior at controlling N and P loss.

Keywords: Revegetation, C:N ratios, nitrogen, phosphorus, compost

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2 Ashlee L. Dere, Graduate Research Assistant, Richard C. Stehouwer, Associate Professor, Kirsten E. McDonald, Project Associate, Dept. of Crop and Soil Sciences, The Pennsylvania State University, University Park, PA 16802.
A TWO-PHASE PROCESS FOR REVEGETATION OF ACIDIC BAUXITE TAILINGS IN THE AMAZON REGION, BRAZIL

L. E. Dias; Franco, A.A.; Campello, E.F.C.; Faria, S.M.; Castilho, A., Henriques, J.C., and W.L. Daniels

Abstract: This paper presents the methodology developed by the association of Mineração Rio do Norte S.A. with Embrapa/Agrobiologia and the Soil Department of Federal University of Viçosa to promote revegetation of tailings ponds from bauxite mining in Porto Trombetas, Para State, Brazil. The tailings have a fine texture (77% clay), are low in nutrients, have low pH (4.5) and high P-fixation capacity. This technology is based upon a two-phase process. In the first phase, seeds of leguminous trees and shrubs, inoculated with N-fixing bacteria and mycorrhizae (VAM fungi), are hydroseeded over the tailings with fertilizer. This initial phase accelerates the tailings drying and incorporates carbon and nutrients into the tailings surface. In the second phase, after substrate consolidation, native secondary and pioneer species are planted with the objective of ensuring more biological diversity and sustainability in the system. Among the evaluated species, Sesbania virgata, S. exasperata, Cecrópia sp., Parkia discolor, Styrphnodendron guinensi, Leucaena leucocephala, Hidrocoria corumbosa and Chamaecrista flexuosa have been used with success in the first phase, and Sclerolobium paniculatum, Clitoria farchildian, Eugenia sp., Tapirira guyanensis, Dalbergia spruceana and Enterolobium maximum have been successful in the second phase. Four years after revegetation of the first tailings pond, monitoring results indicate a significant increase of biological activity in the substrate and the presence of different species from natural invasion and regeneration, indicating that primary successional processes are active. These results indicate that the two-phase revegetation process may be more appropriate for the tailings ponds in Porto Trombetas than conventional reclamation practices.

Additional Key Words: P-fixation, vesicular arbuscular mycorrhizae, leguminous trees.

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REVEGETATION OF ACID FORMING MINE SPOILS IN PARACATU, MINAS GERAIS STATE, BRAZIL¹

Luiz Eduardo Dias², Igor Rodrigues de Assis and W.L. Daniels

Abstract: Paracatu is located in northwest Minas Gerais State, 230 kilometers from Brasilia, the capital of Brazil, and for the last two centuries has been an important gold mining site. With more of 600 ha of acid-sulfate soils across the open cut mine to be revegetated, the company is working to develop a method to reliably establish sustainable vegetation and minimize acid drainage. With this goal, we established a field experiment to evaluate five soil placement combinations to isolate (saddle) and/or cover the acid substrate. We also evaluated five plant species and three combinations to revegetate the materials. The five cover treatments were composed of three layers to: 1) isolate/saddle the substrate; 2) break capillarity and, 3) form a suitable surface material for plant growth. Ore (from mining zone B1) or clay was used as the saddle layer and sand, lime gravel, and sand plus oxalic acid were tested as capillary barriers. Then KCl and NaCl were also added to induce jarosite formation (geochemical barrier) to reduce availability of Fe and As in the drainage. As a cover layer, we tested B1 and local B horizon clay. Each (3) experimental block was comprised of five plots (to test the layers materials) with eight split sub-plots to evaluate the species and combinations. Ten months after establishment, we took samples of the layers to evaluate density and porosity, and the revegetation species were sown. Preliminary results showed that the saddle layer with clay resulted in higher density/less porosity. Non-compacted clay, when used to form the third layer, had higher water retention than B1 ore. This characteristic is very important to reduce water movement into underlying acid-sulfate materials. Among the evaluated species, Crotalaria juncea performed best followed by Melinis minutiflora. For most tested plant species and mixtures, the use of clay as the first and third layer coupled with sand plus KCl and NaCl as the capillary barrier resulted in optimal biomass production.

Additional Key words: Acid mine drainage, gold mine reclamation, acid sulfate soils.

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Abstract: The concentration of Mn in pond water attributed to acid mine drainage is a common problem for many mining operations. A retention pond at the restored Freeman United mine at Industry Illinois had continually tested above acceptable levels for Mn concentration even after repeated treatment with gypsum. It was noted that the NRCS soil profile descriptions of the pre-mined soil series which originally comprised the watershed area of the retention pond had naturally occurring accumulations of Mn. Due to the occurrence of Mn in the undisturbed soil profiles, it is possible that the concentration of Mn in the water is the result of inherent concentrations of Mn from the original soil profiles and not that of acid rock drainage.

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

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

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

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THE USE OF PEAT PELLETS TO REMOVE COPPER AND COBALT FROM MINE DRAINAGE¹

Paul Eger², Eric Paulson, and Doug Green

Abstract. A low temperature carbonization process has been used to convert peat into a hardened ion exchange material. Peat pellets of about 9.5 mm are produced, which are then crushed to form a low-cost ion exchange media.

Pellets were tested for their ability to remove copper and cobalt from several different mine drainages in northeastern Minnesota. Drainage pH ranged from around 5 to about 7.5, total copper ranged from about 0.01 to 3 mg/l, and cobalt from about 0.008 to 0.02 mg/l.

Treatment was most effective for copper with a removal efficiency of from 80-95%. The total volume treated decreased with increasing concentration, and ranged from 900 bed volumes at a copper input of 3 mg/l to over 7000 bed volumes at low input copper concentrations. Total copper removal ranged from 180 to 2900 mg/kg. Cobalt broke through more quickly than copper with total removals ranging from 70 to 95 mg/kg. A modified TCLP test was conducted and showed that copper and cobalt were tightly bound to the pellets. The pellets retained over 99.5% of the copper and cobalt.

Projected costs for the pellets are on the order of $2.20/kg or about 5% of a commercial resin.

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ITRC – IMPROVING REGULATORY ACCEPTANCE FOR NEW APPROACHES TO MINE WASTE ISSUES

Paul Eger, Cherri Baysinger, and Steve Hill

Abstract: Mining practices and the lack of mine land reclamation and restoration have led to sites with significant environmental and human health issues. Historical and current practices have led to operating sites with mine waste issues that must be addressed when operations cease. Typical remedial solutions are often lengthy and expensive, and are unacceptable to the mining community, the regulatory community and to the public. Some mined sites contain enough residual mineralization that further development, remining and subsequent reclamation may be economically feasible. Some current operations may even have the infrastructure in place to co-manage the cleanup of legacy waste while in operation. However, current regulations often provide barriers to these approaches. Innovative approaches and technologies need to be developed and implemented at current and former mining projects that solve our environmental issues and remove existing regulatory barriers. To help achieve this goal, the Interstate Technology and Regulatory Council (ITRC) started a team to address mine waste issues in 2007.

The ITRC is a state-led, national coalition helping regulatory agencies, site owners, and technology developers and vendors achieve better environmental protection through the use of innovative technologies. Through open communication among the 50 member states, federal, industrial, and stakeholder partners, ITRC is streamlining and standardizing the regulatory approval process for better, more cost-effective, environmental technologies. ITRC receives funding from the Departments of Defense and Energy, as well as the US Environmental Protection Agency. ITRC conducts its work by establishing teams to address the major environmental problems facing the states. ITRC teams contain at least 5 state members as well as representatives from federal agencies, industry (owners and operators), community stakeholders, academia, and American Indians. The mine waste team has written a white paper and is currently collecting case studies focused on the treatment of mining influenced water and solid waste. The team will evaluate technologies and produce a technical and regulatory guidance document and a related free internet training on the document. To avoid duplication, the ITRC is establishing a memorandum of understanding with the Acid Drainage Technology Initiative (ADTI) to cooperate and coordinate activities.

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SURVIVAL AND GROWTH OF NATIVE HARDWOODS ON A RECLAIMED SURFACE MINE

Paul Emerson and Jeff Skousen

Abstract: Surface mining in West Virginia has been taking place for nearly a century. Most of this land was once covered in eastern deciduous forest. These diverse forests provide a variety of benefits for both humans and animals. Returning the post-mined land to a productive forest requires the consideration of many factors including, but not limited to: compaction, vegetative competition, tree species selection, substrate depth, and physical and chemical properties of the substrate. The objective of this research is to evaluate tree survival and growth in weathered brown sandstone and in unweathered gray sandstone. Three, 2.8-ha plots were constructed with varying substrates at the surface: 1) 1.5 m of weathered brown sandstone, 2) 1.2 m of weathered brown sandstone, and 3) 1.5 m of unweathered gray sandstone. Half of each 2.8-ha plot was compacted, where dozer tracks completely covered the surface, while the other half had only one pass of a dozer. Percent fines in the upper 20 cm on brown sandstone increased from 51% the first year to 61% the third year, while on the gray sandstone decreased from 38% to 34%. Percent sandstone on the brown sandstone treatment decreased from 48% to 40% from the first to the third year, while on gray sandstone it increased from 59% to 66%. Brown sandstone’s pH of 5.1 stayed consistent over three years, while gray sandstone’s pH was 7.9 the first year and increased to 8.4 by year three. In March 2005, 11 hardwood species were planted in each plot. After one growing season, tree survival on the non-compacted areas of each treatment was >99% across all species, whereas the compacted areas showed 88% tree survival. By year three, survival had decreased to 78% on non-compacted areas and 79% on compacted. Height and diameter for each species was obtained each year of the study. In year one there was little difference between treatments across all species (average height 38.6 cm for 1.5 m brown sandstone vs. 38.9 cm for 1.5 m gray sandstone). The equation, volume index = height x (diameter)^2, was used to evaluate volume of the trees. Survival was also calculated for years two and three. Average volume of trees on brown sandstone was significantly greater than on gray sandstone. However, survival of trees was significantly greater on gray sandstone versus brown sandstone.

Additional Key words: substrate composition, substrate depth, compaction, tree survival, tree volume, hardwoods

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REMEDIAL AND RECLAMATION COST ESTIMATING FOR LARGE METAL MINE SITES

Gunnar R. Emilsson and Charles Freshman

Abstract. Accurately estimating construction costs is an important part of any remedial action. Many different approaches to cost estimating remedial action construction costs exist, including using compiled unit costs from similar projects and quotes from vendors or contractors. While these costing methodologies work well at smaller sites, they often are difficult to apply at large, complex mining sites. When actual construction costs are compared to estimated costs identified in Records of Decision, significant discrepancies have been noted at several sites. One of the major areas of disagreement between actual versus estimated costs occurs when costs used by mining companies to complete reclamation or treatment are applied to sites taken over by the government, who is forced to use independent third party contractors. Another variance occurs when projects are delayed due to additional investigations and/or incremental funding is available.

This paper has three primary objectives to assist estimators in developing more accurate cost estimates for mining sites. First, it discusses several approaches to estimating remedial and reclamation costs at large metal mining sites, based on the authors’ experiences at several such sites in Montana. These sites include active mines, mines owned by mining companies who have gone bankrupt, and sites being addressed under Superfund cleanup. Second, actual construction reclamation costs incurred by third-party contractors are compared to the original estimates, and the differences are analyzed. Finally, recommendations to improve large mine site reclamation cost estimating are presented.

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FOURTH-YEAR TREE RESPONSE TO THREE LEVELS OF SILVICULTURAL INPUT ON MINED LANDS

C. Fields-Johnson, C. E. Zipper, D. Evans, T.R. Fox, J.A. Burger

Abstract: There is renewed interest in restoring forests on surface mined lands in the Appalachians. Many lands reclaimed since the passage of the Surface Mining Control and Reclamation Act of 1977 (SMCRA) have dense ground covers and compacted soil materials, in some cases associated with unfavorable soil chemical properties. To address these concerns, three previously reclaimed mined sites were located in Ohio, Virginia and West Virginia. At each site, Eastern white pine, hybrid poplar, and mixed Appalachian hardwoods were planted at three levels of silvicultural intensity (weed control only, weed control with subsoil ripping, and weed control with subsoil ripping and fertilization). Each combination of species and treatment was repeated three times in each of the three states for a total of 9 replications and 81 treatment plots. Trees were measured in October of 2007 after 4 years of growth. Across all states and treatments, the survival rate was 63% for mixed hardwoods, 55.1% for hybrid poplar and 42.1% for Eastern white pine. Total biomass index per tree was 10,024 cm$^3$ for hybrid poplar, 258 cm$^3$ for Eastern white pine, and 138 cm$^3$ for mixed hardwoods. Use of ripping plus weed control as a pre-planting silvicultural treatment increased survival across all states and species from 44% to 64%, and increased average biomass index from approximately 1,000 cm$^3$ to 5,000 cm$^3$ per tree over weed control only. All species achieved their highest biomass values for this study on the West Virginia shale-based spoils and their highest survival rates on the Virginia sandstone-dominated spoils. When restoring forest vegetation to previously reclaimed mine sites with unfavorable soil and vegetation properties, the use of weed control and subsoil ripping, with or without fertilization, can aid survival and growth.

Additional Key Words: compaction, ground cover, fertility, reforestation, native hardwoods, white pine, hybrid poplar, reclamation

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Abstract. Based on a period of 505-2595 days of operating lab-scale wetlands (bioreactors) treating simulated lead mine drainage containing Pb, Zn, and sulfate, a model of flow and metals removal, both equilibria and kinetics, was developed using PHREEQC, a freely-available aqueous geochemistry model. To develop parameters for the model, the fundamental question: “Where does the metal go?” had to be answered. Although the model predicts sulfide formation, we observed limited metal sulfides based on extractive assays. Despite the presence of sulfide in pore water, our wetlands display significant uptake of metals from the water via adsorption instead of via sulfide precipitation. Our operating results have shown that plants do not have a noticeable impact on removal of metals in these wetlands beyond perhaps recharge of organic matter by decaying plants. We speculate that beyond know inaccuracies in extractive assays; the metals undergo very slow reactions in-situ which cause changes in the form of the metals from adsorbed to less soluble forms, presumably due to sulfides present from the biological sulfate reduction. Overall, metals removal in our wetlands appears to follow a two-step process: first adsorption to the sediment, then sulfide formation.

