ECONOMIC ISSUES AND POLICIES AFFECTING RECLAMATION IN WYOMING’S OIL AND GAS INDUSTRY¹

Matt Andersen² and Roger Coupal

Abstract This study examines economic issues that affect the decision to reclaim land disturbed by oil and gas development. We start with a discussion of the current reclamation bonding requirements in Wyoming, which are intended to insure the proper reclamation of disturbed land. Next, a simple economic framework is proposed for modeling reclamation decision making by oil and gas producers. The most important issue affecting the decision to reclaim is the cost of reclaiming the disturbed land; therefore, we use a dataset provided by the Wyoming Oil and Gas Conservation Commission to conduct a detailed analysis of reclamation costs for orphaned oil and gas wells. We also consider issues concerning the timing of reclamation costs and some environmental considerations. Finally, we discuss some deficiencies in the current bonding system, and offer some suggestions on how the current system could be improved in terms of providing more economic incentives for operators to fully reclaim disturbed lands.

Additional Key Words: bonding requirements, reclamation costs.


² Matt Andersen, Assistant Professor, and Roger Coupal, Associate Professor and Department Head, Department of Agricultural and Applied Economics, University of Wyoming, Laramie, WY 82071.
THE FORESTRY RECLAMATION APPROACH AND THE MEASURE OF ITS SUCCESS IN APPALACHIA

Patrick N. Angel, James A. Burger, Victor M. Davis, Christopher D. Barton, Michael Bower, Scott D. Eggerud, and Paul Rothman

Abstract: The Appalachian Regional Reforestation Initiative (ARRI) is a broad-based citizen/industry/government program working to encourage the planting of productive trees on abandoned and active coal mine lands. Forestry research has confirmed that highly productive forestland can be created on reclaimed mine land by using a five step straightforward methodology called the Forestry Reclamation Approach (FRA). Data taken from Office of Surface Mining and state regulatory permit and bond release documents indicate that since the start of ARRI in 2005, a gradual increase in the planting of trees on coal surface mines has occurred. ARRI states reported about 9.4 million trees planted in 2005, 11.1 million trees planted in 2006, and 12.8 million trees planted in 2007. However, despite an aggressive technical outreach by ARRI, serious cultural barriers and other impediments to proper surface mine reforestation remain pervasive in the Appalachian coalfields. In 2007, the ARRI states reported that of the 12.8 million trees planted, only 3.4 million trees were planted using the full 5 steps of the FRA. The number of trees planted on conventionally reclaimed sites which were not FRA compliant was estimated at 9.4 million. One or more of the 5 steps of the FRA where not utilized on over two-thirds of the trees planted on surface mines in Appalachia over the past three years.

Additional Key Words: The Appalachian Regional Reforestation Initiative, ARRI, coal surface mine reforestation, tree planting, end-dumping, loose-grading.


2 Patrick N. Angel is a Forester/Soil Scientist, Office of Surface Mining, United States Department of Interior, London, KY 40741. James A. Burger is a Professor of Forestry and Soil Science, Department of Forestry, VA Tech, Blacksburg, VA 24060. Victor M. Davis is a Reclamation Review Specialist, OSM, USDI, Knoxville, TN 37902. Christopher D. Barton is an Assistant Professor of Forest Hydrology and Watershed Management, Department of Forestry, University of Kentucky, Lexington, KY 40506. Michael Bower is a Program Specialist, OSM, USDI, Pittsburgh, PA 15220. Scott D. Eggerud is a Program Development Forester, West Virginia Department of Environmental Protection, Charleston, WV 25304. Paul Rothman is an Environmental Scientist, Kentucky Department for Natural Resources, Frankfort, KY 40601.
GEOTECHNICAL CONSIDERATIONS FOR SOLAR PANEL INSTALLATION ON MINE TAILINGS

Srikant Annavarapu, Terril Wilson, Moe Momayez, Alex Cronin

Abstract. Geotechnical stability considerations are important for the installation of solar panels on mine tailings areas. Active tailings deposition areas consist of coarse-grained, free-draining relatively stable particulate mass at the perimeter with fine-grained, low shear strength mass around the supernatant pond in the deposition area. An evaluation of the geotechnical stability of the supports for the solar panels constructed, which will have their foundations placed on mine tailings, is essential so that the orientation of the solar panels can be maintained within suitable limits. An assessment of the forces imposed on the solar panel supports, including the distributed weight of the solar panel arrays and effect of wind loading on the flat array surfaces, also need to be considered in the design of suitable foundations for these supports. This paper enumerates some of the geotechnical issues related to the installation of solar panel arrays on active and inactive mine tailings areas.


2 Srikant Annavarapu is Graduate Associate, Department of Mining & Geological Engineering, University of Arizona, Tucson AZ, 85721, Terril Wilson is Adjunct Professor and Moe Momayez is Assistant Professor. Alex Cronin is Assistant Professor, Department of Physics, University of Arizona.
MINE INSPECTION ASSISTANCE USING REMOTE SENSING IMAGERY

Clairene Bailey, Nancy A. Osborne, Natalie L. Carter, David T. Beaman, Contributors

Abstract. With advances in mining technology, surface mines are becoming larger and more complex. The use of satellite imagery and remote sensing technology may provide a way to reduce the cost associated with field inspection of larger mine sites.

As part of its West Virginia oversight process, the OSM Charleston Field Office normally procures a helicopter service to fly an OSM reviewer over a sample of active and bond released mine sites. Drainage controls, downslope spoil placement, fly rock, fill construction, etc. are observed on active operations. Bond released mine sites are reviewed for seeps, vegetation, highwall elimination, and overall reclamation success for postmining land use.

The purpose of this project is to determine if satellite imagery is economically and technologically feasible to reduce the cost associated with helicopter overflights. In addition, this project will attempt to identify any mining features only available using satellite imagery and remote sensing technology.

Four study areas were selected in West Virginia. Helicopter overflights have been completed and satellite imagery received. The multi-spectral and panchromatic imagery was reviewed and analyzed for mining features. A preliminary cost analysis was performed and indicated a cost savings by viewing the satellite imagery for current mining activities as opposed to a field inspection. Development of a tool to aide in identifying relevant features is being considered.

Additional Key Words: Mine, Aerial, Inspection, Remote Sensing


2 Clairene Bailey, Hydrologist, Department of Interior, Office of Surface Mining Reclamation and Enforcement, Charleston, WV 25301
IMPACTS OF OIL AND NATURAL GAS ON PRAIRIE GROUSE: CURRENT KNOWLEDGE AND RESEARCH NEEDS

Jeffrey L. Beck

Abstract. The direct and indirect impacts of energy development on prairie grouse have been an increasing concern for scientists and land managers. The need to better understand impacts and develop appropriate mitigation measures has led to studies designed to identify specific and cumulative effects of oil and natural gas development on grouse populations and habitats. The purpose of this review is to summarize current knowledge on the effects of oil and gas development and production on prairie grouse based on publications that report empirical evidence about these impacts. It is important to understand the design of each study including use of control and treatment areas, sample sizes, and other factors to assess the strength of inference. Consequently, in addition to reporting general findings, I also provide an evaluation of study design and rigor. Reviewed studies were designed as (i) observational studies, where radio-marked birds were used to assess parameters of interest such as survival and nest success relative to impacts from oil and gas development or (ii) correlative studies evaluating cause and effect relationships such as lek counts and habitat selection in relation to development infrastructure such as well pad or road densities. Most of the currently available information on impacts is focused on lek abandonment and changes in male lek attendance. Fewer studies have examined nest success, nest initiation, survival, other vital rates, or habitat selection. The mechanistic properties of disturbances are not well understood as they relate to oil and gas development and prairie grouse. Based on this literature review, it is suggested that there is a need for further research to more clearly elucidate impacts of oil and gas development on prairie grouse to provide suitable mitigation actions to offset these impacts.

Additional Key Words: anthropogenic disturbance, energy development, male lek attendance, population demographic rates

2 Jeffrey L. Beck is Assistant Professor of Wildlife Habitat Restoration Ecology, University of Wyoming, Laramie, WY 82071
DEVELOPMENT OF RHIZOBIACEAE AND FABACEAE SYMBOIOSES FOR ENHANCING BIOLOGICAL INPUTS OF NITROGEN IN RECLAMATION OF DISTURBED LANDS IN WYOMING

N.A. Bird and S.E. Williams

Abstract. Leguminous nitrogen fixation is an important biological function which has been commonly used to improve nitrogen levels in disturbed land. In Wyoming, native legumes are abundant but few are used as reclamation species because seed is often difficult to obtain, germination rates are low and growth is often poor. This research examines inoculation of native and non-native legume seed with bacteria isolated from root nodules of native legumes as a way of perhaps improving germination and growth. Root nodule bacteria have been isolated from a diversity of native legume nodules including lupines and vetches. Bacteria isolates were tested for infectivity and effectivity in a previous study. In this study, the effective bacteria isolates were tested at a recently disturbed field site (a surface strip mine) and in a controlled greenhouse environment on two subspecies of lupine (Lupinus argenteus), cicer milkvetch (Astragalus cicer) and sainfoin (Onobrychis viciifolia). Four isolates were tested on each plant species and compared to controls. All treatments were replicated five times. The experimental design was the same for the field and greenhouse studies, with both experiments being completely randomized. Soil was taken from the field site to use in the greenhouse experiment. All plants were grown for four months and harvested. Each experimental unit was measured to determine biomass, the extent of nodulation and nodule development, total nitrogen and \(^{15}\text{N}:{^{14}\text{N}}\) natural abundance as a measure of nitrogen fixation. Results suggest sainfoin is an effective nitrogen fixing plant that establishes well. The other legumes had highly variable germination and inconclusive nitrogen fixation rates.

