AMENDING BAUXITE RESIDUE SANDS WITH RESIDUE FINES TO ENHANCE GROWTH POTENTIAL

Jonathan D. Anderson, Richard Bell and Ian Phillips

Abstract: Long term success of rehabilitation on bauxite-processed residue storage areas is dependant on establishing a capping stratum which will satisfy water use and nutrient cycling requirements of the intended plant community. Bauxite residue sand is the primary growth media for rehabilitating residue disposal areas (RDAs) in Western Australia however; the sustainability of the vegetation cover can be compromised by the poor water-retention and nutrient cycling properties of the residue sand. This glasshouse study was conducted to determine if adding untreated or altered residue fines (< 150 μm) to residue sand (> 150 μm) would improve the characteristics of the final storage capping layer for sustained plant growth. Residue sand was amended by adding increments (1, 2, 3, 5, 10, 20 % w/w) of untreated or treated (carbonated or seawater washed) residue fines to determine whether these materials affected the chemical and physical properties of the growth media, and their ability to support vegetative growth (Acacia saligna), compared with the current practice of using only residue sand. Addition of residue fines increased water retention and extractable nutrient concentrations relative to untreated residue sand. However, the addition of residue fines increased both the electrical conductivity and exchangeable sodium percentage. Vegetative growth over a 3-month growing period varied with rate of residue fines addition, and residue fines pre-treatment (seawater > carbonated = unaltered). However, the addition of residue fines did not yield greater growth when compared with unamended residue sand. The importance of differences found in water retention and nutrient concentrations among residue treatments for plant growth need to be investigated in a water-limited field environment.

Additional Key Words: Acacia saligna, carbonation, nutrient concentrations, seawater treatment, water retention, Western Australia

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2 Jonathan D. Anderson, Ph.D. Candidate, School of Environmental Science, Murdoch University, Murdoch, Western Australia 6150 email: j.anderson@murdoch.edu.au Richard Bell, Professor, School of Environmental Science, Murdoch University, Murdoch, Western Australia 6150 email: r.bell@murdoch.edu.au Ian Phillips, Rehabilitation Researcher, Alcoa World Alumina Australia, Pinjarra Western Australia 6208 email: ian.phillips@alcoa.com.au
Preliminary Assessment of Time Trends in Bioavailable Metals in the Tri-State Lead/Zinc Mining District through Analyses of Tree Cores

William J. Andrews, Robert W. Nairn, and William G. Minarik

Abstract. The Tri-State mining district in the central U.S. was a major source of zinc and lead from the early 1800s to 1970, producing 11.7 million tons of zinc, and 2.8 million tons of lead. Soils and streams in more than 70 square miles of the mining district and downstream areas are contaminated by metals. Little environmental monitoring was conducted in the district until the late 1970s, when metals-laden water started to flow from the abandoned mines. To retrospectively determine trends in metals bioavailability during unmonitored decades and recent trends in metals, cores extracted from 36 trees distributed throughout the district were analyzed by laser-ablation-inductively-coupled plasma/mass spectroscopy (LA-ICP/MS). Preliminary analyses indicate that most metals concentrations decreased after cessation of mining. Recent reclamation activities appear to have increased the amount of bioavailable metals in the environment, probably through mobilization in air during disturbance and transport of tailings for use as aggregate, or through runoff of newly-available metals-contaminated fine sediments.

Additional Key Words: dendrochemistry, LA-ICP/MS

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2 William J. Andrews, PhD Student and Graduate Research Associate, and Robert W. Nairn, Associate Professor, Center for Restoration of Ecosystems and Watersheds, School of Civil Engineering and Environmental Science, University of Oklahoma, Norman, OK 73019; William G. Minarik, Adjunct Professor, McGill University, Montreal, Canada H3A 2A7.
TREE GROWTH AND NATURAL REGENERATION ON THREE LOOSE-GRADED SURFACE MINE SPOIL TYPES IN KENTUCKY: PRELIMINARY FINDINGS

Patrick N. Angel, Christopher D. Barton, Richard C. Warner, Carmen Agouridis, Sarah L. Hall, Richard J. Sweigard, Donald H. Graves

Abstract: Reforestation research on mined lands has shown that loosely graded topsoil, weathered sandstone and/or other non-toxic topsoil substitutes are suitable growing media for establishing native forests in Appalachia. Reclamation practitioners however, have expressed confusion as to what constitutes the best available material other than topsoil. Six research plots were established on a surface mine for the purpose of evaluating the influence of three different loose-graded spoil types on tree performance. The three spoil types are: (1) predominately brown weathered sandstone; (2) predominately gray un-weathered sandstone; and (3) mixed weathered and un-weathered sandstones, and shale material (mine-run spoil). The total area of each plot is approximately 4,050 square meters (one acre). Four species of tree seedlings were planted into the spoils. Growth and survival of the planted trees were evaluated for two years. As an indicator of natural succession potential, percent ground cover of volunteer vegetation on the three spoil types was also evaluated. Preliminary observations indicated that by the second year (2006) after planting, the gray plots had an overall higher average survival (96%) than the mixed (84.5%) and brown plots (83%). The brown sandstone plots however, showed significantly more growth in height and diameter than the gray and mixed plots. Ground cover from natural regeneration was found to be 42.3 percent on the brown plots (40 different species), 2.6 percent on the mixed plots (21 different species), and less than 1 percent on the gray plots (6 different species).

Additional Key Words: tree performance, compacted spoil.

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2 Patrick N. Angel, Forester/Soil Scientist, Office of Surface Mining, United States Department of Interior, London, KY 40741 and Doctoral Graduate Student in Soil Science, University of Kentucky (UK), Lexington, KY 40506. Christopher D. Barton, Assistant Professor, Department of Forestry, UK. Richard C. Warner, Extension Professor, Biosystems and Agricultural Engineering (BAE), UK. Carmen Agouridis, Assistant Research Professor, BAE, UK. Sarah L. Hall, MS Student in Forestry, UK. Rick J. Sweigard, Chair and Professor, Mining Engineering, UK. Donald H. Graves, Extension Professor Emeritus and Retired Chair of the Department of Forestry, UK.
ADAPTIVE WATERSHED MANAGEMENT IN THE COPPER BASIN:
EVALUATION OF EARLY SUCCESSES

K.Y. Bell, C.L. Stokes, F. Miller, K.L. Faulk

Abstract: The Copper Basin Mining District Site (Site) has been host to 150 years of copper mining, beneficiation and mineral processing, and sulfuric acid and other chemical production processes that have left a legacy of environmental degradation that has affected the Ocoee River. In order to improve the health of the Ocoee River, the US Environmental Protection Agency, Tennessee Department of Environment and Conservation, and Glenn Springs Holdings, Inc. a subsidiary of Occidental Petroleum Company, agreed to conduct a cooperative, voluntary environmental restoration and redevelopment of the Copper Basin. Part of this agreement was to develop and implement interim actions to alleviate contaminant loading to the Ocoee River so that short-term progress could be realized while long-term remedial actions were identified and implemented in upper parts of the watersheds.

Use of an adaptive management approach to watershed restoration has resulted in early identification of the most significant problems. The major benefit of this process has been early remediation of the worst problems in a complex set. This has allowed valuable resources traditionally utilized for full site characterizations to be applied toward remedial activities, which could potentially change the original character of the Site. Results of the early restoration successes in this hard-rock mining impacted watershed are presented along with long-term remedial actions being conducted in upper parts of the watersheds. Measurable success has been achieved in part because of the flexibility resulting from regulatory collaboration and stakeholder cooperation.

Additional Key Words: watershed restoration, in-pit water treatment, adaptive management, voluntary clean-up

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2 Katherine Y. Bell (will present the paper, email: kybell@bwsc.net) and Carrie L. Stokes are Environmental Engineers and Kenneth L. Faulk is a Geologist with Barge, Waggoner, Sumner & Cannon, Inc. Nashville TN 37201; and Franklin Miller is a Vice President, Glenn Springs Holdings, 2480 Fortune Drive, Suite 300, Lexington, Kentucky 40509.
Abstract: Croplands in the mid-western United States subjected to surface mining pose a difficult problem for reclamation. The most perplexing problem associated with reclamation is excessive soil compaction due to the usage of heavy earthmoving equipment. Such compaction has been shown to affect the productivity of the crops grown later. This article describes design modifications to and a dynamic mechanical control system for a prototype mechanism mounted on the front of a conventional bulldozer that reconstructs soil with minimal compaction.

The mechanical system consists of a powered helical auger, approximately 1 m in diameter, mounted on a conventional bulldozer. Soil placed by scrapers or trucks in windrows or shallow strips on graded overburden is displaced laterally to form an uncompacted rooting zone approximately 1.2 m deep. Soil can be deposited in one layer or the B- and A-horizons can be deposited separately. Modifications of the system and development of a dynamic control system to improve capacity and assure a level soil surface are described.

Excavation of a 1 ha field at the University of Kentucky Coldstream Research Farm to test the performance and efficacy of the system is described. Replicated strips (6.1 m x 120 m) are being reconstructed in triplicate using the following treatments: A- and B-horizon mixed, A- and B-horizon separated, A- and B-horizon mixed with 50 Mg/ha of compost added, and A- and B-horizon separated with 25 Mg/ha added to each horizon during deposition. Soil reconstruction capacity will be reported for each treatment, as well as soil bulk density and soil cone index six months after reconstruction.
Abstract: Since the enactment of the Surface Mining Control and Reclamation Act (SMCRA) thousands of grassland habitats have been created in eastern North America. In western Pennsylvania over 50 species of birds including, eleven species that are either listed as threatened, endangered or as special concern, have been observed using grasslands and wetlands on reclaimed mines. In addition to these bird species, the endangered Massasauga (Sistrurus catenatus catenatus) has been observed foraging on grasslands on two mine sites in western Pennsylvania. Although the development of wildlife habitats can be incorporated into the reclamation of mine lands, the specific habitats for threatened and endangered species are generally not a defined objective of the reclamation of mine lands. Because threatened and endangered species nest and forage on grasslands and wetlands on mine lands, they should be given consideration during the reclamation of mine lands.

Additional Key Words: Threatened and Endangered Species, Grasslands, Wetlands,
Abstract. Water produced as a byproduct of coal bed natural gas (CBNG) production may be used for irrigation when its water quality permits. Produced water, which is typically sodium-bicarbonate type, may cause clay dispersion, potentially resulting in reduced soil permeability. These effects may be mitigated by the application of sulfur and gypsum amendments to the soil surface. Both contribute calcium to the soil’s cation exchange complex; gypsum through dissolution and sulfur by bringing naturally occurring calcite into solution.

In this study, soil samples were collected from two irrigated and two non-irrigated fields along the Powder River in northeast Wyoming. At the time of sampling, one field had been irrigated for three years, while the other had undergone irrigation for three months. We used the isotopic ratio of naturally-occurring strontium of the soil, irrigation water and amendments to trace the influence of gypsum amendments on the soil column. We show that because of strontium’s chemical similarity to calcium, the strontium isotopic ratio identifies inputs, changes to the calcium cycle, and downward movement of calcium from gypsum in fields irrigated with CBNG-produced water. Gypsum supplies more of the calcium on the cation exchange complex in fields that have undergone irrigation and gypsum application for three years compared to those with irrigation and amendment application for three months. Calcium supplied by gypsum is apparently downwardly mobile in soil to depths of up to 30 cm on the field irrigated for three years. Prolonged application of gypsum may help the clays maintain a plant available source of calcium which will help mitigate some of the negative effects of using sodium rich CBNG water for irrigation. The conclusions drawn by this study may help design future treatment options for CBNG produced water beneficial uses, while still protecting the integrity of the soil to which it is applied.

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2 Elizabeth L. Brinck, University of Wyoming, Department of Geology and Geophysics, Laramie, WY 82072 email: LIDDI@uwyo.edu (presenter) 3 Dr. Carol D. Frost, Professor of Geology, University of Wyoming, Department of Geology and Geophysics, Laramie, WY 82072, email: frost@uwyo.edu
MICROBIAL ACTIVITY IN THE PEERLESS JENNY KING SULFATE REDUCING BIOREACTOR SYSTEM.¹

Emma Buccambuso², Linda Figueroa², Jim Ranville², Thomas Wildeman², David Reisman³

Abstract: The Peerless Jenny King treatment system is a series of four sulfate reducing bioreactor cells installed to treat acid mine drainage in the Upper Tenmile Creek Superfund Site located in the Rimini Mining District, near Helena MT. The system consists of a wetland pretreatment followed by the four cells connected in a serpentine manner. The mining impacted water flows from the wetland through each cell before discharge. Sulfate reducing bioreactors mitigate acidity and metal contamination through the microbial production of sulfide. The produced biogenic sulfide precipitates metals, and the microbial process of reducing sulfate to sulfide produces alkalinity.

The health of the entire microbial community present in such systems is important for remediation to be effective. Classes of microbes generally present in such systems include fermenters, methanogens and sulfate reducers. The health can be measured in terms of active microbial populations and positive interactions between populations for the support of sulfate reduction. The goal of this research is to measure the activity of each class utilizing analyses that quantify the groups by their function, as opposed to the traditional molecular techniques of identifying bacteria. Gas chromatography, HPLC-DAD, and ICP-AES are used to identify and quantify the end products of metabolism. The microbial activity can then be characterized and changes can be monitored over time. Results from 2005 sampling of Cell 3 within the system indicate that the activity of sulfate reducing bacteria is much higher than the numbers present would indicate. These results combined with those from 2006 sampling indicate that methanogenesis is a minor process within this cell. The calculation of the stoichiometry of carbon utilization by SRB is much higher than what would be predicted from known stoichiometric ratios of carbon used per sulfate reduced.

Additional Keywords: acid mine drainage, microbial populations, stoichiometry

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² Emma Buccambuso (corresponding author), Environmental Scientist, Tetra Tech, Inc. Lakewood, CO, email emma.buccambuso@tetratech-ffx.com ²Linda Figueroa, Associate Professor, Environmental Science and Engineering, Colorado School of Mines, Golden CO 80401, email lfiguero@mines.edu ²Jim Ranville, Associate Professor, Department of Chemistry and Geochemistry, Colorado School of Mines, Golden CO 80401, email jranvill@mines.edu ²Thomas R. Wildeman, Professor Emeritus, Department of Chemistry and Geochemistry, Colorado School of Mines, Golden CO 80401 email twildema@mines.edu ³David Reisman, Director, Engineering Technical Support Center, National Risk Management Research Laboratory, ORD/EPA, Cincinnati, OH 45268
ETHANOL-FED OR SOLID-PHASE ORGANIC SULFATE REDUCING BIOREACTORS FOR THE NATIONAL TUNNEL DRAINAGE, CLEAR CREEK/CENTRAL CITY SUPERFUND SITE?\textsuperscript{1}

Emma Buccambuso\textsuperscript{2}, Alison Ruhs , Linda Figueroa ,James J. Gusek, Thomas Wildeman  Mike Holmes  and David Reisman

Abstract: The U.S. Environmental Protection Agency (EPA) is planning to treat mining influenced water (MIW) from the National Tunnel Adit that discharges to North Clear Creek near the City of Blackhawk, Colorado. North Clear Creek is part of the Clear Creek/Central City Superfund Site, and the National Tunnel is a major contributor of contaminants to this tributary. The EPA would like to determine the trade-offs between two modes sulfate reducing bioreactor (SRBR). One is an ethanol-fed SRBR and the other is a solid substrate fed SRBR. Ethanol fed and solid substrate-fed SRBR were operated in parallel. The bioreactors were constructed from 55-gallon drums. The nominal hydraulic residence time for the bioreactors initially was approximately 3 days for the period of July through September 2006 and later increased to 9 days for the period of October through November 2006. Measurable sulfate removal (approximately 100 mg/L as S) was noted by the end of July for all bioreactors. Sulfate removal increased through August 2006 and on September 7, 2006 was 170 to 200 mg/L as S. Sulfate removal decreased to 50 to 100 mg/L by the end of September. This decrease coincided with a drop in MIW and ambient air temperatures. The flow was decreased by a factor of three at the beginning of October, which resulted in increased sulfate removal in October and November relative to the end of September. Removal of zinc was observed prior to the onset of sulfate reduction. There was some variability in removal of zinc but greater than 95% zinc removal was observed for all bioreactors after the end of July. Both types of SRBRs were capable of reducing zinc concentrations to below 0.1 mg/L. The effect of cold temperatures was greater in the solid phase substrate bioreactors than the ethanol fed bioreactors. This suggests that cellulolytic fermenters were affected to a greater extent than sulfate reducers by cold temperature because they indirectly provide the soluble substrate for the sulfate reducers.

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\textsuperscript{2} Emma Buccambuso, Environmental Scientist (II), Tetra Tech, Lakewood, CO 80228, Alison Ruhs, Environmental Scientist, USEPA NEIC, Denver, CO 80225, Linda Figueroa, Associate Professor, Colorado School of Mines, Golden, CO 80401, James J. Gusek, Sr. Consultant, Golder Associates Inc., Lakewood, CO 80228, Thomas R. Wildeman, Professor Emeritus, CSM; Michael Holmes, Remedial Project Manager, US EPA Region 8, Denver, CO 80202, David Reisman, Director ETSC, USEPA NRMRL , Cincinnati, OH 45268
NRCS HISTORIC CLIMAX PLANT COMMUNITIES AS REFERENCE AREAS

Bruce A. Buchanan\textsuperscript{2} and Justin A. Tucker

\textbf{Abstract:} Establishing reference areas for western states reclamation invites a host of interesting challenges. Areas adjacent to the mine property may be so poorly managed they are no longer representative of the original plant communities. Additionally, an original reference community may no longer exist. One potential solution is to use the historic climax plant community (HCPC) concept established by the NRCS as a reference area. This paper discusses the process of reference area selection for several areas in New Mexico and compares the historic climax plant community concept to standards established using either a reference area or technical value. Although the use of the HCPC concept as a reclamation standard appears promising, its use invites almost as many problems as it seeks to resolve.

\textbf{Additional Key Words:} disturbance areas, reclamation standards

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\textsuperscript{2} Bruce Buchanan, Ph.D. is the President of Buchanan Consultants, Ltd., Farmington, NM, 87401; Justin Tucker, PhD. is the project development manager for Buchanan Consultants, Ltd.,
ROLE OF ACCELERATED OXIDATION FOR REMOVAL OF METALS FROM MINE DRAINAGE¹

Don Budeit²

Abstract. The kinetics of iron oxidation can dictate the effectiveness of both passive and active mine drainage treatment systems. Iron oxidation rates can be improved by increasing pH and by aeration. Devices that aerate mine water may also increase pH in many mine waters by causing dissolved carbon dioxide to outgas. This paper briefly documents several case histories where accelerated oxygen transfer was used to reduce water treatment costs. At two sites where the water was net alkaline, AMDTreat was used to calculate comparative costs for the Maelstrom Oxidizer and conventional passive treatment systems. This comparison indicated that using the Oxidizer at those two sites decreased the land required for settling ponds by a factor of ten to twenty and decreased capital and maintenance costs by over 50% due to the high iron loading. The system was also effective in treating acidic mine water; a cost comparison at one site indicated a chemical cost savings of 46%.

¹ Paper was presented at the 2007 National Meeting of the American Society of Mining and Reclamation, Gillette, WY, 30 Years of SMCRA and Beyond June 2-7, 2007. R.I. Barnhisel (Ed.) Published by ASMR, 3134 Montavesta Rd., Lexington, KY 40502.
² Don Budeit, President, Environmental Solutions LLC, 314 Polo Club Drive, Moon Township, PA 15108 412 262-2606
RED OAK SEEDLING RESPONSE TO DIFFERENT TOPSOIL SUBSTITUTES AFTER FIVE YEARS¹

James A. Burger, David Mitchem and W. Lee Daniels²

Abstract: Northern red oak is a valuable commercial species occurring throughout the Appalachian Coalfields Region. It reportedly grows on mined land, but little is known about preferred site and soil conditions for this species on mined land. The purpose of our field study was to test red oak survival and growth rates on a variety of topsoil substitutes. The study is located in Wise Co., Virginia on the Marcum Hollow member of the Upper Wise Formation. The site was mined in 1979 and reclaimed in 1980. In 1981, field plots were constructed with different topsoil substitutes spoil mixes and pitch × loblolly pines were planted in 1983. In 2001 the pines were removed and replaced with red oaks in the winter of 2001-2002. Four replicate plots of five different mine spoil mixes were planted with nine red oak seedlings each. Mine spoils consisted of different proportions of weathered sandstone and un-weathered siltstone. Tree survival, height and diameter were measured each year for five years. Results show that survival and growth was best on topsoil substitutes consisting of a mix of sandstone and siltstone. Trees survived and grew poorly on plots constructed from either pure sandstone or siltstone. Reasons for the poor oak performance on the high sandstone plots were not clear, but could possibly be related to lower pH and available Ca levels. Poor oak performance on the pure siltstone plots was most likely related to higher rock fragment and lower bulk water holding content.

Additional Key Words: Reclamation, coal mined land, forest management, soil quality, mine soils.