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DIRECT-SEEDING VERSUS CONTAINERIZED TRANSPLANTATION OF AMERICAN CHESTNUTS ON LOOSE MINE SPOILS IN THE CUMBERLAND PLATEAU\textsuperscript{1}

Michael E. French\textsuperscript{2}, Christopher D. Barton, and Donald Graves

\textbf{Abstract:} American chestnut (\textit{Castanea dentata} (Marsh.) Borkh.) was formerly an important timber and nut-producing hardwood throughout the forests of eastern North America. The introduction of an exotic fungal blight (\textit{Cryphonectria parasitica} (Murr.) Barr) in the early 20\textsuperscript{th} century devastated \textit{C. dentata} populations. Blight-resistant chestnut backcrosses will be available for widespread distribution through The American Chestnut Foundation’s breeding program in the near future. The development of blight-resistant backcrosses is only the first step of the restoration process. For successful introduction, information must be attained about the site requirements, establishment, and growth of American chestnut. An immediate obstacle to the restoration is \textit{Phytophthora cinnamomi} (Rands), another introduced pathogen that causes a root rot disease. Surface mine spoils in the Appalachian coal region and elsewhere may initially be devoid of \textit{Phytophthora} and prove suitable for the establishment of founder populations of blight-resistant chestnut hybrids which may then act as reservoirs for chestnut dispersal into surrounding forests. Four family lines of American chestnuts were planted in mine-run spoil using two planting techniques in the spring of 2006. The two planting techniques were direct-seeding and containerized transplantation. Each line and planting technique was replicated three times for a total of 24 plots, with each plot containing approximately 21 seedlings planted on approximately 2 meter by 2 meter spacing. After two growing seasons, seedling response varied by pedigree and planting technique. Indicators of stress (i.e. the formation of basal sprouts, a second leader, or blight infection) were significantly higher on containerized transplants than seedlings that were direct-seeded (56.2\% vs. 11.7\%). Overall, seedlings that were direct-seeded showed higher survival than transplanted seedlings (61.8\% vs. 51.2\%), while seedlings from containers exhibited better height growth (48.0 cm vs. 41.7 cm) and diameter growth (5.3 mm vs. 4.3 mm).

\textbf{Additional Key Words:} reforestation, restoration, Phytophthora.

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TWO-YEAR SULFATE REDUCING BIOREACTOR PILOT TEST RESULTS AT THE GOLINSKY MINE, CALIFORNIA

James Gusek, Thomas Rutkowski, Eric Blumenstein, and Brad Shipley

Abstract. The Golinsky site is a small underground copper mine complex consisting of abandoned mine workings and remnants of smelter operations located on a steep hillside above Little Backbone Creek, a tributary to Lake Shasta. The mine pool is typical acidic mining influenced water (MIW) with a pH of 2.5 to 4 containing heavy metals including Fe, Al, Cu, Zn, Cd, and Mn. The US Forest Service committed to a bench and pilot scale testing program to demonstrate that the SRBR technology would work at the remote site and reduce metal loading on Lake Shasta.

A pilot scale SRBR test system was constructed in 2004 and decommissioned in September, 2006 after 26 months of year-round operation. Despite overloading and other operational challenges (e.g., the site is only accessible by boat), the pilot system performed as expected. At the conclusion of the pilot test run, the pilot scale effluent was field-titrated with raw MIW. The results of this effort suggest that SRBR-treated MIW has geochemical benefits beyond the expected straight dilution effects. That is, the elevated alkalinity and sulfide concentrations of the SRBR effluent appear to be capable of providing additional treatment of raw MIW in a simple mixing and settling operation. The titrated mixtures were also tested for toxicity using MetPLATE™ testing kits. A first-phase treatment module is being designed based on the pilot test results.

Additional Keywords: passive treatment, mining influenced water, heavy metals, sulfate reducing bioreactor; aquatic toxicity
DIFFERENTIAL UPTAKE OF TRANSITION ELEMENTS BY MESQUITE OBTAINED FROM PLANTS GROWN IN IMPACTED AND CLEAN SITES

Nazmul Haque, Jose R. Peralta-Videa, Jorge L. Gardea-Torresdey

Abstract: In this research, the uptake of Cu, Mo, Zn, As(III) and Cr(VI) by mesquite (Prosopis spp.) roots and shoots from two different sources was studied. The first source was seeds collected from plants grown in mine tailings in Arizona, USA (Seeds A) and the other source was seeds from a commercial vendor (Seeds B). In addition, the effects of above mentioned elements on plant growth and nutrient uptake were also investigated. Plants were grown for seven days in hydroponic media containing different concentrations of Cu, Mo, Zn, As(III) and Cr(VI) (0, 1, 5 and 10 mg L⁻¹). Plants grown from Seeds A grew faster and taller at a concentration of 1 mg L⁻¹ of Cu, Mo, Zn, As(III) and Cr(VI) than at 0 mg L⁻¹; whereas plants grown from Seeds B had opposite response. This suggests that the seeds obtained from the mesquite plants grown in mine tailings have more phytotoxic tolerance than that of the Seeds B. However, 90% of the plants from both seeds grown in 5 and 10 mg L⁻¹ of Cu, Mo, Zn, As(III) and Cr(VI) did not survive. This indicates that uptake of Cu, Mo, Zn, As(III) and Cr(VI) was influenced by its concentration in the growth medium. Uptake of Cu, Mo, Zn, As(III) and Cr(VI) by mesquite plants grown from Seeds A was 1.8 times greater than that of plants grown from Seeds B. At 1 mg L⁻¹, the root and shoot elongation of plants grown from Seeds A was significantly greater than that of plants grown from Seeds B. Plants grown from Seeds A absorbed micro and macronutrients to a lesser extent as compared to those grown from Seeds B. Morphological (xylem and phloem) changes inside the plants grown from both seeds are currently being investigated by infrared (IR) imaging and scanning electron microscope (SEM) techniques. The significant amount of Cu, Mo, Zn, As(III) and Cr(VI) concentrated in the plants grown from Seeds A, as well as the more extensive elongation of roots and shoots than that of Seeds B, indicate that mesquite seeds obtained from plants grown in mine tailings could be better adapted seeds for plants that could be potential hyperaccumulator of Cu, Mo, Zn, As and Cr in the mine tailings.

Additional Key Words: Uptake, Hyperaccumulator, Metals, Seed source, Mesquite.

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REGULATORY APPROACHES TO COMPLYING WITH WATER QUALITY STANDARDS

Jarvis Harper

Abstract. Reported detections of elevated contaminants of concern (COC) are becoming more prevalent in industrial/mining discharges. Complying with Federal and State stream standard for COCs is becoming increasingly difficult for many dischargers. For example, EPA has proposed 5 μg/l selenium as the chronic numerical criterion for receiving streams. Potential treatment options for waters contaminated with selenium include physical, biological, and chemical methodologies. However, treatment methodologies that will reduce selenium concentrations to levels below 5 μg/l are expensive and have not been highly successful in field applications. An alternative approach to compliance with selenium, or COCs, may be to alter the regulatory aspects. Several options are discussed including permit modifications, mixing zones, maximizing stream assimilative capacities, modifications to the designated use of a water body, variances, Use Attainability Analyses, increasing the numeric criteria in receiving streams, site-specific numeric water quality criteria changes, and environmental improvement projects. Each discharge, receiving stream, permit, and locality has unique circumstances that preclude a “cookbook” approach to compliance with water quality standards but numerous options are available to assist dischargers with compliance issues.

Additional Key Words: mixing zone, assimilative capacity, designated use, attainable use, variance, use attainability analysis, environmental improvement project

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EFFECTIVE PASSIVE TREATMENT OF A LARGE FLOW OF ALKALINE FE-CONTAMINATED MINE WATER

Robert S Hedin

Abstract: The Marchand passive treatment system was constructed in 2006 for a 6,000 L/min (1,650 gpm) discharge from an abandoned underground bituminous coal mine located in western Pennsylvania, USA. The system consists of six serially-connected ponds followed by a large constructed wetland. Treatment performance was monitored between December 2006 and December 2007. The system inflow was net alkaline with pH 6.2 and 74 mg/L Fe, 1 mg/L Mn, and <1 mg/L Al. The final discharge averaged pH 7.5, 214 mg/L CaCO₃ alkalinity, and 0.8 mg/L Fe. The settling ponds removed 84% of the Fe at an average rate of 26 gFe m⁻²·day⁻¹. The constructed wetland removed residual Fe at a rate of 4 gFe m⁻²·day⁻¹. Analyses of dissolved and particulate Fe fractions indicated that Fe removal was limited in the ponds by iron oxidation and in the wetland by particulate iron settling. The treatment effectiveness of the system did not substantially degrade during cold weather or at high flows. The system cost $1.3 million (2006) or $153 per L/min ($580 per gpm) installed capacity. Annual maintenance and sampling costs are projected at $10,000/yr. The 25 year present value cost estimate (4% discount rate) is $1.45 million or $0.018 per 1,000 L ($0.067 per 1000 gal) of treated flow.

Additional Keywords: mine drainage, passive treatment, iron oxidation

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THE TRANSFER OF KNOWLEDGE BEYOND MINING

R. Neil Humphries

Abstract: The program of presentations at this, the 25th Annual ASMR and 10th IALR Meetings, is a testimony to the immense contribution mine restoration has made and continues to make to the fields of scientific and technical knowledge in the USA. Notably, this has also been the case for some 30 or more years. During the sessions here in Richmond we might take the opportunity to reflect on how and where the knowledge we are presenting or listening to might be applied in other contexts, such as land redevelopment, highways to the benefit of society as a whole. Also, we all have experience of seeing the ‘wheel’ being reinvented on a number of occasions for no particular benefit.

To get us to think about the possibilities, I shall illustrate a number of examples from the UK and from which the knowledge has since been successfully applied on a national basis to other situations over the past 20 or so years. Of course, we all know this has not happened by accident and largely because of the need to address the wholesale potential effects of mining on the environment. In this context, mining has often been in the forefront of environmental concern and regulation, hence an impetus to find solutions based on new knowledge. The main drivers in the UK have been i) legislation, policy and regulation, ii) costs, efficiency and competitiveness, iii) increasing asset value and multiple uses, iv) increase in environmental awareness, and v) increasing stakeholder and pressure group involvement.

This plenary presentation will briefly explore these in the context of six examples from the UK involving legally protected species, biodiversity, water quality, wastes, soil handling and habitat transfer. The process of knowledge transfer is of course not one-way, and there are many examples of mining embracing knowledge from other activities and areas. So when reflecting, lets consider how a two-way flow of knowledge might be used to the benefit of mankind and the wider environment, be it as a result of mining or other land or resource use, and wherever globally it may be.

Additional Key Words: protected species, biodiversity, water quality, wastes, soil handling, habitat transfer

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EVALUATION OF LEACHATE CHEMISTRY FROM COAL REFUSE
BLENDED AND LAYERED WITH FLY ASH

Joe Hunt, Matt Eick, W. Lee Daniels and Mike Beck

Abstract: One widely proposed method to stabilize and reclaim acid-forming coal refuse piles in the Appalachians is to use alkaline fly ash as a liming agent within the refuse disposal fill. Significant amounts of fly ash and other coal combustion products have been back-hauled to the region under the assumption that net water quality effects will be positive. Previous lab column and field leaching studies by our group focused on bulk blending fly ash with acid-forming (pyritic) refuse. While this may be the preferable way to co-dispose the two materials, it is difficult to practically execute in the field. A better representation of field conditions is a “pancake layer” of ash above the refuse. A new leaching column study was initiated to evaluate the leachate chemistry from acid forming coal refuse-fly bulk ash blends vs. ash over refuse layers. On a 20% v:v basis, an acidic and alkaline ash were blended with, or layered over, acid-forming coal refuse and sandstone and packed into PVC columns (7.5 cm x 50 cm) which were leached with 2.5 cm DI water twice a week for 24 weeks. Leachates were analyzed for pH, electrical conductivity, and a suite of elements of concern with a focus on the oxyanions of As, Cr, Mo, and Se. A sequential extraction was performed on the four materials prior to leaching which showed a significant portion of the elements of interest residing in the residual fraction for the refuse and sandstone and in the Fe- and Mn-oxide bound fractions for the ashes. At the conclusion of the leaching phase, a second sequential extraction performed on the materials revealed a general trend for As, Cr, Mo, and Se to be associated with Fe and Mn oxide fraction to a greater extent than in the pre-leached materials. The refuse controls acidified within 4 weeks to approximately pH 2.0. Bulk-blended treatments maintained higher leachate pH than corresponding layered treatments. Significant As and Cr leaching only occurred in the refuse control columns, reaching as much as 30 mg/L in Week 8 for As, and 7 mg/L in Week 16 for Cr. Leachate Mo produced a spike of 13.4 mg/L from the alkaline ash control in the first leaching event, but all other leachates were < 2 mg/L. All refuse treatments eluted initial spikes of Se between 1 and 2.1 mg/L in the first week of leaching, but dropped to < 0.5 mg/L after 2 weeks for all treatments except the refuse control. These results show that significant leaching of As, Cr, Mo, and Se is unlikely as long as bulk solution pH is maintained between pH 4 and 12 for these materials. Bulk-blended treatments maintained a higher leachate pH than layered treatments, but there were no significant differences in oxyanion leaching between the two co-disposal methods over the course of this study. Blending of alkaline ashes, when feasible, with coal refuse would be the preferable co-disposal method to limit the leaching potentials of these potentially toxic trace elements, but layering of ash appears to also be an appropriate co-disposal method. Longer term column and/or field studies should be conducted to determine if there could be release of elements of concern under these conditions beyond the timeframe estimated by this study.

Additional Key Words: Coal combustion products, acid mine drainage, leaching columns, oxyanions, water quality.

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SETTLEMENT EVALUATION OF END DUMPED COAL MINE SPOIL FILL

Wayne A. Karem and Craig S. Lee, PE

Abstract. Strip mining for coal reserves has been and will continue to be a cost effective means of obtaining energy sources for the needs of the United States. A byproduct of strip mining is thousands of acres of relatively flat land created by placing the spoil material in valleys and over previously mined benches. These mine spoil fills offer an opportunity to build large developments and industrial facilities. However, due to the many unknowns associated with the performance of mine spoil fills there is reluctance to invest large sums of money into a mine spoil fill site due to the risk of detrimental settlement. This paper discusses research conducted on two previously mined sites that are currently being developed into industrial parks. The sites were strip mined using mountain top removal and contour mining methods. The mine spoil was placed using end dumping methods. End dumping consists of using dump trucks and scrapers to remove the spoil from the mining area and hauling it to the disposal areas.

The purpose of the research on the two sites was to develop a reasonable predictive model to evaluate the future settlement of the mine spoil fill. Settlements were monitored using surface monuments and extensometers located throughout the site. The extensometers were monitored for five years. The results of the settlement monitoring indicated that on end dumped mine spoil fill sites which are less than 100 feet (30m) thick and over 10 years old, large settlements associated primary compression of the fills have stopped and the fill is in a secondary compression phase. Future additional settlements due to secondary compression were found to be less than 1 inch (2.5 cm) over the five year monitoring period.