Additional Key Words: nitrogen fixation, remediation of disturbed land, mine reclamation, Fabaceae, legumes, lupine, cicer milkvetch, sainfoin, soil bacteria, rhizobia.

---


2 Nicole A. Bird is a Masters Candidate, University of Wyoming, Laramie WY 82071. Stephen E. Williams is a Professor of Soil Biology and Biochemistry and Director of Wyoming Reclamation and Restoration Center, University of Wyoming.
A QUALITATIVE RECLAMATION ASSESSMENT HANDBOOK FOR ABANDONED HARDROCK MINE LANDS1.

Pamela S. Blicker2, Dennis R. Neuman, and Stuart R. Jennings

Abstract. The Abandoned Mine Lands Inventory System (AMLIS) includes nearly 1100 abandoned mines in Montana. The Montana offices of the Bureau of Land Management and the U.S. Forest Service as well as the Montana Department of Environmental Quality AML Program have been working to clean up these abandoned mine lands since 1995. The agencies in general have given priority to sites with mill tailings and waste rock dumps situated in stream channels, and in Montana the clean up of impacted lands on a watershed basis through interagency cooperation has been emphasized. There is an emerging desire of the federal agencies to begin monitoring these reclaimed sites in a systematic way. The overall objective for developing the “Qualitative Reclamation Assessment Handbook for Abandoned Hardrock Mine Lands” is to provide a common platform to evaluate reclaimed mine sites so that federal agencies responsible for risk management and land management can easily communicate and work in partnership to accomplish their respective missions. The handbook contains assessment forms and protocol designed to evaluate pertinent attributes found at specific locations within a reclaimed mine site (repository, wetland, etc.). These attributes may include vegetation cover, status of a cap or liner, roads, evidence of AMD, and several others. The outcome envisioned by the agencies includes identifying maintenance needs, generating temporal information for trend analysis, and identifying remedial methods and technologies that have proven to be effective and those that have resulted in poor performance. The data and information collected during a reclamation assessment can then be used to evaluate the status of the reclamation work and whether or not the conditions at the site remain protective of human health and the environment.

2 Pamela Blicker, Dennis Neuman, and Stuart Jennings, Reclamation Scientists, Reclamation Research Group, LLC., Bozeman, MT 59715.
OVERCOMING THE OBSTACLES OF OPERATING A BIOCHEMICAL REACTOR AND AEROBIC POLISHING CELL YEAR ROUND IN CENTRAL MONTANA

E. P. Blumenstein and J.J. Gusek

Abstract: A demonstration-scale passive treatment system (PTS) including a biochemical reactor (BCR) and an aerobic polishing cell (APC) has been constructed at a historic gold mine in Central Montana. This site provided the challenge of being located where the frost depth is over four feet and temperatures dropped to negative 40˚ F in the winter of 2007-2008. The demonstration-scale PTS, including the APC, was operated through the winter. This paper presents the results of the testing as well as the special consideration and precautions taken to ensure the PTS could function properly year round.

The BCR uses a mixture of organic components including wood chips, sawdust, hay, limestone, manure, and crushed basalt to remove constituents of concern (COC), including thallium, selenium, zinc, and nitrate from the mining influenced water (MIW) at the site. As the MIW passes through the BCR, a suite of biological and chemical reactions (biological reduction, metal sulfide precipitation, metal hydroxide precipitation, adsorption, etc.) combine to reduce the COC concentrations in the effluent. Over the first 14 months of BCR operation thallium was removed at >99%, selenium was removed at >99% until BCR maintenance disturbed the substrate in the fall of 2008, and zinc and nitrate were removed to non detect levels throughout. The BCR has operated successfully through two winters where temperatures reached levels as low as -40˚ F for up to weeks at a time.

Due to the natural degradation of the organic substrate mixture used in the BCR, the water exiting the cell has elevated levels of organic matter as well as manganese, iron, and arsenic. These constituents are removed in an APC, which is comprised of a series of ponds that contain vegetation and large surface area to promote aeration of the water. As oxygen is introduced to the water, the biochemical oxygen demand, manganese, iron, and arsenic are changed from dissolved to particulate form and either settle or are filtered out by the vegetation in the APC. The APC has yet to operate through a full winter without retrofits and upgrades.

Additional Key Words: biochemical reactor, aerobic polishing cell, thallium, selenium, mining influenced water, winter operation


2 Eric P. Blumenstein, E.I.T., and James Gusek, P.E., Golder Associates Inc., Golder Associates Inc., 44 Union Blvd, Suite 300, Lakewood, CO, 80228,
EVALUATING THE POTENTIAL IMPACT OF SURFACE MINING ON WATER QUALITY AND MACROINVERTEBRATE COMMUNITIES IN A NATIVE BROOK CHAR FISHERY

Fred J. Brenner, Jennifer L. Stenglein and Matthew R. Ridge

Abstract. Little Sandy Creek and its tributaries, located in Sandy Creek watershed of northwest Pennsylvania, are protected as cold water fisheries and portions of Little Sandy Creek proper are further protected as high quality waters by the Pennsylvania Department of Environmental Protection. Because of these designated protected uses, mining operations discharging into Little Sandy Creek and its tributaries were required to meet in-stream criteria and adequate buffers had to be maintained around all streams, groundwater discharges and wetlands within the permit boundaries. In order to insure adequate on-site treatment, the mining company increased the size of all erosion-sedimentation and treatment ponds by 25 percent. Prior to the commencement of mining, water samples and aquatic communities were surveyed upstream and downstream of the mine site on all streams within the permit boundaries. During mining, water samples were collected monthly from each of two unnamed tributaries to Little Sandy Creek and Little Sandy Creek proper upstream and downstream of the mine site and the aquatic communities were sampled quarterly from each location. There were no adverse impacts on either water quality or in the diversity of aquatic communities in streams located within the permit boundaries. Little Sandy Creek continued to support a reproducing native brook char (Salvelinus fontinalis) population and the endangered Eastern Massasauga rattlesnake (Sistrurus catenatus catenatus) was observed foraging on the mine site two years post-mining.

Additional Key Words: coldwater fishery, endangered species, watershed

---


2 Fred J. Brenner is Professor of Biology, Grove City College, Grove City, PA 16127, Jennifer L. Stenglein is a Master’s candidate in Environmental Science, University of Idaho, Moscow, ID 83844. Matthew R. Ridge is a Junior Biology Major at Grove City College, Grove City, PA
Patterns of Annual Brome Abundance in Reclaimed and Native Rangelands in the Northern Great Plains: A Case Study from the Big Sky Mine, Southeastern MT

David L. Buckner and Shannon Downey

Abstract: Annual bromes, primarily cheatgrass (Bromus tectorum) and Japanese brome (Bromus japonicus) are Eurasian winter annual plants that have come to be considered “invasive”. As such they are not included purposely in seed mixes used for mine reclamation. Examination of long-term vegetation monitoring data from reclaimed and reference areas at the Big Sky Mine in Rosebud County, MT offer insight into the dynamics of the presence of these weeds in a Northern Great Plains setting. Over the past 22 years, annual brome cover as a percent of total vegetation cover in the native open ponderosa pine (Pinus ponderosa) woodland vegetation at the Big Sky Mine has varied from as low as 0.3% in 2002 to as high as 50.7% in 1991. In reclaimed areas over the same period, annual bromes ranged from as little as 1.5% to as much as 25.1% of total vegetation cover. As of 2008 Native Reference Area vegetation was 37.0% annual bromes while reclaimed areas had declined to 6.5% annual bromes. Biomass production in reclaimed areas has exceeded reference area levels by 50 to 75% on most years. Precipitation in these adjacent areas can be presumed to have been very similar and grazing of both areas has been light to non-existent over the period. These data suggest that strong perennial herbaceous growth suppresses annual brome abundance especially during periods favorable precipitation. Native area vegetation periodically experiences outbreaks of annual bromes as drought stresses increase and then annual bromes decline as the competitive strength of the native perennials returns. High abundance of annual bromes is a symptom of reduced or lagging competitive strength of perennial plants: it is suggested that at least in the Northern Great Plains, annual bromes constitute a litmus test for community competitive strength, and are not of themselves a conquering invasion.

Additional Keywords: Invasibility, reclamation biomass production, cheatgrass, downy brome, Japanese brome, invasive plants, cycles of invasions.