¹ Paper was presented at the 2007 National Meeting of the American Society of Mining and Reclamation, Gillette, WY, 30 Years of SMCRA and Beyond June 2-7, 2007. R.I. Barnhisel (Ed.) Published by ASMR, 3134 Montavesta Rd., Lexington, KY 40502.
² James A. Burger is Professor and David Mitchem is Senior Laboratory Specialist, Department of Forestry, and W. Lee Daniels is Professor of Soil Science, Department of Crop and Soil Environmental Sciences, at Virginia Polytechnic Institute and State University, Blacksburg, VA 24061.
COAL MINING GEOSPATIAL DATA FOR THE NATION\textsuperscript{1}

Bill Card\textsuperscript{2} and Len Meier

\textbf{Abstract.} Digital geospatial data describing past, present, and proposed coal mining operations can provide significant benefits to government agencies, business interests, and the public when planning land use activities in coal-bearing areas of the nation. In September 2005, the Office of Surface Mining Reclamation and Enforcement (OSM) established the National Coal Mining Geospatial Committee (NCMGC) to promote the use of geospatial technology for implementing the Surface Mining Control and Reclamation Act of 1977 (SMCRA). The NCMGC is supported by OSM’s Technical Innovation and Professional Services (TIPS) program and operates as a partnership between OSM and the states authorized to implement SMCRA. Committee members represent the geospatial technology interests of the states, tribes, and OSM offices. SMCRA organizations with representation in the NCMGC include the Interstate Mining Compact Commission (IMCC), National Association of Abandoned Mine Lands Programs (NAAMLP), and the Western Interstate Energy Board (WIEB). In June 2006, the NCMGC hosted the first National Meeting of SMCRA Geospatial Data Stewards in Denver, CO. These stewards are designated by each state/tribe regulatory and/or AML program to represent their geospatial technology interests and provide national coordination. Meeting accomplishments included identifying local needs for advancing use of geospatial data; identifying goals within organizations to obtain and use geospatial data; and identifying NCMGC activities at a national level to advance the use of geospatial technology within SMCRA organizations. The stewards approved development of the first two national coal mining data layers: coal surface mining boundaries and coal underground mining boundaries. The NCMGC formed a Coal Mining Spatial Data Standards ASTM Task Group to establish voluntary standards for these two layers. The NCMGC also created a Coal Mining Spatial Data Infrastructure Team to prototype methodology to collect selected coal mining datasets contributed by each participating state/tribe. These data will be assembled into national datasets for use in SMCRA business processes and distribution to the nation. Automation, reuse, and dissemination of coal mining geospatial data will bring multiple benefits to government, the coal mining industry, other business interests, academia, and the public. These benefits will include improved regulation of active coal mining operations, more successful reclamation of abandoned mine lands, and better public policy at local, state, and national levels.

\textbf{Additional Key Words:} surface coal mining, underground coal mining

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\textsuperscript{2}Bill Card is GIS Coordinator at U.S. Department of the Interior’s Office of Surface Mining in Knoxville, TN, 37902. Len Meier is Chief of Program and Technology Support Branch, U.S Department of the Interior’s Office of Surface Mining in Alton, IL, 62002.
ISOTOPIC AND GEOCHEMICAL CHARACTERIZATION OF THE POWDER RIVER, WYOMING AND MONTANA

Shaun A. Carter, Jason Mailloux, Carol D. Frost*, Shikha Sharma, Michael T. Meredith

Abstract. In the past 10 years, coalbed natural gas (CBNG) production in the Powder River Basin (PRB) of northeastern Wyoming has increased dramatically. When CBNG co-produced water is discharged on the surface, the salts in this water may be flushed into rivers with potentially detrimental effects. In order to assess the possible impact of discharge of co-produced water to the Powder River (PR) we obtained baseline major ion and stable Sr, O and H isotopic analyses on samples of the PR taken from its headwaters to its confluence with the Yellowstone River. A total of 18 samples were collected in September 2006 when the river was near its lowest flow. PR water is generally sodium-sulfate rich, similar to other inland arid river systems, including the Colorado and Rio Grande. Plots of our preliminary data for TDS and SAR show that SAR is generally at or below 10, with an average value of 8.5, except in northern Wyoming where CBNG activity is concentrated. Water with higher SAR enters the main stem of the PR from tributaries including Beaver Creek (SAR = 21), although the impact on SAR of the main stem is modest. TDS ranges from 563.2 near the confluence in Montana, to 2054 at Sussex, WY, with an average value of 1375. ²⁷Sr/⁸⁶Sr ratio generally decreases downstream along the length of the PR. The radiogenic (high) ratios of river water near the headwaters reflect the input of radiogenic Precambrian erosional debris from the Bighorn and Granite Mountains. As the water moves downstream, the Sr isotopic ratio decreases because of the addition of Sr in water that has interacted with younger, less radiogenic Phanerozoic sedimentary rocks. The Sr isotopic ratio of CBNG co-produced water in the vicinity of Beaver Creek is also radiogenic, but its low Sr concentration minimizes the impact on the ²⁷Sr/⁸⁶Sr ratio of the PR. ²⁰¹⁸O and ²¹²H of PR water are isotopically light, indicating that the source of water may be dominated by precipitation from the Bighorn Mountains even in autumn. Many samples plot below the Global Meteoric Water Line, indicating that evaporation has affected the river water, particularly near Broadus, MT. Results from this study will provide a foundation for assessing the effects of CBNG discharge on surface water chemistry and be useful in developing reasonable water quality standards that promote sustainable coalbed methane production.

Additional Key Words: environmental geochemistry, isotopes, arid river systems

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² Shaun A. Carter, Graduate Student, Jason Mailloux, Graduate Student, *Carol D. Frost, Professor (Presenter), Shikha Sharma, Research Scientist, Michael T. Meredith, Research Scientist, Dept. of Geology & Geophysics, University of Wyoming, Laramie, WY 82071
MODELING OF GROUNDWATER CONTAMINATION OF TRACE ELEMENTS FROM CBNG DISPOSAL PONDS

Benito Chen-Charpentier and Frederico Furtado

Abstract. When producing coalbed natural gas (CBNG), water containing trace elements is also produced. A large percentage of this water is stored in disposal ponds, where it slowly evaporates. The evaporation process has the effect of increasing the concentration of trace elements such as arsenic, selenium and barium to much higher levels. The bottom of these ponds is not completely impermeable with the consequent filtration of some of the water into the surrounding soil. The water may eventually flow into underground aquifers. A very important question is to determine if the trace elements actually reach the groundwater and in what concentration. The answer is very important to decide if anything needs to be done to avoid contaminant of sources of drinking and farm-uses water. Mathematical models of flow and transport in porous media will help in this task. We have a two dimensional computer model that will simulate the flow of water from the pond into the non-saturated porous medium beneath it. The model is based on Darcy’s law and conservation laws for the trace elements. The mathematical equations were discretized and a computer program was written and implemented on a computer cluster. Sample results will be presented.

Additional Key Words: mathematical models; contaminant filtration

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2Benito Chen-Charpentier, Professor, and Frederico Furtado, Associate Professor, Department of Mathematics, 1000 E. University Ave., University of Wyoming, Laramie, WY 82071.
THE USE OF WATERSHED COOPERATIVE AGREEMENT PROGRAM FUNDS TO RECLAIM SMALL ACID MINE DRAINAGE PROBLEMS

John W. Coleman

Abstract: Acid mine drainage (AMD), which is a by-product of many abandoned surface and underground coal mines, is detrimental to the environment. The toxic runoff has destroyed thousands of miles of streams and adjacent areas. Though programs are in place to attempt to ameliorate the AMD concerns, AMD continues to pose a potential problem in many areas, despite regulations, improved prediction, and prevention techniques.

On March 31, 1997, Kathrine L. Henry, Acting Director of OSM, issued a memorandum “A Message Concerning Acid Mine Drainage”, stating, “The prevention of future acid and toxic discharges from coal mining operations into surface and ground waters and the remediation of mining-related pollutational discharges are high priorities of the Office of Surface Mining Reclamation and Enforcement (OSM). To advance these priorities, OSM previously established the Appalachian Clean Streams Initiative (ACSI), with a primary focus on eliminating acid and toxic mine drainage from abandoned mines, and the Acid Drainage Technology Initiative, which concentrates on the prevention and remediation of AMD from modern coal mining.”

In response to the Acting Director’s concerns, OSM established an AMD Policy Team and after extensive input from all affected parties developed policy goals, objectives and strategies to protect the hydrologic balance in coal mining areas from the effects of AMD. Two and a half years later, during 1999, OSM initiated the Watershed Cooperative Agreement Program (WCAP) as part of the Appalachian Clean Streams Initiative. The purpose of this program was to develop partnerships and assist local not-for-profit organizations in funding for the remediation of small local AMD concerns. This program expanded rapidly in several eastern states, as strong and very proactive local watershed groups and other environmentally conscious organizations looked for ways to assist in cleaning up the environment --- especially as it affected the water of the area and its potential effects on their economy and living environment.

Implementation of the WCAP in Iowa, Kansas and Illinois is in its infancy. Amelioration of the AMD concerns was recently completed on their first projects. Future success will depend on funding and expansion of the program through education and public involvement.

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2 John W. Coleman, Senior AML and Regulatory Program Specialists, Office of Surface Mining, Alton, IL, 62002
DETECTION OF DIESEL CONTAMINATION FROM STORAGE TANKS AT TWO MINING SITES USING GEOPHYSICAL TECHNIQUES

Jeffrey S. Cooper² and Song Jin²

Abstract. Mining sites are often impacted by leaky storage tanks containing diesel that can adversely effect nearby groundwater. Remediating the effected area requires accurate characterization of the contamination plume. Determining the extent of hydrocarbon spills is typically done by hand sampling events. Though this method can provide useful results, it is a labor intensive activity and allows for the possibility of introducing error in mapping the actual impact in a given area. Likewise, sampling involves intrusive, destructive practices such as mechanical coring. Often, this can lead to the introduction of mobile contaminants into previously undisturbed areas. The practice of using electromagnetic induction surveys has shown that is possible to map the extent of hydrocarbons in a nondestructive, noninvasive way. This study was designed to provide a model to show the response of diesel contamination on such a survey.

Geophysical surveys were undertaken at two coal mining sites near Gillette, Wyoming, using the EM34-XL™. Surveys were conducted using 10 m and 20 m coil separations in both dipole orientations. Areas known to contain diesel contamination were shown as resistive anomalies. Samples from monitoring wells at the two sites were correlated to the survey results for validation. It was shown that electromagnetic induction surveys could be used under the circumstances to map the diesel contamination plume and that ground conductivity could be successfully correlated to obtain a general concentration of subsurface diesel.

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² Jeffrey S. Cooper is Scientist, Western Research Institute (WRI), Laramie, WY. Song Jin is Principal Scientist at WRI.
NICKLE PLATE ABANDONED MINE POOL “BLOWOUT”
WASHINGTON AND ALLEGHENY COUNTIES, PENNSYLVANIA

Timothy Danehy; Richard Beam; Scott Horrell; Robert Dolence; Jeffrey Ankrom; Bruce Leavitt; Wayne Fuchs; Shaun Busler; Clifford Denholm; Margaret H. Dunn

Abstract. On 01/25/05, a 10,000-gpm “blowout” of the century-old Nickle Plate Mine (Pittsburgh coalbed) occurred in a public sidewalk about 12 miles southwest of downtown Pittsburgh, PA. The US Office of Surface Mining, first responder, installed diesel pumps and drain lines along public streets to control and convey the discharge to a nearby stream. On 02/22/05, the Pennsylvania Department of Environmental Protection, Bureau of Abandoned Mine Reclamation issued a 90-day emergency contract to Environmentally Innovative Solutions, LLC to provide a permanent control. With numerous partners (federal, state, local agencies; local residents and businesses), property access, stream and mine pool water quality data, historical mine mapping, and other pertinent site information were acquired.

Nine options were developed and evaluated. Paramount in design considerations was public health and safety followed by effectiveness, reliability, community and environmental impact, long-term maintenance requirements, installation cost, and aiding future work including grouting to address mine subsidence issues and treatment of the abandoned mine drainage. Piezometers and test pits were installed in city streets, private driveways, and on undeveloped property and mine pool response tests were conducted. After data evaluation, the mine pool was manipulated to discharge about ½-mile northeast of the “blowout” on undeveloped land to an AMD-degraded receiving stream. By 05/20/05, a primary gravity drain, a secondary drain, and an early warning system at the “blowout” had been completed. Subsequent monitoring confirms the facilities are functioning as designed.

Additional Key Words: public-private partnership, emergency contract.

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2 Timothy Danehy, QEP; Robert Dolence, VP; Jeffrey Ankrom, Proj. Mgr.; Wayne Fuchs, Job Foreman; Shaun Busler, GISP; Cliff Denholm, Env. Sci.; Margaret H. Dunn, PG, CPG are with Environmentally Innovative Solutions, LLC, Cranberry Twp. Office, 3016 Unionville Road, Cranberry Twp., PA 16066. Richard Beam, PG and Scott Horrell, Project Manager, are with the Pennsylvania Department of Environmental Protection, Bureau of Abandoned Mine Reclamation, Cambria Office, 286 Industrial Park Road, Ebensburg, PA 15931. Bruce R. Leavitt PE, PG, Consulting Hydrogeologist, is located at 2776 S-Bridge Road, Washington, PA 15301.
CONVERSION OF POTOMAC RIVER DREDGE SEDIMENTS TO PRODUCTIVE AGRICULTURAL SOILS

W. Lee Daniels, G. Richard Whittecar and Charles H. Carter III

Abstract. River channel and harbor dredging activities in the eastern USA generate hundreds of millions of yards of dredge materials annually with very little used beneficially. The Woodrow Wilson Bridge project across the Potomac River at Washington D.C. generated in excess of 450,000 m$^3$ of silt loam, high pH, low salt dredge materials. The materials were barged to Shirley Plantation on the James River in Charles City Co. Virginia, and placed into an upland utilization area atop a previously reclaimed sand and gravel mine. The strongly reduced inbound sediments were very low in sulfides, pesticides, and other contaminants. The materials were dewatered, treated with varying rates of yardwaste compost and planted to wheat (Triticum vulgare) in the fall of 2001 and corn (Zea mays) in 2002 and 2003. Winter wheat yields in 2001 were similar to local agricultural lands despite animal damage and less than ideal establishment conditions. Average corn yields in 2002 were greater than long-term county prime farmland yields in a severe drought year (2002) and equaled county averages in a wet year (2003). Soil pit and auger observations revealed significant oxidation and formation of a deep Ap-AC-C profiles with coarse prismatic structure within two years after placement. Overall, the chemical and physical properties of these materials are equal or superior to the best topsoils in the region, supporting federal initiatives to utilize suitable dredge materials in upland environments whenever possible.

Additional Key Words: Sand and gravel mining, oxidation, water quality, beneficial use.

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2 W. Lee Daniels is Professor, Dept. of Crop and Soil Env. Sci., Virginia Tech, Blacksburg, VA, 24061-0404; 540-231-7175; wdaniels@vt.edu. Rich Whittecar is Assoc. Professor, Dept. of Ocean Earth & Atmos. Sciences, Old Dominion Univ., Norfolk, VA 23529-0276. Charles Carter is Principal, Weanack Land Limited Partners, 461 Shirley Plantation Road, Charles City, VA 23030.
APPALACHIAN REGIONAL REFORESTATION INITIATIVE AND THE FORESTRY RECLAMATION APPROACH$^1$

Victor M. Davis$^2$

Abstract: The Appalachian Regional Reforestation Initiative (ARRI) is a broad-based citizen/industry/government program working to encourage the planting of productive trees on active and abandoned coal mine lands. Using a combination of private and governmental resources, the program facilitates and coordinates citizen groups, university researchers, the coal industry, corporations, the environmental community, and local, state, and federal government agencies that have an interest in creating productive forestland on reclaimed mined lands. Forestry research conducted by various academic institutions has confirmed that highly productive forestland can be created on reclaimed mine land by using a Forestry Reclamation Approach (FRA). The Office of Surface Mining Reclamation and Enforcement (OSM) and the Appalachian region states have determined that this technology can be implemented under the current state and federal regulations. Tree planting is documented throughout Appalachia in the regulatory programs in Ohio, Pennsylvania, Maryland, Kentucky, Virginia, Tennessee, and West Virginia. Although trees are being planted, the reclamation plans generally do not reflect the current technology. The mission of ARRI is to promote and encourage the use of the FRA technology in reclamation of both active and abandoned coal mine sites. Part of our effort is to provide FRA training and to explain the multiple benefits of creating productive forestland. These multiple benefits include restoration of clean water and air resources, carbon sequestration, soil conservation, wildlife and endangered species habitat, recreational opportunities, and timber production.

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$^2$ Victor M. Davis is a Reclamation Review Specialist, OSM, 710 Locust Street, Knoxville, TN 37902. Vic serves as a member of the ARRI Core Team and Co-Liaison for the ARRI Academic Team.
EGG-CRATE MINE SUBSIDENCE

Maynard L. (Mike) Dunn, Jr.

Abstract: Steep-sided or near-vertical ground failures over shallow room-and-pillar works are well known and thoroughly covered in the literature. Variously termed pothole, sinkhole, cockpit, and chimney (or chimney cave) subsidences, these failures tend to occur without warning and sometimes many years after mining, usually as single or small clusters of events. Recently, during background work on a Pennsylvania bituminous AML fire, a regular pattern of light and dark areas on vintage aerial photographs was seen to closely match abandoned room-and-pillar works. On the ground, this pattern proved to be complete subsidence into the mine voids with only minor settling over the pillars and ribs. The differential subsidence has produced a topography closely resembling an egg crate – thus the term coined here, “egg-crate subsidence.” Examination of additional historic aerial photographs of the region revealed the egg-crate patterns are common. Where egg-crate subsidence patterns exist, secondary mining seems to be rare owing to roof support problems during the initial mining. Unmined coal and old works are ideal sites for fire, water pollution, and land use development problems. Although re-mining has eliminated many egg-crate subsidence areas, enough remain, at least in western Pennsylvania, to pose long-term nuisances. Some of the conditions contributing to egg-crate subsidence (time, depth, mining height and method, etc.) will be presented as will the value of preserving and digitizing old aerial photography and mine maps. New data and remote sensing techniques are being studied which may be able to add these egg-crated areas to the AML inventory.

Additional Key Words: shallow underground mining, fire hazard, historic aerial photos, remote sensing

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2 Maynard L. (Mike) Dunn, Jr., Geologist, Office of Surface Mining and Reclamation Enforcement, 3 Parkway Center, Pittsburgh, PA 15220; e-mail: mldunn@osmre.gov.
Abstract. The Raccoon Creek Watershed in southwestern Pennsylvania is severely impacted by abandoned coal mine drainage as a direct result of its rich mining history and energy production. The pollution emanates from an interconnected network of underground mine workings that underlie most of the upper Raccoon Creek Watershed. A study of the local hydrogeology through the installation and monitoring of piezometers and compilation with evaluation of historical mine mapping and water monitoring (mine discharges and streams) indicates that the pollution originates from three separate, but adjacent, mining areas. Utilizing siphons and horizontal borings, the opportunity exists to consolidate the drainage to a single discharge point for treatment and/or for potential use by a near-by circulating, fluidized-bed, power plant (under construction). Additional investigation is needed to determine feasibility. This innovative approach to an areal problem is expected to simultaneously restore multiple streams while saving treatment costs and advancing the current state of treatment possibilities.

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2 Kyle J. Durrett, Geoscientist, and Timothy P. Danehy, QEP, are with BioMost Inc., Cranberry Twp., PA 16066. Bruce Leavitt, PE, PG, Consulting Hydrogeologist, is located at 2776 S-Bridge Road, Washington, PA 15301.
SOLVING MINE DRAINAGE PROBLEMS AT SOUDAN STATE PARK – ONE STEP FORWARD, TWO STEPS BACK

P. Eger

Abstract. Soudan State Park contains Minnesota’s first iron mine and offers tours through parts of the old underground mine workings. The mine began in 1884 as an open pit before switching to an underground operation in 1892. U.S. Steel operated the mine from the 1920's until it closed in 1962.

The average mine dewatering discharge is around 60 gallons per minute and contains copper and cobalt in excess of the permit standards of 0.020 mg/L copper and 0.005 mg/L cobalt. Annual average concentrations have varied from 0.083 to 0.5 mg/L copper and 0.006 to 0.026 mg/L cobalt. Despite at least 60 years of discharge, all the copper and cobalt are removed in about a 5-acre portion of a downstream wetland. Copper concentrations in the peat ranged from around 100 to 3380 mg/kg, and cobalt from 20 to 260 mg/kg. Both metals are strongly bound to the peat; less than 0.5% was removed in laboratory extraction tests.

About 94% of the total copper and 44% of the total cobalt come from one area in the mine. In 1998, DNR proposed to treat this water in an organic substrate/limestone bed. Remaining low levels of metals in the mine discharge would be removed within the 5 acres of the wetland that already had elevated concentrations. To compensate for the use of the wetland, an equivalent area of wetlands would be restored in a state park in the southern part of the state. This proposal was approved in 1999 and the wetland mitigation was completed.