This research resulted in developing a predictive settlement model that will assist in understanding the settlement characteristics of similar mine spoil fill sites. This model will result in less conservative site development options, providing cost savings without increasing the risk of detrimental settlements when building on end dumped mine spoil fill sites.

Additional Key Words: Valley fills, Borehole Extensometers,

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A COAL INDUSTRY APPROACH TO SUSTAINABILITY

Michael Karmis, John Craynon, and Deborah Shields

Abstract: Coal is and will continue to be a basic element in a modern, balanced energy portfolio. In the United States, Australia and Europe, as well as in China and India coal offers an important low cost and secure energy solution to sustainability challenges for the foreseeable future. In recent years, the global coal and energy production industries have been engaged in several efforts to identify and accelerate the deployment and further development of innovative, advanced, efficient, cleaner coal technologies. A number of U.S. coal producers are also involved in sustainable development activities, including economic support of communities and regions and environmental protection and restoration. These companies have corporate sustainable development policies and guidelines in place that provide guidance for operations, and some report annually on their contributions to sustainability.

This paper will discuss the need for integration of public policy, law, environmental management and engineering, particularly as they relate to the recovery of energy and mineral resources. An overview of global energy policies will be presented, including the new energy policy adopted by the European Commission, emphasizing technological advancement in the areas of clean coal and carbons sequestration. The legal, social and environmental requirements for mining operations will be discussed as integral parts of the optimized mining and reclamation plan, in a framework similar to the more traditional mining engineering considerations. Finally, the paper will discuss how such a systematic approach may be structured and is necessary in order to achieve economic and environmental sustainability, environmental protection and restoration, and effective, efficient and economically-sound mining and reclamation.

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EVALUATION OF THREE DIFFERENT PURITIES OF CRAB-SHELL FOR THE REMEDIATION OF MINE IMPACTED WATER\textsuperscript{1}

Kristopher M. Korte, Caroline E. Newcombe, and Rachel A. Brennan\textsuperscript{2}

Abstract: Crab-shell chitin has been shown to effectively reduce $SO_4^{2-}$, enhance alkalinity, and remove metals from mine impacted water (MIW) at the bench scale and in field trials. To date, this research has been conducted using inexpensive, raw crab shell (ChitoRem\textsuperscript{TM} SC-20), which in addition to chitin, contains CaCO$_3$ and residual protein. All three of these components contribute to MIW treatment simultaneously, and are therefore difficult to uncouple. In this experiment, three different purities of crab shell (SC-20, SC-40, and SC-80) and limestone were tested for their ability to remediate natural MIW from an abandoned coal-mine in central Pennsylvania. The goals of this project were: 1) to compare the efficiency of metals and sulfate removal between different purities of chitin; and, 2) to begin to uncouple the contributions of chitin, protein, and calcium carbonate when raw crab shell chitin is used for the treatment of acid mine drainage.

Sacrificial batch microcosms containing natural MIW, stream sediment, and either SC-20, SC-40, SC-80, or limestone were established in duplicate and incubated at room temperature for up to 117 days. The most complete and rapid metals removal was observed with SC-20, followed by SC-40, SC-80, and limestone. SC-20 removed more than 99% of Al, Fe, and Zn and more than 98% of dissolved Mn. SC-40 exhibited similar metals removal, but at slower rates. SC-80 and limestone were not effective at removing Mn. Alkalinity production followed similar trends, with SC-20 surpassing the other substrates with a total alkalinity of 1175 mg/L as CaCO$_3$ after 117 days. Elevated NH$_4$ production was observed at early times only with SC-20, indicating that it is residual protein, not chitin, releasing this nutrient. It is likely that the rapid dissolution of CaCO$_3$ from the crab shell, coupled with NH$_4$ release and biological $SO_4^{2-}$ reduction all contributed to elevated alkalinity values and consequently superior metals removal with SC-20. Preliminary geochemical modeling suggests that the probable mechanisms for metals removal with SC-20 include precipitation of Al and Fe oxides/hydroxides and manganese carbonates, as well as physical adsorption onto components of the crab shell.

Additional key words: chitin, CaCO$_3$, protein, acid mine drainage, metals, bioremediation

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TRANSFORMATION OF PHOSPHORUS AND NITROGEN IN DEEP ROW BIOSOLIDS INCORPORATION TECHNOLOGY IN COASTAL PLAIN MINING SITES IN VIRGINIA


Abstract: Deep row incorporation of biosolids is a unique alternative land application method that will prevent odor problems and may permit the application of considerably higher than currently permitted biosolids rates. The goal of our research is to assess environmental consequences of employing deep row incorporation of biosolids to restore productivity of mined land for the production of hybrid poplar as a potential bioenergy crop. Our objectives are to quantify the transformations of nitrogen and phosphorus applied to the soil as entrenched biosolids. The study is being conducted on a mineral sands mine reclamation site near the Coastal Plain-Piedmont fall line in Dinwiddie County, Virginia. The experimental design consists of 5 treatments – two biosolids types each applied in subsurface trenches at two rates and an unamended control. Application rates were 328 and 656 Mg ha\(^{-1}\) for the lime-stabilized biosolids and 213 and 426 Mg ha\(^{-1}\) for the anaerobically digested biosolids. Each treatment was replicated four times and arranged in a randomized complete block design. The site has been instrumented with suction and zero-tension lysimeters for collection and analysis of leachate from which were determined subsurface loss of nitrogen and phosphorus. Gas chambers have been used to collect soil air samples for accounting of denitrification rates from the entrenched biosolids. Redox potential was determined in the incorporated biosolids to describe the biosolids environment influencing nitrogen and phosphorus chemical transformations. During the first 10-14 months following biosolids application, initial nitrogen loss occurred largely as ammonium and organic N and, after 7-10 months, mostly as nitrate N. There was no significant leaching of phosphorus. Low redox potential in the biosolids’ seam validated the occurrence of anaerobic conditions. Higher nitrous oxide emissions occurred from the anaerobically digested biosolids than from the lime stabilized biosolids. The deep row biosolids incorporation technology, when applied to coarse-textured soils, does not appear to be environmentally viable with respect to potential nitrogen loss to groundwater.

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GENERATION OF 400-500 MG/L ALKALINITY IN A VERTICAL ANOXIC LIMESTONE DRAIN¹

J.A. LaBar, R.W. Nairn and G.A. Canty²

Abstract: Alkalinity generation in a vertical anoxic limestone drain (VALD) at an abandoned coal mine discharge near Hartshorne, Oklahoma was evaluated. The VALD consists of a 9-m² abandoned vertical air shaft filled with approximately 22 m of >90% CaCO₃ limestone overlying approximately 34 m of dolomitic stone. The VALD and a downstream passive treatment system were designed to treat a net-acidic discharge (~40 L/min) characterized by elevated concentrations of metals (Fe 765 mg/L; Mn 18 mg/L; Na 1900 mg/L), anions (Cl⁻ 225 mg/L; SO₄²⁻ 7800 mg/L), with pH 5.4 and net-acidity 1400 mg/L. System construction was completed in late 2005, but discharge from the VALD did not occur until January 2007 due to a prolonged regional drought. Upon initial discharge, alkalinity concentrations from the VALD outflow were 550±14 mg/L. During the first year of operation, alkalinity concentrations consistently remained >400 mg/L. The effects of elevated pCO₂, mine water ionic strength, detention time, and other factors impacting alkalinity concentrations exiting the VALD were assessed. It appears that multiple factors, especially the brackish nature of these particular mine waters, influence treatment effectiveness. In addition, the down-gradient 12-cell passive treatment system is effectively removing metals and discharging net alkaline waters to the receiving stream.

Additional Key Words: acid mine drainage, carbonate chemistry, ionic strength, geochemical modeling

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² Julie A. LaBar, Research Scientist, and Robert W. Nairn, Associate Professor, Center for Restoration of Ecosystems and Watersheds, School of Civil Engineering and Environmental Science, University of Oklahoma, 202 West Boyd St., Norman, OK 73019, email: labar@ou.edu, and Geoffrey A. Canty, Vice-President, Watershed Restoration, Inc., P.O. Box 1292, Norman, OK 73070.
SUBSOILS AS TOPSOIL SUBSTITUTES FOR SURFACE COAL MINE RECLAMATION IN MISSISSIPPI: ALLUVIAL FLOODPLAINS

David J. Lang\textsuperscript{2} and George Hawkey\textsuperscript{3}

Abstract: Alluvial soils in the Upper Coastal Plain soil resource area in the state of Mississippi occur in narrow floodplains. Prime farmland soil was collected in 4 foot increments to a depth of 16 feet. Soil collected from Kirkville and Oaklimiter sites was placed in 5 gallon pots in the greenhouse with five replications. Soil fertility (P, K, Ca, Mg and CEC) increased (P<0.05) as depth increased indicating that deep alluvial subsoils have a greater productive capacity. Soil pH was acidic (4.5 to 5.2) and tended to be similar with depth from the Oaklimiter site, but decreased curvilinearly to a depth of 12 feet from the Kirkville site. Pearl millet was planted in the summers of 2005 and 2006 followed by annual ryegrass in the winters of 2006 and 2007. Soil was remixed and limed with 2 tons dololmite per acre after year one. Pearl millet growth in 2005 increased linearly (P < 0.05) as subsoil depth increased at both sites. Manganese (Mn) levels in pearl millet increased linearly as subsoil depth increased from both soils to greater than 2000 ppm but was apparently not toxic to pearl millet. Ryegrass growth increased curvilinearly to a depth of 12 feet from Oaklimiter subsoils but decreased linearly as depth increased from Kirkville due to elevated Mn levels in ryegrass. Mn levels above 500 ppm were toxic to ryegrass. Liming increased pH to as high as 7.6 in soil from Kirkville and to 7.2 from Oaklimiter and had a neutral impact on pearl millet growth. Ryegrass growth following lime was greater as depth increased from Kirkville subsoils and was similar in Oaklimiter. Mn levels in both pearl millet and ryegrass were reduced to non-toxic levels following lime indicating that lime ameliorated subsoils would be suitable as topsoil.

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ASSESSING VISUAL QUALITY CHANGE 25 YEARS AFTER POST-MINING HOUSING DEVELOPMENT IN PLYMOUTH, MINNESOTA

E.J. Lee and J.B. Burley

**Abstract**: Reclamation specialists are interested in scientifically based tools to assist in the evaluation of the post-mining surface mining environment. In this investigation, we compared twenty photographic pairs taken 25 years apart (1980 to 2005) to assess the changes in visual quality on a sand and gravel post-mining site developed for housing. To compare the photographs, we employed an equation that explains 67 percent of respondent preference, with an overall p-value for the equation ≤0.0001 and a p-value <0.05 for each regressor. Difference in scores of about 10 points indicates a perceived and detectable difference in visual quality. Regressors employed in the equation include an environmental quality index (which includes economic, cultural, and ecological predictors), plus other more typical physical landscape regressors. We used the Wilcoxon matched-pairs signed-rank test to statistically compare differences between the two sets of photographs. Since 2.71 was larger than 1.96, we rejected the null hypothesis and accepted the hypothesis that the two photographic pairs were statistically different, (p<0.05). The photographic set from 2005 was measurably more aesthetically pleasing than the 1980 photographic set. The mean score for the 2005 photographic set was 6 points more pleasing than the set from 1980. This change in mean score meant that although the site was numerically more pleasing after 25 years, visitors to the site may not be able to perceive the difference in aesthetic quality.

Additional Key Words: landscape architecture, landscape planning, environmental psychology, landscape design, environmental indicators

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2 Eun Jeng Lee, Jon Bryan Burley (will present paper), Landscape Architecture Program, School of Planning, Design, and Construction, Michigan State University, 101 UP&LA Building, E. Lansing, MI 48824, burleyj@msu.edu
HYDROLOGIC AND AQUATIC IMPACTS FROM A LANDSLIDE IN THE TENNESSEE COAL FIELDS

Robert Liddle and Steve Bakaletz

Abstract: The purpose of this paper is to describe practical methods used by the Office of Surface Mining to evaluate environmental impacts from a landslide and devise a mitigation strategy. On January 27, 2005, a 10-hectare (25-acre) landslide occurred on a steep mountainside at High Point Mountain in Scott County, TN. The landslide included spoil from a pre-law contour coalmine and a reclaimed cross-ridge coalmine. Sediments from the landslide washed into Smoky Creek, a tributary to New River, which flows into the Big South Fork of the Cumberland River. Initial suspended sediment concentrations below the landslide were about 5000 mg/L, while total sediment concentrations peaked at about 24,000 mg/L. After 4 months, the landslide had stabilized and suspended sediment concentrations fell to less than 10 mg/L. Sand and gravel sized particles settled out within 610 meters (2000 feet) below the landslide tributary, while fine silts and clays were carried over 32 kilometers (20 miles) downstream. Groundwater from the adjacent mine spoils was modeled using the USGS MODFLOW software; results indicated mine spoil discharges would reach equilibrium within 292 days. Acid-base accounting accurately predicted no acid mine drainage would occur. Stormwater was modeled using the TVA TENN-I double triangle model, and net sediment erosion was modeled using the ERODE-I model. Model results compared well with actual field data and should be useful in evaluating other landslides. Biological evaluations were conducted on the impacted stream and compared to adjacent streams to show area productivity. Steams were sampled for fish, benthic invertebrates, crayfish, and amphibians by biologists with the Tennessee Wildlife Resources Agency, National Park Service and Tennessee Valley Authority. Aquatic life, while initially smothered, had begun to recover after 22 months. The NRCS WEPP model was used to evaluate different mitigation strategies. Mitigation consisted of seeding the landslide with grasses, planting trees, and implementing vegetative filters. In conclusion, the landslide resulted in an intense short-term release of sediments similar to a construction site, which subsided in about 3 months. Models proved satisfactory in estimating impacts.