2 David L. Buckner, Senior Plant Ecologist, ESCO Associates Inc., P.O. Box 18775, Boulder, CO 80308 and Shannon Downey, Reclamation Ecologist, Montana Department of Environmental Quality, Helena, MT
A SUMMARY OF SOME LAND SURFACE AND WATER QUALITY MONITORING RESULTS FOR CONSTRUCTED GEOFLUV LANDFORMS

Nicholas Bugosh

Abstract: Modern mining methods can drastically change landforms in the project area. Traditional reclamation grading methods often do not address all the criteria that must be met for the desired post-mining land use including water quality standards, in-stream uses, vegetation diversity and other reclamation criteria. Inability to meet or mitigate for these changes caused by the proposed reclamation landform can even stop mining activity from proceeding. A new, natural approach to landform grading called GeoFluv™ (Bugosh, 2003) offers a cost-effective alternative for sustainable mineral development than can satisfy the reclamation criteria and is the heart of the Natural Regrade computer software module (Bugosh, 2006). Monitoring results of land surfaces and storm water discharge quality, including runoff that meets NPDES discharge limits before reaching sediment treatment ponds, at constructed projects strongly support the effectiveness of the GeoFluv design method at meeting the reclamation criteria (NMED, 2007). The objective of this paper is to summarize subjective observations of reclamation landforms constructed according to the GeoFluv design and the related objective data from large projects over approximately a seven year period to provide a status report of the effectiveness of the method for minimizing erosion and meeting water quality goals.

Additional Keywords: fluvial geomorphic, GeoFluv, sustainable, landform, erosion, water quality, vegetation diversity, invasive species


2 Nicholas Bugosh, GeoFluv Technical Director, Carlson Software, 7003 Avondale Road, Fort Collins, CO 80525
CAPABILITY OF RECLAIMED MINED LAND FOR SUPPORTING REFORESTATION WITH SEVEN APPALACHIAN HARDWOOD SPECIES

James A. Burger and A. G. Fannon

Abstract. Reforestation of the Appalachian coalfields with native hardwoods is becoming increasingly popular. However, establishing some hardwood species has been difficult due to the poor quality of many mine soils. The purpose of this study was to contrast after 15 years the growth, survival, and overall performance of seven hardwood species planted on three mine sites in Southwestern Virginia. The seven hardwood species were divided into species groups of a non-native fuelwood species, upland hardwoods, riparian species, and a valuable but off-site hardwood species. Overall tree performance was examined as a function of mine soil chemistry and fertility. Eastern cottonwood grew fastest, and black walnut grew slowest. By age 15, the native hardwoods, white and northern red oaks and yellow poplar, grew better than the American sycamore and white ash riparian species. They also responded to a mine soil fertility gradient while the others did not. The overall forest capability of the post-mined condition of these sites was far less than the pre-mined capability. The average weighted site indices (by extent of all soil series) of 10,000 acres in the vicinity of the mined sites are 82 and 77 for yellow poplar and northern red oak, respectively. Reduction in yellow poplar site index between the pre- and post-mined capability was 26 feet, and the difference for red oak was 15 feet. Northern red oak, white oak, and yellow poplar, all upland native commercial hardwood species, would be better choices for general reforestation than riparian species; however, better reclamation procedures then those used when this study was established (compacted mix of overburden materials with heavy herbaceous ground cover) are needed to restore forest land capability to pre-mining conditions.

Additional Key Words: reclamation, mine soil quality, site index


2 James A. Burger is Garland Gray Professor Emeritus in the Department of Forestry, and Amy G. Fannon is a Graduate Research Assistant in the Department of Crop and Soil Environmental Sciences, both at Virginia Polytechnic Institute and State University, Blacksburg, VA 24061.
FIELD GPS VS. REMOTE SENSING WORKFLOWS FOR LANDFORM REVIEW: SELECTING THE RIGHT TECHNOLOGY FOR THE JOB¹

Roger Calhoun², Larry Evans, Michael Shank, and Michael Richmond

**Abstract:** The Office of Surface Mining Reclamation and Enforcement (OSM) and the West Virginia Department of Environmental Protection (WVDEP) have reviewed the costs and benefits of two very different types of data gathering to accomplish a specific mission. The agencies generated cross sections of large land disturbances using Trimble Geo Explorer series GPS receiver units ranging from the submeter GeoXT with EVEREST™ multipath rejection technology to the GeoXH with Trimble H-Star™ and optional Zephyr™ external antenna capable of approximately 25 cm. vertical accuracy post processed. Next, they tested the suitability of Lidar data for the same purposes and generated projected cost using that method on the same sites. The potential use of photogrammetry was also considered. By maintaining an accounting of all the time associated with both methods, the agencies gained a better perspective on the costs and benefits of these technologies for future decisions.

In this project, the mission involved comparing pre, proposed and final graded slopes on eight large surface mines in steep slopes in West Virginia as part of the review of “Approximate Original Contour “ requirements under the coal mining regulatory program. The agencies found that use of remote sensing technologies, such as aerial based Lidar, can be a cost savings over obtaining digital information using GPS field devices on the ground.

**Additional Key Words:** Cross Sections, Remote Sensing, Coal Mining.

---


² Roger Calhoun is Field Office Director, OSM, Charleston, WV 25301, Larry Evans, is Manager, Technical Applications and GIS Unit, WVDEP, Charleston, WV 25304, Michael Shank is GIS Database Administrator I, WVDEP, Charleston, West Virginia 25304 and Michael Richmond is a Civil Engineer, OSM, Charleston, WV 25301.
Abstract: Almost 1.5 years and 3.5 years after the December 26, 2004 tsunami disaster, soil samples (10-20 cm) were taken from two adjacent sites located in the agricultural area of Banda Aceh, Aceh Province, Sumatra Island, Indonesia in order to investigate the impact of seawater flooding. The tsunami disaster deposited sediments containing extremely high concentrations of salts and heavy metals. The salt contents (detected as B, Na, Ca, Mg, and Cl), as well as the salinity levels (detected by electrical conductivity, EC) in tsunami-impacted soils still remained significantly increased compared to non-impacted soils, even after 1.5 and 3.5 years of intrinsic bioremediation. Heavy metals such as Pb, Cd, Zn, Cu, Ni, Co, Fe and Cr were significantly higher in impacted soils than in non-impacted soils in 2006, and they remained relatively increased in 2008, except for Cd and Pb which were significantly reduced. Furthermore, the tsunami disaster has led to an increase in macronutrients, such as N, P, K, and S, as well as to an increase in soil organic C content and C/N ratio. The tsunami-impacted soils, as assessed by Fourier transform infrared (FTIR) analysis, contained greater amounts of hydrophilic than hydrophobic organic compounds. The mean pH of soils in tsunami-impacted soils was 7.4 (in 2006) and 7.1 (in 2008), while in non-impacted soils the pH was 5.1 (in 2006) and 5.5 (in 2008). The soil mineral composition, as assessed by XRD analysis, revealed that the tsunami-impacted soils contained the major minerals (quartz, plagioclase and goethite), minor minerals (hornblende and lepidocrocite) and clay minerals (kaolinite, smectite and illite). Non-impacted soils contained major minerals (quartz, plagioclase, goethite and hornblende), minor minerals (lepidocrocite and cristobalite) and clay minerals (kaolinite and smectite). Thus, the tsunami disaster had potentially negative impacts, such as salt and heavy metal pollution, as well as potentially positive impacts, such as increases in major macronutrient contents and clay mineral composition, on agricultural soils.

Additional Key Words: Heavy metals, Salts, Soil organics, Soil minerals, FTIR, XRD.


2 Siti Khodijah Chaerun is an Assistant Professor, School of Life Sciences and Technology, Bandung Institute of Technology, Ganesa 10, Bandung 40132, West Java, Indonesia; William B. Whitman is Professor of Microbiology, Department of Microbiology, The University of Georgia, Athens, GA 30602; Stephan J. Wirth and Ruth H. Ellerbrock are a Senior Researcher, Leibniz Centre for Agricultural Landscape Research (ZALF), Eberswalder Str. 84, D-15374 Müncheberg, Germany.
BIOGEOCHEMICAL CHARACTERIZATION OF AGRICULTURAL SOILS POLLUTED BY INDUSTRIAL WASTEWATERS: IMPLICATIONS FOR BIOREMEDIATION

Siti K. Chaerun\textsuperscript{2}, and William B. Whitman

\textbf{Abstract:} Agricultural soils located in Rancaekek, Bandung, West Java, Indonesia have been heavily polluted by industrial effluents for many years. Recent efforts to remediate the heavily polluted sites have failed due to incomplete understanding of the site characteristics. Hence, this study dealt with the biogeochemical characterization of these soils to acquire a better understanding of the biogeochemical impacts and eventually improve their soil quality so that they would again be suitable for agriculture. The polluted soils contained much higher salt concentrations, higher salinity, and elevated levels of heavy metals (Cr, Mn, Co, Ni, Cu and Zn) than unpolluted soils at control sites. Both soils had pH values of 5.9 - 6.6. The polluted soils also had higher levels of maximum water holding capacity (MWHC: 0.8 g water/g soil), exchangeable sodium percentage (ESP: 27-51\%), sodium adsorption ratio (SAR: 2.6-7.3) and swelling factor (0.4-0.6) than unpolluted soils (MWHC: 0.7 g water/g soil, ESP: 1.3-2.3\%, SAR: 0.1-0.2, swelling factor: 0.03-0.04). The soil basal CO\textsubscript{2} respiration (as overall potential soil microbial activity) in polluted soils was significantly higher than that unpolluted soils ($P < 0.05$). BIOLOG analysis showed that the functional diversity of the microbial community in polluted soils was significantly greater than that in unpolluted soils. NCS and ED-XRF analyses revealed that polluted soils contained elemental sulfur, which was lacking from unpolluted soils. XRD analysis showed that both polluted and unpolluted sites contained important minerals and clay minerals that are essential for both plant and microbial growth. These results indicate that the industrial wastewater-polluted agricultural soils have major changes in their biogeochemical characteristics, therefore being informative to the development of bioremediation strategies of these soils.