Despite having approval, land ownership issues and some internal reluctance about using a natural wetland stalled construction. In 2002, the Department signed a compliance agreement and installed an ion exchange unit to remove the majority of metals from the largest source. As soon as the unit was installed, a white precipitate appeared in the inflow water and plugged the unit. In 2006, the Department was fined and signed a stipulation agreement. The current proposal is to construct a wetland at the park to treat the entire mine flow. The estimated cost for this proposal is about 4-5 times the original treatment plan developed in 1998.

Additional Key Words: wetland treatment, copper, cobalt

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2 Paul Eger, Principal Engineer, Minnesota Dept. of Natural Resources, St. Paul MN 55155 email: paul.eger@dnr.state.mn.us
SURVIVAL AND GROWTH OF NATIVE HARDWOODS ON A RECLAIMED SURFACE MINE

Paul Emerson and Jeff Skousen

Abstract: Current regulations for commercial forestry post-mining land use require the placement of more than 1.5 m of weathered brown sandstone and topsoil on the spoil surface after regrading to the final land topography. Commercially valuable hardwood trees are to be planted in this substrate, and survival and growth of these trees must be monitored over a 12-year bonding period. Success of the commercial hardwood planting is based on the growth of white pine (Pinus strobus), which must achieve greater than 0.5 m of average growth per year for four or more consecutive years. The objective of this research is to evaluate whether tree survival and growth in weathered brown sandstone is superior, equal, or inferior to tree survival and growth 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 on brown sandstone decreased from 52% the first year to 39% the second year, while on the gray sandstone it decreased from 38% to 30%. Percent sandstone on the brown sandstone treatment increased from 45% to 57%, while on gray sandstone it increased from 59% to 66%. Brown sandstone had a pH of 5.3 and an EC of 416, while gray sandstone’s pH was 7.9 and EC was 205 in 2005. 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. Average height and diameter for each species was also obtained after one growing season and showed 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 and 39.6 cm for all compacted vs. 41.4 cm for all uncompacted treatments).

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

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2 Paul Emerson, Research Assistant, West Virginia University, WV, 26506 and Dr. Jeff Skousen, Professor of Soils and Land Reclamation Specialist, West Virginia University, WV 26506
EVALUATION OF A TWO-STAGE PASSIVE TREATMENT APPROACH FOR MINING INFLUENCED WATERS

L. Figueroa, A. Miller, M. Zaluski, and D. Bless

Abstract: A two-stage passive treatment approach was assessed at a bench-scale level using two Colorado Mining Influenced Waters (MIWs). The first-stage was a limestone drain with the purpose of removing iron and aluminum and mitigating the potential effects of mineral acidity. The second stage was a sulfate reducing bioreactor composed solely of 50% corn stover and 50% walnut shells by volume. The primary difference in the two MIWs was the concentration of zinc 5-7 mg/L for the National Tunnel Adit drainage (NTA) vs. 65-75 mg/L for the Silver Cycle Adit drainage (SCA). The limestone pretreatment columns reduced the zinc in the NTA MIW to 1-2 mg/L and the SCA MIW to 38 - 56 mg/L. The two SCA biocolumns had similar zinc removal but different sulfate removal with time. The sulfate reduction rate (SRR) for the SCA columns peaked at day 50 but at 0.5 mol S/m^3/d for column 1 and 0.3 mol S/m^3/d for column 2. Average SRR after day 50 was 0.24 and 0.13 mol S/m^3/d for columns 1 and 2, respectively. The NTA columns (3 and 4) sustained an averaged SRR of 0.3 mol S/m^3/d for days 30-130. The effluent zinc after startup from the two systems were < 0.1 mg/L and <2 mg/L for the NTA and SCA treatment systems, respectively. Other significant results included startup of sulfate reduction in both sets of bioreactors without the typical “manure” inoculum. The time to start up was not negatively affected by the lack of a designated inoculum. Another important result was the longer start up time required and the overall lower sulfate reduction observed for the higher zinc MIW.

Additional Key Words: MIW, acid mine drainage, water treatment, sulfate reduction, bioreactor, limestone

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2 Linda Figueroa, Associate Professor, Environmental Science and Engineering, Colorado School of Mines, Golden, CO 80401, email: lfiguero@mines.edu; Andrew Miller, Graduate Research Assistant, Environmental Science and Engineering, Colorado School of Mines, Golden, CO 80401, email: amiller@mines.edu; Marek Zaluski, Staff Hydrogeologist, MSE Technology Applications (MSE-TA), Butte, MT, 57901, email: marek.zaluski@mse-ta.com; Diana Bless, US EPA Manager of Mine Waste Technology Program, Systems Analysis Branch, Sustainable Technology Division, National Risk Management Research Laboratory, Cincinnati, OH 45268; email: bless.diana@epa.gov.
SURVEY OF LOW FLOW DRAINAGES AND SEEPS IN COLORADO TO ASSESS IMPLEMENTABILITY OF PASSIVE TREATMENT OPTIONS

L. Figueroa², M. Zaluski³, D. Bless⁴, and M. Holmes⁵

Abstract: Low flow drainages and seeps are typically not evaluated for mitigation due to the perceived low impact on the watershed. However, localized metals concentrations and acidity can be at levels of concern. Future passage of a “Good Samaritan Act” should increase activity at currently perceived low impact sites to improvement overall watershed water quality. This paper details an assessment of 25 sites in Colorado for implementability of passive treatment systems. Criteria included water quality, flow, regulatory status, accessibility and topography. Field reconnaissance was conducted at each site. Water quality information was extracted from existing sources when possible. Water quality analysis of grab samples was completed for selected sites. The ranking factors and decision analysis should prove useful in developing a data base of low flow drainages and seeps on abandoned and orphaned mine sites that can be used in watershed assessments and incremental improvements in TMDLs.

Known mine drainages within the Central City/Clear Creak Superfund site and within a one-hour drive time from the Colorado School of Mines were identified. Efforts in field reconnaissance at identified sites and sampling of the water quality is summarized in a matrix (contained in a separate excel files entitled “Potential_Drainages_091505.xls” and Data Matrix 091505 v7.xls). Not all sites identified and visited are presented in both files. Several version of the Data Matrix were produced in August and September 2005. Extensive photographic documentation of the sites was taken (The file size of the photographic documentation precludes inclusion with this document or attachment via email). Only the most promising sites were sampled for water quality. The Silver Cycle Mine site at the head of Gilson Gulch was identified as the best candidate.

Additional Key Words: site assessment, acid mine drainage, water treatment, watershed planning, and TMDL

²Linda Figueroa, Associate Professor, Environmental Science and Engineering, Colorado School of Mines, Golden, CO 80401, email: lfiguero@mines.edu ³Marek Zaluski, Staff Hydrogeologist, MSE Technology Applications (MSE-TA), Butte, MT, 57901, email: marek.zaluski@mse-ta.com ; ⁴Diana Bless, US EPA Manager of Mine Waste Technology Program, Systems Analysis Branch, Sustainable Technology Division, National Risk Management Research Laboratory, Cincinnati, OH 45268; email: bless.diana@epa.gov ; and ⁵Michael Holmes, Remedial Project Manager, US EPA Region 8 (EPR-SR), 999 18th Street, Suite 300 Denver, CO 80202-2466, email: holmes.michael@epa.gov
EVALUATION OF MINE SPOIL SUITABILITY FOR THE INTRODUCTION OF AMERICAN CHESTNUT HYBRIDS IN THE CUMBERLAND PLATEAU

Michael E. French, Christopher D. Barton, Donald Graves, Patrick N. Angel, and Frederick V. Hebard

Abstract: American chestnut (Castanea dentata (Marsh.) Borkh.) was formerly the most important hardwood species throughout the forests of eastern North America. The introduction of an exotic fungal blight (Cryphonectria parasitica (Murr.) Barr) in the early 20th century decimated C. dentata populations. Blight-resistant chestnut hybrids may soon be available for widespread distribution through The American Chestnut Foundation’s breeding program, although the development of blight-resistant hybrids is only the first step of the restoration process. For successful introduction, more information must be attained about site requirements necessary for successful establishment and growth of American chestnut. Surface mine spoils in the Appalachian coal region and elsewhere may 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. Six research plots composed of three different loose-graded spoil types have been constructed in the Cumberland Plateau of eastern Kentucky to evaluate their effects on tree performance. The three spoil types are: (1) predominately brown weathered sandstone; (2) predominately gray un-weathered sandstone; and (3) equally mixed brown and gray sandstones and shale. C. dentata sub-plots were planted within each of the six plots to serve as proxies for the blight-resistant chestnut hybrids. Preliminary data suggest that initial survival rates are significantly higher (100%) on the mixed spoil material over that of the weathered brown sandstone (79.5%). Survival on the un-weathered grey sandstone (93.2%) was not significantly different than that observed on the other two spoil types.

Additional Key Words: reforestation, restoration, hardwood.

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2 Michael E. French, MS Graduate Student in Forestry, University of Kentucky (UK), Lexington, KY 40506, email: mefren0@uky.edu (will present the paper). Christopher D. Barton, Assistant Professor, Department of Forestry, UK, email: barton@uky.edu. Donald Graves, Extension Professor, Department of Forestry, UK, email: dgraves@uky.edu. Patrick N. Angel, Forester/Soil Scientist, Office of Surface Mining, United States Department of Interior, London, KY 40741 and Doctoral Graduate Student in Soil Science, UK, email: pangel@osmre.gov. Frederick V. Hebard, Staff Pathologist, The American Chestnut Foundation, email: fred@acf.org.
HYBRID TREATMENT SYSTEMS FOR VERY ACIDIC MINING INFLUENCED WATER

James J. Gusek, and Kevin W. Conroy

Abstract. The treatment of mining influenced water (MIW) has traditionally been addressed with two distinct technologies: active treatment with its associated chronic operating costs that include labor, power, reagents, and residue disposal, and passive treatment with its typical requirement of acidity-dependent land areas for bioreactors, aeration wetland cells, and ponds. With the development of “semi-passive” lime-dosing and caustic soda dosing units driven by water wheels, the concept of a “hybrid” treatment system might be worth considering at some MIW sites, particularly those exhibiting high mineral acidity concentrations. The marriage of active and passive technologies is not new. It was first introduced at the Wheal Jane Mine test facility in Cornwall, England in the mid-1990’s. However, technology advances that include semi-passive auto-dosing systems and highly-automated active systems might be applied in situations where land available for MIW treatment is in short supply or the MIW chemistry is too aggressive for passive treatment alone. An example comparing capital and operating costs and land requirements of passive, active, and hybrid systems shows the potential advantages of implementing hybrid systems.

The synergy of combining these two technologies in a multi-stage system might offer more than just cost savings. The separation of “non-revenue” metal residuals such as gypsum-rich iron oxy-hydroxides from potential revenue-generating residuals such as copper, lead, and zinc sulfides might facilitate sustainable metal recovery economics that could offset some of the treatment cost burden. Minimizing the footprint of the MIW treatment system compared to a purely passive installation would be an additional advantage.

Additional Keywords: passive treatment, active treatment, heavy metals, economics, sustainability

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2 James J. Gusek, P.E., is a Senior Consultant with Golder Associates Inc., 44 Union Blvd #300, Lakewood, CO 80228, jgusek@golder.com Kevin W. Conroy, P.E., is a Principal and Water Treatment Group Leader at Golder Associates Inc., 44 Union Blvd #300, Lakewood, CO 80228, kconroy@golder.com
THE USE OF STEEL SLAG IN PASSIVE TREATMENT DESIGN FOR AMD DISCHARGE IN THE HUFF RUN WATERSHED RESTORATION

James Hamilton, Jim Gue, and Cheryl Socotch

Abstract: In 1996 the Ohio Department of Natural Resources (ODNR) along with state, local, government agencies, and citizen’s group formed the Huff Run Watershed Restoration Partnership, Inc. (HRWRP) to clean up the poor water quality in the Huff Run Watershed. The Lindentree and Lyons passive treatment systems were designed and installed with the use of steel slag to produce several hundred times more alkalinity per equal volume as compared to limestone to help treat the acid mine drainage (AMD) in the watershed due to years of unregulated surface and deep mining.

The Huff Run Watershed is located in Mineral City, Tuscarawas County, Ohio. The primary goals for any of the projects in the Huff Run Watershed are: the reclamation of toxic mine spoil and exposed coal refuse, drain existing acidic impoundments with alkaline treatment of AMD during dewatering and thereby eliminating the main sources of AMD seepages; constructing grass-lined and alkaline rock (limestone riprap and steel slag) channels for collection and diversion of surface water; construction of alkaline rock channels followed by settling ponds and aerobic wetlands as part of the passive treatment system for future AMD seepages; and restoration of the existing central main drainage channel. Both projects encompass 33.6 acres of the watershed and utilized steel slag to supersaturate relatively good water to neutralize low pH waters. Post-construction monitoring for the Lindentree and Lyons projects was conducted in years 2003 and 2005, respectively.

Steel slag is a co-product from the making of steel. The melting process creates an amorphous glassy solid matrix where the oxides are encased in calcium-aluminate-silicates. This glassy matrix is soluble and has a high neutralization capacity for acid mine drainage. Once the steel slag is soluble, the pHs of the dissolved fluids ranges from 10 to 11. Combining these flows with pHs in the ranges of 3 and 4 is showing a net alkalinity going into the Huff Run Watershed. As steel slag does not armor over like limestone, it is expected to provide a long term source of alkalinity.

Site discharges from both the Lindentree and Lyons projects have been net-alkaline, providing a buffer to acidic conditions currently found in the lower reaches of the Huff Run Watershed. The Lindentree, Lyons, and other ODNR projects, should provide a better understanding of the use of steel slag in future AMD remediation projects in the future.

Additional Key Words: Acid mine drainage, alkaline treatment, steel slag,

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OSM TIPS SERVICE SHARES ADVANCED COMPUTER BASED TECHNOLOGY NATIONWIDE

Louis Hamm

Abstract. Providing a common set of technology tools to regulators and reclamation specialists in the Office of Surface Mining (OSM) is helping to streamline the mandates of the Surface Mining Control and Reclamation Act (SMCRA).

The Technical Innovation and Professional Services (TIPS) Team consists of 32 people in four OSM offices. In cooperation with State and Tribal regulatory and reclamation agencies, as well as OSM offices nationwide, TIPS provides the latest off-the-shelf scientific and engineering software and hardware tools to federal, state, and tribal experts. These are the same tools used commonly by the mining industry. With the industry regulators and reclamation specialists at the state, tribal, and federal level using the same tools, exchange of information is facilitated and the regulatory and reclamation processes are expedited. This has become an extraordinarily efficient way to carry out the reclamation and regulatory mandates of the Surface Mining Control and Reclamation Act.

TIPS began in 1987 as a team of nine persons serving 28 customer locations in 24 states. Today the Team provides scientific and engineering modeling software, hardware, and full training classes to 700 customers in 96 office locations at 24 states, three tribes, and 15 federal offices.

This team of innovators holds costs low through shared licensing of the software via the Internet and centralized federal procurement contracts. TIPS also provides full software support and training classes at no cost to its customers. These are specially tailored courses, customized specifically around mining applications of the software. Customers value this training so much that they volunteer as instructors. Over half of all TIPS instructors today come from the customer base.

The innovators of TIPS have fostered electronic exchange of data between federal, state, and tribal agencies for 20 years. Their hard work has brought mining reclamation and regulation to increasing levels of efficiency. The most recent two years have brought significant department cooperation and subsequent progress for TIPS, and they continue to pursue new technology and the tools to promote better and more efficient enforcement of the Surface Mining Act.

Additional Key words: TIPS, technology tools, software, hardware, OSM, GIS, GPS, CAD, mapping, geospatial, remote sensing, mobile computing, science and engineering tools, Surface Mining Act

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2 Louis Hamm is the Chief of the TIPS and Technology Transfer Branch at the Western Region of the Office of Surface Mining in Denver, CO 80202. Mr. Hamm is one of the nine original TIPS staff.
DETERMINATION OF PHYTOREMEDIATION POTENTIAL OF DESERT BROOM GROWN IN A MINE TAILINGS RECLAMATION PROJECT

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

Abstract: This research was conducted out at a copper mine tailings reclamation project (CMTRP) located in the Globe-Miami mining district near Claypool, AZ, USA. Desert broom (Baccharis sarothroides) is a very environmentally friendly and available plant that might have phytoremediation potential, grows at the CMTRP. Therefore, in this research metal concentrations both in the tailings and plants (elemental ratio from soil to plant) were investigated. The metal concentrations in the soil cover and tailings were determined using ICP-OES. Based on the concentration, the elements were classified as high level elements (HLE): (K > Al > Fe > S > Ca > Mg > Na > Cu > P) and low level elements (LLE): (Mn > Pb > Mo > Cr > Vn > Zn > As > Ni > Co). The concentration of Cu, Pb, Mo, Cr, Zn, As, Ni, and Co in tailings was 454.9, 209.7, 89.32, 85.6, 51.2, 49.2, 39.3, and 36.3 mg/kg, respectively. The concentration for HLE and LLE in the soil cover was 10–15% higher than that of the tailings except for Cu and Mo. The concentration of Cu, Pb, Mo, Cr, Zn, As, Ni, and Co in desert broom (Baccharis sarothroides) was 819.3, 152.7, 74.3, 56.7, 39.9, 43.1, 97.3, and 26.3 mg/kg for roots and 1212.7, 102.2, 106.7, 104.4, 56.12, 34.3, 31.2, and 10.1 mg/kg for shoots, respectively. Considering the translocation factor (TF), enrichment coefficient (EC), and the concentration of elements in shoots 10 – 500 times more than those in a normal plant, desert broom could be a potential hyperaccumulator of Cu, Pb, Cr, Zn, As, and Ni for application in phytoremediation of copper mine tailings.

Additional Key Words: Phytoremediation, Hyperaccumulator, Heavy metals, Mine tailings, Desert broom.

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2 Nazmul Haque, Environmental Science and Engineering, The University of Texas at El Paso, El Paso, TX 79968, Jose R. Peralta-Videa and Jorge L. Gardea-Torresdey, Department of Chemistry, The University of Texas at El Paso, El Paso, TX 79968, Gary L. Jones, Phelps Dodge Miami Inc, P.O. Box 4444, Claypool, AZ 85532
GENETICALLY ENGINEERED MYCORRHIZAL FUNGI FOR REFORESTATION

Shiv Hiremath and Gopi Podila

Abstract: With the increasing demand on forest products and increased and tighter regulations for harvesting trees from public land, there is more need for commercial farming of forest trees. This means one needs to utilize all the available commercial land whether or not it is ideal for optimal growth of forest trees species. In addition, excessive use of forest lands for mining has produced vast regions unsuitable for natural reforestation. Mycorrhizal fungi play an important role in reforestation by providing the plant several benefits that are critical for its survival and growth in a nutrient poor and water deficient environment. Reclaimed mine sites are chemically, physically, and biologically altered and often lack the necessary quality and quantity of mycorrhizal fungi to sustain a tolerant plant community.

Although the use of naturally occurring mycorrhizal fungi dates back to several decades, efforts to genetically engineer them for expanded use in agriculture, forestry and horticulture have just begun. The mycorrhizal fungi are ubiquitous in nature and interact with a wide variety of plants. They are closely associated with roots and, in the case of ectomycorrhizal fungi, form a mantle around the root surface. This type of physical association and symbiotic interaction makes them excellent candidates to be genetically engineered for use in a variety of situations where suboptimal conditions exist for growth and survival of the host plant. The fungi can be utilized as biological factories to provide the plant beneficial factors required for its growth, protection from pests, and relief from stress conditions such as acidity and heavy metal toxicity. For example, ectomycorrhizal fungi expressing specific insecticidal proteins will be able to protect seedlings from root damaging insects. This is just one example, but the scope is very broad. This novel technology, once developed, has the potential to be adapted for handling a variety of problems associated with forest decline and decrease in biomass. In addition, this type of technology could be the beginning of many further research endeavors that will utilize mycorrhizal fungi to manipulate the plant host in many physiological and ecological ways. The system developed can be used as a part of Integrated Pest Management programs along with traditional management and control methods.

Additional Key Words: mycorrhizal fungi, reclamation, genetic engineering.

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2 Shiv Hiremath, Research Scientist, USDA Forest Service, Delaware, OH 43015, email: shiremath@fs.fed.us. Gopi Podila, Professor & Chair, Department of Biological Sciences, University of Alabama at Huntsville, Huntsville, AL 35899. email: podilag@email.uah.edu.
DESIGN AND REPORTING CRITERIA FOR REED BED AND FEN RESTORATION IN MINERAL WORKINGS

R Neil Humphries and Roger Meade

Abstract. Hanson Quarry Products Europe and the statutory nature conservation body for England, English Nature (now Natural England), have a Partnership Agreement whereby Hanson in 2002 became the UK Habitats Champion for reed bed and fen recovery. Both reed bed and fen habitats are identified as a priority to halt their recent decline and to be enhanced and expanded in the UK Biodiversity Action Plan (BAP). The mineral extraction industry can significantly contribute to the 2010 national recovery targets. In 2003 English Nature commissioned, and subsequently published in 2007, 'Design & Reporting Criteria' to guide and facilitate the successful creation of reed bed, other swamp and fen vegetation as an after use of mineral extraction sites, and their subsequent reporting for inclusion in the national UK and local Habitat BAP inventories and audits. Reed bed is a specific type of open-water transition fen dominated by the common reed *Phragmites australis* and fen a generic term for this and other wetland types influenced by water that has been in contact with rock or soil. The term 'fen' embraces a very wide range of vegetation composition from low sedge and moss dominated to tall reed and tall-herb swamp types, and grading into the ‘wet’ end of meadows and woodland types. The scope for the creation of the various types of fen is dependent on a number of key physical factors (climate, hydrology, substrate (soils and geology) and fertility), but also in practice, land management and the availability of plant material. The physical factors were broadly considered for reed bed and 65 other published types of fen occurring in the UK from which the scope and opportunity for restoration in mineral workings, and generic design guidelines for their creation, are set out for use by planners and other practitioners alike. In concert, 'Reporting Criteria' were devised to enable the consistent and objective reporting of reed bed swamp and fen habitats created as a result of mineral site restoration. The reporting criteria are in line with the UK National Biodiversity Network definitions enabling incorporation of the data into UKBAP & Local BAP inventories.