Additional Key Words: Erosion, modeling, MODFLOW, sedimentation, TVA, water quality, WEPP

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2 Robert Liddle, Hydrologist, Office of Surface Mining Reclamation and Enforcement, Knoxville, TN, 37920; Steve Bakaletz, Biologist, National Park Service – Big South Fork National River and Recreation Area, Oneida, TN, 37841
ACID MINE DRAINAGE REMEDIATION IN A SMALL WATERSHED

Jaclyn D. Long

Abstract: In 1979, the Maryland Abandoned Mine Inventory (MAMI) estimated that over 450 miles of Maryland streams had been damaged by acid mine drainage (AMD) from abandoned pre-law coal mine sites. Aaron Run, a sub-drainage of the Savage River Watershed, has been severely impacted by acid mine drainage from pre-law mining activities, and is now listed on Maryland’s 1998-303 (d) list of Water Quality Limited Segments (WQLSs) for pH impairment. In 2005 the Maryland Department of Environment, Bureau of Mines (MDE-BOM) submitted a proposal, and received funding through the Environmental Protection Agency’s (EPA) 319 program to demonstrate de-listing of Aaron Run. Overall, the remediation plan developed and carried out by the MDE-BOM, proposes to mitigate AMD impacts at 3 project locations, to raise the entire stream’s average pH from approximately 3.3 to 7.0, and eliminate the majority of all AMD inflow. Treatment technologies will include Aluminator© systems, limestone leach beds and a limestone doser, in 2008. MDE-BOM initiated the formation of the Savage River Watershed Association (SRWA) along with numerous cohesive partnerships. These partnerships have facilitated applying for match funding through OSM Watershed Cooperative Grants, and other sources. The SRWA has provided in-kind services through volunteer effort to help with the monitoring of Aaron Run. The Savage River Watershed Association hired an OSM/VISTA (Office of Surface Mines/Volunteer in Service to America) in June 2007 to assist with monitoring of planned project sites and to build capacity of the organization. The Aaron Run Watershed Restoration initiative is an ideal opportunity to exemplify a holistic approach to watershed restoration through joint efforts. There is potential to de-list a watershed from Maryland’s 1998-303(d) list, restore a currently extirpated population of native brook trout, remediate numerous AMD impacts, and protect important economic fisheries resources. Because the Savage River is known for its pristine quality and is frequently used as a reference site to characterize the quality of other streams, it is truly a priority conservation system. Success of the Aaron Run restoration effort may lead the way for future regional watershed restoration efforts.

Key Words: brook trout, OSM/VISTA, water quality monitoring, Maryland

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ACIDITY DECAY CURVES OF 40 ABOVE DRAINAGE MINES IN WEST VIRGINIA\textsuperscript{1}

B. Mack\textsuperscript{2} and J. Skousen

\textbf{Abstract:} Several measurements of acidity concentrations from 40 above-drainage underground mines over 38 years were plotted against a range of acidity decay curves. The objective of this study was to determine the average amount of acidity lost over time. Ideal acidity decay curves of 2, 5, and 10\% were used for this comparison. The 40 sites were split into two main groups by coal seam (Upper Freeport and Pittsburgh). Acidity values from the 34 Upper Freeport sites were split further into four different groups (by 1968 acidity) and an exponential trend line was drawn through the data to determine how well the groups matched the ideal decay curves. Both the Pittsburgh and Upper Freeport groups most closely matched the 5\% decay curve. Acidity values from the T&T #2 mine, which was closed 12 years ago, were also plotted against the same three decay curves. T&T most closely matched the 10\% decay curve during its first 12 years after closure. This is likely due to the relatively short time since mine closure of T&T compared to the 50-70 years since mine closure for the 40 sites. In addition, T&T is likely still going through its initial flushing phase, which includes the flushing of accumulated metal salts from the mine.

Additional Key Words: AMD, pyrite, mine closure, underground mines

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ASSESSMENT AND CLOSURE OF THE GLENGARRY ADIT, NEW WORLD MINING DISTRICT, COOKE CITY, MONTANA

M. B. Marks, A. R. Kirk, and M. Cormier

Abstract: The Glengarry adit is an underground gold mine developed between 1925 and 1934 in the New World Mining District of south-central Montana. The adit has been a historic source of metals-laden, acidic water that discharged into Fisher Creek, a major tributary to the headwaters of the Yellowstone River. The adit discharge contributed more than 30 percent of the metals load to Fisher Creek, had an average historical flow of about 363 L/min (80 gpm), Cu and Fe concentrations near 7 and 78 ppm respectively, and a pH of 2.2. The USDA-Forest Service undertook a rehabilitation and closure project to address this adit discharge in 2000, with a goal of minimizing or eliminating this discharge.

Assessment included reconditioning 915 meters of underground workings and characterizing water inflows. Four principal sources of water inflows were identified. Chemical mass loading analysis allowed quantification of the impact of each of these sources to surface water quality, as well as a means of evaluating effectiveness of potential closure options. Closure alternatives considered included plugging, containing, or diverting water-flows. Engineering design work on the selected alternative was completed in 2002 and a contract awarded in 2003. Closure consisted of a combination of surface and underground grouting of water-bearing fractures and faults, selective backfilling of three segments of the underground workings, and strategic placement of five water-tight underground adit and raise plugs. A non-water tight portal plug was also constructed. Closure work was completed in 2005 and resulted in an average metals concentration reduction of 83 percent, a metal load reduction of 99.8 percent and an adit discharge flow reduction of 97 percent.

The closure method used at the Glengarry Mine offers an effective approach considered to be a walk-away solution to handling sources of contamination from adit outflows. No future operational, maintenance, or treatment costs are anticipated. A long-term district-wide program to monitor water quality and aquatic health will be implemented once other reclamation construction projects in the District are complete.

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PERFORMANCE OF MESOCOSM-SCALE SULFATE-REDUCING BIOREACTORS FOR TREATING ACID MINE DRAINAGE IN NEW ZEALAND

Craig A. McCauley, Aisling D. O’Sullivan, Paul A. Weber and Dave A. Trumm

Abstract: Water chemistry was monitored monthly for ten months from an acid mine drainage (AMD) seep emanating at Stockton Coal Mine within the Mangatini watershed in New Zealand. Metal concentrations of the seep water were Fe (4.31-146 mg/L), Al (7.43-76.7 mg/L), Cu (0.0201-0.0669 mg/L), Ni (0.0629-0.261 mg/L), Zn (0.380-1.39 mg/L), Cd (0.000540-0.00134 mg/L) and Pb (0.0049-0.0056 mg/L), pH was 2.49-3.34 and total acidity (pH 8.3) was 78.5-626 mg/L as CaCO₃. Water chemistry signature prompted laboratory mesocosm studies measuring the effectiveness of sulfate-reducing bioreactors (SRBRs) for generating alkalinity and sequestering metals.

Alkaline materials utilized in the SRBRs included industrial waste products such as mussel shells, nodulated stack dust (NSD) derived from the cement industry, and limestone. Organic substrate materials included post peel, a by-product from fence post manufacture, Pinus radiata bark and compost. Seven SRBRs comprised of varying substrate mixes received aerated AMD for nearly four months. AMD was sourced from the pond that collected the seep water. The SRBR containing NSD successfully removed all metals, but effluent was caustic with pH>9. Bioreactors consisting of 20-30% mussel shells were most successful at immobilizing metals and generating circumneutral effluent. Systems containing mussel shells sequestered more than 0.8 moles of metals/m³ of substrate/day at stable operating conditions and yielded effluent concentrations (removal efficiencies) of 0.120-3.46 mg/L Fe (96.5-99.8%), 0.0170-0.277 mg/L Al (99.5-99.9%), <0.0005-<0.001 mg/L Cu (>99.7-99.9%), <0.0005-0.0020 mg/L Ni (99.3->99.7%), <0.001-0.005 mg/L Zn (99.7-99.9%), < 0.00005 Cd (>98.3->98.9%) and <0.0001-0.0001 Pb (99.5-<99.7%). The system consisting of limestone as the only alkalinity generating material was less effective (15.4-64.3 mg/L Fe). Results from duplicate systems but different reactor shapes indicated reactor dimensions influence flow characteristics and therefore treatment efficacy.

Additional Key Words: SRBR, bioreactor, AMD, engineered wetlands, vertical-flow wetlands, mine-water treatment, sulfate reduction, Stockton Mine.

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RESEARCH INITIATIVES FOR DEVELOPING PASSIVE-TREATMENT TECHNOLOGIES FOR AMELIORATING ACID MINE DRAINAGE IN NEW ZEALAND

Craig A. McCauley¹, Aisling D. O’Sullivan, Paul A. Weber, Dave A. Trumm, Andrew K. Brough, and Mark W. Milke

Abstract: The challenging complexities associated with acid mine drainage treatment require logical, novel and practical interdisciplinary research approaches for understanding and optimizing appropriate passive-treatment technologies. The major focus of this research pertains to engineered wetland-type systems. Water chemistry and flow were monitored at numerous seeps at Stockton Mine, an active coal mine located in New Zealand, to find a site suitable for implementing pilot-scale engineered wetlands systems. Numerous seeps were eliminated as feasible candidate sites due to current or proposed mining activities, complex hydrogeology, topographical challenges, land space availability issues or water chemistry. The Manchester Seeps site was monitored for ten months and deemed a good candidate site for implementing sulfate-reducing bioreactors (SRBRs).

Substrate materials used in SRBRs were sourced mainly from industrial waste products including alkalinity generating and organic materials. Substrate materials were analyzed for various chemical and geotechnical properties including hydraulic conductivity. Mesocosm SRBRs operated for almost four months in a laboratory to determine system efficacy and optimize design criteria (see McCauley et al, this issue). Tracer studies and system autopsies were later performed. Pilot-scale systems were designed and constructed on site based on site-specific climatic and topographic characteristics using results of mesocosm tests. Pilot-scale systems incorporated a staged-treatment approach. The initial stage included a sedimentation basin to remove sediment that could potentially clog subsequent treatment stages. The second stage involved three SRBRs in parallel to test varying substrate mixtures and hydraulic configurations. The final treatment stage consisted of aerobic wetlands or iron floc settling basins in parallel for “final polishing” of SRBR effluent.

Additional Key Words: Sulphate-Reducing Bioreactors, SRBR, AMD, passive treatment, constructed wetlands, engineered wetlands, mine water treatment, Stockton Mine, tracer studies, system autopsies

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THE INFLUENCE OF SOIL RECONSTRUCTION TECHNIQUES ON MINERAL SANDS MINE SOILS IN VIRGINIA

K.R. Meredith, W.L. Daniels, Z.W. Orndorff, M.M. Alley, and C.D. Teutsch

Abstract: Significant deposits of heavy mineral sands (primarily ilmenite and zircon) are located in Virginia in Dinwiddie, Sussex and Greensville counties. Most deposits are located under prime farmland, and thus require intensive reclamation when mined. The objective of this study was to determine the effect of four different mine soil reconstruction methods on soil properties and associated rowcrop productivity. Treatments compared were 1) Biosolids-No Tillage, 2) Biosolids-Conventional Tillage, 3) Lime+NPK fertilized tailings (Control), and 4) 15-cm Topsoil+lime+NPK over lime+P treated tailings. Treated plots were cropped to corn (*Zea mays* L.) in 2005 and wheat (*Triticum aestivum* L.) in 2006. Yields were compared to nearby unmined prime farmland yields. Over both growing seasons, the two biosolids treatments produced the highest overall crop yields. The Topsoil treatment produced the lowest corn yields due to relatively poor physical and chemical conditions, but the effect was less obvious for the following wheat crop. Reclaimed land corn and wheat yields were higher than long-term county averages, but they were consistently lower than unmined plots under identical management. Detailed morphological study of 20 mine soil pedons revealed significant root-limiting subsoil compaction and textural stratification. The mine soils classified as Typic Udorthents (11), Typic Udifluvents (4) and Typic Dystrudepts (5). Overall, these mined lands can be successfully returned to intensive agricultural production with comparable yields to long-term county averages provided extensive soil amendment and remedial tillage protocols are implemented. However, a significant decrease (~25 to 35%) in initial productivity should be expected relative to unmined prime farmland.

Additional Key Words: biosolids, compaction, mine soils, reclamation, heavy minerals.

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2 K.R. Meredith, Graduate Res. Asst., W. L. Daniels, Professor, Z. W. Orndorff, Senior Research Associate, M.M Alley, Professor, Dept. of Crop and Soil Env. Sciences, Virginia Tech, Blacksburg, VA. C.D. Teutsch, Virginia Tech, S. Piedmont AREC, Blackstone, VA.
WATERSHED-SCALE ENVIRONMENTAL MONITORING TO PRIORITIZE MINE DRAINAGE PASSIVE TREATMENT IMPLEMENTATION


Abstract: As part of a large multi-entity, multi-year effort to address environmental contamination in a portion of the Tri-State Mining District, we conducted regular water quality and quantity evaluations of several hard-rock mine drainage discharges and in-stream locations for the main stem of Tar Creek, its tributaries and streams in adjacent watersheds. Metals (Al, As, Ca, Cd, Co, Cr, Cu, Fe, K, Mg, Mn, Na, Ni, Pb, and Zn), anions (sulfate, nitrate, nitrite, phosphate, chloride, fluoride and bromide) and physical parameters (pH, Eh, T, SC, DO, turbidity, alkalinity), along with volumetric discharge rates, were monitored monthly from October 2004 to October 2007. Mine drainage discharges were determined to be net-alkaline with elevated Fe, Zn, Pb, Cd and sulfate concentrations and were typically characterized by elevated pCO₂ and seasonal hydrologic variability. Discharges were prioritized for passive treatment based upon contaminant loading to receiving waters and the likelihood of significant watershed-scale improvements. Conceptual passive treatment designs were developed for eight discharges and final engineering plans were completed for two discharges. All designs incorporate oxidative iron removal via aerobic mechanisms, and trace metal removal via reductive microbial and geochemical precipitation processes. Multiple process units in parallel trains allow for manipulation of system hydrology and sequential treatment options. Watershed-scale implementation requires meeting both technical and non-technical challenges.

Additional Key Words: hard-rock mining, oxidation ponds, vertical flow cells, iron, lead, zinc, cadmium

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2 Robert W. Nairn, Associate Professor, Keith A. Strevett, Professor, Julie A. LaBar, Research Scientist and Alissa Sutter, Jonathan Clifton, William Strosnider, Jessica Brumley, Darcy Lutes, Beatriz Santamaria, Jennifer McAllister, Alex Brewer, MaKenzie Roberts and Kyle Kauk, Graduate Research Assistants, Center for Restoration of Ecosystems and Watersheds, School of Civil Engineering and Environmental Science, University of Oklahoma, Norman, OK, email:nairn@ou.edu.
DEVELOPMENT AND APPLICATION OF PRE-REMEDIAL DESIGN TOOL FOR THE CLARK FORK RIVER SUPERFUND SITE

D. Neuman, P. Hansen, D. Smith, K. Knutson, and S. Brown

Abstract: In 2004, the Environmental Protection Agency released a Record of Decision for the remediation of one of the nation’s largest Superfund sites – the upper Clark Fork River in western Montana. Fluvially deposited hard rock mine, mill, and smelter wastes from the Butte/Anaconda industrial complex have contaminated the river’s floodplain. These acid metalliferous materials vary in depth from a few centimeters to at least one meter. Phytotoxic conditions limit agricultural production, barren river banks are unstable, and the amount of Cu released to the river results in both acute and chronic impacts to aquatic receptors. As stipulated in the Record of Decision, exposed tailings are to be removed, backfilled with appropriate quality cover soil, and revegetated. Streambanks will be stabilized by “soft” engineering – vegetation fabric, willows, logs, and root wads. Areas of impacted soils and vegetation will be treated in place, using careful addition of lime and other amendments, soil mixing, and revegetation. The Record of Decision also specified all land within the site be classified so impacted areas requiring remediation could be identified. Such a classification system, called the Riparian Evaluation System (RipES) uses key indicators of landscape stability and plant community dysfunction to categorize delineated portions of the site as unique polygons. Each polygon is associated with exact location, surface area, waste volume, and other attributes displayed as geographic information system layers over base area photographs. During the 2006/2007 field seasons, the first 80 km of floodplain were classified into one of four major types: (1) streambank length classified by stability type, (2) exposed tailings, (3) impacted soils and vegetation areas, or (4) slightly impacted soils and vegetation areas. For each of these polygons, a RipES score was derived to determine the most appropriate cleanup remedy specified by the record of decision. In this paper, the RipES system will be described and examples of remedial polygons will exhibited. This pre-remedial design approach is applicable to other large metal-contaminated watershed sites.