\textbf{Additional Key Words:} ESP, Heavy metals, Salinity, SAR, Soil basal CO\textsubscript{2} respiration, BIOLOG.

---

\textsuperscript{1} Poster was presented at the 2009 National Meeting of the American Society of Mining and Reclamation, Billings, MT \textit{Revitalizing the Environment: Proven Solutions and Innovative Approaches} May 30 – June 5, 2009. R.I. Barnhisel (Ed.) Published by ASMR, 3134 Montavesta Rd., Lexington, KY 40502.

\textsuperscript{2} Siti Khodijah Chaerun is an Assistant Professor, School of Life Sciences and Technology, Bandung Institute of Technology, Ganesa 10, Bandung 40132, West Java, Indonesia; William B. Whitman is Professor of Microbiology, Department of Microbiology, The University of Georgia, Athens, GA 30602.
MICROBIAL BIOMASS IN RECLAIMED SOILS FOLLOWING COAL MINING IN VIRGINIA

H.G. Clayton, A.F. Wick, and W.L. Daniels

Abstract: It is well known that soil microbial communities reestablish following disturbance, but limited research has been done on how long this takes in eastern reclaimed coal mine soils. The objective of this study was to track the development of total microbial biomass in reclaimed mine soils following coal mining in southwestern Virginia. A chronosequence of sites was established based on locally documented shifts in vegetation species with succession (0-2, 5-7, 18-20, and 38-42 yr old) on reclaimed sites with undisturbed adjacent sites used as a reference. The 0-2 yr old sites were covered with annual and perennial grasses and forbs, the 5-7 yr sites by thick stands of Lespedeza cuneata, the 18-20 yr sites predominately with Festuca arundinaceae and patches of deciduous trees, and the 38-42 yr old sites with a mix of planted conifers and native Appalachian hardwoods with a grass understory. Undisturbed sites predominately supported mixed Appalachian hardwoods with a mixed forb/grass understory. Four samples were taken from each site age (3 replicates) at the 0-5 cm depth. Chloroform-fumigation-extraction was used to determine total organic carbon from lysed microbial cells as a proxy for microbial biomass. Microbial biomass carbon (MBC) did not vary significantly among any of the site ages sampled; however, a general trend of increasing MBC from a low level in the more recently reclaimed sites (131-138 g microbial C kg$^{-1}$ soil) to a higher level of MBC in the 16-20 and 38-42 yr sites (280 and 244 g microbial C kg$^{-1}$ soil, respectively) was observed. This indicated a recovery of soil microbial communities with time; possibly well within the 5-year vegetation liability release period mandated by the Surface Mining Control and Reclamation Act (SMCRA).

Additional Key Words: Succession, chronosequence, Appalachian hardwoods, soil quality.

TOPSOIL: WHAT IS IT AND WHO CARES?¹
R.G. Darmody, W.L. Daniels, J.C. Marlin, and D.L. Cremeens

Abstract. Topsoil means many things to many people, but to everyone it represents the best part of the soil from a plant-growth perspective. Many activities alter the soil profile including surface mining, agriculture, and urban development. Of these, mining is subject to state and national regulations for protection of soil and the USDA has a series of programs to protect topsoil from erosion. The extensive use of mass grading to remove topsoil from entire subdivisions during construction will likely create pressure for additional standards and regulations governing topsoil protection and replacement, as will national efforts to restore brownfields. Topsoil is the subject of mine reclamation regulations and is viewed as something to be protected and preserved, but also something that regulators will allow, in certain situations, to be removed or buried and replaced by a topsoil substitute. When there is a need for a suitable growth medium to support vegetation at a site that has lost its native topsoil due to mining or other earth moving activities, a wide range of materials can be used as topsoil, including subsoil or selected overburden materials. The Surface Mining Control and Reclamation Act (SMCRA) was the first federal statute to specifically define operations involving the handling, storage, and substitution of topsoil. Within SMCRA, “topsoil” is not specifically defined, but the A horizon is identified in the prime farmland subsection, and by implication it is topsoil. SMCRA also specifically allows for the use of topsoil substitutes when the pre-mining A+E horizons are less than 15 cm thick. Blasted sedimentary overburden materials are routinely converted into successful topsoil substitutes in the Appalachian coal mining region, but compaction commonly limits their productivity, and post-mining pH must be carefully matched to intended post-mining vegetation. A wide range of organic and mineral wastes and residual products can be beneficially used for either in-situ soil reconstruction or on-site remediation. Similarly, many run-of-mine mineral wastes can be successfully combined with organic composts to produce commercially viable manufactured topsoils. This paper will review the authors’ experience with “topsoil”, both in a scientific and practical, applied sense. Of necessity, it will focus on surface mine issues, while raising other issues and discussing some case studies.

Additional Key Words: Cover Soil, A Horizon, SMCRA, Landfill Covers, Surface Soils, Restoration, Reclamation, Manufactured Topsoil, Brownfields.

²Robert Darmody is Professor of Pedology, Dept of Natural Res. and Env. Sciences, Univ. of Illinois. Urbana, IL 61801, W. Lee Daniels is Professor, Virginia Tech Dept. of Crop & Soil Env. Sci., Blacksburg, VA 24061-0404, John Marlin is a senior research scientist at Illinois Sust. Tech. Center, Inst. of Natural Resource Sustainability, Univ. of Illinois, and David Cremeens is a Senior Lead Soil Scientist at GAI Consultants, Inc., Pittsburgh, PA.
REVEGETATION OF ACID FORMING GOLD MINING SPOILS CONTAINING HIGH LEVELS OF ARSENIC

Igor R. de Assis, Luiz E. Dias, Renato W. Veloso, and W. Lee Daniels

Abstract: This work was conducted at a large gold mine in Paracatu, MG, Brazil, between March 2000 and November 2005. The waste rock studied was a phyllite which contained (in addition to gold) sulfides such as pyrite and arsenopyrite. The objective was to evaluate the survival and growth of plant species on different combinations of plant growth substrate layers deposited over the spoil. Each combination tested consisted of a cover-layer and a final sealing-layer, both deposited over the remaining, slightly-weathered rock spoils. The treatments were as follows: (T1) a cover layer with 50 cm of partially weathered spoil (B1) with lime added over a compacted sealing layer with 30 cm of B1; (T2) a cover layer with 25 cm of limed native soil over 25 cm of limed B1 over a compacted sealing layer of 30 cm of B1; (T3) a cover layer with 50 cm of limed B1 over a compacted sealing layer of 20 cm of limed soil over 20 cm of unlimed B1; and (T4) a cover layer with 25 cm of limed soil over 25 cm of limed B1 over 20 cm of compacted limed soil over 20 cm of unlimed B1. The plant species used were Acacia farnesiana, A. holosericea, A. polyphylla, Albizia lebbeck, Clitoria fairchildiana, Flemingia sp., Mimosa artemisiana, M. bimucronata, and Enterolobium timbauva. Experimental data included diameter of the stem collar (DC), plant height, and survival counts. The greatest survival rate was observed with T4, at 80%. In general, M. bimucronata and A. farnesiana species showed the highest survival rate. The Scott-Knott test a p ≤ 5% indicated that A. holosericea had the greatest growth-response, while A. polyphylla, Flemingia sp., and E. timbauva exhibited lower growth rates. The bioavailable soil As content from (T1), (T2), (T3), and (T4) was 14.69, 0.00, 10.41, and 0.00 mg dm$^{-3}$, respectively. These experimental results support the conclusion that presence of native soil is essential for establishment of plants and minimization of plant toxins like As in mine reclamation efforts, and that appropriate implementation of layer combinations such as studied here allows greater survival rates and biomass gains.