Additional Key Words: biodiversity, action plans, climate, landform, hydrology, substrate

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2 Dr R N Humphries is a Director of White Young Green Environmental Ltd, Sherwood Business Park, Annesley NG15 0DR, United Kingdom. Dr R Meade was previously the Senior Peatland Advisor & UK Chair of the Wetland Habitat Action Plan Steering Group, English Nature and is now the Principal of Roger Meade Associates, Great Salkeld, Penrith CA11 9LL, United Kingdom.
THE INFLUENCE OF MANAGEMENT PRACTICES ON MICROBIAL AND TOTAL SOIL NITROGEN

L.J. Ingram², P.D. Stahl², and J.D. Anderson²,³

Abstract: Nitrogen (N) is usually the nutrient most limiting production in semiarid ecosystems and at very low concentrations can seriously impact ecosystem processes. Soil from five mines, incorporating a number of commonly used land reclamation practices (grazing vs. un-grazed; stockpiled vs. direct hauled soil; shrub mosaic vs. grass seed mix; and stubble mulch vs. hay mulch), were sampled and analyzed for soil total N (TN) and microbial biomass N (MBN). All mines were located in semiarid Wyoming in either mixed-grass or sagebrush steppe ecosystems. The various management practices investigated appeared to have little influence on TN. Reclaimed soils averaged 30% less TN than undisturbed native soils, suggesting that N could potentially limit vegetation production. Only two reclaimed sites (grass and shrub) at Mine 1 contained a greater mass of TN than an undisturbed site, and while the reason is unclear, greater precipitation (20% higher relative to the other sites sampled) may be responsible. The microbial communities present in undisturbed soils appear to uptake N more efficiently than microbial communities present in reclaimed soil, relative to total soil N. As N fertilizer is only rarely used in Wyoming surface mines, N can only accumulate in a reclaimed soil via wet or dry deposition or by N-fixation by free-living micro-organisms or through symbiotic relationships. However, as legumes are typically only a small component of the vegetation, presumably deposition and/or microbial fixation of N are responsible for the majority of N accumulation in these ecosystems. Despite the low TN in reclaimed soils, high plant production on these reclaimed soils suggests that TN is not limiting production.

Additional Key Words: semiarid, surface coal mines, nutrient cycling, Wyoming.

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² Lachlan J. Ingram, Post-Doctoral Research Associate, Jonathan Anderson, Graduate Student, Peter D. Stahl, Associate Professor, Department of Renewable Resources, University of Wyoming, Laramie, WY, 82071, e-mail: lachy@uwyo.edu (Lachlan Ingram) ³ Currently at The School of Environmental Science, Murdoch University, Perth, Western Australia, 6150, Australia.
LONGITUDINAL CHANGES IN POTENTIAL TOXICITY OF COAL BED NATURAL GAS PRODUCED WATER ALONG BEAVER CREEK IN THE POWDER RIVER BASIN, WYOMING

Laurie A. Johnson, Connie J. Boese, Brady A. Morris and Joseph S. Meyer

Abstract. In the Powder River Basin (PRB) in northeast Wyoming, coal bed natural gas (CBNG) is being extracted from coal seams at depths up to 500 m. Produced waters that are concurrently pumped from a coal seam by a CBNG operator commonly are piped to a central discharge point in or near the well field and sometimes are discharged into ephemeral drainages like Beaver Creek, a tributary to the Powder River. In the PRB, CBNG produced waters tend to be dominated by sodium bicarbonate (NaHCO₃), leading to regulatory concerns about potential toxicity to aquatic organisms in receiving streams. Additionally, CO₂ and total ammonia (NH₃) concentrations are high in produced waters from some of the deeper coal seams. Those elevated concentrations are a concern if degassing of the CO₂ causes the pH of the discharged water to increase high enough from the initially circumneutral pH values to convert large percentages of the ammonium ion (NH₄⁺) to the more toxic NH₃ in the receiving stream. In this study, we evaluated the fate and effects of ammonia and NaHCO₃ in CBNG produced water that was discharged into Beaver Creek from August 2006 through March 2007. The study included (1) instream monitoring of the fish and amphibian population along a longitudinal gradient in the creek, (2) instream toxicity tests using caged fathead minnows (FHM; Pimephales promelas) along the same longitudinal gradient, (3) concurrent ambient-pH and CO₂-adjusted toxicity tests conducted in the laboratory with the same batch of FHM exposed to effluent water and to stream water collected along the longitudinal gradient, (4) analyses of water quality parameters in the effluent and the stream, and (5) a supplemental study to determine if ammonification occurs during transport and storage of stream-water samples, thus elevating the total NH₃ concentration from the stream to the lab. The results of this seasonal study provide additional data to evaluate the potential toxicity of CBNG produced waters, the biogeochemical changes occurring in the effluent that mitigate NH₃ toxicity, the appropriateness of standard laboratory toxicity tests for predicting instream effects, and the appropriateness of the current frequency of mandated toxicity tests. This information will help regulatory and management agencies, industry, and environmental-interest groups to more accurately assess the risk to aquatic life from CBNG produced waters.

Additional Key Words: ammonification, ammonium, fathead minnow, instream toxicity, NaHCO₃, Pimephales promelas, unionized ammonia
Abstract: Significant quantities of water are being produced and discharged as a by-product of coalbed natural gas (CBNG) development in the Powder River Basin (PRB). Elevated salinity and sodicity in CBNG water has become a major concern, particularly with regard to its use or disposal. If land applied, elevated salinity and/or sodicity in CBNG water may adversely affect soil physical properties such as structure, infiltration, permeability, and aeration. Soil chemical properties impacted by CBNG water utilized for irrigation include changes in nutrient supply, modification of the soil exchange complex with dispersion, and pH effects. A sodic soil has been shown to maintain good soil structure if the salinity level is maintained above the threshold electrolyte concentration (TEC). In this study, cropland that was irrigated with Piney Creek (control) and CBNG waters were sampled two years after CBNG water irrigation and compared to baseline and post irrigation data to evaluate changes in soil physical and chemical properties. CBNG water was treated with gypsum (CaSO₄₂H₂O), sulfur (S) via a S burner, or both, and soils were amended with CaSO₄₂H₂O, elemental S, or both (GS). Changes in soil physical and chemical properties were monitored using a split plot experiment. Single ring infiltration experiments were conducted within each plot to determine if infiltration rates were affected by water type and/or water and soil treatments. A significant decrease in infiltration rate was observed for plots irrigated with CBNG water without soil amendments or water treatments. Soil samples were taken and analyzed for chemical parameters including pH, electrical conductivity (EC) and sodium adsorption ratio (SAR) before CBNG water application and two seasons following final CBNG water application. Decreases in EC and SAR were determined for most CBNG irrigated plots. Higher EC levels were detected in S and GS plots due to delayed microbial conversion of S. It appears Na⁺ is moving through the soil profile with all soil amendment and water treatment combinations; however, CBNG-GSB+GS treatment results in the lowest SAR in the A and Bt₁ horizons.

Additional Key Words: salinity, sodicity, sodium adsorption ratio, gypsum, sulfur, Coalbed Methane, Coalbed Natural Gas

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2 Christopher R. Johnston, Graduate Student, and George F. Vance, Professor, Department of Renewable Resources, 1000 E. University Ave., University of Wyoming, Laramie, WY 82071-2000: chrisj@uwyo.edu; and Girisha Ganjegunte, Assistant Professor, El Paso Agricultural Research and Extension Center, Texas A&M University System, 1380 A&M Circle, El Paso, TX 79927.
AERATION TO DEGAS CO₂, INCREASE PH AND IRON OXIDATION RATES, AND DECREASE TREATMENT POND SIZE IN TREATMENT OF NET ALKALINE MINE DRAINAGE

Carl S. Kirby, Adam Dennis, and Adam K. Kahler

Abstract. Flow-through reactor field experiments were conducted at two large net alkaline mine discharges in central Pennsylvania. The goal was to drive off CO₂, increase pH, and document increased Fe(II) oxidation rates compared to passive treatment methods.

Both discharges were low Mn, low Al, net alkaline discharges with pH of ≈ 5.7 and Fe(II) concentration of ≈ 16 mg/L. Flow rates were ≈ 3000 and 15 000 L/min. Three-hour aeration experiments with flow rates scaled to a 14-L reactor resulted in pH increases from 5.7 to greater than 7, temperature increases from 12 to 22 ºC, dissolved oxygen increases to saturation with respect to the atmosphere, and Fe(II) concentration decreases to less than 0.05 mg/L. The same experiment at one of the sites with a 13-hour run time and no active aeration had a pH change from 6.1 to 6.3 and decrease in Fe(II) concentration from 16.3 to 13.8 mg L⁻¹.

Results from an Fe(II) oxidation model, using field-measured pH, temperature, dissolved oxygen, and initial Fe(II) concentration and written in a differential equation solver, were the same as the field experiments within analytical uncertainty. The maximum oxidation rate was 1.3 x 10⁻⁴ mol L⁻¹ sec⁻¹. The model was also modified to predict alkalinity, P₂CO₂, and pH changes based on initial conditions and aeration rate. This modified model also matched the data within analytical uncertainty, is more predictive than the first model, and should serve as a tool for predicting pond size needed for aerated Fe(II) oxidation at the field scale without the need for field pilot studies.

Using a published Fe removal rate of 20 g m⁻² day⁻¹ and Fe loading from field data, 3.6 x 10⁵ and a 3.0 x 10⁴ m² passive oxidation treatment ponds would be required for Site 21 and Packer 5 discharges, respectively. Fe(II) oxidation modeling of actively aerated systems predicted that a 1 m deep pond with 10 times less area would be adequate to lower Fe(II) concentrations to less than 1 mg L⁻¹ at summer and winter temperatures for both sites. The use of active aeration for net alkaline discharges with high CO₂ concentrations can result in considerably reduced treatment area for oxidation and may lower treatment costs, but settling of iron hydroxides was not considered in this study. The reduced capital cost for earthmoving will need to be compared to energy and maintenance costs for aeration.

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2Carl S. Kirby is Associate Professor, Department of Geology, Bucknell University, Lewisburg PA 17837. Adam Dennis and Adam Kahler were senior undergraduate students, Department of Geology, Bucknell University, Lewisburg PA 17837
RECLAMATION OF WASTE ROCK STOCKPILES
AT CLEVELAND-CLIFFS MICHIGAN OPERATIONS

Allan E. Koski

Abstract: Cleveland-Cliffs Michigan Operations (CCMO) produces 13.0 million long tons of high quality iron ore pellets annually for consumption in the blast furnaces of both domestic and foreign steel producers. Annual total material movement is approximately 80 million long tons, of which half is waste rock. Since the inception of mining in 1962, over 1.3 billion long tons of waste rock have been placed in waste rock stockpiles. Geographically the mining area is rolling to rugged topography. Landforms are the product of repeated continental glaciation and vary from till and outwash plains to steeply sloped hills with dendritic surface drainage patterns. Sandy glacial drift is the parent material for soils in the area, the thickness of which varies from bedrock to several hundred feet thick in localized areas. The local climate is classified as cool to temperate with 110 to 130 frost-free days and the area generally experiences a surplus water regime with an annual precipitation of 35 inches, of which half is in the form of snow. Current and developing reclamation practices for waste rock stockpiles will be reviewed. These include the use of paper mill residuals, municipal biosolids and a developing program with composted municipal solid waste. In addition to the pulp and paper mills, waste water treatment plant and county landfill, other entities involved include the county soil conservation district, a forestry services contractor, an explosives contractor, and a well drilling contractor.

Additional Key Words: municipal biosolids, paper mill residuals, composted municipal solid waste, ammonium nitrate, trees and shrubs.

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2 Allan E. Koski is Senior Engineer, Cleveland-Cliffs Michigan Operations, Ishpeming, MI 49849
A PRELIMINARY LABORATORY STUDY OF SUBAQUEOUS DISPOSAL OF CONTAMINATED MINE WASTE

J. A. LaBar and R.W. Nairn

Abstract: Understanding the fate and transport of contaminants produced from mine waste leaching in both surface and ground water environments is essential in effective remediation designs. At the Tar Creek Superfund Site in Oklahoma, subaqueous disposal of chat waste rock (processed dolomitic chert contaminated with elevated lead, zinc and cadmium) is being considered as a remedial option via injection of dry or slurried material directly into flooded underground mines or collapse features. Laboratory studies were conducted to simulate subaqueous disposal of these lead-zinc mine wastes into both contaminated mine pool waters (anoxic, elevated dissolved solids) and into surface waters (oxic, low dissolved solids). Mean contaminant concentrations of chat used in the study were: 1,314 mg/kg Pb, 16,895 mg/kg Zn and 33 mg/kg Cd. Concentrations varied with particle size; greatest concentrations were found in the <0.425 mm size fraction. A total of 360 bench-top microcosms were employed and sampled periodically for one year. Resulting water-column contaminant concentrations varied temporally but demonstrated an initial flush followed by a longer-term attenuation. Results of this study will help develop better understanding of the impacts of disposing of chat in aqueous environments, a currently suggested method of land remediation.

Additional Key Words: tailings, hard rock mine, mine drainage, waste rock disposal, lead, zinc, cadmium

1 Paper was presented at the 2007 National Meeting of the American Society of Mining and Reclamation, Gillette, WY, 30 Years of SMCRA and Beyond June 2-7, 2007. R.I. Barnhisel (Ed.) Published by ASMR, 3134 Montavesta Rd., Lexington, KY 40502.

2 Julie A. LaBar, Graduate Research Associate and Robert W. Nairn, Associate Professor, Center for Restoration of Ecosystems and Watersheds, School of Civil Engineering and Environmental Science, University of Oklahoma, Norman, OK, email: Julie.A.Labar-1@ou.edu
THE ROLE OF LARGE STORMS IN DETERMINING MEAN ANNUAL
SEDIMENT YIELD

Leonard J. Lane

Abstract: Erosion and sediment yield monitoring programs are often conducted over short time periods. The resulting short-term databases are used for a variety of purposes including estimation of mean annual soil erosion rates and mean annual sediment yield, simulation model parameterization and calibration, design of erosion/sediment control practices and structures, and to estimate rates of landscape evolution for geomorphic design of reclamation systems. Analyses of data from plots and small watersheds in Missouri, Iowa, and Arizona are used to examine the importance of large storm events in determining mean annual soil erosion rates and mean annual sediment yield from small watersheds. Under a wide range of climate, environmental, land use, and management factors, large storms were found to dominate mean annual sediment yield. This large-storm dominance was observed over a range of spatial scales, from experimental plots (88 sq m) to small watersheds (up to 33.5 ha), spanning the size of many reclamation projects. Storm size is determined using frequency analyses techniques for sediment yield from measured data to facilitate comparisons between humid and arid sites. Probability theory is used to determine the probability of observing a storm of a specified return period during a given length of monitoring. These results are shown to have direct application in interpreting the adequacy of monitoring data at reclamation sites and in evaluating the performance of soil erosion and sediment transport models in capturing the temporal variability of mean annual sediment yield. However, the state-of-the-science is such that process-based models need some actual calibration data to determine their parameter values. Thus, the limitations of the length of monitoring periods carry over into simulation modeling, evaluation of alternative reclamation systems based on monitoring data and simulation modeling, and ultimately, to the quality of the site reclamation.

Additional Key Words: soil erosion, sediment transport, frequency analyses, probability theory, simulation modeling, and evaluating site reclamation.

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2 Leonard J. Lane, Hydrologist, L. J. Lane Consulting, Inc., 411 E. Suffolk Dr., Oro Valley, AZ 85704, email: ljlane2@msn.com
Abstract. Acid mine drainage (AMD) is one of the most prevalent pollution problems in the Appalachian region of the United States. The acidity concentration of AMD from a particular source is influenced by many different factors. Some researchers have shown that acidity concentrations in above-drainage underground mines vary over time, with large fluctuations relating to the season of year or flow characteristics. The objectives of this study were to determine the changes in acidity, Fe concentrations, and flow over 38 years from 34 Upper Freeport underground mines in West Virginia. Water analyses were compiled from studies in 1968, 2000, and 2006 to evaluate these changes. The 34 underground mines were separated into three groups based on sampling season. Flow, acidity, and Fe values were averaged for each sampling year within each group. All three groups of mines had decreases in flow since 1968. Group 1 decreased by 69%, Group 2 by 84%, and Group 3 by 47%. All three groups also showed large decreases in acidity concentrations. Group 1 decreased by 80%, Group 2 by 73%, and Group 3 by 83%. Five mines were also selected to determine changes in Fe concentrations over time, which showed an average decrease of 83%. Further sampling of these sites will continue to quantify the effects of time on discharge amount and quality, and will help in determining the length of treatment and costs.

Additional Key Words: discharge, acidity, metals, pH
ASSESSING VISUAL QUALITY THROUGH A GIS-BASED REMOTE ACCESS METHODOLOGY

A. Mazure and J.B. Burley

Abstract. Reclamation specialists, planners, designers, governmental agencies, non-profit environmental organizations, and citizens are interested in scientifically based tools to assist in the study of the environment. In this investigation, we present a science based visual and environmental quality predictive model useful in preparing and assessing landscape treatments for a wide variety of applications including surface mine reclamation. The equation explains 67 percent of respondent preference, with an overall p-value for the equation \( p < 0.0001 \) and a p-value < 0.05 for each regressor. Regressors employed in the equation include an environmental quality index (which includes economic, cultural, and ecological predictors), plus other more typical physical landscape regressors. The equation can be explained with an Intrusion/ Neutral Modifier/ Temporal Enhancement Theory which suggests that human intrusions upon other humans result in landscapes of low preference and which also suggests that landscapes containing natural and special temporal features can enhance the value of a landscape scene. The investigation implies that economic, ecological, and aesthetic indicators covary together and are not necessarily orthogonal constructs. Recently, we have applied this equation to constructed GIS 3-D images of real environments to test for similarity between photographic images and ArcGIS 9.0 images. We have discovered a concordance of similarity between photographs and computer generated images \((p<0.05)\).

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

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2 Amy Mazure, Capital Consultants, Inc., 725 Prudden St., Lansing, MI 48906, United States, mazuream@msu.edu, Jon Bryan Burley, Landscape Architecture Program, School of Planning, Design, and Construction, Michigan State University, 101 UP&LA Building, E. Lansing, MI 48824, United States, burleyj@msu.edu
WILDLIFE MITIGATION TECHNIQUES AT SURFACE COAL MINES IN NORTHEAST WYOMING

Gwyn McKee

Abstract. Wildlife issues at surface coal mines in the Powder River Basin of northeast Wyoming have been a topic of discussion since operations first began in the early 1970s. Since then, wildlife monitoring and mitigation programs have evolved to address changing concerns, and incorporate new information and techniques. Over the last 26 years, biologists with Thunderbird – Jones & Stokes (J&S) have developed, enhanced, and/or implemented mitigation measures for numerous avian species of concern, including nesting raptors and mountain plovers (Charadrius montanus). The appropriate use of mitigation techniques has yielded proven methods to minimize conflicts between nesting raptors and surface coal mine operations, and thus reduced the potential for work stoppages. By February 2006, J&S had relocated (both active and inactive nests) or created more than 100 nests for seven different raptor species. Nesting raptors used 65% of the previously active nests after mitigation measures were implemented, and 22% of previously inactive nests. The establishment of mitigation programs for other avian species of concern has also benefited companies willing to experiment with innovative reclamation techniques for wildlife habitat. One coal mine supported a unique effort to reestablish mountain plover habitat by translocating black-tailed prairie dogs (Cynomys ludovicianus) into man-made colonies in reclamation. Although mountain plovers have not yet been documented in those colonies, the prairie dogs have expanded the original boundaries and maintained the low, sparse vegetation characteristic of mountain plover nesting habitat.

1 Paper was presented at the 2007 National Meeting of the American Society of Mining and Reclamation, Gillette, WY, 30 Years of SMCRA and Beyond June 2-7, 2007. R.I. Barnhisel (Ed.) Published by ASMR, 3134 Montavesta Rd., Lexington, KY 40502.