Additional key words: reclamation, mining, Superfund, impacted land classification

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CHITIN AS A FRACTIONAL AMENDMENT TO SPENT MUSHROOM COMPOST TO ENHANCE THE EFFICIENCY AND EFFECTIVENESS OF TREATMENT OF MINE IMPACTED WATER

Caroline E. Newcombe and Rachel A. Brennan

Abstract: The slow-release, fermentable, organic substrates commonly used to support the biological treatment of mine impacted water (MIW) are often deficient in nitrogen, thereby limiting the activity of sulfate reducing bacteria and inhibiting the performance of passive treatment systems. Recently, our laboratory has shown that chitin (poly-N-acetylglucosamine), a nitrogen-rich, sustainable waste product of the shellfish industry, is capable of enhancing the activity of sulfate reducing bacteria and improving the efficiency of MIW treatment. This research explores the possibility of using chitin as a fractional amendment to spent mushroom compost substrate (SMS) to facilitate the development of a cost-effective, practical approach for thorough MIW bioremediation.

Microcosm experiments were conducted to test the ability of varying mixtures of ChitoRem® SC-20 crab-shell chitin and SMS to support bacterial communities for the remediation of MIW. Six different fractions of chitin ranging from 0 to 100% were combined with SMS to give a total substrate mass of 0.25 g and then added to serum bottles containing 100 mL MIW and 0.5 g stream sediment (bacterial source). Control microcosms were similarly prepared: Abiotic Controls contained MIW, sterilized substrate, and no sediment, whereas Negative Controls contained only MIW and sediment. All microcosms were established in duplicate and shaken continuously in the dark. After four weeks, the microcosms were sacrificed. Aqueous samples were tested for pH, alkalinity, acidity, volatile fatty acids, dissolved organic carbon, ammonia, anions, and dissolved metals. Notably, MIW treated with chitin:SMS substrate mixtures of 1:4, 1:1, and 1:0 yielded sulfate concentrations 49%, 68%, and 86% lower than MIW treated with SMS alone. The corresponding iron concentrations were 43%, 99.7%, and 100% lower than the iron concentration in MIW treated only with SMS.

Metagenomics were applied to sediment samples to document changes in microbial diversity following treatment with chitin and SMS and correlated with the observed pollutant reduction rates. The ultimate aim of this work is to identify specific microbial groups that are responsible for enhancing MIW treatment, and provide insight on substrate compositions that could be utilized to increase their population and activity to improve the design of MIW treatment systems.

Additional Keywords: Acid mine drainage, bioremediation, crab shell, passive treatment.

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2 Caroline E. Newcombe is a graduate student and Rachel A. Brennan is an Assistant Professor in the Department of Civil and Environmental Engineering at The Pennsylvania State University, University Park, PA 16802.
REVEGETATION OF TIN-MINED LAND USING VARIOUS LOCAL TREE SPECIES IN BANGKA ISLAND, INDONESIA

Eddy Nurtjahya, Dede Setiada, Edi Guhardja, Muhadiono, and Yadi Setiadi

Abstract: Bangka is the largest tin producing island in Indonesia. Sand tin tailing may have 95% sand, C-organics less than 2%, cation exchange capacity less than 1.0, and its soil temperature may reach 45°C. The objective of this research was to study the growth of ten selected local tree species in various planting densities and soil treatments on a barren tin-mine. The study aimed to identify agricultural techniques which improved microclimate for those species, and enhanced natural recolonisation. A planting density of 10,000 seedlings ha\(^{-1}\) and legume cover crops gave the highest survival rate, cover, and litter production. It was suggested that higher planting density improved the microclimate faster. As *Hibiscus tiliaceus*, *Ficus superba*, *Calophyllum inophyllum*, and *Syzygium grande* had the highest individual survival and cover, and therefore show potential for revegetating sandy tin tailings.

Additional Key Words: revegetation, sand tin tailings, local tree species

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Abstract: The Friends of Deckers Creek’s (FODC) Clean Creek Program (CCP) began in the fall of 2002. Through the CCP, FODC has been monitoring chemical and biological conditions at 13 sites throughout the watershed. We monitor water quality quarterly, and we assess fish and macro-invertebrate communities annually. It is important to monitor all of these sites so that we are able to assess the overall health of the Deckers Creek watershed to guide our restoration efforts. Large amounts of stream data are required to start new remediation project while monitoring the effects of past projects. However, due to the complexity of analyzing fish and macro-invertebrate community data, this paper will only focus on the water quality aspect of the CCP. The methods for testing water through the CCP include measuring pH, conductivity, temperature, and dissolved oxygen using handheld electronic devises calibrated daily. Along with these measurements, FODC takes three samples of water from each of the 13 sites that are analyzed at the National Research Center for Coal and Energy Analytical Laboratory. These three samples are used to determine the levels of nutrients, metals and potentially harmful bacteria in the water. Specifically, the samples are tested for total iron, aluminum, manganese, hot acidity, alkalinity, sulfate, and fecal coliform bacteria. The water quality results for 2007 have been collected and compiled. Through the CCP we are able to monitor the success of our remediation projects and find sites for future remediation.
Abstract: Excavation of sulfidic materials during construction has resulted in acid rock drainage (ARD) problems on disturbed lands throughout much of Virginia. In particular, exposure of sulfide-bearing Tertiary marine sediments in the Coastal Plain has become increasingly prevalent. Once exposed, these sediments rapidly produce acid sulfate soils which do not readily support vegetation. To date, the most extensive case of acid sulfate weathering problems in the Coastal Plain occurs at Stafford Regional Airport (SRAP) in Stafford, Virginia. Field plots were established at SRAP in 2002 to evaluate a variety of amendments for remediation and revegetation of acid sulfate soils. The plots were constructed in a completely randomized design with 5 treatments and 4 replications per treatment. Prior to treatment, surface (0–15cm) soil samples were collected from all plots to determine pH and peroxide potential acidity (PPA). Treatments included two rates of lime-stabilized biosolids (184 and 92 Mg ha\(^{-1}\)) with small amounts of additional lime to achieve calcium carbonate equivalences (CCE) of 53 and 27 Mg ha\(^{-1}\), two rates of lime (47 and 23 Mg ha\(^{-1}\) CCE) with N, P, and K fertilizers, yardwaste compost (101 Mg ha\(^{-1}\)) with lime (24 Mg ha\(^{-1}\) CCE) and P and K fertilizers, and a control. The plots were seeded with a mix of acid- and salt-tolerant grasses. Soil and vegetation samples were collected in duplicate from each plot after 1 and 2 years. No significant differences were observed among the amended treatments for surface soil pH, surface soil EC, or vegetation production for either of the sampling dates, indicating that all of the tested amendment combinations were effective in stabilizing these materials.

Additional Key Words: acid sulfate soils, lime-stabilized biosolids, peroxide potential acidity, pyrite, yardwaste compost.
USING ENVIRONMENTAL PERMITS FOR BOOSTING THE ENVIRONMENTAL PERFORMANCE OF LARGE-SCALE LIGNITE SURFACE MINING ACTIVITIES IN GREECE

Francis F. Pavloudakis2 Zach Agioutantis3

**Abstract.** More than 350 Mm$^3$ of materials are excavated annually from the mines of the Ptolemais basin which produce about 50 Mt of lignite. This lignite is subsequently supplied to Thermal Power Plants located in the vicinity of the mines. Mining activities currently occupy a total of 16,000 ha. Unless appropriate preventive and mitigation measures are applied, environmental conditions will deteriorate in numerous ways due to the scale of the operations and the applied surface mining method.

From calendar year 2002, it is required that the Ptolemais mining complex complies with environmental permits set by Ministerial Decisions signed in common by the Ministers of Environment, Development, Culture and Agriculture. For the core mining activity, which consists of four pits with an annual lignite production of more than 35 Mt, the permits were signed eight years after the submission of the relevant Environmental Impact Assessment study. During this long period of negotiations, the mine operator was called many times to submit supplementary information that was deemed necessary in order to agree to the terms and conditions that were finally included in the permit.

This paper presents the main terms and conditions of these permits, which provide a framework for developing and implementing an integrated environmental management system. This system comprises several preventive and mitigation measures related to waste management and monitoring of environmental quality, which are applicable from the early stages of mine operation. The implementation of this system is completed after the mine closure with a series of site-specific land rehabilitation and post-mining monitoring activities.

Based on the experience gained so far from the implementation of the terms and conditions prescribed in the permits, this paper also presents some critical aspects regarding the benefits of this process, the regular implementation of auditing procedures and the effective settlement of conflicts between mining companies, supervising authorities and other stakeholders.

Additional Key Words: Impact assessment, land reclamation, rehabilitation

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STANDARD WEATHERING PROCEDURE FOR COAL OVERBURDEN, INTER-LABORATORY STUDY OF LEACHATE COMPOSITION

Eric F. Perry 2, Joan Cuddeback, Keith B. C. Brady and Roger J. Hornberger

Abstract: Simulated weathering tests are used to estimate leachate quality from rocks containing varying concentrations of pyrite and carbonates at mines. Five rock samples of coal overburden materials were subjected to a standardized column leaching test at eight commercial, university and government laboratories. Splits from sized, homogenized bulk samples were loaded in duplicate columns, incubated under humid air containing 10% CO₂, and leached every 7 days for a 14-week period. Leachates were analyzed for mine drainage parameters including acidity, alkalinity, metals, sulfate and selected trace elements.

Relative percent difference (RPD) and relative standard deviation (RSD) statistics show the variation within individual labs and among the group of labs. Fe, Al, Se, Zn and Acidity exhibited the greatest variability in results across all rock samples and labs. RPD’s usually exceeded 30% for these parameters. The variation in Fe and Acidity increased with weathering duration. Ca, Mg, Na, SO₄²⁻, and specific conductance were the most consistent parameters. Mass weighting the chemical concentrations to account for differences in sample mass and leachate volumes did not noticeably improve the RPD and RSD statistics. Cumulative quantities leached were, however, consistent among labs for most parameters.

About 2 to 6% of the total S present in the rocks was leached during the test. One rock sample was near saturation for gypsum, and some SO₄²⁻ may have been retained in the column. Acid neutralizing capacity was depleted at a faster rate than acid producing potential. Carbonate dissolution varied, with 3 of 5 rocks producing solutions that were saturated for calcite, while two rocks produced under-saturated solutions. Four of five rocks had less than 5% of total Ca and Mg leached, with similar or smaller leaching fractions for other elements. More than 90% of the Fe mobilized by pyrite weathering was retained in the column for all samples. One acid forming sample leached elements more aggressively than the rocks producing neutral leachates.

The inter-lab results show that the standard column test can yield consistent estimates of mine water composition, and differentiate the behavior of various rock and mineral assemblages.

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IDENTIFYING COST-EFFECTIVE RESTORATION STRATEGIES IN MINING IMPACTED WEST VIRGINIA WATERSHEDS

J. Todd Petty, Brady Gutta, Richard Herd, Jennifer Fulton, James Stiles, Michael Strager, Julie Svetlick, and Paul Ziemkiewicz

Abstract. The recently reauthorized Abandoned Mine Land (AML) Program provides West Virginia the opportunity to implement a strategic watershed-based approach for restoring waterbodies impaired by historic pre-law mining. Over the next 15 years the West Virginia program will grow from roughly $23 M/year to a range of $60 to $90 M/year. Under this expanded AML program, the WVDEP Office of Abandoned Mine Land and Reclamation has established a goal of maximizing statewide recovery of cold and warm-water fisheries in AMD impaired watersheds. Given that the magnitude of water quality impairment from pre-law mining is too widespread to address in the traditional source by source treatment approach, restoration actions are being prioritized based on producing the greatest ecological and economic benefits per unit cost. In this paper, we present a process for developing strategic, watershed-based restoration plans in areas heavily impacted by pre-law mining. This process integrates various AMD treatment alternatives into a GIS-based decision support system that quantifies the maximum possible ecological and economic outcomes. We describe an innovative method of representing ecological value of stream segments to create inputs for cost-benefit analysis of various treatment options, and we apply this process to the Three Fork watershed in north central West Virginia. We considered three AMD remediation alternatives in our analyses. The “optimal” alternative is projected to cost approximately $4 M over a 20-year restoration period. This alternative is also expected to recover nearly 36 km of cold and warmwater fishery to the watershed and produce a Net Present Value of approximately $700 K after 20 years. Less optimal alternatives cost less but also resulted in significantly lower ecological benefit. The process presented here can be used to make objective decisions about how best to recover AMD impacted watersheds and may be applicable throughout the eastern coal mining region.

Additional Key Words: ecological benefits, fisheries, mine land reclamation, net present value of restoration, watershed restoration

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MACRONUTRIENT ACCUMULATION AND RELATIONSHIPS IN A SCOTS PINE (*PINUS SYLVESTRIS* L.) ECOSYSTEM ON RECLAIMED OPENCAST LIGNITE MINE SPOIL HEAPS IN CENTRAL POLAND

Marcin Pietrzykowski

**Abstract:** The aim of this study was to determine the sources, accumulation rate and relationships between macronutrients in reclaimed mine soils (RMS) and aboveground plant biomass on external slopes of lignite mines in central Poland. The study was conducted on two different types of sites with 10-year-old Scots (*Pinus sylvestris* L.) pine stands located on Quaternary loamy sands (QLS) and on Tertiary acidic carboniferous sands following neutralisation (TCS). The control plot was located in the same vicinity on an external slope in a natural pine ecosystem on a Haplic Podzol in a young mixed coniferous forest habitat (NPE). The nutrient resources, apart from N, were higher in RMS than in comparable Haplic Podzols, however, N primarily accumulated in the mineral horizons. In forest soils, the main macronutrient resources were accumulated in organic horizons, which in natural soils of coniferous forest habitats constitute the main source of nutrients. The proportion of individual macronutrients accumulated in the biomass vs. pools in soil was much lower on the external slope RMS than in the natural site, which in view of the potential richness of RMS, indicated poorer sorption and utilization of macronutrients in aboveground plant biomass than in natural habitats. Other important linear correlations (*p* = .05) were found between the sources of nutrients in RMS and elements accumulated in biomass (most clearly in case of K, Ca and Mg), which indicates important relationships between soil and vegetation in the first stages of ecosystem development as stimulated by reclamation.