Additional Key Words: Arsenopyrite, land reclamation, legumes

---


2 Igor R. de Assis is a Ph.D. Student, Luiz E. Dias is Associate Professor, and Renato W. Veloso is a M.S. Student, Soils Department – Federal University of Viçosa, Viçosa, MG – Brazil. Av. Ph Rolfs, s/n. 36570-000, W. Lee Daniels is Professor, Department of Crop and Soil Environmental Sciences, 0404, Virginia Polytechnic Institute and State University, Blacksburg, Virginia 24061.
EVALUATION OF ACID MINE DRAINAGE TREATMENT USING Artemia sp. AND Allium cepa AS BIOINDICATORS OF TOXICITY AND GENOTOXICITY1.

Tamires M. Defaveri2, Fernanda Z. da Silveira, Tiago Bortolotto, Reginaldo Geremias, Jairo J. Zocche and Claus T. Pich

Abstract. Coal mining produces residues containing high levels of heavy metals and other components that contaminate surface and ground water. This research evaluated the efficiency of physical, chemical, and biological treatment of acid mine drainage using alternative biological indicators Artemia sp. (brine shrimp) and Allium cepa L. (onion). Samples were collected at four stations that are located at specific treatment system: 1) pH control and precipitation, 2) biological damping pond outlet, 3) wetland inlet, and 4) wetland outlet. Acute toxicity analysis using Artemia sp. was performed at sample concentrations of 25, 50, 80, 90, and 100%. Toxicity in A. cepa was observed as root growth inhibition after a seven-day exposure period at 100% effluent concentration. Genotoxicity was observed in A. cepa meristematic cells using the comet assay that evaluates DNA strand breaks in single cells. Artemia sp. test results indicated a reduction of lethality in station 4 (less than 30%) when compared to station 3 (100%), indicating that the wetland is effective at reducing residue toxicity for these organisms. The high lethality at Station 3 was investigated and resulted in the discovery that contaminated ground water from residue leachate was entering the treatment system between Stations 2 and 3. Root growth inhibition showed no significant results, indicating that the effluent has no activity to A. cepa considering this parameter. The comet assay results indicate that stations 1 and 2 are genotoxic and a significant reduction can be observed after the biological processes, particularly at the wetland output. Thus, the results obtained indicate that Artemia sp. is a suitable bioindicator for toxicity assays of this effluent and that A. cepa is only suitable for evaluating genotoxicity. We can also observe that the treatment process is efficient at eliminating effluent toxicity and reducing genotoxicity.

Additional Key Words: Coal, Wetland, Bioremediation, DNA Damage.


2 Tamires M. Defaveri, Fernanda Z. da Silveira and Tiago Bortolotto are students of Biological Sciences Curse, Reginaldo Geremias is a Professor, Jairo J. Zocche is a Ph.D. and Claus T. Pich is a Ph.D. Candidate of Dept. of Biological Sciences of Extremo Sul Catarinense University, UNESC. 1105, University Avenue, CEP: 88806-000, Criciúma, Santa Catarina State, Brazil.
Prioritizing Abandoned Uranium Mine Land Reclamation Using a GIS Model

Linda S. DeLay, Susan A. LucasKamat, and James R. Smith

Abstract: Abandoned uranium mines left a legacy of probable contamination in New Mexico. The New Mexico Mining and Minerals Division is collaborating with state, federal and tribal agencies to inventory and prioritize the reclamation of abandoned uranium mines. As a pilot project, the New Mexico Abandoned Mine Land Program sampled data from 38 abandoned uranium mine disturbances. Mine attributes, including radiation readings, mine disturbance areas, waste pile volumes, shaft and adit dimensions, cultural features and mine access roads, were collected using Trimble Pro XRS and XH GPS units utilizing a Pathfinder data dictionary. Radiation measurements were collected using Ludlum Model 14-C and Model 19 survey meters. Data of the various mine attributes were integrated into a personal geodatabase.

ESRI ArcGIS Spatial Analyst was used to build a model to prioritize the 38 abandoned uranium mines for remedial action. Mines were ranked by potential risk exposure to populations. Model inputs included the mine locations and proximity to dwellings, domestic wells and watercourses, density of mine openings and presence of high radiation readings. Thirty-five percent of the sites were less than 1.2 kilometers (0.7 miles) from a domestic well and less than 16 meters (52.5 feet) from watercourses. Sixteen percent were within 8 kilometers (5 miles) of a densely populated area; two sites were surrounded by dwellings.

ESRI ArcGIS Spatial Analyst was used to reanalyze the model with additional data for 108 abandoned uranium mine disturbances. Changes in priority ranking of mine sites are examined and discussed.

Additional Key Words: geodatabase, ArcGIS, Spatial Analyst, model

---


2 Linda S. DeLay is a GIS Analyst Specialist, Coal Mine Reclamation Program, New Mexico Mining and Minerals Division, 1220 S. St. Francis Dr., Santa Fe, NM 87505. Susan A. LucasKamat is a Geologist, Mine Registration Program, New Mexico Mining and Minerals Division, James R. Smith is a Reclamation Designer, Abandoned Mine Land Program, New Mexico Mining and Minerals Division.
POTENTIAL OF THREE LEGUME SPECIES FOR PHYTOREMIEDIATION OF ARSENIC CONTAMINATED SOILS

Luiz E. Dias, Roseli F. Melo, Jaime W. V. Mello, Juraci. A. Oliveira, and W. L. Daniels

Abstract. Phytoremediation strategies utilize plants to decontaminate or immobilize soil pollutants. Among soil pollutants the metalloid arsenic (As) is the one of primary concern. Elevated soil As results from anthropogenic activities such as use of pesticides (herbicides and fungicides), use of certain fertilizers, metal mining, iron and steel production, coal combustion, and from coproduction during natural gas extraction. This study evaluated the potential of pigeon pea (Cajanus cajan), wand riverhemp (Sesbania virgata), and lead tree (Leucaena leucocephala) for phytoremediation of soils polluted by As. Soil samples were placed in plastic pots, incubated with different As doses (0, 50, 100, and 200 mg dm\(^{-3}\)) and then sown with seeds of these three species. Ninety days after sowing, the plants were evaluated for height, collar diameter and dry matter of young, intermediate and basal leaves, stems and roots. Arsenic concentration was determined in different aged leaves, stems and roots to establish the translocation index (TI) between plant roots and aerial plant components. The evaluated species showed distinctly different characteristics with respect to As tolerance, since the lead tree and wand riverhemp were significantly more tolerant than pigeon pea. High As levels found in wand riverhemp roots suggest the existence of an effective mechanism of accumulation and compartmentalization in order to reduce As translocation to aboveground tissues. Pigeon pea is a sensitive species and could serve as a potential bioindicator plant, whereas the other two species have potential for phytoremediation programs in As polluted areas. However, further studies are needed with longer exposure times in actual field conditions to reach definitive conclusions on the relative phytoremediation potentials on these species.

Additional Key Words: remediation, decontamination, Cajanus cajan, Sesbania virgata, Leucaena leucocephala.


A METHOD FOR ASSESSING VEGETATION ADEQUACY FOR PHASE II BOND RELEASE IN MONTANA\textsuperscript{1}

Shannon Downey\textsuperscript{2} and Alan Boehms

\textbf{Abstract.} Phase II bond release is defined in Montana as “soil replacement and soil tillage being completed and perennial vegetation establishing that is consistent with revegetation criteria” (ARM 17.24.1116). Office of Surface Mining Reclamation and Enforcement (OSMRE) rules (30 CFR 800.40) define Phase II bond release as “after revegetation has been established on the regraded mined lands in accordance with the approved reclamation plan.” These definitions are similar, but not identical, and neither definition mandates quantitative measures that provide objective standards for judging success or failure. In the past, judgments have sometimes differed between various mine inspectors. This problem is exacerbated in years where high production of introduced opportunistic species, such as annual bromes (\textit{Bromus tectorum}, \textit{B. japonicus}) or yellow sweetclover (\textit{Mellilotus officinalis}), may obscure the perennial vegetation.

A method for determining the adequacy of vegetation establishment for Phase II bond release for surface coal mines in Montana is described. The method is designed to be quick, easy, and objective. It is used only for areas where questions or disagreements between regulatory personnel exist. The method assesses the percentage of 0.1 m\textsuperscript{2} sample hoops that contain adequate perennial vegetation. We provide details for the method used in Montana, and we discuss potential adaptations for other geographic areas as well.