2 McKee, Gwyn, Branch Leader/Senior Wildlife Biologist, Thunderbird - Jones & Stokes, Gillette, WY 82718 email: gmckee@jsanet.com.
SOIL BULK DENSITY IMPACTS OF AN OAK MAT NATURAL GAS DRILL PAD CONSTRUCTION TECHNIQUE

C. S. McWilliams, D. J. Dollhopf, K. C. Harvey and D. J. Dale

Abstract: Traditional drill pad construction techniques for natural gas production displace the existing plant community and result in surface disturbances requiring costly soil remediation and revegetation procedures. At the Jonah natural gas field, Sublette County, Wyoming, EnCana Oil and Gas (U.S.A.), Inc. is evaluating the use of oak mats to minimize disturbance to soil and plant resources by facilitating drilling and completion activities atop continuous 15.2 centimeter thick oak platforms. One concern with both traditional and oak mat drill pad construction techniques is the potential for increases in soil bulk density. In this study, dry soil bulk density was measured before-and-after oak mat drill pad construction at 17 drill pad sites for 0-5.1, 0-15.2 and 0-30.5 centimeter depth increments to quantify changes in soil bulk density in relation to growth limiting bulk densities described in the literature. Similar bulk density measurements were taken at six conventional-reclaimed drill pads to allow comparison between the construction techniques. Of the 17 oak mat locations, four drill pad areas exhibited no statistically significant change in bulk density as a result of the oak mat procedure. Of the 13 remaining oak mat drill pads, one or more depth increments had significant soil bulk density increases of 0.06 to 0.17 g/cm³ as a result of drilling on top of the oak mats. Literature review indicated plant growth may be impaired when the dry soil bulk density is greater than 1.5 g/cm³. Of the oak mat soil profile depths measured, 95% remained below this value, while a substantially higher proportion of conventional-reclaimed drill pad soil profile depths exceed this threshold.

Additional Key Words: soil bulk density, natural gas development, drill pad construction, Jonah Field, and land reclamation

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2 Colin S. McWilliams, Soil Scientist, email: colin@kcharvey.com, Douglas J. Dollhopf, Ph.D., Professor Emeritus of Soil Science, Kevin C. Harvey, Principle Soil Scientist, KC Harvey, LLC, 233 Edelweiss Dr. Ste. 11, Bozeman, MT 59718 and Dessa J. Dale, Reclamation Specialist, EnCana Oil and Gas, P.O. Box 2060, Pinedale, WY 82941.
MAKING AND BUILDING A FLUVIAL GEOMORPHIC RECLAMATION DESIGN AT AN ACTIVE DRAGLINE MINE USING THE GEOFLUV™ DESIGN METHOD

David Measles  Nicholas Bugosh

**Abstract.** A surface coal mine in southwest Wyoming designed and regraded 100 acres in 2006 using the *Natural Regrade* software with the GeoFluv™ design approach. Most of the spoil grading was done with a walking dragline. Final contours were completed with dozers. The GeoFluv™-design software allows the user to design a stable reclaimed land surface using geomorphic input data. The challenges involved in implementing the GeoFluv™ design method included learning the differences between GeoFluv™ design and conventional surface modeling methods, designing surface contours and drainage longitudinal profiles that conform to the limits in the permitted post-reclamation contours, gaining buy-in from mine management and operations personnel, adapting the GeoFluv™ design to the Caterpillar CAES GPS equipment grading systems. The GeoFluv™ design was successfully implemented. The dragline and dozers stayed on schedule and the completed land surface had more topographic variation than normally achieved by conventional design. Future projects may include a 600-acres reclamation area with stream channels that are perpendicular to the highwall.

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2 David Measles, Senior Mining Engineer, Bridger Coal Company, 932 Nine Mile Road, Point of Rocks, WY 82942. Nicholas Bugosh, GeoFluv Technical Director, Carlson Software, Rocky Mountain Region / Carlson Software, 19 Old Town Square, Suite 238, Fort Collins, CO 80524.
ASSURING STABILITY OF MINIMIZED VALLEY FILLS: A REVIEW OF POTENTIAL CAUSES OF INSTABILITY AND AVAILABLE COUNTERMEASURES

Peter R. Michael and Michael J. Superfesky

Abstract. A particular geotechnical design and construction challenge faces the coal industry. It is shared by state and federal regulatory personnel responsible for approval of excess spoil or valley fills in steep-sloped Appalachia. Competing regulatory requirements under the Clean Water Act (CWA) and Surface Mining Control and Reclamation Act (SMCRA) encourage the construction of smaller valley fills (so that stream impacts are minimized), while also assuring long-term stability. To satisfy both CWA and SMCRA requirements, mining companies may opt to site valley fills further upstream on steeper foundation slopes. Three recent investigations documented the potentially destabilizing effect of steeper foundations on mass stability: A 2002 study by the U.S. Office of Surface Mining Reclamation and Enforcement (OSM) found that, among the relatively small number of fill failures in a 23 year period, a disproportionate number had foundations in excess of 20 percent slope. The results of a more recent OSM investigation of a 2004 fill failure in Kentucky seemed to confirm the negative effect of a steep foundation. Finally, a 2006 joint study between the Kentucky Department of Natural Resources and OSM emphasized the influence of weak, soil-like materials on fills placed on steep natural slopes. This paper reviews long-standing issues pertaining to proper design and construction measures with respect to valley fills, especially “durable rock” fills, and discusses how they will become more critical as spoil minimization is practiced. Stabilizing countermeasures available within the existing State and Federal regulatory framework are also discussed.
EVALUATION OF LOW SPOIL COMPACTION TECHNIQUES FOR HARDWOOD FOREST ESTABLISHMENT ON AN EASTERN KENTUCKY SURFACE MINE

Adam Michels, Christopher Barton, Tamara Cushing, Patrick Angel, Richard Sweigard, and Donald Graves

Abstract. To return surface mined areas in eastern Kentucky to productive forests, the compaction of mine spoil must be minimized or ameliorated. Four methods to reduce compaction on reclaimed surface mines were compared at the Bent Mountain research site in Pike County, Kentucky. The methods included: single shank ripped spoil, triple shank ripped spoil, excavated spoil, and rough graded spoil. Normally graded spoil was also examined as a control to represent a traditional reclamation practice. A single shank ripper was used in gently sloping areas to a depth of ≈ 2-m, while the triple shank ripper was used primarily on level spoil to a depth of ≈ 1.5-m. Both rippers were pulled with a D-11 dozer. Excavated spoil was created by digging out compacted spoil to a depth of ≈ 1-m and dropping it in place. The end dump or rough graded spoil was created by dumping mixed sandstones and shale spoil from a dump truck to a depth of 2 to 2.5-m followed by minimal grading (single pass) with a D-9 dozer to strike-off the piles. All sites were planted with native hardwood species in 2004. Three plots measuring 50 x 50-m were established within each spoil treatment. All trees within the research plots were tagged and have been examined each year for survival and growth characteristics. Bulk density was also measured annually using a nuclear density probe. Preliminary results show several statistically significant differences in tree height and survival. Survival for white oak (Quercus alba) was significantly higher for all reclamation methods compared to the control, and end dump was significantly higher than excavated. Green Ash (Fraxinus pennsylvanica) height was significantly greater for all reclamation methods compared to the control, and single shank ripped was significantly higher than all methods. For black locust (Robinia pseudoacacia) height and northern red oak (Quercus rubra) survival all methods except excavated were significantly greater than the control.

Additional Key Words: hardwood tree performance, compacted spoil, bulk density.

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2 Adam Michels, M.S. Graduate Student in Forestry, University of Kentucky (UK), Lexington, KY 40506, email: acmich2@uky.edu . Christopher D. Barton, Assistant Professor, Department of Forestry, UK, email: barton@uky.edu; Tamara L. Cushing, Assistant Professor, Department of Forestry, UK, email: Tamara.Cushing@uky.edu; Patrick N. Angel, Forester/Soil Scientist, Office of Surface Mining, United States Department of Interior, London, KY 40741 email: pangel@osmre.gov; Richard J. Sweigard, Chair and Professor, Mining Engineering, UK, email: rsweigar@engr.uky.edu; Donald H. Graves, Extension Professor Emeritus and Retired Chair of the Department of Forestry, UK, email: dgraves@uky.edu
COMPARISON OF SLUDGE CHARACTERISTICS BETWEEN LIME AND LIMESTONE/LIME TREATMENT OF ACID MINE DRAINAGE\(^1\)

A. W. Miller\(^2\), P. L. Sibrell, T. R. Wildeman

**Abstract:** The U.S. Geological Survey, in cooperation with the Colorado School of Mines and the U.S. Environmental Protection Agency, has demonstrated the application of pulsed limestone bed (PLB) treatment of acid mine drainage (AMD) at the Argo tunnel discharge near Idaho Springs, Colorado. Current technology for AMD treatment at the Argo facility is neutralization with lime. However, lime neutralization often results in large amounts of highly hydrated metal oxide sludge, leading to high disposal costs. Use of the PLB process as a pretreatment typically offers cost savings not only through lower reagent costs, but also through decreased sludge volume. In this study we compared the characteristics of sludges created using lime only to a sludge that was pretreated with the PLB, followed by lime treatment. Lime treatment was performed batch-wise in a 60 gallon cone-bottom stirred tank where the pH was elevated to 10, and held for an hour. A sample of sludge from the operating treatment plant was also tested for comparison. The PLB/lime treatment was accomplished by first passing the water through the PLB system, followed by batch lime treatment to pH 10 as before. The sludge qualities were evaluated through settled sludge volume, filterability through a bench-scale filter press, and the moisture percentage in the filter cake. The PLB/lime treatment resulted in a decrease in sludge volume of 34% after 24 hours, with good filtration performance, and a final cake solids content of 22% versus 19% for the lime sludge. A decrease in lime consumption of 45% was also obtained with the PLB pretreatment.

**Additional Key Words:** acid mine drainage, mining impacted water, treatment, fluidized bed reactor, limestone, sludge, filtration

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2 Andy Miller, Environmental Science and Engineering Division, Colorado School of Mines, Golden, CO 80401, e-mail: amiller@mines.edu (will present the paper). Philip L. Sibrell, Engineer, USGS – Leetown Science Center, 11649 Leetown Rd., Kearneysville, WV 25430, email: psibrell@usgs.gov. Thomas R. Wildeman, Department of Chemistry and Geochemistry, Colorado School of Mines, Golden, CO, 80401, e-mail: twildema@mines.edu.
IDENTIFYING MOSQUITO LARVAE HABITAT CREATED BY CBNG DISCHARGE WATERS USING REMOTE SENSING

Scott N. Miller\(^2\), Hannah R. Griscom, Ramesh Sivanpillai, Li Zou

**Abstract.** Water disposal methods such as pond storage and in-channel releases that are associated with coalbed natural gas production (CBNG) have increased the amount of standing water in the Powder River Basin, Wyoming. These standing waters have been shown to be potential larval habitats for the *Culex tarsalis* mosquito, the primary vector of West Nile Virus (WNV) in Wyoming. This paper presents preliminary findings from an ongoing research effort focused on identifying environmental and anthropogenic risk factors for WNV associated with CBNG production. Field research suggests that retention pond design and water disposal techniques may serve as either mitigating or compounding factors for risk. Ninety percent of drainages receiving discharge waters tested positive for *C. tarsalis* while only 23% of reservoirs showed larvae presence. A GIS-based risk model based on field observations for CBNG production areas has been developed and tested in which the primary risk factors are *C. tarsalis* larval habitat and water disposal mechanisms. Preliminary findings using Landsat imagery show a sharp increase (75%) in potential *C. tarsalis* habitat resulting primarily from CBNG discharge waters. These estimates, based on large-scale remote sensing data, are a conservative estimator of WNV risk associated with the creation of mosquito habitat in active CBNG production in the Powder River Basin. High resolution imagery (Quickbird and SPOT) has been tested and found to identify habitat regions below the lower limit of detection with Landsat.

**Additional Key Words:** GIS, risk analysis, West Nile Virus, coalbed methane

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\(^2\)Scott N. Miller is an Assistant Professor of Watershed Management, Dept. 3354, University of Wyoming, 1000 E. University Ave., Laramie, WY 82071, Email: snmiller@uwyo.edu, Hannah R. Griscom is a Graduate Research Assistant, Dept 3354, Univ. of Wyoming; Ramesh Sivanpillai is an Assistant Research Scientist, Wyoming GIS Science Center, Dept. 4008, Univ. of Wyoming; Li Zou is a GIS Developer for GIS Consortium, 188A Skokie Valley Road, Highland Park, IL 60035.
Abstract. The demand for natural gas is increasing due to the global energy crisis. Due to the demand for natural gas there have been major explorations in the Rocky Mountain States. One of the largest areas for natural gas extraction is the Powder River Basin, Wyoming. The process of extracting natural gas involves pumping water from coal seam aquifers that is mixed with the natural gas. Once the water and gas reach the surface they are separated and product water is disposed into a nearby disposal pond. The objectives of this study were to monitor water quality components, model the components in a water quality model, and monitor trace metals in the sediments of the disposal ponds. Samples were collected and analyzed for major cations, anions, and trace metals. Results from one year of sampling suggest wide ranges in pH, oxidation reduction potential, electrical conductivity, temperature, and dissolved oxygen. Concentrations for sodium were high when compared with the concentrations of the other major cations. Practical sodium adsorption ratios calculated from the concentrations of sodium, magnesium, and calcium ranged from 6.3 to 51.86. True sodium adsorption ration calculated from the activities of sodium, magnesium and calcium ranged from 7.07 to 88.05. The highest concentration of trace metals in both wells and disposal ponds were barium and boron. Sediment samples were also collected and a Toxic Characteristic Leaching Procedure was preformed to determine leachability and toxicity of trace metals. The two trace metals detected in sediment leachates were barium and manganese. When compared to groundwater drinking water standards both barium and boron concentrations in sediment leachates were above the limits.

Additional Key Words: Please ADD
RESPONSE OF GRASS SPECIES TO SOIL SALT CONTENT AND SOIL MOISTURE ON LANDS DEVELOPED FOR COALBED METHANE


Abstract: In areas where land is disturbed to extract energy resources such as coalbed methane, improper soil management may result in soils impaired by elevated salinity. The objectives of this study were to evaluate the emergence and growth of three native grass species (Pseudorogeneria spicata, Hesperostipa comata, and Pascopyrum smithii) as a function of soil salt content and matric potential. The study consisted of nine treatments, combining three soil salinity levels (0.80, 5.0 and 11.0 dS/m) and three matric potential ranges (-0.1 to -1.0, -1.0 to -7.0, and less than -7.0 bars). Seedling emergence, plant height, aboveground biomass, and belowground biomass were significantly decreased by increasing soil salinity and decreasing soil moisture. This resulted in large reductions in growth when soil moisture was decreased within a salinity treatment. Emergence for plants grown in elevated salinity increased as much as 26.7 % when moisture was high. At low soil moisture, elevated salinity resulted in emergence losses as high as 88.3 %. Losses in aboveground biomass ranged from 23.0 to 97.9 % at moderate salinity and 27.3 to 98.5% at high salinity. Results indicate that the impacts of elevated soil salinity are highly influenced by soil moisture.

Additional Key Words: land reclamation, soil salinity, soil matric potential, revegetation, and soil salvage

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2 Melissa D. Mitchem, Douglas J. Dollhopf, James W. Bauder former graduate student and Professors, respectively, Department of Land Resources and Environmental Sciences, and B.E. Olsen, Professor, Department of Animal and Range Sciences, Montana State University, Bozeman, MT, 59717
BIOLOGICAL SOURCE TREATMENT FOR THE TREATMENT AND PREVENTION OF ACID MINE DRAINAGE

Jeffrey M. Morris and Song Jin

Abstract. A biological source treatment (BST) technique has been developed to address acid mine drainage (AMD) at its source. The BST technique utilizes down-hole injections of microbial inoculum and substrate amendments to establish a hydrophobic biofilm on the surface of metal sulfide, which raises groundwater pH to circum-neutral levels and prevents further oxidation of AMD source material. Microcosm studies in the laboratory demonstrated that the BST technique can effectively raise the pH of pyrite-containing AMD water to circum-neutral levels under aerobic conditions in as little as 7 d, and the pH remains at these levels for > 19 months. Microbial analysis identified >70 species forming a complex biofilm-like structure over the pyrite. The biofilm dominantly consisted of facultative anaerobes, which potentially interact with obligate anaerobes, such as sulfate-reducing bacteria, to maintain an oxygen-free micro-environment surrounding the pyrite, even though the outer water stays aerobic. The biofilm became established in water samples with an initial pH as low as 2, and subsequently caused the water pH to increase to circum-neutral levels. Concurrently, concentrations of aluminum, arsenic, copper, iron, lead, nickel, and zinc all decreased substantially compared to baseline concentrations in sterile microcosms. A field study of the BST technique was conducted at a reclaimed coal mine in central Tennessee (USA) and results indicated a modest increase in pH in the treated area (an average of 0.7 pH units and as much as 1.5 units). Dissolved (0.45 µm-filtered) iron concentrations decreased on average by 4 mg/L and as much as 84% (from 93 to 15 mg/L), conductivity decreased on average by 75 µS/cm, and sulfate decreased on average by 79 mg/L in monitoring wells down-gradient from BST injection sites. Electromagnetic surveys were conducted to identify AMD source material and monitor BST performance by measuring changes in groundwater resistivity throughout the site. These surveys revealed a treatment zone created between injection wells where the resistance of contaminated groundwater from up-gradient AMD sources increased as it flowed past injection wells, thus, suggesting this technique could be used to treat AMD sources directly or intercept and neutralize sub-surface AMD.

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Dr. Jeffrey M. Morris is a Lead Scientist and Dr. Song Jin is a Principal Scientist at Western Research Institute, Laramie, WY 82072.
Abstract. Production of coalbed methane has released large amounts of ground water to native stream channels in the eastern Powder River Basin in the vicinity of the largest coal mines in the United States. Water is pumped from coalbed methane wells to relieve pressure in the coal seam and release methane gas from the seam into the well. Rapid drawdown of water levels in the coal due to coalbed methane production has been observed in mine monitoring wells. Optimally for methane production, water levels in the coal are kept near the top of the coal seam. Following a number of years of water production from coalbed methane wells, water levels in the coal aquifer decline to below optimal levels and pumping ceases. Discharge of coalbed methane produced water has rendered normally ephemeral and intermittent streams temporarily perennial and produced short and long term effects to surface and alluvial water quality. Through diversion or pumping, coalbed methane produced water has also flowed through reclaimed stream channels and temporarily changed the character of the channels. Within the mine sites, coalbed methane produced water has aided dust suppression efforts and reduced the need for pumping from deep water supply wells. Salts have been dissolved from native stream channels and often deposited on mine haul roads through road watering. Produced water flowing in reclaimed stream channels has aided wetlands establishment efforts, raised backfill water levels, and helped to enable pronounced changes in ground water quality.

Additional Key Words: Coalbed Methane, Geochemistry, Reclamation, Wetlands, Alluvial Valley Floors, Selenium, Dust Suppression.
ESTIMATION OF GROUNDWATER RECHARGE IN THE POWDER RIVER BASIN

Fred L. Ogden and Kerri Puckett

Abstract. This paper evaluates the uncertainty associated with a water budget model developed to predict the recharge rate to deep aquifers in the Powder River Basin (Northeastern Wyoming). The controlling factors in this model are springtime snowmelt, streambed infiltration, infrequent convective rainfall, and evapotranspiration. The dominant recharge mechanism for the deeper aquifer units was assumed to be infiltrated water at the aquifer margins, where the formations daylight at the edges of the basin. Historical records were used to model infiltration along the formations and gaps in spatial and temporal data were filled using radar-rainfall estimates and climate model reanalysis. Model estimates were compared to field measured values. The uncertainty associated with each component of the water budget model is quantified using a Monte Carlo analysis and error bounds were established for each input parameter, ultimately trying to develop a new methodology to estimate groundwater recharge in semi-arid areas using recent advances in instrumentation and remote sensing.

Additional Key Words: evapotranspiration, infiltration, soil moisture, precipitation, measurements, modeling, development, research, methodology.

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2 Fred L. Ogden, Professor and Cline Distinguished Chair of Engineering, Environment and Natural Resources, and Kerri Puckett, Graduate Student, Department of Civil and Architectural Engineering, University of Wyoming, Laramie, WY 82071 USA
EXAMINATION OF DISSOLVED CONCENTRATIONS OF As, B, Cd, Hg, Se, AND Al IN WATER QUALITY FROM THE BACKFILL AQUIFER, EASTERN POWDER RIVER BASIN, WYOMING, 2005

Kathy Muller Ogle

Abstract. Water quality of the backfill aquifer associated with coal strip mining is a developing area of analysis where data are allowing regulators to move from depending on predictive techniques to reliance on data collected from the backfill aquifer. The chemical concentrations of dissolved arsenic, boron, cadmium, mercury, selenium, and aluminum in the backfill aquifer were examined. The data are from 84 wells located at 11 mines in the eastern Powder River Basin. A total of approximately 2,500 samples have been collected from 1977 to 2005 from monitoring wells in the backfill aquifer. Each chemical constituent is statistically summarized and compared to appropriate water quality standards. Changes in concentration of selected constituents from individual wells with longer periods of record are examined over time.