Additional Key Words: reclamation, Scots pine, ecosystem, macronutrients.

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Abstract: Mining-influenced water (MIW) is acidic, metal rich water formed when sulfide minerals react with oxygen and water. There are various options for the treatment of MIW; however, passive biological systems such as biochemical reactors (BCRs) have shown promise because of their low cost and maintenance requirements. The purpose of this study was to explore the effect of organic substrate on microbial communities present in pilot-scale BCRs treating MIW in order to understand how substrate-microbe interactions drive performance. Three organic substrates were evaluated: ethanol (ETOH); and two lignocellulose-based mixtures: hay and wood chips (HYWD), and corn stover and wood chips (CSWD). The microbial community compositions were characterized by cloning of 16S rRNA genes and \textit{apsA} genes associated with sulfate reduction. Quantitative polymerase chain reaction (Q-PCR) was applied to quantify \textit{Desulfovibrio-Desulfomicrobium} spp. and methanogens. Results revealed distinct differences in microbial compositions and relative quantities of total and sulfate-reducing bacteria (SRB) among the BCRs. In particular, the greatest proportion of SRBs were observed in the ETOH BCRs, but the total number of bacteria was low. The HYWD and CSWD BCRs had highly similar bacterial communities, which were complex in composition in comparison to the ETOH BCRs. Methanogens were found to be present in all BCRs at low levels and were the highest in the lignocellulose-based BCRs. This study demonstrates that substrate influences microbial community composition and diversity, which may play an important role in performance and reliability.
THE CONSTRUCTION AND INSTRUMENTATION OF A PILOT TREATMENT SYSTEM AT THE STANDARD MINE SUPERFUND SITE, CRESTED BUTTE, CO1

David Reisman2, Thomas Rutkowski 3, Pat Smart 3, and James Gusek3

Abstract: A pilot biochemical reactor (BCR) was designed and constructed to treat mine-influenced water emanating from an adit at a remote site in southern Colorado which receives an average of 400 inches (10.2 meters) of snowfall each season. The objective of the study is to operate and monitor a BCR on a year-round basis in a harsh mountain environment. There are several unique attributes of the treatment and monitoring system. It has been constructed at an elevation of 11,000 feet a.m.s.l. (3353 meters), and is designed to operate year-round. Since the site has limited winter accessibility due to snowfall, a remote monitoring system was designed to collect samples and field parameters throughout winter months. An automated sampling system powered by solar cells is used to sample the system influent and effluent on a weekly basis and an elaborate Teledyne ISCO™ (ISCO) satellite monitoring system tracks data on an hourly basis with data being uploaded to a web site. Winter water samples will be gathered from the autosamplers in the spring and analyzed for metals. Fall influent and effluent water quality results from the treatment system are reviewed. These include field parameters reported via satellite and metal concentrations from water quality samples. Since there are limited data on biochemical and sulfate-reducing reactors operating in elevated and harsh winter locations, the acquired data are unique for mine-influenced water remediation.

Additional Keywords: ARD, MIW, biochemical reactor, BCR, sulfate reducing bioreactor, SRB, satellite data transmission, heavy metals remediation, passive treatment, Green Remediation

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REVEGETATION OF GOLD MINE TAILINGS IN NOPIMING PROVINCIAL PARK, MANITOBA

Sylvie Renault², John Markham, Laura Davis and Mike Martin

Abstract: It has been estimated that over 10,000 abandoned/orphaned mine sites are present in Canada with 149 sites in the province of Manitoba. Nopiming Provincial Park in South-eastern Manitoba contains a number of abandoned gold mines that are part of the Archean Rice Lake Greenstone Gold Belt. The gold extraction (by cyanidation) from the quartz veins resulted in the formation of large volume of tailings (11 ha) on the Gunnar mine site. Small scale field experiments were designed in 2006 and 2007 to test the effects of tilling, fertilizing, microbial inoculation and tailings amendment with paper-mill sludge on plant establishment and growth. Microbial inoculation of some plants, such as jack pine (Pinus banksiana) with rhizobacteria, has improved their survival rates in tailings in absence of paper-mill sludge. The addition of paper-mill sludge (5.6 kg m⁻²) to tailings in the 2006 experiments increased the growth of red fescue (Festuca rubra) and alfalfa (Medicago sativa). However, the results of the 2007 experiments showed that although amendment of tailings with paper-mill sludge and fertilizer improved the growth of willow (Salix sp) and tamarack (Larix laricina), there was no significant effect of paper-mill sludge on plant survival and grass/legumes cover. The results suggest that the wet conditions in spring 2007 partly diminished the beneficial effects of tilling, paper-mill sludge and fertilizer on plant growth. These preliminary results suggest that paper-mill sludge amendment following tilling could be beneficial for plant growth in gold mine tailings if drainage of tailings is taken into account during revegetation. These results also lay the groundwork for larger scale revegetation studies at the Gunnar mine tailings.

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² Sylvie Renault, Associate Professor, John Markham, Assistant Professor, Laura Davis and Mike Martin, students, Department of Biological Sciences, University of Manitoba, Winnipeg, R3T 2N2, MB, Canada
EVALUATING CRAB-SHELL CHITIN, LACTATE, AND SPENT MUSHROOM COMPOST FOR ACID MINE DRAINAGE REMEDIATION IN CENTRAL PENNSYLVANIA

M. A. Robinson-Lora, and R. A. Brennan

Abstract: Acid mine drainage (AMD) is a major environmental consequence of mining activity. This is a recurring problem around the world, and especially in some specific areas of United States, including Pennsylvania. Remediation of AMD has three requirements: pH neutralization, reduction of sulfate concentrations, and removal of dissolved metals. The aim of this study was to evaluate the sustainable waste material, crab-shell-chitin, as a multifunctional substrate for AMD remediation. The performance of chitin was evaluated under different raw water characteristics (comparative sites test), and compared with lactate and spent mushroom compost (comparative substrates test).

Sacrificial, duplicate microcosms were prepared in serum bottles containing AMD water, sediment (microbial source), and the evaluated substrate. For the comparative sites test, three microcosm sets were prepared using AMD water from three different sites within central Pennsylvania, and all were treated with crab-shell-chitin. For the comparative substrates test, the AMD source was held constant and the substrate varied between crab-shell-chitin, sodium lactate, and spent mushroom compost. Microcosms were incubated in the dark, at room temperature, and under anoxic conditions for up to 50 days.

Crab-shell-chitin (ChitoRem™ SC-20) increased the pH from pH 3.0 – 3.5 to near neutral in 2 – 3 days. Increases in pH were much faster in the microcosms containing chitin than with the other substrates. In microcosms containing chitin, steady alkalinity generation and acidity removal were observed at average rates of 35 and -27 mg CaCO₃/L-d, respectively. The activity of SO₄²⁻ reducing bacteria was evident after 7 – 9 days of incubation, with reduction rates of 11.9 – 17.8 mg SO₄²⁻/L-d. Similar changes in alkalinity, acidity, and SO₄²⁻ were also observed in lactate-containing microcosms, but they only started after 27 days. No alkalinity generation or sulfate reduction activity was observed in bottles containing spent mushroom compost. Aluminum and Fe removal was observed with all substrates, but it was much faster with chitin. Chitin was the only substrate able to partially remove manganese (>73%).

The results of this study indicate that crab-shell-chitin is a promising material to be used as a substrate or amendment for AMD remediation. Its slowly fermentable nature makes it a suitable electron donor source to support the activity of sulfate reducing bacteria. In addition, the rapid release of its built-in carbonate minerals effectively neutralize acidic waters and facilitate the precipitation of dissolved metals.

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ALKALINE ADDITION PROBLEMS AT THE SKYTOP/INTERSTATE-99 SITE, CENTRAL PENNSYLVANIA

Arthur W. Rose and Hubert L. Barnes

Abstract. In 2002-3, approximately $8 \times 10^5$ m$^3$ of pyrite-bearing Bald Eagle sandstone and Reedsdale shale were removed from a large road cut through Bald Eagle Ridge near State College, PA. The rock contained an average of about 4.5% pyrite as veins and fine veinlet networks across 200 m of road cut. Smaller amounts of ZnS and other heavy metal sulfides accompany the pyrite. The rock was placed in 9 nearby locations, including large waste piles and several valley fills, two “buttresses” and a lane elevation along about 0.8 km of hillside that was threatening to slide into the road. During excavation of the cut, pyrite was recognized as a potential problem and considerable lime was added as layers to the various piles. Despite the lime addition, highly acidic seeps emerged from the piles and fills, with pH 2.0 to 2.7, Fe 90-1500 mg/L, and acidities as high as 18,000 mg/L (as CaCO$_3$). These results clearly show that addition of lime and other alkaline materials as layers is not effective.

In experiments to test remediation methods, Bauxsol slurry was sprayed onto part of the buttress area but failed to prevent continuing acid seepages. Inspection trenches showed little penetration of the Bauxsol, and demonstrated the presence of the added lime as impermeable lime layers within the buttress. Bucket tests of mixtures of alkaline circulating fluidized-bed ash with pyritic rocks, when well mixed, gave alkaline effluents. These and similar field and lab experiments indicate that thorough mixing of alkaline materials with pyritic rock is crucial for maintaining non-acid effluent. Experiments with a slurry of Mg(OH)$_2$ show promise. However, ultimately the movable acid rock is being moved to a lined landfill and mixed with a large excess of waste lime material.

Additional key words: acid rock drainage, acid mine drainage, Bauxsol, lime addition

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2 Arthur W. Rose ([rose@ems.psu.edu](mailto:rose@ems.psu.edu)) and Hubert L. Barnes are Professors Emeriti of Geochemistry, Pennsylvania State University, University Park, PA 16802.
SUBSTRATE DEGRADATION AND METAL REMOVAL PERFORMANCE OF A 1,500-GALLON SULFATE-REDUCING BIOREACTOR FOR MINING-INFLUENCED WATER TREATMENT

Ana Ruiz², Linda Figueroa², Marek Zaluski³, Diana Bless⁴

Abstract: The successful long-term operation and sustainability of passive systems for the treatment of mining influenced water (MIW) affected by metals and acidity has been challenged by a lack of understanding on organic substrate design. Metabolic activity of sulfate-reducing bacteria (SRB) in bioreactors produces H₂S that precipitates dissolved metals, and it is the main mechanism that removes metals from solution. Fermentation products of the organic substrate provided support the SRB indirectly. The relation between changes in bioavailable carbon (C) in the substrate, SO₄²⁻ reduction and metal removal was thus studied.

The systems under investigation are two identical 1,500-gallon tanks filled with volume fractions of 0.7 walnut shells, 0.25 corn stover, and 0.05 manure. The tanks have an operating volume of approximately 1,100 gallons, receive influent water at a nominal rate of 1 L/min, and have an estimated hydraulic residence time of about 1.5 days (based on 50% porosity). The bioreactors receive mining influenced water from the National Tunnel in Black Hawk, CO that has a typical metals concentration of 35mg/L Fe, 8mg/L Zn, and 0.6mg/L Cu; pH is circumneutral at 5.5 ±1.0.

To assess bioavailable C in the substrate, hot water and acid soluble C and lignin-to-cellulose ratios were periodically analyzed. Preliminary chemical analysis of the substrate suggests that only the hot water extractable fraction (organic acids and labile polysaccharides) changed during the first three quarters of operation. The lignin-to-cellulose ratio during the same period was relatively unchanged, suggesting that the rate of organic substrate depletion was low. Sulfate reduction was variable but sufficient to promote efficient removal of Cu and Zn. After the first 12 months of operation, the average percentages for metal removal in the duplicate bioreactors were >99% for Cu and Zn and 70% for Fe, the latter ranging between 40 and 95%.

The low rate of substrate depletion suggests the substrate mixture may provide long-term support of the sulfate-reducing consortium. The bioreactors were able to successfully remove Cu and Zn but Fe removal was problematic. This suggests that extent of SO₄²⁻ reduction was not sufficient to effectively remove iron in the National Tunnel MIW.

Additional Key Words: walnut shell, corn stover, solid phase substrate analysis, metal concentrations
WATER QUALITY BEFORE AND AFTER RECLAMATION AT THE ABANDONED VALZINCO Zn-Pb MINE SITE, SPOTSYLVANIA COUNTY, VIRGINIA


Abstract: The Valzinc deposit was a massive sulfide ore body, dominated by pyrite, sphalerite, galena, and chalcopyrite. It was mined intermittently in the first half of the 20th century by underground methods. The host rocks were metamorphosed felsic volcanic rocks. Mine wastes were dominated by flotation tailings deposited in the stream channel, which were subsequently partially transported downstream by fluvial processes. Acid-base accounting results indicate that the tailings are net acid (net neutralizing potential = -268 to -138 kg CaCO₃/tonne) and leach significant quantities of Fe, Al, Zn, Pb, Cu, Cd, and SO₄²⁻.

Pre-reclamation quarterly sampling of the stream below the site documented low-pH waters having elevated concentrations of Fe, Al, Zn, Pb, Cu, Cd, and SO₄²⁻. Reclamation began in 2001 and major construction was completed in 2002. Reclamation included the removal and encapsulation on site of tailings, application of bactericide, installation of limestone drains, construction of wetlands, and revegetation. Results of recent sampling of the site (June 2007) indicate an increase in pH from 3.4 to 5.1, an increase in hardness of 37 %, and decreases in total dissolved solids (68 %), Fe (94 %), Al (98 %), Zn (77 %), Pb (99.5 %), Cu (97 %), Cd (94 %), and SO₄²⁻ (81 %) relative to mean pre-reclamation values. Even though significant reductions in dissolved metals have been achieved and positive biologic indicators of ecosystem health are present, the concentrations of Cu and Zn remain above hardness-based acute ecosystem toxicity criteria. The elevated concentrations, in part, appear to be a natural, pre-mining characteristic of the watershed. The elevated concentrations also highlight the sensitivity of calculated hardness-based toxicity criteria for soft waters. The hardness-based criteria do not account for the mitigating effect of dissolved organic carbon on metal toxicity in wetland areas such as at Valzinc.