\textbf{Additional Key Words:} vegetation standards, mine reclamation


\textsuperscript{2} Shannon Downey is a Fish and Wildlife Biologist, US Fish and Wildlife Service, Helena, MT, 59601; when this work was completed she was a Reclamation Ecologist, Montana Department of Environmental Quality, Helena, MT 59620; Alan Boehms is a Permitting Coordinator, Office of Surface Mining Reclamation and Enforcement, Casper, WY 82601.
MONTANA’S FRAMEWORK FOR ESTABLISHING TECHNICAL VEGETATION STANDARDS

Shannon Downey, Darrel Myran, and Rick Williamson

Abstract. In order to achieve Phase III bond release, vegetation on reclaimed surface mines must be compared with unmined reference areas or technical vegetation standards. Technical standards may be developed from historical data or from USDA, USDI, or other relevant government or academic publications. The reference areas or standards used must represent lands with “good ecological integrity,” and cover and production must equal the comparison within specified tolerances. Other requirements include that the vegetation be “diverse, effective, and permanent,” primarily native (except for improved pastureland), and have similar seasonality to unmined vegetation. One of the impediments to Phase III bond release in Montana has been the difficulty in developing a metric for such factors as diversity and ecological integrity. Exact comparisons with reference areas were problematic in a practical as well as a theoretical sense. In the interests of moving forward with bond release on reclaimed lands that were well past the 10-year responsibility period, the Montana Department of Environmental Quality established a framework for mine operators to use in developing technical vegetation standards. The framework is based on the use of Ecological Site Descriptions from USDA Natural Resources Conservation Service and the methodology presented in Interpreting Indicators for Rangeland Health (TR 1734-6 USDI Bureau of Land Management). We describe the framework and provide an example of vegetation standards consistent with the framework that were developed for the Absaloka Mine in southeastern Montana.

Additional Key Words: mine reclamation, Phase III bond release, ecological site descriptions, rangeland health.


2 Shannon Downey is a Fish and Wildlife Biologist, US Fish and Wildlife Service, Helena, MT, 59601; when this work was completed she was a Reclamation Ecologist, Montana Department of Environmental Quality, Helena, MT 59620; Darrel Myran is Vice President, Westmoreland Resources, Inc., Hardin, MT 59034; Rick Williamson is Senior Ecologist, Office of Surface Mining Reclamation and Enforcement, Denver, CO 80201.
RECENT DEVELOPMENTS IN CLOSE RANGE PHOTOGRAMMETRY FOR MINING AND RECLAMATION

Maynard L. (Mike) Dunn, Jr.

Abstract: Detailed topography is important, if not vital, to not only characterize Abandoned Mined Land (AML) problems (landslides, subsidences, refuse piles, highwalls, etc.) but also to verify active mining and reclamation (monitoring backfilling and grading, stream reconstruction, Prime Farmland stockpiling and replacement, confirming as-built designs, etc.) Traditional and newer methods for acquiring detailed topography have been limited to: (1) aerial photogrammetry and on-site surveys; and (2) high-precision Geographic Positioning System (GPS) surveys and Light Detection and Ranging (LiDAR). Unfortunately, all four of these methods have the same expensive downsides: If an organization does the work in-house, resources must be diverted from other tasks. If contracted, the organization may have to pay a premium for timely work. In addition, there are always scheduling issues and in-house work, may mean special training and expensive equipment. Close Range Photogrammetry (CRP) has a lot of potential to supplement and maybe even replace traditional methods like surveying, kinetic GPS, tripod LiDAR, and aerial photogrammetry. However until last year, CRP was not practical and often as costly as the other methods. In mid-2008, new software became available that could turn a $200 digital camera into a precision mapping tool. The Technical Innovations and Professional Services (TIPS) Remote Sensing Team is evaluating the software and techniques under a variety of field conditions; comparisons, examples, and problems found during the research are presented as are suggestions for future work.

Additional Key Words: remote sensing, terrestrial photogrammetry, non-metric camera, point clouds, field scanning

2 Maynard L. (Mike) Dunn, Jr. is a Geologist, Office of Surface Mining and Reclamation Enforcement, 3 Parkway Center, Pittsburgh, PA 15220,
MINE WATER TREATMENT AT SOUDAN STATE PARK

P. Eger

Abstract: Soudan State Park contains an underground iron mine which discharges on average around 60 gallons per minute. Annual average concentrations of copper ranged from 0.083 to 0.5 mg/L and 0.006 to 0.026 mg/L for cobalt, both in excess of current permit standards.

The Department of Natural Resources has been working on the site for over 10 years. However, due to budget problems, land ownership issues, internal policies and an unexpected change in water quality, the discharge still exceeds standards. In 2006, the Department was fined and signed a stipulation agreement. A consulting firm was hired to evaluate treatment options and recommended building a wetland treatment system. A sulfate reducing bioreactor and an aerobic polishing pond was proposed. Construction, which was to start in June 2008, was bid at about $600,000.

The new permit authorizing the construction included a mercury monitoring requirement. Northern Minnesota lakes have fish consumption advisories due to elevated mercury levels and low level mercury monitoring is part of all new NPDES permits. Total mercury of 40 – 60 ng/l, much higher than the 6.9 ng/l standard, was measured in the discharge. Mercury concentrations were elevated throughout the upper portion of the mine with some values exceeding 100 ng/l.

Limited data from previous studies had shown that although wetland treatment systems could remove total mercury, low levels of methyl mercury could be produced. Given the high level of mercury in the discharge and the concern over methyl mercury production, construction was postponed. The Department was asked to develop an interim treatment process that would reduce copper and cobalt without increasing methyl mercury. Three systems were evaluated including: ion exchange process, peat pellets (APTsorb™) and chemical treatment with a rotating cylinder. The RCTS™ was chosen for additional evaluation. Preliminary results have indicated that treatment with magnesium hydroxide could achieve permit levels for copper and cobalt.

Additional Key Words: wetland treatment, rotating cylinder treatment system, ion exchange, peat pellets, copper, cobalt, mercury


2 Paul Eger, Principal Engineer, Minnesota Dept. of Natural Resources, St. Paul MN 55155,
FIRST YEAR RESPONSE OF MIXED HARDWOODS AND IMPROVED AMERICAN CHESTNUTS TO COMPACTION AND HYDROSEED TREATMENTS ON RECLAIMED MINE LAND

C. Fields-Johnson, C. E. Zipper, J. A. Burger and D. M. Evans

Abstract. There is increasing interest in the restoration of native Appalachian hardwood forests using the Forestry Reclamation Approach (FRA) on sites that are being reclaimed following surface mining for coal. Additionally, much interest has developed in the deployment of American chestnut trees that have been improved through breeding to have both blight resistance and timber tree stature. Including chestnuts in planting mixes for the FRA is one potential method to efficiently re-introduce them in the central Appalachian region, but the viability of this method needs to be assessed. There are further questions regarding how choices of herbaceous vegetation and grading practices affect tree survival and growth and plant succession on reforested mine sites. A new experiment combining components of the FRA with plantings of American chestnut trees was begun in the spring of 2008 on active coal-mining sites in Virginia with the goal of directly assessing the effects of grading and groundcover treatments on reforestation success, using a planting mix that includes American chestnut. On each of the three sites: half of the experimental area was smooth-graded and tracked-in as per common reclamation practice, and the other half was loose-graded as recommended using the FRA. Within each grading treatment plot, one third of the area was hydro-seeded with a conventional herbaceous vegetation mix, one third was seeded with a tree compatible herbaceous mix and one third was seeded with annual ryegrass. All treatments were planted with a mix of native hardwood trees. The loose-graded sections were also planted with six genotypes of chestnut, including pure American, Chinese, and American x Chinese crosses. Tree survival and growth, groundcover, and native plant volunteers were measured. After one growing season, tree survival was not affected by any of the experimental treatments. The tree compatible mix and the conventional mix provided significantly more ground cover by August than did the annual rye. Loose grading reduced soil loss compared to smooth grading. Chestnut trees grown from planted nuts were competitive with other species’ survival rates.

Additional Key Words: compaction, ground cover, reforestation, native hardwoods, American chestnut, reclamation, mine land succession


2 Christopher Fields-Johnson, Graduate Research Assistant, James A. Burger, Professor of Forestry, Dept. of Forestry, VA Tech, Blacksburg, VA, 24061. Carl E. Zipper, Associate Professor, Department of Crop and Soil Environmental Science, VA Tech, Daniel M. Evans, Research Associate, Department of Forestry, VA Tech.
PERFORMANCE OF A FULL-SCALE HORIZONTAL-FLOW WETLAND FOR ZINC

Mark Fitch and Jeff Schoenbacher

Abstract. Park City Municipal Corporation (PCMC) long before being recognized as an Olympic venue was known as one of the great American silver mining towns. As a result, during a century of active mining, the Park City mining district produced millions of ounces of silver in addition to a substantial amount of mine tailing waste. As a result, the City since 1985 has been remediating these impacts with state and federal oversight. One particular challenging CERCLIS site, that was previously a historic mine tailings pond is known as Prospector Square Development (CERCLIS Listing Silver Creek Tailings UTD98051404). This site has been very challenging due to the metals that impact shallow ground water that eventually drain into the Silver Creek Watershed. To address the water quality impairment the City and Missouri University of Science and Technology teamed-up to investigate the feasibility of constructing a horizontal-flow wetland to treat this pollutant source. This effort comprised of building a pilot cell in June of 2004, leading to the construction of a full scale horizontal-flow wetland in the fall of 2008. The design of the pilot and full scale biocell was based upon lab-scale research conducted by the Missouri University of Science and Technology. In October of 2008, the Prospector Drain effluent was introduced to the system and to date analytical results reveal that the biocell is treating the Prospector Drain outfall below the Silver Creek Total Maximum Daily Load (TMDL) endpoint goals for zinc .39 mg/L and cadmium .00075 mg/L. The water chemistry of the influent, that originates from the historic silver mine tailings pond, is impaired with zinc and cadmium and has low iron with a pH of roughly 6.5. The construction of this unit encountered many challenges related to constituent relations, regulatory scrutiny, constructability, and start-up. Nonetheless, this unit since implementation is considered a success for improving water quality within the Silver Creek Watershed.