Analysis indicates that mobilization of dissolved arsenic, cadmium, mercury, selenium and aluminum was not commonly encountered. Nondetection was common in the data set with dissolved arsenic not detected in 90 percent of the samples, dissolved cadmium at 95 percent, dissolved mercury at 98 percent, dissolved selenium at 81 percent and dissolved aluminum at 84 percent. Dissolved boron was detected in 84 percent of the samples, but generally at low concentrations. Dissolved boron had a median concentration of 0.1 mg/l.

Additional Key Words: coal mining, spoils water quality, reclamation, water chemistry, arsenic, boron, cadmium, mercury, selenium, aluminum, aquifer

1 Paper was presented at the 2007 National Meeting of the American Society of Mining and Reclamation, Gillette, WY, 30 Years of SMCRA and Beyond June 2-7, 2007. R.I. Barnhisel (Ed.) Published by ASMR, 3134 Montavesta Rd., Lexington, KY 40502.

2 Kathy Muller Ogle, Program Principal, Wyoming Department of Environmental Quality, Land Quality Division, Cheyenne, Wyoming, 82002.
GROUNDWATER MONITORING AT COAL BED NATURAL GAS PRODUCED WATER IMPOUNDMENTS: THE WYOMING DEQ DATABASE

T. Osborne, U. Williams, M. Smith, D. Fischer, K. Frederick

Abstract: Unlined impoundments are widely used for storage of water produced from coal bed natural gas (CBNG) operations in the Powder River Basin, but little published information exists regarding their potential effects on shallow groundwater resources. The Wyoming Department of Environmental Quality (DEQ) requires that CBNG operators characterize shallow groundwater at each CBNG impoundment site. If groundwater is found within the upper 150 to 200-feet of the surface, a well must be completed, a static water level measured and background water quality analyzed. At sites with Class III (Livestock) groundwater the DEQ requires operators to implement a “Compliance Groundwater Monitoring Plan” which typically entails installation of several wells and quarterly sampling of water quality.

The DEQ has maintained a database of groundwater monitoring results from CBNG impoundments since 2004. This is the first published summary of these data. As of December 2006, the database contained a total of 1106 impoundments. Groundwater was not encountered in about 45% of the 1,250 wells and boreholes. The database contains a total of 874 monitoring wells. The permitting status indicates that 75% of impoundments have been exempt from further groundwater monitoring (where no groundwater was encountered or it was Class IV), 15% have on-going monitoring requirements, 7% were not issued a permit, and 3% have their permit status pending. A total of 454 background water samples were analyzed for total dissolved solids (TDS) and other constituents. Approximately 80% of the background TDS concentrations were less than 5,000 mg/l, the class of use limit for class III groundwater. Although there are data gaps, particularly in the early data, this database will evolve and provide a valuable basis for assessing the effects of CBNG impoundments on shallow groundwater.

Additional Key Words: Shallow groundwater quality, water quality database, impoundments

1 Paper was presented at the 2007 National Meeting of the American Society of Mining and Reclamation, Gillette, WY, 30 Years of SMCRA and Beyond June 2-7, 2007. R.I. Barnhisel (Ed.) Published by ASMR, 3134 Montavesta Rd., Lexington, KY 40502.
2 Thomas J. Osborne, P.H., and Monte P. Smith, P.G., HydroSolutions Inc, 1537 Avenue D, Suite 340, Billings, MT 59102 3Don Fischer, P.G., and Ursula Williams, P.G., Wyoming Department of Environmental Quality, 1866 S. Sheridan Avenue, Sheridan, WY 82801 4Kevin Frederick, P.G., Program Manager, Wyoming Department of Environmental Quality, 122 West 25th Street, Herschler Building, 4th Floor-West, Cheyenne, WY 82001
PASSIVE REMOVAL OF SELENIUM FROM GRAVEL PIT SEEPAGE USING SELENIUM REDUCING BIOREACTORS

Jessie Pahler², Russell Walker², Thomas Rutkowski³, and James Gusek³

Abstract: Water quality in the lower Colorado and Gunnison Rivers in western Colorado, and many of their tributaries, is impaired by selenium, which originates from the local Mancos shale. Because of the diffuse and widespread nature of this source, there are limited opportunities to reduce selenium inputs. One option is to treat selenium-contaminated surface water at strategic locations, such as point-source discharges. Gravel extraction is common along these rivers, and treatment of discharges from pit dewatering presents an opportunity for reducing selenium loading.

The goal of this study is to determine: 1) whether a passive selenium-reducing bioreactor can accomplish high-efficiency selenium removal from the basic, saline water typical of the Grand Valley; 2) whether zero-valent iron is beneficial as a bioreactor component; and 3) optimum detention time. To date, bacterial reduction of selenium has been successfully accomplished using power-, and equipment-intensive “active” treatment systems. The passive bioreactors we are testing can function unattended, ideally by a gravity feed (no pumps), and the "fuel" for the bacteria would be agricultural wastes (e.g., wood chips, hay, cow manure inoculum) and other materials (e.g., quarried limestone) collected locally.

Four 208-liter (55 gallon) bioreactors were constructed with varying amounts of cow manure, hay, sawdust, wood chips, limestone, and zero-valent iron. Influent to the reactors is drawn from a dewatering trench in a gravel pit next to the Colorado River near Grand Junction, Colorado. The reactors were operated, with varying detention times, over a six-month period from July through November 2006. The results of this study demonstrate that passive bioreactors can accomplish up to 98% removal of Se from surface and ground waters in the Grand Valley of western Colorado. A bioreactor designed to promote microbial processes functioned as efficiently as reactors incorporating ZVI, in spite of the potential of the ZVI to enhance the biological removal process. The highest removal rates were achieved using a detention time of 12 hours, but circumstances prevented optimization of detention time.

Additional Keywords: Selenium reduction; passive treatment; agricultural runoff

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2 Jessie Pahler and Russell, Walker Mesa State College, Grand Junction, CO

3 Thomas Rutkowski, and James Gusek, Golder Associates Inc., Lakewood, CO
ASSESSMENT OF RECLAMATION POTENTIALITY IN THE LIGNITE MINES OF NORTHERN GREECE¹

T. Panagopoulos²

Abstract: Landscape reclamation at the lignite spoil heaps of Ptolemaida, Greece is complex and difficult due to adverse ecological conditions. Natural revegetation could be the first step before reclamation began, thus it was surveyed and 7 plant communities were identified, described and mapped. In order to understand the variation of some soil physical and chemical properties in an experimental block and its effect on revegetation production, graphical interpretation of those soil properties was done with the use of geostatistics in a geographic information system (GIS). Soil properties were related to natural vegetation succession and both could be indicators in assessment of reclamation potentiality on the site. Geostatistics were used to estimate soil properties and natural vegetation composition with a minimum number of samples. A geographic information system with geostatistic support helped to map with precision site quality without increasing sampling cost and facilitated solutions locally on species selection and soil amendment problems.

Additional Key Words: geostatistic, geographic information system, uncertainty, precision agriculture and phytosociology.

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² Thomas Panagopoulos, Professor of Landscape Reclamation, Department of Landscape Architecture, University of Algarve, Faro, 8005-139 email: tpanago@ualg.pt
VISUAL IMPACT AND RECLAMATION OF LIMESTONE QUARRIES IN ALGARVE PORTUGAL

T. Panagopoulos, R. Matias and B.R. Ramos

Abstract: Limestone quarries are the most important open cast mining activities in Portugal. Obtaining public acceptance in a rehabilitation project is still considered a challenge. This challenge can be accomplished by reducing the visual adverse impacts and by incorporating aesthetic aspects in quarry rehabilitation projects. With the development of more stringent practice codes and environmentally based guidelines, quarry managers must provide more detailed and comprehensive environmental impact assessment along with their development plans. The visual impact assessment should be made available for public review and demonstrate that the proposed operations will achieve the visual quality objectives. Geographic information systems provide a remarkably efficient means of understanding impacts of quarrying in mountainous areas which is often lost in two-dimensional presentations. To facilitate this understanding, new technologies similar to those found in a flight simulator, were developed to help people visualize change. In this study it will be presented the reclamation project and the visual impact assessment of a group of limestone quarries in the fragmented Mediterranean landscape of Algarve, Portugal. Viewshed analysis of the quarries showed what areas of the disturbed surface can be seen by observers for any visible position and how many observers can see the position. The reclamation method could help governmental officials to take the appropriate decision: accept, reject or suggest aesthetical modifications in any proposed project of the study area.

Additional Key Words: landscape ecology, geographic information system, aesthetic, visual quality, quarry reclamation project.

1 Paper was presented at the 2007 National Meeting of the American Society of Mining and Reclamation, Gillette, WY, 30 Years of SMCRA and Beyond June 2-7, 2007. R.I. Barnhisel (Ed.) Published by ASMR, 3134 Montavesta Rd., Lexington, KY 40502.
2 Thomas Panagopoulos, Professor of Landscape reclamation, Department of Landscape Architecture, University of Algarve, Faro, Portugal, 8005-139 email: tpanago@ualg.pt. Rita Matias and Bibiana Ramos, Consulting Landscape Architects, VERDESIGN, Lda., 8100 Loulé, Portugal, email: bibianaramos@mail.telepac.pt
PHYSICAL AND CHEMICAL PROPERTIES OF TOPSOIL USED FOR BIOLOGICAL RESTORATION OF COAL MINE WASTE-BASED STRUCTURES IN THE UPPER SILESIAN COAL BASIN IN POLAND

A. Patrzalek and M. Pozzi

Abstract: In the Upper-Silesian Coal Basin in southern Poland large areas of coal mine waste heaps, riverbanks and shoulders of transportation routes built of coal mine waste are biologically restored by the initiation of soil-forming processes. The purpose of this research was to determine, using laboratory research and observation “in situ” (field), some physical and chemical properties of mixtures of topsoil composed in the forming process (coal mine waste and sewage sludge), before placing them on the coal mine waste heaps and riverbanks, and after a period of 1-3 years, when the layer has been fully penetrated by root mass. Adequate physical properties of topsoil in the process of forming mixtures protect the spoil-banks against erosion. Poor water retention ability should be taken into consideration when selecting the plants for biological restoration. High levels of macro components and increased sorption guarantee long and appropriate supply of nutrients. The application of analysed soil-forming mixtures for biological restoration of coal mine waste heaps and spoil-banks, along with proper selection of plants, assist in maintaining a durable, self-sustaining ecosystem.

Additional Key Words: coal refuse, coal waste, mine reclamation, (angle of shearing resistance, apparent cohesion, water retention, sorption complex)

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2 Anna Patrzalek, Professor of Water Management, Institute of Applied Geology, Silesian University of Technology, 2 Akademicka street, 44-100 Gliwice, Poland, email: anna.patrza@polsl.pl, Marek Pozzi, Professor of Mining and Environmental Geology Institute of Applied Geology, Silesian University of Technology, 2 Akademicka street, 44-100 Gliwice, Poland, email: marek.pozzi@polsl.pl (he will present the paper).
MANAGING THE LARGE-SCALE RECLAMATION MONITORING NETWORK AT SYNCRUDE CANADA LTD.¹

M. Phillip² and M. O’Kane

Abstract. Syncrude Canada Ltd. (Syncrude) operates the Mildred Lake mine, one of the world’s largest operating mines, situated in the Athabasca Oil Sands Region of northeastern Alberta. This region will produce more than 50% of Canada’s oil supply within the next ten years with Syncrude alone supplying 20% of the nation’s oil. It is estimated that more than 21,000 ha of boreal forest will require reclamation as a result of large tracts of land disturbed during operations. Oil sand operators receive operating licenses from the provincial government based on achievable closure and reclamation plans, and the ability to demonstrate successful reclamation is a competitive advantage in a region where limits on development due to cumulative environmental impacts are a reality.

Monitoring the performance of field trials is commonly performed at mine sites to guide development of, and build support for, final reclamation closure. The objective of this paper is to allow mine operators to understand “real” costs associated with reclamation monitoring. Once reclamation has been completed, monitoring may be continued to document success in an effort to gain bond release. Mine sites typically utilize automated data acquisition systems to the greatest extent because of reduced labor requirement. However, due to the variety of data collected, the differences in cover and waste materials, and the inevitable need for manual intervention and monitoring, the effort required to install and maintain a network of data acquisition systems can be significant. At the beginning of the 2005 field season, Syncrude operated a network of 27 automated data acquisition systems that collect surface runoff, meteorological, and in situ soil data to track the water and salt balance of reclaimed areas. This paper describes the development of Syncrude’s integrated watershed reclamation monitoring system, and the effort, time, and costs associated with maintaining the system.

Additional Key Words: Mine Closure, Monitoring Cost.

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² Mark Phillip is an Environmental Engineer with O’Kane Consultants Inc., 10014B Main Street, Fort McMurray, AB, Canada T9H 2G5. Mike O’Kane is President of O’Kane Consultants Inc., Ste. 1740 – 246 Stewart Green SW, Calgary, AB, Canada T3H 3C8.
CALIFORNIA’S STATEWIDE RECLAMATION STANDARDS, A QUANTITATIVE APPROACH TO MEASURING RECLAMATION SUCCESS

James S. Pompy

Abstract: California’s Surface Mining and Reclamation Act of 1975 (SMARA) was amended in 1991 to require that the State Mining and Geology Board (Board) adopt regulations specifying minimum, verifiable statewide reclamation standards. The state legislature directed the Board to adopt standards to include, but not be limited to, (1) wildlife habitat; (2) backfilling, regrading, slope stability, and recontouring; (3) revegetation; (4) drainage, diversion structures, waterways, and erosion control; (5) prime and other agricultural land reclamation; (6) building, structure, and equipment removal; (7) stream protection; (8) topsoil salvage, maintenance, and redistribution; (9) tailing and mine waste management. Each mine reclamation plan approved in California must include site specific performance criteria for measuring reclamation success. While site specific performance criteria may be based on pre-mining conditions, reclamation to a beneficial end use is the goal, not restoration. Reclamation standards are set to be achievable in a reasonable timeframe. Where best management practices focus on reclamation methodology, performance standards focus on results. Performance standards provide mine operators with clear expectations for reclamation, and regulators with a clear trigger for determining reclamation success and return of financial assurances.

Additional Key Words: revegetation, plant cover, species richness, factor of safety, slope stabilization, drainage control, in-stream mining, California State Mining and Geology Board.

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2 James S. Pompy, Manager, Reclamation Unit, Office of Mine Reclamation, 801 K Street, M.S. 09-06, Sacramento, CA 95814
THE IMPACT OF SMALL MAMMAL BROWSING ON VEGETATION SUCCESS ON A RECLAIMED MINE IN NEW MEXICO

Tim R. Ramsey, Bruce A. Buchanan, Jesse Haen

Abstract: Although traditional livestock or wildlife grazing species may be excluded from impacting a reclaimed area through fencing, small animals (such as rabbits) are able to persist on the site. Beyond anecdotal evidence, there is little known about the extent to which small animals have an impact on plant production on reclaimed areas. The impact of their browsing may be extremely important, specifically where reclaimed areas do not have significantly greater cover or production than the standard. Thirty-eight randomly located, 1 m² exclosures were constructed to prevent browsing by rabbits, and the vegetation production from these exclosures was compared with that from 38 randomly located sample plots of the same size. The yearly new growth was clipped and weighed to determine production. Vegetative production inside the exclosures was significantly greater than it was outside of the exclosures. Statistical, as well as visual evidence are used to demonstrate the destructive capacity of small animals.

Additional Key Words: Small Mammals, Vegetation Impact, Reclamation

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2 Tim Ramsey is a Senior Environmental Specialist with BHP-Billiton- San Juan Coal Company, Waterflow, New Mexico, 87421. Bruce Buchanan, PhD. is the President of Buchanan Consultants, Ltd., Farmington, New Mexico, 87401. Jesse Haen, is a Reclamation Scientist with Buchanan Consultants Ltd.
SOIL MICROBIAL COMMUNITY COMPOSITION IN RECLAIMED SOIL UNDER DIFFERENT VEGETATION IN WYOMING MINELANDS

S. Rana, P.D. Stahl, L.J. Ingram, and A.F. Wick

Abstract. Vegetation is known to be an important determinant of soil microbial community structure and although cool season grass communities dominate most reclaimed mine sites in Wyoming, a variety of other plant communities may be found. The primary objective of this paper is to examine and compare microbial community recovery in reclaimed soils vegetated by different types of plant communities. Phospholipid fatty acid (PLFA) analysis was used to characterize soil microbial community structure under three types of plant communities (cool season grass, warm season grass and sagebrush steppe). Results indicate that all major soil microbial groups are reestablishing in reclaimed mine soils regardless of vegetation. Further, microbial communities in reclaimed sites dominated by sagebrush appear to recover more rapidly than those in soils vegetated by warm season and cool season grass communities. Mechanisms responsible for these differences will also be discussed in this paper.

Additional Key Words: Soil Microbial Community, Wyoming, PLFA, sagebrush steppe.
Abstract: Recovery of sustainable soils is important in surface mine reclamation. Belowground soil fauna contribute too many soil processes including nutrient cycling, mixing of organic and mineral materials, and redistribution of organic matter and microorganisms. Our objective in this study was to examine recolonization of reclaimed mine land sites by soil fauna, arthropods and nematodes. We expect species composition of arthropod and nematode assemblages to be very different in reclaimed soils than in nearby undisturbed soils, since undisturbed soil may have different physical, chemical, and biotic characteristics. Soils were sampled on two surface coal mines in the Powder River Basin of Wyoming. At one mine, a chronosequence of reclaimed sites (less than 1 yr, 6, 11, and 17 yrs) dominated by Wyoming big sagebrush was sampled and at the other mine a chronosequence (10 months, 15, and 27 yrs) dominated by cool season grasses was examined. Nearby undisturbed soils were sampled at each mine for comparison.

Additional Key Words: semiarid, microfauna, nutrient cycles
THE INFLUENCE OF DIFFERENT GROUND COVER TREATMENTS ON THE GROWTH AND SURVIVAL OF TREE SEEDLINGS ON REMINED SITES IN EASTERN TENNESSEE

John Rizza, Jennifer Franklin, and David Buckley

Abstract: There is growing interest in the reforestation of surface mined lands for various land uses including forest products and wildlife habitat. These objectives can be met by planting native tree species and seeding a ground cover to control erosion. However, many ground covers compete aggressively with tree seedlings in this region, preventing establishment. A research project was designed with two main objectives; to investigate the competitive effects of different ground cover species on the growth and survival of tree seedlings, and to identify the relationship between the growth and function of tree seedlings and microsite variables. Five tree species, native to the eastern hardwood forest surrounding the mine site, were planted in 2005: yellow poplar (Liriodendron tulipifera L.), sugar maple (Acer saccharum Marsh.), northern red oak (Quercus rubra L.), eastern redbud (Cercis canadensis L.), and Virginia pine (Pinus virginiana Mill.). Five different ground cover treatments were applied to the planted area. Two mixes consisted of native warm season grasses (NWSG), two standard reclamation mixes, and one control. Growth and survival, seedling transpiration, soil respiration, and groundcover biomass were analyzed. At each seedling, light measurements and percent herbaceous cover based on the Braun-Blanquet scale were collected. Seedling survival was related to size at planting, and to the density of ground cover. Survival was highest in moderate amounts of cover, although root collar diameter growth decreased with increasing cover in redbud and pine. Tree seedling growth and survival tended to be greatest in the native warm season grass treatments.

Additional Key Words: reclamation, native warm season grasses (NWSG), soil respiration, transpiration, photosynthetically active radiation (PAR), percent herbaceous cover, reforestation, surface mining.

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2 John Rizza is a Graduate Research Assistant, University of Tennessee, Knoxville, TN 37996, email: jrizza@utk.edu . Jennifer Franklin, Assistant Professor, University of Tennessee, Knoxville, TN 37996, email: jafranklin@utk.edu . David Buckley, Associate Professor, University of Tennessee, Knoxville, TN, email: dsbuckley@utk.edu
MODE OF GYPSUM PRECIPITATION IN VERTICAL FLOW PONDS

Arthur W. Rose, Terry Morrow, Margaret Dunn and Clifford Denholm

Abstract: Gypsum (CaSO₄·2H₂O) precipitates were observed in limestone beds at four vertical flow ponds (VFP) treating acid mine drainage, but the textures and localization show that it precipitated within other materials, not in contact with the open solution.

At the Filson 1 VFP, gypsum was found within clay and organic matter left as residues on the surface of partly dissolved fragments of impure limestone. It was also found in the contact zones between fragments. At the Tangascootack 1 VFP, gypsum coated limestone and was overlain by amorphous Al precipitate. At the Jennings VFP, gypsum was present in limestone-bearing compost and within Al-rich gel occupying pores in limestone gravel. At Middle Branch, Kettle Creek, gypsum occurred in Al-rich gel and on limestone. At all sites, the effluent water was undersaturated with gypsum.

Gypsum at these sites is interpreted to have formed in situations where limestone dissolution was characterized by diffusive transport of Ca away from the limestone surface. In this situation, the Ca concentration near the limestone surface is considerably higher than in the open solution, so that gypsum was oversaturated and precipitates, even though the open solution was undersaturated.

The occurrence of gypsum as coatings or as a component of an impurity layer probably slows the dissolution of limestone, and makes the VFP less effective in neutralizing acidity.