Additional Key Words: zinc, lead, copper, aquatic ecosystem, volcanic-associated massive sulfide

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ATTRIBUTES OF RECONSTRUCTED PRIME FARMLAND AFTER SURFACE COAL MINING COMPARED TO PRE-MINED CONDITIONS

H. Raymond Sinclair, Jr., Robert R. Dobos, and Karl W. Hipple

Abstract: Important farmland consists of prime farmland, farmland of statewide importance and local importance, and unique farmland. Prime farmland has the best combination of soil chemical and physical characteristics and suitable climate for producing food, seed, fiber, forage, and oilseed with minimum inputs of fuel and plant nutrients. Further characteristics are none to very slight hazard for wind and water erosion, none to small limitation to maintain soil quality, and sustainable. Reconstruction of Prime farmland soils after surface mining for coal are set forth in federal rules and regulations. Illinois has soil reconstruction criteria for non prime farmland soils (high capability land) that are very similar to soil reconstruction for prime farmland soils. Most of the high capability land also qualifies as farmland of statewide importance. Prime farmland soils, before the current federal law, were not reconstructed as cropland. The present federal law requires that prime farmland be reconstructed to cropland with yields equal to or more than the premined soil. Reconstructed prime farmland after surface mining for coal is dominantly massive (no soil structure) whereas typically a premined soil has structure. It has higher soil bulk density that is critical or limiting for crop root growth, lower soil root zone available water capacity, slower hydraulic conductivity, and lower corn yield than the pre-mined silty loess or lacustrine soils, loamy lacustrine soils, and some loamy glacial till soils. A possible explanation of yield differences for reconstructed mined soil and premined soil is the methods and procedures used to determine their yields. The present and future soil reconstruction of prime farmland soils will need to address saturated hydraulic conductivity (Ksat), develop technology to enhance infiltration of precipitation, and movement of water within the soil profile to result in a field capacity water content of 8 to more than 12 inches. All future soil reconstruction needs to use appropriate conservation practices and shape the landscape to increase infiltration of water into the soil.

Additional Key Words: 62 ILL. ADM. CODE.1825, permeability, soil climate, root zone available water capacity, 62 ILL. ADM. CODE.1816, 30 CFR 823

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CASE STUDIES – BENCH SCALE BIOCHEMICAL REACTOR RESULTS FROM TWO SITES AT THE ELIZABETH MINE, VERMONT

Patrick Smart, David Reisman, James Gusek, and Edward Hathaway

Abstract: A passive treatment study involving eight bench-scale biochemical reactors (BCRs) was conducted at the Elizabeth Mine Superfund Site near South Strafford, Vermont from April 2005 through October 2006. The bench BCR cells are vertical flow reactors that were fabricated from 200 liter plastic drums; the cells contained different mixtures of organic media developed with local sources of wood chips, sawdust, crushed limestone, and cow manure. The abandoned Elizabeth Mine consists of underground workings, open cuts, pit lakes, and multiple mine waste piles (tailings, waste rock, and process residues), all of which discharge mining-influenced water (MIW) with elevated concentrations of heavy metals, including Fe, Al, Cu, and Zn, into a tributary of the Connecticut River. A portion of the site is listed on the National Register of Historic Places; the mine supplied the Union with Cu during the Civil War. It closed in the 1950’s.

In 2005, four of the bench BCR cells accepted mildly acidic MIW from the South Open Cut, whose pit lake chemistry has not discouraged local college students from swimming in it despite a pH of 3. Another four bench BCR cells accepted leachate MIW from an abandoned tailings storage facility, TP-1, whose chemistry is much more aggressive than the South Open Cut water. The eight cells remained on-site throughout the winter, where they were routinely exposed to sub-freezing temperatures. In April 2006, the four South Cut cells were transported to the TP-1 area. The eight bench cells treated comparable MIW chemistries for 26 weeks during 2006.

This paper assesses the performance of a passive treatment system when the reactors are subjected to sustained sub-freezing temperatures followed by dramatic changes in MIW chemistry. The discussion highlights operational challenges such as vandalism and construction challenges in a remote setting, as well as performance data from 2005 through 2006. The appropriateness of the technology for the passive treatment of MIW at the two sites will be discussed.

Additional Key Words: passive treatment, acid rock drainage, sulfate reducing bioreactors
ACID MINE RECLAMATION IN SPOTSYLVANIA COUNTY, VIRGINIA, USA: USING WATER CHEMISTRY AND VEGETATION RE-ESTABLISHMENT AS A MEASURE OF SUCCESS

Robert G. Sobeck, Jr.2, James E. Perry, Allen Bishop and Edward Epp

Abstract: In watersheds of the mid-Atlantic region of the US where sulfide spoils occur from mining operations, geochemical reactions develop additional acids in the soil and water supply. The resulting condition lowers ambient pH to very low values (2 to 4 SU). The low pH impairs the soil chemistry and water quality to the extent that native flora and fauna can not survive on the site. This work presents the design and evaluation of remedial work implemented to abate acid mine drainage from a sulfide mine (Valzinco Mine) in the Piedmont Province of Virginia, USA. Water quality conditions were measured before and after the remediation work, and documented the re-establishment and abundance of native wetland and aquatic vegetation within the site. Data showed that average pH increased from 3.4 to 5.1 and a decrease in total dissolved solids (Fe, Al, Zn, Pb, Cu, Cd, and SO4^2-) over the study period. Initial wetland vegetation, both planted and volunteer, quickly colonized the site with an average ground cover of >74% after five years. Aquatic vegetation cover averaged >50% after 2 years and many plots had coverage >100%. Composition, species richness, and abundance of the new vegetation communities was similar to that of near-by reference (un-affected by mine activities) wetland (>75%, 6.0 spp. m^-2 vs. 5.5 spp. m^-2, average cover 74% vs. 67%, respectively). Two amphibians (southern leopard frog, pickerel frog) and two aquatic reptiles (brown water snake and northern water snake) were captured on the site during the fifth year, indicating a return of herpatifauna to the wetland and aquatic communities. We conclude that the increase in pH, decline in total dissolved minerals, success of the re-vegetation of the site, and return of the reptiles to the site, is a strong indication that the remedial work successfully restored the soil and water chemistry closer to pre-mining conditions. Therefore, we suggest that the successful restoration of this site was based on sound hydrological and biogeochemical principles that can be applied to restoration efforts in other acid damaged watersheds in the mid-Atlantic region.

The reader is also directed to another paper in this volume by Seal et al which presents additional material on this project. The geologic setting, mine location, geochemistry and water quality sampling data are published there.

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IRONING OUT YOUR SYSTEM: REMOVAL OF FERRIHYDRITE PRECIPITATES FROM MINING INFLUENCED WATER PIPELINES

K. Spangler, L. Figueroa, and B. Honeyman

Abstract: Iron hydroxide coatings are responsible for the failure of some mining influenced water (MIW) treatment systems. Iron hydroxide coatings can reduce the effectiveness of limestone drains, clog vertical flow reactors and bioreactors, and reduce the hydraulic efficiency of pipelines and hydraulic control structures. Physical disruption of iron hydroxide coatings is not always possible. Strong acids are effective at dissolving iron hydroxide precipitates but are not safe for field application. We examined the dissolution of iron hydroxide coatings using various combinations of slightly alkaline citrate, bicarbonate and dithionite solutions in batch laboratory tests. Iron hydroxide coatings were collected from a pipeline transporting iron-containing MIW. Solutions of citrate alone and citrate plus bicarbonate were effective at partially dissolving the iron hydroxide precipitates. A solution of citrate, bicarbonate and dithionite (CBD) completely dissolved the iron hydroxide coating in laboratory tests. In November 2007, 170-L of the CBD solution was applied to a clogged field pipeline that had originally supported a flow of over 30 liters per minute (lpm) to two bioreactors in October 2006. However, the flow to both bioreactors had reduced to less than one-lpm by November 2007, which was not enough to provide at least one-lpm to each bioreactor. After the initial application, the flow increased to three-lpm. Subsequent field applications of the CBD solution in November and December 2007 increased the flow to five-lpm. This paper presents the results of the laboratory investigation and the field application of the CBD solution. The CBD solution is a safe and user-friendly method to remove iron hydroxide coatings from a broad range of MIW treatment systems and hydraulic structures.

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2 Kathryn Spangler, Linda Figueroa and Bruce Honeyman, Div. of Environmental Science and Engineering, Colorado School of Mines, Golden, CO, 80401, e-mail: kspangle@mines.edu,
COST ESTIMATION OF AMD TREATMENT AT AML SITES

James M. Stiles

Abstract: Cost estimation of AMD treatment is an important component to the West Virginia approach for the ecosystem restoration of watersheds affected by historic AMD sources. Because the degree of ecosystem restoration depends upon post-treatment water quality conditions, a mass balance of the mean net acid load from tributaries and seeps was employed to calculate the required treatment from various treatment technologies. The investigated technologies included passive treatment, at-source pebble quicklime (calcium oxide) dosing, and in-stream pebble quicklime dosing. This analysis assumed that the maximum alkaline production level of passive treatment was 80% of the net acid load, and the maximum excess alkalinity was 1,000 mg/L CaCO₃ equivalents for pebble quicklime dosing. The prescribed treatment level was designed to raise the minimum net alkalinity level to 50 mg/L CaCO₃ equivalents and reduce the aluminum, iron, and manganese concentrations to the levels specified in the WV stream water quality standards. Treatment technologies were evaluated on the basis of the estimated cost of implementation and operation. This analysis has determined that in-stream pebble quicklime dosing is the most cost effective treatment technology for watersheds affected by historic AMD sources.

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RECLAMATION AND REVEGETATION IN THE COPPER BASIN: LONDON MILL AREA

C. Stokes, F. Russell, F. Miller, K. Faulk

Abstract: The Copper Basin, located in southeast Tennessee, is the site of extensive copper mining and processing operations dating back to the mid-1800s. The London Mill area within the Copper Basin, which included a mine and a flotation plant to separate metal sulfides from waste rock, was abandoned in 1987. Under a voluntary agreement, Glenn Springs Holdings, Inc., a subsidiary of Occidental Petroleum Company, has developed and implemented a remedial plan for the London Mill area to address safety and human health hazards and conduct environmental restoration activities. The remedial approach for the London Mill area required a combination of reclamation activities including elimination of physical hazards, removal or isolation of waste materials, diversion of clean water, collection and treatment of mine-impacted water, and stabilization of surface conditions.

Additional Key Words: acid-rock drainage, acid-sulfate materials

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A HYDROLOGICALLY NETWORKED WATERSHED MODEL FOR EVALUATING AMD TREATMENT SCENARIOS¹

Michael P. Strager², Vishesh Maskey, J. Todd Petty, Brady Gutta, Jennifer Fulton, Richard Herd, James Stiles, Julie Svetlik, and Paul Ziemkiewicz

Abstract. A GIS-based decision support system was developed to aid in restoration planning by integrating various chemical and ecological modeling components that the West Virginia Water Research Institute has developed over the past five years. Using the popular GIS platform of ArcMap, computer code was written in Visual Basic .Net environment to develop an extension for GIS to visually illustrate remediation and alternative outcomes. Building upon the existing 1:24,000 segment level or “reachshed” delineation of watersheds for all of WV and a network model to examine pass through issues, the user is able to compare treatment options and locations for building spatially explicit AMD restoration plans. The advantage of the system is its straightforward mass-balance water quality model and logical decision alternative matrix with costs and ecological benefits. It is possible to visually iterate and illustrate outcomes downstream of various treatment/restoration scenarios. The result is a spatially explicit cumulative watershed modeling framework for quantifying stream conditions at multiple scales.

Additional Key Words: spatial decision support system, cumulative analysis, GIS

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A LEGACY OF NEARLY 500 YEARS OF MINING IN POTOSÍ, BOLIVIA: STREAM WATER QUALITY

W.H. Strosnider, F. Llanos, and R.W. Nairn

Abstract: Silver, lead, tin, and zinc ores has been intensively mined and processed at Cerro Rico de Potosí, Bolivia since 1545. Acid mine drainage and processing plant effluent are prime sources of water contamination in the headwaters of the economically and ecologically vital, yet highly impacted, Rio Pilcomayo watershed. Streams receiving drainage from the slopes of Cerro Rico and surrounding landscapes were sampled during the dry (July-August 2006) and wet (March 2007) seasons of one water-year. In-stream waters contain total metals concentrations of up to 16 mg/L As, 4.9 mg/L Cd, 0.97 mg/L Co, 1100 mg/L Fe, 110 mg/L Mn, 4.1 mg/L Pb, and 1500 mg/L Zn with pH and specific conductivity ranging from 2.8-9.5 and 160-5070 μS/cm, respectively. Many of the studied water bodies are more degraded than class “D” of the Bolivian receiving water body criteria, rendering them unfit for domestic or agricultural use. However, some of these waters are currently being used for irrigation and livestock watering. The data indicate that historic and current mining activities have transformed these key natural resources into potential human and environmental health hazards.

Additional Key Words: acid rock drainage, arsenic, cadmium, iron, pyrite, aqueous geochemistry, water quality, tailings and mineral processing

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COW-CALF PRODUCTION ON RECLAIMED SURFACE MINED PASTURES IN APPALACHIASC. D. Teutsch, M. Collins, and D.C. Ditsch

Abstract: Reclaimed surface mined land in Appalachia could provide grazing for livestock. Research is needed to determine optimal stocking densities (SD) and the sustainability of grazing reclaimed land. In 1997, a grazing study was initiated near Chavies, KY. A 151 ha mountain-top-removal site was divided into two replicates of 12, 24, and 36 ha pastures and adjacent ungrazed areas. Each pasture was stocked with 10 cow-calf units resulting in stocking densities of 0, 0.28, 0.41, or 0.83 cow-calf units per hectare. In October, cows at the highest SD were lighter (476 kg) than cows at the medium (509 kg) and low (505 kg) SD (P<0.01). Pregnancy rates in October were 100% at the high SD compared with 88% at the medium SD and 85% at the low SD (P<0.05). Calf weights were greater on the highest SD in June and August of 1997, but not different in October (P<0.10). In 1998, calf weights on the medium SD were greater throughout the grazing season (P<0.10) and averaged 268, 255, and 247 kg at the medium, low, and high SD respectively (P<0.10). Calves at the high SD were lighter than calves at the low SD for all weigh dates in 1999 after the initial weighing in April. Calf weight per ha was greatest at the high SD in all three years (P<0.05). Grazing intensity was high in all years at the high SD (P<0.01) and groundcover was lower, indicating that this SD may not be sustainable. These data indicate that the medium and low SD may be sustainable for reclaimed mined land pasture ecosystems.