2 Mark Fitch is an Associate Professor of Civil Architectural and Environmental Engineering, Missouri University of Science and Technology, Rolla, MO 65409-0030. Jeff Schoenbacher is Environmental Coordinator for Park City Municipal Corporation, Park City, Utah 84060-1480.
SOIL RESPREAD DEPTHS: DO WE KNOW ENOUGH TO IMPLEMENT CHANGE?¹

Sarah J. Flath²

Abstract: Current North Dakota soil respread regulations are based on research conducted in the mid 1980’s. Regulations include a buffer that was added to the respread depths suggested by research to account for the unknown behavior of reclaimed sites over time as spoil weathers and plant communities mature. These unknowns have since been largely addressed by long-term studies of reclaimed sites. Studies have also shown that season of growth (C₃ vs. C₄) and origin (native vs. introduced) do not change the response of perennial grasses to soil respread depth. Therefore, respread recommendations may now be based on the results of research that include introduced species, and possibly without the addition of a buffer. After a review of literature it appears that respread depths may be reduced. A reduction in soil respread depths would result in less soil salvaged, stockpiled and respread, thus reducing reclamation costs for the mine without negatively effecting reclamation success. However, before changes to respread requirements are made, we must be confident this will not have a negative impact on the revegetation success of a site or of its capability to support other land uses in the future. Therefore, before ND mines can put into practice the recommendations of past research, issues regarding the effects on annual cropland, woody species and the behavior of sodium in the reclaimed soil profile must be resolved.

² Sarah J. Flath is the Operations Planner for North American Coal, Freedom Mine, Beulah, ND 58523
EFFECTS OF SEEDLING SIZE AND GROUND COVER ON THE FIRST-YEAR SURVIVAL OF PLANTED PINE AND HARDWOODS OVER AN EXTREME DROUGHT\textsuperscript{1}

J.A. Franklin\textsuperscript{2} and D.S. Buckley

Abstract: Poor growth and survival has been noted in tree seedlings planted into an existing ground cover. Such observations are ascribed to competition between root systems of ground cover and trees for water and nutrients. During drought, competition for water becomes intense and could result in mortality. Seedlings of shortleaf pine, green ash, northern red oak, and shagbark hickory were planted on twelve plots on a loosely graded ridge-top in eastern Tennessee that had been reclaimed and planted with native warm season grasses in 2006. Plots were planted in spring of 2007 with pine alone, hardwoods (ash, oak and hickory) alone, or alternating pine and hardwood seedlings. Planting was followed by an extreme and extended drought. In December of 2007, survival of shortleaf pine averaged 35\%, while northern red oak averaged 95\%, green ash 87\%, and hickory 88\%. Seedling size at time of planting was related to the probability of survival, with larger seedlings showing low mortality rates. Survival was greater on the northwestern facing slope, while seedlings on the southeastern slope had the greatest growth. Cover of native grasses at the time of planting ranged from 8 to 44\%, but there was no clear relationship between ground cover density and seedling survival.

Additional Key Words: competition, Quercus, Carya, Pinus, Fraxinus

\textsuperscript{1}Paper was presented at the 2009 National Meeting of the American Society of Mining and Reclamation, Billings, MT, Revitalizing the Environment: Proven Solutions and Innovative Approaches May 30 – June 5, 2009. R.I. Barnhisel (Ed.) Published by ASMR, 3134 Montavesta Rd., Lexington, KY 40502.

\textsuperscript{2}Jennifer Franklin, Assistant Professor, University of Tennessee, Department of Forestry, Wildlife, and Fisheries, 274 Ellington Plant Science, Knoxville, TN 37996. David Buckley, Associate Professor, University of Tennessee, Department of Forestry, Wildlife, and Fisheries, 274 Ellington Plant Science, Knoxville, TN University of Tennessee, Knoxville, TN.
ENHANCED MICROBIOLOGICAL GENERATION OF COALBED METHANE\textsuperscript{1}

Lisa Gallagher\textsuperscript{2}, Junko Munakata-Marr, Lee Landkamer, Linda Figueroa, Andy Glossner, Kevin Mandernack, Steve Harris, Yiping Liu, David Bagley, Wesley Rodgers, Franco Basile, Zaixing Huang, Michael Urynowicz

\textbf{Abstract.} Vast reserves of coal represent a very large source of energy in the United States. Research has shown that microorganisms are capable of converting coal to methane, though at widely different rates under controlled laboratory conditions. Laboratory experiments have shown that the gas associated with coal can be microbially enhanced from typical values of 60 SCF/ton to as much as 300 SCF/ton. If 1\% of the coal in the Powder River Basin could be converted to methane by stimulating existing microorganisms in the coal beds, approximately 30 TCF of gas would be produced, dramatically increasing reserves and profitability. Indeed, much of currently produced coalbed methane (CBM) is of biological origin (e.g., Powder River Basin, WY). The methane is produced by methanogenesis, a process in which microorganisms (methanogens) convert substrates such as acetate or CO\textsubscript{2} and hydrogen into methane. However, the processes leading to methanogenesis in coal are not well understood. This project involves a systematic investigation of different components of methanogenesis to better understand how the process could be enhanced and accelerated. Specifically, we are examining the efficacy of adding nutrients needed by the organisms to the coal and chemical pre-treatment of the coal to release soluble organic matter to stimulate methanogenesis. Additionally, we will characterize and monitor the microbial populations, their response to these manipulations, and the chemical pathways to gain an understanding of the processes, the rate limiting steps and the interactions between microbial communities. An improved understanding of the overall process may ultimately allow optimal stimulation of the conversion of coal to methane.

\textsuperscript{1}Poster was presented at the 2009 National Meeting of the American Society of Mining and Reclamation, Billings, MT, \textit{Revitalizing the Environment: Proven Solutions and Innovative Approaches} May 30 – June 5, 2009. R.I. Barnhisel (Ed.) Published by ASMR, 3134 Montavesta Rd., Lexington, KY 40502.

\textsuperscript{2}Lisa Gallagher, and Andy Glossner are Graduate Research Assistants, Colorado School of Mines, Golden, CO 80401, Junko Munakata-Marr, Linda Figueroa, and Kevin Mandernack are Associate Professors, and Lee Landkamer are Graduate Research Assistants, Colorado School of Mines, Golden, CO 80401 is Research Associate. Steve Harris is Microbiologist, US Geological Survey, Geologic Discipline, Denver Federal Center, Bldg. 53, MS 977, Denver, CO 80225. Yiping Liu, Wesley Rodgers, and Zaixing Huang are Graduate Research Assistants, University of Wyoming, Laramie, WY 82071, David Bagley is Professor, Franco Basile is Assistant Professor, and Michael Urynowicz is Associate Professor, University of Wyoming, Laramie, WY 82071.
ACID MINE DRAINAGE IMPACTS ON IRRIGATION WATER RESOURCES, AGRICULTURAL SOILS, AND POTATOES IN POTOSÍ, BOLIVIA


Abstract: Intensive metal mining has occurred for nearly 500 years in the high altitude, arid desert of Potosí, Bolivia. Acid mine drainage (AMD) discharges have contaminated local water resources, rendering them unsuitable for agricultural and domestic use. However, due to water-limited conditions, many agricultural areas in the region make use of AMD-contaminated streams, with elevated trace metal concentrations, for irrigation. This study investigated the effects of AMD contaminated surface water irrigation sources upon the soils and crops to which they have been applied. Soil, water, and potato samples were gathered from four agricultural locations affected by AMD and one reference site. The AMD-influenced irrigation waters had trace metal concentrations that exceeded United Nations Food and Agriculture Organization (UNFAO), Canadian, and Australian guidelines for irrigation water. These waters had pH of 2.75 - 8.55, specific conductance of 150 - 2,900 µS/cm, 1.8 - 99 mg/L Cl⁻ and 32 - 2,000 mg/L SO₄²⁻. Total metals determined concentrations in irrigated waters were in the range of 0-35 mg/L Cu, 0-0.33 mg/L Pb, 0.43-110 mg/L Fe, 0.09-1180 mg/L Zn, 0.05-54 mg/L Mn, and 0-11 mg/L Cd. Agricultural soils contained total metal concentrations in the range of 5-520 mg/kg Cu, 12-670 mg/kg Pb, 12000-34000 mg/kg Fe, 99-3200 mg/kg Zn, 260-4200 mg/kg Mn, and 1-18 mg/kg of Cd. The Cu, Pb and Zn concentrations were greater in the exposed soils than in reference soils. Trace metal concentrations in the exposed soils exceeded Dutch, Canadian, and German guidelines. The levels of Cd, Pb, and Zn in potatoes exceeded commercially-sold vegetable guidelines. The agricultural products produced in this region may represent a potential health risk to subsistence farmers and other consumers.