Additional Key Words: Acid mine drainage, passive treatment, limestone dissolution
MODELING THE CONTROLS ON ACIDITY REMOVAL IN VERTICAL FLOW PONDS

Arthur W. Rose

Abstract. Previous evaluations of vertical flow ponds (VFP) have indicated that these passive treatment systems generally do not remove acidity at a rate greater than 35 g/m²d (Rose, 2004). The reason for this empirical limit has not been clear. In this paper, the chemical processes in VFPs are modeled using the PHREEQC program to show that CO₂ concentrations are a key to acidity removal, and commonly set a limit approximating the above acidity removal rate.

The modeling results indicate that CO₂ generation in the compost layer can be critical in providing elevated levels of alkalinity in effluent at pH 5.5 and above. The increased P_{CO₂} greatly increases the potential amount of CaCO₃ dissolved from the limestone layer. For example, for a simple H₂SO₄ influent solution at pH 3.5 in equilibrium with open-air CO₂ (10⁻³·⁵ atm.), reaction with CaCO₃ in a closed system generates only about 27 mg/L (CaCO₃) of potential acidity removal at pH 7. If Fe²⁺ in this influent exceeds 15 mg/L, the effluent at pH 7 will still be net acid. Reactions leading to increased CO₂ and acidity removal include 1) consumption of dissolved O₂ by compost (potential acidity removal 45 mg/L), 2) reduction of ferric iron (potential acidity removal 60 mg/L for 50 mg/L Fe³⁺), and 3) SO₄ reduction and precipitation of FeS (potential acidity removal about 113 mg/L for 24 mg/L SO₄ reduced). Higher SO₄ removal or precipitation of Al lead to still higher CO₂ and acidity removal. If the influent P_{CO₂} is 10⁻¹·⁵ instead of 10⁻³·⁵, the acidity removed is much higher, about 150 mg/L compared to 27 mg/L for the low-CO₂ case. At typical flow rates of 0.1 L/m²d, an acidity removal of 113 mg/L is equivalent to about 16 g/m²d. If 100 mg/L SO₄ is reduced, as at many systems, then 320 mg/L acidity is removed, equivalent to a rate of 46 g/m²d. For strongly acidic systems, the influent pH, Fe, P_{CO₂} and degree of SO₄ reduction, along with extent of CaCO₃ dissolution, are key factors limiting acidity removal.

Comparison of VFP influent and effluent chemistry with the modeling results indicates that typical VFPs generate only enough CO₂ in their compost layers to remove about 35-40 g/m²d of acidity. At higher loadings, effluent alkalinity is insufficient to neutralize all the acidity from the dissolved Fe²⁺. Provision of a compost layer with enough retention time to accomplish SO₄-reduction as well as O₂ consumption and Fe³⁺ reduction can greatly increase the effectiveness of systems. The modeling method used here can be used to estimate acidity removal in design of a system, though extent of SO₄ reduction remains difficult to estimate.

Additional Key Words: acid mine drainage, passive treatment, limestone dissolution.

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2 Arthur W. Rose is Professor Emeritus of Geochemistry, Department of Geosciences, Pennsylvania State University, University Park, PA 16801.
ASSESSMENT OF INOCULA TO ENHANCE STARTUP OF ETHANOL-FED AND SOLID-PHASE ORGANIC SULFATE REDUCING BIOREACTORS FOR THE NATIONAL TUNNEL DRAINAGE, CLEAR CREEK/CENTRAL CITY SUPERFUND SITE

Alison Ruhs 2, Linda Figueroa 3, Thomas Wildeman 4, Michael Holmes 5, and David Reisman 6

Abstract: The U.S. Environmental Protection Agency (EPA) is planning to construct an Anaerobic Passive Treatment System (APTS) to treat acid mine drainage from the National Tunnel in North Clear Creek near the City of Blackhawk, Colorado. North Clear Creek is part of the Clear Creek/Central City Superfund Site, and the National Tunnel is a major contributor of contaminants to this tributary. The EPA would like to determine the feasibility of constructing an APTS at this location.

Two modes of sulfate reducing bioreactor (SRBR) configurations are under consideration. One mode is an ethanol fed SRBR and the other mode is a solid substrate fed SRBR (two different mixtures). Laboratory proof-of-concept studies to test the performance of locally available microbial inoculum and the effects of start-up conditions were conducted.

The rationale for the laboratory experiments was to establish the best start-up inoculum for two different types of bioreactors: solid phase substrate based – wood, corn stover/hay, limestone/quartz and ethanol based – ethanol as the food source, limestone/quartz, reducing additive. Bag tests were conducted with 3 different substrates (two solids phase mixtures and ethanol), and 7 different inoculum. Sulfate and copper removal from the proof-of-concept experiments suggest that domestic sewage sludge provided the best bacterial inoculum for the ethanol-fed SRBR with horse and goat manure tied for second best.

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2 Alison Ruhs, Graduate Student, 3 Linda Figueroa, Associate Professor, 4 Thomas R. Wildeman, Professor Emeritus, respectively, Department of Chemistry and Geochemistry, Colorado School of Mines, Golden, CO, 80401, 5 Michael Holmes, Remedial Project Manager, US EPA Region 8 (EPR-SR), 999 18th Street, Suite 300 Denver, CO 80202-2466, 6 David Reisman, USEPA, National Risk Management Research Laboratory, ETSC, Cincinnati, OH 45268,
GETTING THE SALT OUT: TECHNOLOGIES AND COSTS TO TREAT CBNG WATERS¹

Eric T. Sajtar, David M. Bagley and Drew W. Johnson²

Abstract: Coalbed natural gas (CBNG) co-produced water in the Powder River Basin (PRB) can contain, among other constituents, sodium ranging from 110-800 mg/L, total dissolved solids ranging from 270-2,010 mg/L, and sodium adsorption ratios ranging from 5.7-33. Untreated CBNG waters may negatively affect aquatic ecosystems, damage soil characteristics, or contaminate aquifers but treated CBNG waters could be a valuable resource for the area. The primary treatment challenge is to cost-effectively remove sodium. Current technologies to treat PRB CBNG waters include ion exchange (Higgins loop or fixed bed processes) and reverse osmosis. Other technologies in various stages of development include: controlled-contact ion exchange, electrodialysis, electrodialysis reversal, high efficiency electro-pressure membranes, electrodeionization, capacitive deionization, advanced zeolites, constructed wetlands, and rapid spray evaporation. Most of the available treatment technologies produce a concentrated brine stream and brine management will likely become the key limiting factor for CBNG water treatment. Brine management options include: deep well injection, evaporation ponds, evaporation crystallization, drying, and constructed wetlands. In this work a toolbox was created for comparing PRB CBNG water treatment and brine management technologies. The technical performance characteristics and cost information for a number of technologies were identified, including the requirements for pre- and post-treatment of the waters as well as brine treatment. The toolbox compares these technologies with respect to both technical performance and cost, using specific CBNG water characteristics and discharge criteria as input, and facilitates rapid identification of suitable technologies while providing a preliminary estimate of the cost.

Additional Key Words: coal bed methane produced waters, treatment processes, brine, sodium, treatment costs

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² Eric T. Sajtar, Graduate Student, David M. Bagley, Associate Professor, and Drew W. Johnson, Associate Professor, Department of Civil and Architectural Engineering, 1000 E. University Ave., University of Wyoming, Laramie, WY 82071-2000
ASSESSMENT OF ECOTITE™ FOR USE IN ACID ROCK DRAINAGE TREATMENT¹

T. W. Schmidt² and B. R. Shultz³

Abstract: Limestone or limestone-based products are often the materials of choice for passively treating acid rock drainage (ARD) when site and discharge characteristics are favorable. However, limestone treatment may require long detention times, large quantities of material, and significant land area for implementation. This condition may result in limited applicability due to the size of treatment areas needed for limestone contact and capture of metal precipitates. In addition, use of limestone materials for passive treatment may be limited by discharge characteristics of the ARD such as high metals and acidity concentrations. ECOTITE™ is a material composed of approximately one-third iron by weight including the minerals ackermanite, magnetite, hematite, goethite, monoxides (e.g., wustite), metallic iron, and iron sulfides. ECOTITE™ has demonstrated an ability to generate alkalinity through dissolution of calcium-silicate minerals with relatively short contact times. In addition, ferric oxides within ECOTITE™ provide adsorption capacity for metal retention. Laboratory and on-site bench scale tests have been conducted to evaluate ECOTITE™ materials for ARD treatment, particularly at sites where conventional passive treatment techniques posed significant challenges. ECOTITE™-based treatment has been tested successfully on a variety of discharge water characteristics. Use of ECOTITE™-based treatment technology may broaden the range of ARD water quality characteristics and flow rates able to be passively treated.

Additional Key Words: acid mine drainage, passive water treatment, iron rich material, adsorption, AMD, ARD

¹ Paper was presented at the 2007 National Meeting of the American Society of Mining and Reclamation, Gillette, WY, 30 Years of SMCRA and Beyond June 2-7, 2007. R.I. Barnhisel (Ed.) Published by ASMR, 3134 Montavesta Rd., Lexington, KY 40502.
² Terry W. Schmidt, P.E., Vice President, Engineering, Skelly and Loy, Inc., 2601 North Front Street, Harrisburg, PA 17110. e-mail: tschmidt@skellyloy.com
³ Bradley R. Shultz, Water Quality Scientist, Skelly and Loy, Inc., 2601 North Front Street, Harrisburg, PA 17110 e-mail: bshultz@skellyloy.com
TREATMENT OF METAL-MINE EFFLUENTS BY LIMESTONE NEUTRALIZATION AND CALCITE CO-PRECIPITATION\textsuperscript{1}

P. L. Sibrell\textsuperscript{2}, T. R. Wildeman, M. Deaton, and D. J. Reisman

\textbf{Abstract:} The U.S. Geological Survey - Leetown Science Center and the Colorado School of Mines have developed a remediation process for the treatment of metals in circumneutral mining influenced waters. The process involves treatment with a pulsed limestone bed (PLB) system, followed by co-precipitation of metal-carbonate impurities. The PLB system is resistant to armoring through the action of intermittently pulsing fluids through beds of limestone. This imparts significant alkalinity to the water, especially when CO\textsubscript{2} has been added to enhance dissolution of the limestone. Then, product water is directed through an inclined channel containing limestone where co-precipitation of metal carbonates occurs, resulting in the removal of additional impurities, such as Zn, Cd and Mn. The maximum pH in the channel reaches 8.3, which is suitable for direct discharge into surface waters. The selectivity of the process results in lower reagent consumption and sludge volumes than would be expected with conventional lime or caustic treatment. The process was tested on four different hard-rock-mine-drainage effluents, and process performance and effluent composition were determined. If the water has only significant concentrations of zinc and minor concentrations of manganese, then removal of 90\% or more of the zinc is achieved. If the water has significant Mn concentration (\approx 50 mg/L) and minor Zn concentration, then removal of manganese is much more difficult and only after significant processing can the concentration of manganese be lowered to below 5 mg/L. Sludge volumes generated by the process are significantly smaller, only 10\% of those generated by hydroxide precipitation.

\textbf{Additional Key Words:} water treatment, carbon dioxide, pulsed limestone bed, aquatic chemistry, mine drainage, manganese, zinc, AMD

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\textsuperscript{2}Philip L. Sibrell, Engineer, USGS – Leetown Science Center, 11649 Leetown Rd., Kearneysville, WV 25430, email: psibrell@usgs.gov,. Thomas R. Wildeman, Professor, email: twildema@mines.edu, and Michelle Deaton, Research Assistant, email: michelle.deaton@gmail.com, Department of Chemistry and Geochemistry, Colorado School of Mines, Golden, CO 80401. David J. Reisman, Director of Engineering Technical Support, Environmental Protection Agency, ORD Engineering Technical Support Center MLK-489, Cincinnati, Ohio 45268, email: Reisman.David@epamail.epa.gov.
EFFECTS OF SOIL PROPERTIES, CLIMATIC FACTORS, AND LANDSCAPE FEATURES OF PRIME FARMLAND SOILS ON VEGETATIVE GROWTH USING PRODUCIVITY INDICES ON RECLAIMED COAL SURFACE MINED SOILS

H. Raymond Sinclair, Jr. and Robert R. Dobos

Abstract: Selected soil chemical and physical properties, climatic factors, and landscape features can be used as indicators of potential vegetative growth for commodity crops on reclaimed soil after coal surface mining. The logic for evaluating vegetative growth is similar to the "Storie Index for Soil Rating." The Storie Index, manipulating selected soil properties, is used to calculate soil productivity indices. Some elements have more impact on plant growth than others. Typically, selected soil properties, e.g., proportion of sand, silt, and clay, pH, bulk density, root limiting earthy soil layer, salinity, sodicity, root limiting non-earthy layers, landscape position, amount of precipitation, organic matter, rock fragments, etc. will determine the root zone available water capacity (RZAWC) of a soil. In normal precipitation years, the RZAWC of prime farmland soils determines the vegetative growth. RZAWC becomes a surrogate for many other soil properties and features. Knowing the RZAWC relationship allows soil scientists to make relatively accurate vegetative growth predictions. The significance of these properties determines the commodity crop vegetative growth using productivity indices of reclaimed soil compared to the pre-mined soil. The question being addressed in this paper, are the relationships of soil properties, climate (both soil and climatic atmospheric), and landscape features understood well enough to guarantee that soils reclaimed after surface mining for coal will be as productive as the pre-mined soil?

Additional Key Words: NASIS, soil climate, soil parent material, prime farmland, and soil profile development.

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Abstract. Recent changes to West Virginia coal mining regulations emphasize commercial forestry as a preferred post-mining land use on surface mined areas. In the spring of 2001, a study was initiated in northern West Virginia to examine the establishment and growth of commercial hardwood trees on a reclaimed surface mined site. We planted seeds and 1-0 seedlings of five hardwood species [red oak (*Quercus rubra* L.), black cherry (*Prunus serotina* Ehrh.), black walnut (*Juglans nigra* L.), white ash (*Fraxinus americana* L.), and yellow-poplar (*Liriodendron tulipifera* L.)] into treatment combinations of north- and south-facing aspects, ripped and unripped minesoils, and mowed and unmowed groundcover. First and 2nd year results showed extremely high survival of planted seedlings (>95% for all species) and seedling establishment from seeds was about 16% for black walnut and <5% for the other species. By the 6th year, black cherry survival averaged 37% for seedlings and 4% for seeds across treatments, red oak was 46% and 2%, yellow poplar was 66% and 0%, black walnut was 81% and 36%, and white ash was 99% and 1%. Average height of trees was greatest with white ash (89 cm), followed by black walnut (65 cm) and yellow poplar (67 cm), then by red oak (45 cm) and black cherry (40 cm). Seedling and seed survival was best on north, ripped, and unmowed plots.

Additional Key Words: aspect, black cherry, black walnut, mowing, red oak, reforestation, ripping, tree planting, tree seeds, tree seedlings, white ash, yellow-poplar.
A LEGACY OF NEARLY 500 YEARS OF MINING IN POTOSÍ, BOLIVIA:
ACID MINE DRAINAGE SOURCE IDENTIFICATION AND
CHARACTERIZATION

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

Abstract: Intensive mining and processing of silver, lead, tin and zinc ores have occurred in various locations within and around the city of Potosí, Bolivia since 1545. Surface and subsurface waters, stream sediments and soils are contaminated with various heavy metals. Acid mine drainage and processing plant effluent are primary contaminants in the headwaters of the economically vital, yet highly impacted, Rio Pilcomayo watershed. Previous studies have documented downstream heavy metal contamination. The acid mine drainage sources documented in this study help to link downstream pollution to primary origins. Selected acid mine drainage sources, from both operating and abandoned mines contributing to local streams, contained total metal concentrations of 0.284-977 mg/L Al, 0.03-191 mg/L As, 0.025-50.68 mg/L Cd, 0.03-161 mg/L Cu, 0.15-7,320 mg/L Fe, 0.3-438 mg/L Mn, 0.03-15.0 mg/L Pb and 1.46-11,760 mg/L Zn, with pH and specific conductance ranging from 2.46-6.39 and 893-19,070 μS/cm, respectively. Data were gathered during the dry season with flows ranging from nil to 4.59 L/s. Metals concentrations and pH values in all mine drainage sources sampled are several orders of magnitude above compliance with Bolivian environmental law.

Additional Key Words: acid rock drainage, aqueous geochemistry, water quality, and mineral processing

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2 William H. Strosnider, Doctoral Student, and Robert W. Nairn, Associate Professor, respectively, Center for Restoration of Ecosystems and Watersheds, School of Civil Engineering and Environmental Science, University of Oklahoma, 202 West Boyd St. Norman, OK 73019 Freddy S. Llanos López, Director of the Major, Department of Mining Engineering, Universidad Autónoma de “Tomás Frías.” Avenida Villazón esq. Arce s/n., Potosí, Bolivia.
THE CALIFORNIA STATE MINING AND GEOLOGY BOARD: REGULATION OF MINE RECLAMATION IN CALIFORNIA

Stephen M. Testa

Abstract. The California State Mining and Geology Board (Board), established in 1885, serves as a regulatory, policy and appeals body representing the state’s interest in geology, geologic and seismologic hazards, conservation of mineral resources and reclamation of lands following surface mining activities. California is the only state in the US in which mine reclamation is regulated through 109 city, county and state lead agencies. Regulation is required pursuant to California’s Surface Mining and Reclamation Act of 1975 (SMARA). When a lead agency fails to administer SMARA in an appropriate manner, the Board can consider assumption of the SMARA lead agency authority. Since 2002, the Board has exercised its assumption of lead agency authority for two counties, 10 cities, and 11 marine dredging operations. The Board performed a review of overall SMARA lead agency performance. This evaluation assessed the lead agency’s performance of periodic mine inspections, adjustment of annual financial assurances and enforcement of the preparation of Interim Management Plans should a surface mine site be characterized as idle for a period exceeding one year. Based on this review, the overall performance of SMARA lead agencies throughout California varies significantly. For the most part, overall performance is poor reflecting a number of factors including primarily financial constraints, and limited or absence of technical expertise. While the Board has not yet exercised its assumption authority following this statewide evaluation, lead agencies are taking notice and looking more closely at their SMARA programs.

Additional Key Words: Surface Mining and Reclamation Act of 1975, mine reclamation policy, lead agency performance

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2Stephen M. Testa, Executive Officer, California State Mining and Geology Board, 801 K Street, Suite 2015, Sacramento, CA 95814.
BACKFILLING OF OPEN-PIT METALLIC MINES\textsuperscript{1}

Stephen M. Testa\textsuperscript{2} and James S. Pompy

Abstract: Thirty years ago, the Congress of the United States required that coal mines be backfilled as a routine element of reclamation when it passed the Surface Mining Control and Reclamation Act. Until recently, that concept has not been generally applied to non-coal surface mines. In 2003, California’s State Mining and Geology Board (Board) evaluated reclamation of open pit metallic mines in the state and determined that they were not being reclaimed, despite California’s Surface Mining and Reclamation Act of 1975 (SMARA). As a result, the Board issued regulations for the backfilling of open-pit metallic mines. The need for such regulation reflected several issues. Open-pit metallic mineral mines often create very large excavations. In addition, metallic mineral mines that employ the cyanide heap leach method for mineral segregation and collection frequently generate very large leach piles which create long term soil and groundwater contamination conditions. It is the intent of SMARA that completed mine sites present no additional dangers to the public health and safety, and that the mined lands are returned to an alternate, useful condition. To date, no large, open pit metallic mines in California have been returned to the conditions contemplated by SMARA, and these sites continue to pose significant environmental problems. The goal of the Board’s regulations was to require mining companies to address the problems identified above and to take responsibility for cleaning up their mine sites after the completion of surface mining operations, and return them to a condition that allows alternative uses and avoids environmental harms, thereby meeting the purpose and intent of SMARA. Board regulations, which took effect in 1993, establish performance standards for reclamation pursuant to SMARA, including standards for backfilling which provide that, where backfilling is required for resource conservation purposes, fill material must be backfilled “to the standards required for the resource conservation use involved”.

Additional Key Words: SMARA, mine reclamation policy.

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\textsuperscript{2} Stephen M. Testa, Executive Officer, California State Mining and Geology Board, 801 K Street, Suite 2015, Sacramento, CA 95814. James S. Pompy, Manager of the Reclamation Unit, Department of Conservation, Office of Mine Reclamation, 801 K Street, MS 09-06, Sacramento, CA 95814.
WEIGHTING INDIVIDUAL DATUM FOR NONPARAMETRIC ANALYSIS

J. A. Tucker and M. Ortiz

Abstract: Many mining permits require a comparison of a stratified reference area to the reclaimed area for bond release. While this is easily accomplished by performing a test that uses stratified sample estimates of means and variances, such as the parametric t-test, nonparametric tests are often required by regulators if the data are not normally distributed or have small sample sizes. We propose three methods of weighting data that weight individual data points such that they can be used for nonparametric comparisons. These methods allow weights to be generated based on the pre-mining distribution of reference areas, the number of samples taken in the reference areas, and a combination of both of the aforementioned weights. These weights maintain comparability of the reference data to the reclaim data by confining the mean of the weights to one. This method provides a solution for nonparametric analysis where permits require comparison of a stratified reference to the reclaimed area.