Additional Key Words: mountain-top removal, beef cattle, reclamation, grazing
IMPACT OF SOIL RECONSTRUCTION METHOD ON YIELD, NUTRITIVE VALUE AND BOTANICAL COMPOSITION OF A MIXED GRASS-LEGUME STAND¹

C.D. Teutsch, W.L. Daniels, Z.W. Orndorff, M.M. Alley, K.R. Meredith, and W.M. Tilson ²

Abstract: Mineral sands mining has disturbed over 400 ha of prime farmland in Dinwiddie County, VA. This land is being reclaimed to a hay and pasture post mining land use. In 2005, an experiment was initiated that compared three soil construction methods. The treatments were 1) Control: rip, lime, P, and routine fertilization per crop management protocols, 2) Biosolids: rip, lime stabilized biosolids at 78 dry Mg per ha, and routine fertilization per crop management protocols, and 3) Topsoil: rip, lime, P to subsoil, 15 cm of topsoil return, and routine fertilization per crop management protocols. The objective of this experiment was to compare the effect of soil reconstruction treatment on the yield, nutritive value and botanical composition of mixed cool-season grass-legume sward. Total seasonal dry matter (DM) yield ranged from 8,500 to 9,500 kg DM per ha and 4,200 to 5,800 kg DM per ha for 2006 and 2007, respectively and was not affected by soil reconstruction treatment or N fertilization in either year (P > 0.05). Crude protein (CP) concentration in the forage tissue was higher for the biosolids treatment for the first and second harvest in 2006, but did not differ in 2007. Crude protein was high enough to meet the requirements of a brood cow at all stages of the production cycle. In 2007, total digestible nutrients (TDN) were higher for the biosolids treatment for the first harvest only. In 2007, TDN was greater for the control and topsoil treatments and was likely influenced by greater quantities of legumes found in these treatments. Depending on year and harvest, legumes contributed between 20 and 35% to the total dry matter for the topsoil and control treatments and were not detectable in the biosolid treatment. Initial results indicate that properly amended mine soils generated from the mineral sands mining and reclamation process can support the production of high quality forage crops.

Additional Key Words: biosolids, mineral sands, reclamation, forages

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IMPACT OF SOIL RECONSTRUCTION METHOD ON NITRATE ACCUMULATION IN FORAGES GROWN FOR LIVESTOCK FEED


Abstract: Past research has shown that the use of biosolids in the reclamation of drastically disturbed lands has increased forage yield and nutritive value with no detrimental effects on soils, vegetation, or water quality. One potential concern when using high rates of biosolids in reclamation programs is the accumulation of concentrations of nitrate in the forage tissue that could be dangerous or even toxic to ruminant livestock (>0.5%). Past reclamation research in which biosolids have been used has not assessed these levels. The objective of this research was to determine the impact of soil reconstruction method on the concentrations of nitrate in forage tissue. This research was conducted at a mineral sands mine located in Dinwiddie County, VA. Soil reconstruction treatments were 1) Control: rip, lime, P, and routine fertilization per crop management protocols, 2) Biosolids: rip, lime stabilized biosolids at 78 dry Mg per hectare, and routine fertilization per crop management protocols, and 3) Topsoil: rip, lime, P to subsoil, 15.25 cm of topsoil return, and routine fertilization per crop management protocols. The levels of biosolids used in this experiment resulted in the accumulation of high levels of nitrate in the forage tissue. One year after the soil reconstruction treatments were imposed and the plots were seeded to a grass-legume mixture, levels of nitrate in forages treated with biosolids were 2.5% (NO₃⁻). This is in the toxic range for ruminant livestock and these forages should not be fed. Initial results indicate that when biosolids are used in a reclamation program, forage must be carefully monitored for accumulation of nitrates in order to avoid potential livestock fatalities.

Additional Key Words: biosolids, nitrates, reclamation, forages

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OPTIMIZING MANAGEMENT OF PAH CONTAMINATED SEDIMENT FROM THE APPOMATTOX RIVER FEDERAL NAVIGATION CHANNEL


Abstract. The USACE-Norfolk District (NAO) and the City of Petersburg, VA are working toward restoring the former Appomattox River Federal Navigation Channel. In this effort, ~350,000 cubic yards of deposited sediment will be removed from -14 feet MLLW up to + 6 feet MLLW over a ~1 mile reach of the Appomattox River. Historical industrial uses have resulted in PAH contamination exceeding 500 mg/kg on average, with hotspots detected in excess of 5,000 mg/kg based on USACE 2004 analytical data. To support the NAO with its assessment of contaminant distribution, upland source control measures, dredge sequencing, sediment capping requirements to address residual contaminants and beneficial reuse options for the dredged material have been evaluated. In support of beneficial reuse as agricultural soil, a lab treatability study has been completed to assess biodegradation potential. Total PAH concentrations in three laboratory test pans after 46 weeks of treatment indicated an overall 80% contaminant reduction using an enhanced bioremediation process. The results of this bench-scale study were used as the basis for the design of a pilot field-scale landfarm study demonstration undertaken during July 2007. After five months of treatment, LMW PAHs in landfarm material appear to have degraded first while HMW PAHs are degrading more slowly, a process which generally mimics the results of the laboratory investigation. Conclusions based on the laboratory and landfarm activities as well as the technical and regulatory issues that must be resolved to allow eventual placement of the material at a mine reclamation site for revegetation purposes will be presented.

Additional Key Words: Biodegradation, Landfarm, Treatability.

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PILOT-SCALE EVALUATION OF SOLID AND LIQUID PHASE
ORGANIC SUBSTRATES USED IN BIOCHEMICAL REACTORS FOR
THE TREATMENT OF MINING INFLUENCED WATER\(^1\)

C. Venot\(^2\), L. Figueroa\(^2\), T.R. Wildeman\(^3\), D. Reisman\(^4\), and M. Holmes\(^5\)

**Abstract.** Sulfate-reducing biochemical reactors (BCRs) were installed to provide a basis for substrate selection for a final treatment remedy for mining influenced water (MIW) from the National Tunnel adit. Black Hawk, CO. The MIW was characterized by elevated metal and SO\(_4^{2-}\) concentrations as well as pH fluctuations from 4.8-6.4. Three pairs of BCRs were installed in 2006, each of which contained a different mixture of solid or liquid-phase substrates. The above-ground BCRs partially froze during the first winter, prompting a redesign of the hydraulic system in May 2007 and the installation of heating and insulation in preparation for the following winter in October 2007. During the hydraulic system re-design, a fourth pair of reactors that contained CHITOREM\(^\circledR\) SC-20 chitin complex was added to provide data on an alternative solid-phase substrate. Results from 2007 suggest that nearly all of the reactors removed greater than 95% of the Fe and Zn and 50-95% of the sulfate from the MIW during September through December 2007. Copper removal was typically above 95%. In addition, chitin complex reactors demonstrated high Mn removal (average removal was 80%) and high alkalinity (average of 4200 mg/L as CaCO\(_3\)) during the same period. The high alkalinity was partially due to high concentrations of ammonium (up to 450 mg/L as nitrogen). Operational challenges due to winter conditions in November and December 2007 caused significant temperature and flow fluctuations; however, effective removal of metals was still observed. The BCRs will be monitored through summer 2008 and the data will be evaluated in late-summer 2008 to determine which substrates (CHITOREM\(^\circledR\) SC-20, ethanol or solid phase organic mixture) are best suited for long-term treatment of the National Tunnel MIW by BCRs.

**Additional Key Words:** Acid mine drainage, chitin complex, limestone dissolution, manganese removal, sulfate-reducing bioreactors, water treatment

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COMPARING CHITIN AND ORGANIC SUBSTRATES ON THE NATIONAL TUNNEL WATERS IN BLACKHAWK, COLORADO FOR MANGANESE REMOVAL

C. Venot, L. Figueroa, R.A. Brennan, T.R. Wildeman, D. Reisman, and M. Sieczkowski

Abstract: The National Tunnel is a part of the Central City / Idaho Springs Superfund site. Because passive treatment is an important possibility for removal of contaminants from the water, the USEPA and the Colorado Division of Public Health and Environment (CDPHE) have been sponsoring a bench-scale study of different organic substrates for sulfate-reducing bioreactors (SRBRs). The substrates being tested include ethanol, woodchips and hay, woodchips and corn stover, and crab-shell chitin. After 6–18 months of operation, all of the reactors are showing significant amounts of sulfate reduction. In all of the reactors, Cu and Zn are removed to below their respective ambient water quality criteria of 0.010 and 0.100 mg/L. As is commonly observed in SRBRs, Mn removal is significantly less, with the exception of the chitin reactors. The reason for chitin’s superior Mn removal may be the dissolution of calcite from the crab shell. In the chitin reactors, Ca has increased from 210 to 870 mg/L and alkalinity has increased from zero to up to 5,000 mg CaCO₃ / L. Furthermore, the pH of the effluent leaving the chitin systems averages 6.9. In most SRBRs, Mn is precipitated as MnCO₃ and significant removal does not occur until the pH is raised to between 7 and 8. This is the case in the other types of SRBRs being tested at the National Tunnel, as their Mn removal efficiencies have only approached 50 % at pH values ranging from 6.5 to 7.5. However, in the chitin reactors, 86% of the influent Mn is being removed from 21.5 mg/L to an average of 3 mg/L. The high removal is very similar to the removal of Mn in pulsed limestone beds that are maximized for the dissolution of calcite. These chitin reactors have been operating for six months while the other substrate reactors have been operating for over one year.

Additional Key Words: Water treatment, limestone dissolution, sulfate-reducing bioreactors

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A COMPARISON OF COAL MINING AND INDIANA BAT POPULATION TREND\textsuperscript{1}

Kimery C. Vories\textsuperscript{2}

Abstract. Bat population census information shows a dramatic decline in the number of Indiana bats (\textit{Myotis sodalis}) since 1965 nationwide. On a regional basis, however, the populations are increasing in the northern States and decreasing in the southern States. More recent data shows that the population has been steadily increasing from 2001-2007. This report compares the data on changes in populations of the Indiana Bat with data representing coal production from the same States and over the same time period. The result of this comparison indicates there are no data that would suggest a correlation between the Indiana Bat population trends and: (1) total coal production, (2) rate of growth or decline in coal mining as indicated by percent change in coal production, or (3) surface mining or underground mining methods. This conclusion would be supported by a comparison of the data from the Forest Service that there are 384 million acres of forest cover in the eastern U.S. with the 3.07 million acres of total permitted acreage of surface coal mines in the 14 States within the Indiana bat habitat (OSM 2004), that results in a maximum of 0.8% of the eastern forest cover that could be impacted by surface coal mining.

Although the regional changes in bat population may be suggestive of changes in climate (a uniform increase in the temperature in winter hibernacula could make hibernacula in southern States too hot and in northern States more suitable), the most likely reason for the decline of the species is tied to human disturbance of their underground winter habitat during hibernation. The current emphasis of the U.S. Fish and Wildlife Service on mitigation of impacts due to coal mining is to protect and enhance summer habitat. This may not be effective when the limiting factor in sustaining a healthy Indiana bat population is having an adequate supply of suitable winter hibernacula. Investigations are needed to determine what, if any, impact coal mining and reclamation is having on the bat populations and what mitigation activities are appropriate and effective. The challenge before the States, USFWS, OSM, the coal mining industry, and bat conservationists is to coordinate these concerns in a way that is both protective of the species and appropriately efficient in terms of mitigation requirements that bring proven positive results for this species.

\textsuperscript{1} Paper was presented at the 2008 National Meeting of the American Society of Mining and Reclamation, Richmond, VA, \textit{New Opportunities to Apply Our Science} June 14-19, 2008.

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SOIL AGGREGATE AND AGGREGATE ASSOCIATED CARBON RECOVERY IN SHORT-TERM STOCKPILES¹
A.F. Wick², P.D. Stahl³, L.J. Ingram³, and L. Vicklund⁴

Abstract: Soil organic matter (OM) is drastically reduced by various processes (erosion, leaching, decomposition, dilution through soil horizon mixing etc.) typically associated with topsoil salvage prior to surface mining activities. Of these processes, loss of physical protection of OM through the breaking up of soil aggregation can result in up to 65% of soil carbon (C) reductions. Objectives of this research were to monitor soil aggregate size distribution and associated C throughout short-term stockpiling and subsequent utilization of topsoil for reclamation. Soil samples were collected from the top 5 cm of a stockpile over a 3 year period (<1, 1.5, 3 yrs) and an adjacent undisturbed, native site. Surface stockpile soils were then tracked to a temporary location following stockpile removal and sampled again. Samples were analyzed for aggregate size distribution, fractions, associated C, and OM turnover with ¹³C natural abundance. Macroaggregation increased and microaggregation decreased after 3 yrs of storage, indicating recovery of aggregation in 3 yrs. Following the second removal, macroaggregate proportions decreased and silt and clay fractions were greater than that observed in the native site soils. The second disturbance resulted in greater destruction of aggregate structure than the initial disturbance during topsoil salvage. Carbon increased significantly between <1 and 1.5 yrs in both aggregate size classes. Macro- and microaggregate light fraction (LF) C decreased with storage time as this material was available for utilization by microbes. Aggregate δ¹³C values indicated up to 65% new C associated with aggregate structure. Topsoil storage was beneficial for aggregation and associated C in the surface layers only where plant roots and microbial communities are active; however, the second movement of the topsoil resulted in loss of soil aggregation without impact to soil C.

Additional Key Words: Isotope, cool season grass, disturbance, mining, coal.

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A PHYSICAL AND CHEMICAL ASSESSMENT OF THE MAUDE MONROE MINE SITE

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Abstract: The Maude Monroe Mine in Clear Creek County Colorado is an orphaned site and is one of the earliest precious metal mines in Colorado. Because of close location of the site to Interstate 70, the Clear Creek Watershed Foundation (CCWF) desires to turn it into a museum site. As part of the field session course for the environmental engineering option at the Colorado School of Mines (CSM), 16 undergraduate students spent one week performing a physical and chemical assessment of the site. The basis for the assessment was the Mine Waste Decision Tree and the physical and chemical assessment tests that have been developed by CSM and the U.S. Geological Survey. The objectives for the session were to familiarize the students with the issues involved with metals in the aquatic environment and to introduce the students to sampling and assessment procedures that can be used during a site visit. The highlight of the week was the site visit. Students were divided into four groups and tasked with performing physical assessments of important mine waste piles, and using the composite-sampling method for sampling those piles. This focused the activities of the students while at the site and provided ample material to use for analytical activities. Different groups were given assignments of: metals analysis, data management, aquatic toxicity, and human toxicity. Finally, each group made a presentation based on their assignment which provided the CCWF useful information to determine what should be done with the site in the future.

Additional Key Words: Mine wastes, metals contamination, site assessment

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Abstract: Iluka Resources Old Hickory mineral sands mining operation is located in Dinwiddie and Sussex Counties in southeastern Virginia. Pre-mining land use in the area is primarily agricultural, dominantly in row crops (soybeans, corn, peanuts, and cotton) and forage production. These farms are highly productive, and returning the land back to productivity is a key component to ensuring mine sustainability in the area. Collaborative efforts between industry, academia, and local landowners have led to several advances in reclamation techniques at the site. Co-deposition of tailings, deep ripping, use of soil amendments, and other reclamation techniques are discussed.

Additional Key Words: Iluka Resources, Ilmenite, Zircon, Prime farmland, Biosolids, Carraway-Winn Reclamation Research Farm, Tailings