Additional Key Words: statistics, stratified samples, bond release, reference areas, statistical tests

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2 Justin Tucker is the project development manager for Buchanan Consultants, Ltd., Farmington NM, 87401; Mel Ortiz is a Professor of Biostatistics at the University of Texas, School of Public Health, El Paso, TX, 79968.
POTENTIAL UTILIZATION OF NATURAL ZEOLITES FOR TREATING COALBED NATURAL GAS (CBNG) PRODUCED WATERS STUDIES

George F. Vance2, Hongting Zhao, Michael A. Urynowicz, Girisha K. Ganjegunte and Robert W. Gregory

Abstract: Fast development of the coalbed natural gas (CBNG) industry in many parts of the western U.S. has resulted in the co-production of potentially saline-sodic waters, hereafter referred to as CBNG water. Management of CBNG water is a major environmental challenge because of its quantity and quality. In this study, the potential utilization of calcium (Ca2+) rich natural zeolites were examined for removal of sodium (Na+) from CBNG waters. Zeolite samples examined were from the St. Cloud (ST) zeolite mine in Winston, NM and the Bear River (BR) zeolite mine in Preston, ID. The zeolite materials were used in adsorption kinetic/isotherm studies and column experiments. A surrogate CBNG water that simulated the water chemistry of CBNG waters was used in the various studies described herein. Results indicated that a Langmuir model fit the adsorption data well. The maximum adsorption capacities from the adsorption isotherms for ST-Zeolite and BR-Zeolite were 9.6 and 12.3 (mg/g), respectively, accounting for approximately 38% and 39% of their measured CEC values. Column studies indicated that a metric tonne (1000 kg) of ST-zeolite and BR-zeolite can be used to treat 16,000 and 60,000 liters of CBNG water, respectively, in order to lower the sodium adsorption ratio (SAR, mmol½ L⁻½) of the simulated CBNG water from 30 mmol½ L⁻½ to an acceptable level of 10 mmol½ L⁻½. Based on the results of this study Na+ removal with zeolite appears to be a cost-effective water treatment technology for maximizing the beneficial use of poor-quality CBNG water. Ongoing studies are evaluating water treatment techniques involving the direct application of zeolite to CBNG waters and development of a field scale prototype.

Additional Keywords: Zeolite, Adsorption, Coalbed Methane Produced Water, Clinoptilolite, Langmuir, Powder River Basin, Sodium Adsorption ratio, SAR.

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2 George F. Vance, Professor, and Hongting Zhao, Research Scientist, Department of Renewable Resources, 1000 E. University Ave., University of Wyoming, Laramie, WY 82071-3354: gfv@uwyo.edu; Michael A. Urynowicz, Assistant Professor, Department of Civil & Architectural Engineering, 1000 E. University Ave., University of Wyoming, Laramie, WY 82071-3295; Girisha K. Ganjegunte, Assistant Professor, Texas Agricultural Experiment Station, Texas A&M University, 1380 A&M Circle, El Paso, TX 79927; and Robert W. Gregory, Senior Geologist, Wyoming State Geological Survey, P.O. Box 1347, Laramie, WY 82073.
BENEFICIAL USES OF WATER PRODUCED BY COAL BED NATURAL GAS DEVELOPMENT: MORE SURFACE WATER CAN BE GOOD FOR FROGS AND OTHER WILDLIFE¹

William E. Vetter and Kimberley Brown²

Abstract. The potential effects of surface-discharged coal bed natural gas (CBNG) water on local wildlife populations are not yet fully understood, but the Powder River Basin Final Environmental Impact Statement (FEIS), Biological Opinion (BO), and Biological Assessment (BA) acknowledge the potential for both benefits and negative impacts. A myriad of vertebrate species would likely benefit from the increased availability of aquatic habitats, particularly within this arid landscape. Wetland obligates such as fish, amphibians, turtles, muskrats, and mink would likely increase. Other benefits could include the increased availability of drinking water for big game, brood rearing habitat for waterfowl, and foraging habitat for shorebirds. The potential value however, is largely dependent on the type, quality, and temporal availability of these created and supplemented wetlands. One CBNG operator has initiated a study to investigate northern leopard frog use of wetlands on a development area in northern Campbell County, Wyoming. That ongoing project has included two years of spring and summer surveys for amphibians at seven to eight wetlands. Leopard frogs and several other species of amphibians were documented using both natural and CBNG-supplemented wetlands. Results to date have provided some insight regarding the site characteristics that are valuable for leopard frogs at different times of year. That information can influence impoundment design, construction practices, water management strategies, and final reclamation to benefit frogs and other wildlife.

Additional Key Words: none

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² William Vetter, CBNG Project Manager/Wildlife Biologist, and Kimberley Brown, respectively, CBNG Project Director/Wildlife Biologist, Thunderbird – Jones & Stokes, 1901Energy Court, Gillette, WY 82718
A TECHNICAL REVIEW OF THE FINAL REPORT OF THE NATIONAL ACADEMY OF SCIENCES “MANAGING COAL COMBUSTION RESIDUES IN MINES”\(^1\)

Kimery C. Vories\(^2\)

**Abstract.** On March 1, 2006, the National Research Council released to the public its final report by the National Academy of Sciences “Managing Coal Combustion Residues (CCRs) in Mines.” Based on the news release of the National Academy of Sciences (NAS), putting coal ash back into mines for reclamation is a viable option for disposal, as long as precautions are taken to protect the environment and public health. The report also acknowledged that CCRs could serve a useful purpose in mine reclamation, lessen the need for new landfills, and potentially neutralize acid mine drainage. The report recommends development of enforceable Federal standards that give the States authority to permit the use of CCRs at mines but allows them to adopt requirements for local conditions.

The report lists 40 findings or recommendations under 12 categories. This paper addresses the merits of these findings on a case by case basis against existing regulatory requirements, the applicability of data evaluated, and consideration of extensive data and scientific studies relevant to the subject. The NAS has chosen to use the term “Coal Combustion Residues” where OSM has historically used the term “Coal Combustion By-Products.” The terms are interchangeable. The author is in agreement with the NAS findings that support: (1) the use of these materials in mine reclamation; (2) the need for specific Federal regulations under the Surface Mining Control and Reclamation Act of 1977 (SMCRA) that spells out the minimum permitting, bonding, and environmental performance standard requirements when they are placed on active coal mines; (3) the research priorities to specifically address the hydrogeologic fate of CCBs and any leachate generated by those CCBs in relation to public health and environmental quality; and (4) to develop mining appropriate leachate tests. A limitation of the report is its inability to: (1) acknowledge the significant differences between regulatory programs that control placement of CCBs at mines; (2) evaluate available ground water monitoring data and scientific research within the context of the applicable regulatory programs; and (3) acknowledge the volumes of scientific studies and State regulatory data that shows no degradation of water quality due to placement of CCBs at SMCRA mines for the last 29 years. The following review is strictly the opinion of the author and carries no institutional endorsement.

**Additional Key Words:** Coal Combustion By-Products, and Surface Mining Control and Reclamation Act

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\(^2\)Kimery C. Vories, Natural Resource Specialist, US DOI Office of Surface Mining, Mid-Continent Regional Office, 501 Belle St., Alton, Illinois 62002
ROOTING DEPTH OF 3 YEAR OLD SEEDLINGS INTO OVERBURDEN PILES AT A HIGH ELEVATION HARD ROCK MINE

Anne Wagner, B.A. Buchanan, and S. Buchanan

Abstract: A series of tree survival test plots were established to examine tree survival rates on high elevation overburden piles. The removal of one of these plots, to allow further mining of the underlying material, created the opportunity to evaluate the rooting success of the tree species. It was hypothesized that roots would not be able to penetrate the overburden due to the chemical properties and compaction of the material. After 3 years there was no difference in rooting depth for the trees given different topdressing depths. All of the species exhibited the ability to root beyond the topdressing and follow water into the overburden.

Additional Key Words: reforestation, high altitude reclamation

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2 Anne Wagner, Ph.D. is the Environmental and Health Services Manager with Molycorp, Inc. Questa, NM 87556; Bruce Buchanan, PhD. is the President of Buchanan Consultants, Ltd., Farmington, New Mexico, 87401; Spencer Buchanan is a GIS Specialist with Buchanan Consultants, Ltd.;
COMPARISON OF FOREST REGENERATION IN A SUBSIDENCE ZONE TO A REFERENCE AREA

Anne Wagner², Jeremy Niemeier, Bruce Buchanan, and Justin Tucker

Abstract: Underground mining may create subsidence conditions that disturb the surface vegetation. We examined the impacts on forest regeneration in a high elevation mixed conifer forest within two subsidence zones that are classified based on surface disturbance: less than 10 feet or greater than 10 feet. When compared to a reference area, the subsidence areas have significantly more regeneration of tree species but not significantly different shrub cover. The implication of our findings is that although a different mix of species is colonizing the subsidence areas, these are still appropriate to the ecosystem of the area because they are the early natural successional species of the area. These species appear to be taking advantage of the surface disturbance and subsequent lack of competition from climax species.

Additional Key Words: revegetation, reforestation, high altitude reclamation, subsidence, reference area

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¹ Poster was presented at the 2007 National Meeting of the American Society of Mining and Reclamation, Gillette, WY, 30 Years of SMCRA and Beyond June 2-7, 2007. R.I. Barnhisel (Ed.) Published by ASMR, 3134 Montavesta Rd., Lexington, KY 40502.

² Anne Wagner, Ph.D. is the Manager, Environmental and Public Policy with Molycorp, Inc. Questa, NM 87556; Jeremy Niemeier, is a Reclamation Scientist with Buchanan Consultants, Ltd., Farmington, NM, 87401; Bruce Buchanan, Ph.D. is the President of Buchanan Consultants, Ltd; Justin Tucker, Ph.D. is Project Development Manager with Buchanan Consultants, Ltd.
Abstract: The durability of a potassium permanganate protective coating (passivation) on potentially acidic waste rock was examined for preventing acid generation. There is limited biological and physical data on the environmental impact and durability of passivation technology. The objective was to determine if exposure of passivated acid waste rock to repeated cycles of intensive root growth would affect coating stability. Passivated treatments were compared to limed waste rock in columns with and without plants. Passivation stability was determined by measuring the pH, electrical conductivity (EC), iron, and sulfate of drainage leachate and saturated paste extracts by the use of a hydrogen peroxide stability test. The treatments were kept at field capacity and were leached once a month with reverse osmosis (RO) water. The stability study showed 1) no root system effects on passivation stability; and 2) no difference in expression of potential acidity of waste rock between passivation and adding lime at the rate of 15% (by weight) to the waste rock.

Additional Key Words: sulfidic rock, acidity, root growth, acid mine drainage, potassium permanganate protective coating, hydrogen peroxide stability test

1 Paper was presented at the 2007 National Meeting of the American Society of Mining and Reclamation, Gillette, WY, 30 Years of SMCRA and Beyond June 2-7, 2007. R.I. Barnhisel (Ed.) Published by ASMR, 3134 Montavesta Rd., Lexington, KY 40502.

2 C.E. Werkmeister, Graduate Student, Plant Science Department, South Dakota State University, Brookings, SD 57007. D.D. Malo, Distinguished Professor of Soil Pedology, Plant Science Department, South Dakota State University, Brookings, SD 57007. T.E. Schumacher, Professor of Soil Biophysics, Plant Science Department, South Dakota State University, Brookings, SD 57007. J.J. Doolittle, Professor of Soil Chemistry, Plant Science Department, South Dakota State University, Brookings, SD 57007. G.C. Miller, Professor of Natural Resources and Environmental Science, Mail Stop 199, University of Nevada, Reno, NV 89557. Paper Contact: Thomas E. Schumacher, Professor of Soil Biophysics, Department of Plant Science, South Dakota State University, Brookings, SD 57007, email: thomas.schumacher@sdstate.edu
CONSIDERATIONS FOR EVALUATING COALBED METHANE INFILTRATION POND SITES BASED ON SITE STUDIES IN THE POWDER RIVER BASIN OF MONTANA AND WYOMING¹

John R. Wheaton², Andrew L. Bobst³ and Elizabeth L. Brinck⁴

Abstract. Significant volumes of ground water are produced in association with coalbed-methane (CBM) production in the Powder River Basin in Montana and Wyoming. This water must be managed in a manner that is both economical and sensitive to the semi-arid agricultural area of southeastern Montana and northeastern Wyoming. Infiltration ponds are one of the primary methods of handling production water and have been in use in Montana and Wyoming for several years. A solid conceptual framework of the parameters that control water quality and flow allows for the selection of infiltration pond sites which maximize impoundment life and minimize impacts.

The ponds have several advantages in that they require a low initial investment and can help recharge the shallow ground-water system, which makes the production water available for future uses. However, as the infiltrated water moves through the shallow weathered bedrock, a series of chemical reactions typically take place (primarily dissolution and oxidation) which temporarily increase the total dissolved solids (TDS) due primarily to increases in Mg, Na, and SO₄. As the available salts are removed along the ground-water flow path through the bedrock, the concentrations of dissolved constituents in the ground water tend to decrease. Preliminary interpretations of data suggest that saturated paste extract (SPE) analyses and lithologic investigations may be used to predict the types of changes in water quality that can occur.

The fate and transport of the dissolved salts is controlled to a great extent by the rate of infiltration and the duration of saturated flow from the ponds. The rate of infiltration can be severely reduced as the clays in the pond floor and underlying material are exposed to the high SAR produced water, which causes dispersion and reduced vertical hydraulic conductivity. Order-of-magnitude decreases in vertical hydraulic conductivity have been observed, which represent a trade-off. First, the changes will effectively decrease the volume of water that can be managed via an individual pond. Secondly, the mobilized salts may be effectively sequestered by reduced ground-water flow; substantially reducing the temporal and geographic extent of impacts.

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² John R. Wheaton, Senior Research Hydrogeologist, Montana Bureau of Mines and Geology, Billings, Montana, email: jwheaton@mtech.edu ³ Andrew L. Bobst, Hydrologist, U. S. Bureau of Land Management, Miles City, Montana, email: abobst@blm.gov (will present the paper) ⁴ Elizabeth L. Brinck, University of Wyoming, Department of Geology and Geophysics, Laramie WY, email: LIDDI@uwyo.edu
CONSTRAINTS ON NATURAL REVEGETATION OF HARD ROCK MILLING TAILINGS IMPOUNDMENTS

R.L. White and R.W. Nairn

Abstract: From the mid-19th through mid-20th centuries, widespread underground mining and surface milling operations deposited several hundred million tons of metals-contaminated, organic-deficient, mining waste materials on the land surface of the Tri-State Mining District of Oklahoma, Kansas and Missouri. Following metal recovery operations, fine tailings were allowed to settle in extensive impoundments often covering tens to hundreds of acres. Much of this material remains unvegetated or sparsely covered today, more than 50 years since the cessation of most mining operations. In this study, physicochemical characteristics of seven abandoned tailings impoundments were evaluated. Tailings were found to have circumneutral pH, moderate to high salinity, elevated trace metals (Cd, Fe, Pb and Zn) but limited nutrient (nitrate, ammonium, potassium and phosphate) concentrations and, overall, to demonstrate the presence of considerable barriers to vegetation establishment and growth. Five impoundments were found to be barren, but two impoundments showed substantial vegetation coverage. Physicochemical constraints (lack of moisture, organic matter, and available nutrients) and phytotoxic trace metal concentrations appeared to limit vegetation establishment on tailings impoundments.

Additional Key Words: hard rock mining, tailings, revegetation

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2 Rebecca L. White, Graduate Research Assistant, and Robert W. Nairn, Associate Professor, respectively, Center for Restoration of Ecosystems and Watersheds, School of Civil Engineering and Environmental Science, University of Oklahoma, Norman, OK, 73019,
RECOVERY OF RECLAIMED SOIL STRUCTURE AND FUNCTION IN RELATION TO PLANT COMMUNITY COMPOSITION

A.F. Wick, P.D. Stahl, S. Rana, and L.J. Ingram

Abstract: Recovery of belowground properties, such as soil aggregation and microbial community composition, in relation to aboveground plant community characteristics is important for determination of reclamation success. The objectives of our research were: (1) to track ecosystem recovery based on soil aggregation and microbial biomass in different reclaimed soils (sandy loam and clay loam) and under different plant communities (shrub and cool season grass) through time and (2) to find relationships among aboveground plant composition, soil aggregate size distribution and microbial biomass. We hypothesized that the belowground properties of soil aggregation and microbial communities will recover simultaneously through time and will be highly related to the aboveground plant community composition. Aggregate size distribution did not show any patterns in the sandy loam soils underlying shrub communities; however did show progress towards a native condition in the clay loam soils underlying the cool season grass communities. Soil microorganisms showed recovery after 5 years ($29.6 \times 10^3$ area) in soil underlying shrub communities and after 14 years ($22.0 \times 10^3$ area) in soils underlying cool season grass communities. Macroaggregates were related to bacteria ($r = 0.40$) and fungal ($r = -0.31$) biomass under cool season grasses. Microaggregates were correlated with bacteria biomass under both shrub ($r = -0.26$) and cool season grass ($r = -0.40$) communities and also to living fungal biomass ($r = -0.39$) in the shrub soils. Microaggregation, fungal and actinomycete biomass were correlated in native cool season grasses ($r = -0.25, 0.66$ and $-0.47$, respectively) and annual forbs ($r = 0.52, -0.75$ and $0.49$, respectively) in shrub community soils. Macroaggregates, microaggregates and bacteria were related to native cool season grasses ($r = -0.61, 0.56$ and $-0.39$, respectively), annual grasses ($r = 0.69, 0.71$ and $0.37$, respectively) and annual forbs ($r = 0.69, -0.40$ and $0.41$, respectively). The ability to track aggregate and microbial changes through time as well as find relationships amongst ecosystem variables leads to better reclamation techniques and success.

Additional Key Words: coal mine, phospholipid fatty acids, Wyoming.

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2 Abbey F. Wick, Graduate Student, Peter D. Stahl, Assistant Professor, Sadikshya Rana, Graduate Student, and Lachlan J. Ingram, Post-Doctoral Research Associate, respectively, University of Wyoming, Department of Renewable Resources, Laramie, WY 82071, (307) 766-2263.
ASPECTS OF COALBED NATURAL GAS WATER AND OIL RECOVERY

Xina Xie, Hui Pu and Norman R. Morrow

Abstract. The application of coalbed natural gas (CBNG) water injection to improved oil recovery is being investigated. Such application can be permitted as Class II injection. This is more advantageous economically than Class V injection. Therefore CBNG water injection for improved oil recovery is value-added disposal. Use of CBNG water for oil recovery will also reduce the depletion of fresh water aquifers currently used in Wyoming as a source of injection water. The potential for application of low salinity flooding to a specific reservoir requires tests on cores and crude oil obtained from that reservoir. Information will be presented on the Tensleep reservoir rock from the Teapot Dome field that was selected for laboratory tests of CBNG water injection in Wyoming oil reservoirs.

Additional Key Words: CBNG water, low salinity, low salinity brine injection, improved oil recovery

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2Xina Xie, Senior Research Scientist, Hui Pu, Graduate Student, and Norman R. Morrow, Professor, Department of Chemical and Petroleum Engineering, University of Wyoming, Laramie, WY 82071.
CARBON ACCUMULATION POTENTIALS OF POST-SMCRA COAL-MINED LANDS

C.E. Zipper, J.A. Burger, J.M. McGrath, B. Amichev

**Abstract:** Many coal-surface mines reclaimed under SMCRA in eastern US were not restored to forest vegetation and are not currently in a managed use. Reforestation of these lands could provide benefits including timber production, watershed protection, and carbon (C) sequestration. Our objectives were to determine the suitability of eastern US coal-mined lands’ soil properties for reforestation and to estimate the cumulative potential of these lands to accumulate C through reforestation. Databases of coal mining permits issued under SMCRA were obtained for KY, OH, VA, and WV, and 20 bond-released permits were selected in each state using an area-weighted randomization procedure. Access permissions were obtained for 25 sites (6 each in OH, KY, and VA, and 7 in WV), each of which was sampled at up to 10 randomly selected points. At each sampling point, soil physical properties were determined for the top 30 cm, and soil chemical properties were determined for surface (0 – 10 cm) and subsurface (10 – 30 cm) soil layers. Measured soil properties were used to estimate forest site productivity (SI50) using two methods, and each site’s potential to accumulate C was estimated as a function of SI50 based on relationships derived from soil property and C accumulations on pre-SMCRA surface mines. Assuming these sites to be representative of eastern US mined lands, and that 50% of eastern US post-SMCRA mined lands could be available for reforestation under sufficient financial incentives, post-SMCRA mined lands reforested with pine species have the potential to accumulate on the order of 1.6 Tg C yr\(^{-1}\) over a 30 year rotation, equivalent to about 0.2% of projected US coal-combustion C emissions.

**Additional Key Words:** Carbon sequestration, mine reforestation.

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2 C.E. Zipper, Associate Professor, Department of Crop and Soil Environmental Sciences, Virginia Tech, Blacksburg VA 24061, J.A. Burger, Professor, Department of Forestry, Virginia Tech, Blacksburg VA 24061, J.M. McGrath, Assistant Professor, Environmental Science & Technology, 0214 H.J. Patterson Hall, University of Maryland, College Park, MD 20742-2315, B. Amichev, Graduate Student, Department of Forestry, Virginia Tech.