Additional Key Words: acid rock drainage, farming, potatoes


2 Alan E. Garrido, Graduate Research Assistant, William H. Strosnider, 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, 202 West Boyd St. Norman, OK 73019, Janette Condori, Laboratory Technician, Centro de Investigación Minero Ambiental, Av. Arce esq. Villazón s/n Facultad de Ingeniería Minera, Bolivia.
SELECTION AND RELEASE OF INDIGENOUS PLANT MATERIALS FOR THE ANACONDA SMELTER SUPERFUND SITE - ‘OPPORTUNITY’ GERMLASM NEVADA BLUEGRASS

E.C. Graham, S. Majerus, M.E. Majerus, J. D. Scianna and R.M. Hybner

Abstract: The Development of Acid/Heavy Metal Tolerant Releases (DATR) project [formerly the Development of Acid/Heavy Metal Tolerant Cultivars (DATC) project], was initiated in 1995 to address a critical need for native plants adapted to the edaphic and climatic conditions found in the Anaconda – Butte area. The goal of the project was to select plant materials demonstrating superior tolerance of low pH and/or heavy metal contaminated soils that are also adapted to the severe environmental conditions characterized by the intermountain foothills and mountains of Montana and Wyoming. Whereas most seeds and plants used for mine land reclamation have been cultivar releases from universities, USDA Plant Materials Centers, USDA Agricultural Research Service, or private plant breeders, pre-varietal release is a streamlined process encompassing a series of release classes determined by incremental levels of specified testing. The time interval to release and commercial availability of selected material can be reduced by as much as half by using pre-varietal release versus the traditional cultivar.

To date, the DATR project has assembled 130 seed collections of 72 native species of grasses, forbs, shrubs, and trees within the Upper Clark Fork River Basin (UCFRB). These collections have been planted at various study sites in comparison with non-local native and introduced plant species. Five species indigenous to the UCFRB have demonstrated superior survivability and vigor on amended acidic, heavy metal-contaminated soils at varying elevations in western Montana, and have been released through the DATR project using the Pre-Varietal release mechanism.

Opportunity Germplasm Nevada bluegrass is one of three selections made from indigenous material collected near Anaconda, Montana and tested at Stucky Ridge. In 2006, this selection proved significantly (ANOVA; Tukey; p=0.05) superior to four other seed sources (2 indigenous; 2 cultivars) for percentage stand cover, vigor rating, and biomass production on a lime and fertilizer amended site.

---


2 Elizabeth C. Graham, Environmental Engineer, DATR Project Leader, Shannon Majerus, former DATR Technician, Mark E. Majerus, former Manager, Joseph D. Scianna, Research Horticulturist, and Roger M. Hybner, Manager, all from USDA-NRCS, Bridger Plant Materials Center, 98 South River Road, Bridger, MT. 59014
GRASS ESTABLISHMENT ON NATURAL GAS DRILL PADS IN WYOMING AS IMPACTED BY RECLAMATION TECHNIQUES

Samantha J. Gundlach, Douglas J. Dollhopf, and Kevin C. Harvey

Abstract: In the semiarid West, establishing perennial vegetation is often difficult on newly constructed natural gas drill pads because of harsh site conditions. Southern Wyoming is characterized by low precipitation and sites can have saline and/or sodic soil and steep slopes. Twenty-five combinations of reclamation techniques were evaluated on six Devon Energy Corporation natural gas drill pads in the Washakie Basin near Baggs, Wyoming. Treatments included combinations of soil ripping, fertilizer applications, gypsum or sulfur application, chopped straw or woodchip amendments, imprinting, pitting, mulch, irrigation, fencing and site-specific seed mixes. Grass density was measured ten months after treatment implementation on five drill pads and six weeks after implementation on one drill pad. Irrigation during plant establishment was beneficial on all sites, increasing grass density 92% on average compared to areas not irrigated. Wood chips, gypsum and fertilizer; and chopped straw, sulfur and fertilizer treatments, both with and without irrigation significantly increased grass establishment on saline-sodic soils. Irrigation and fertilizer, and fertilizer alone produced little to no grass establishment on saline-sodic soils, suggesting some treatment for the saline-sodic condition was necessary for grass establishment. Imprinting significantly increased grass densities on both saline and non-saline soils and on sloped sites by providing protected microclimates for seedling growth. Pitting produced lower grass density than imprinting, and most likely cut through the topsoil and exposed lower quality subsoil material. Straw mulch increased grass density when used in combination with irrigation, but did not increase density when used with other treatments on a site with low salinity and sodicity. On the same site, grass density was 89% higher on average when treatments did not include fertilizer. At least one reclamation treatment on each site produced grass density of at least 80% of that found in the adjacent native range. These reclamation techniques can significantly decrease the time required to reach plant re-vegetation requirements.

Additional Key Words: semiarid land reclamation, soil amendment, straw mulch, woodchips, pitting, imprinting

2 Samantha J. Gundlach is a Range Scientist with KC Harvey, Inc., Bozeman, MT 59715, Douglas J. Dollhopf, Ph.D. is Professor Emeritus Soil Science and Land Rehabilitation, Montana State University, Bozeman, MT 59715, and Kevin C. Harvey is President and Chief Scientist of KC Harvey, Inc., Bozeman, MT.
USING ARCPAD® TO IDENTIFY SOIL PROBE LOCATIONS FOR VERIFYING SOIL RESPREAD THICKNESS ON RECLAIMED LAND

William T. Gunnerson

Abstract: North Dakota Public Service Commission (NDPSC) policies require that soil respread thickness be verified by soil probing reclaimed land prior to bond release approval. The topsoil and subsoil thicknesses observed from soil probing were compared to those presented on the bond release application soil respread thickness map. Soil respread thicknesses usually vary within the bond release area as grade approvals were submitted during contemporaneous reclamation. The objective of this paper was to identify soil probe locations within soil respread thickness boundaries using tablet computer software. The use of ArcPad software with GPS positioning on a tablet computer allowed accurate probe placement within soil respread thickness boundaries when displayed on geo-referenced raster images or as shapefile polygons. The topsoil and subsoil thickness observations and supporting data were recorded in an ArcPad QuickForm® created for the soil probe location shapefile. The QuickForm was activated by capturing a GPS point at each probe location. Additional data fields of the soil probe shapefile attribute table were populated after adding the shapefile to an ArcMap® map document. The shapefile attribute table was exported to analyze the data in spreadsheet form. Soil probe locations collected as spatial data in ArcPad allow subsequent analysis and display in an ArcMap map document.

Additional Key Words: suitable plant growth material, grade approval, bond release, point location


2 William T. Gunnerson is an Environmental Scientist, Reclamation Division, North Dakota Public Service Commission, Bismarck, ND 58505-0480
A PERIODIC TABLE OF PASSIVE TREATMENT FOR MINING INFLUENCED WATER

James J. Gusek

Abstract. The technical community of regulators and engineers that specializes in passive water treatment should be familiar with the passive treatment “decision tree” that was published by the former US Bureau of Mines about 14 years ago. The decision tree was originally intended to address mining influenced water (MIW) from coal mines. But since then, the breadth of passive treatment has expanded to embrace precious and base metal mines, uranium mines, and even gravel pits. Each MIW has its unique signature, either imposed by the natural geochemical conditions of the ore body and surrounding mine waste, or by resource recovery processes that may include heap leaching or traditional hydrometallurgical technologies. In the context of the elements of the periodic table, the decision tree certainly could be improved as it was originally developed to focus on coal geology derived MIW which typically contains acidity/alkalinity, iron, aluminum and manganese. For example, the expanded decision tree could consider residual ammonia or nitrates from blasting, cyanide from heap leach pad rinsing, trace amounts of selenium, or other parameters that may require passive treatment at a given mine, coal or otherwise. However, developing an individual decision tree for each MIW element or suite of elements and their species would be a daunting task and would probably introduce more confusion where simplicity is desired.

With apologies to Dmitri Ivanovich Mendeleev, a “Periodic Table of Passive Treatment” could become a useful design tool to satisfy the need to embrace a larger range of MIW chemistries. The revised, color-coded table presented in this paper focuses on identifying passive treatment methods that have been observed to work on specific elements or species of elements typically found in MIW that is based on the author’s experience or other practitioner’s of the technology. The author offers it as a starting point that could be enhanced with further study, to include geochemical modeling and speciation investigations in existing passive treatment systems.

Additional Key Words: MIW, acid rock drainage treatment, metal, coal


2 James J. Gusek is a Senior Consultant, Golder Associates Inc., 44 Union Blvd, Suite 300, Lakewood, CO 80228.
A TOOL FOR SELECTING APPROPRIATE VEGETATION FOR
RESTORING DISTURBED SITES IN EASTERN MONTANA AND
ADJACENT AREAS1

Paul L. Hansen, William H. Thompson, J. Gant Massey, and Max Thompson

Abstract: The recently published Classification and management of upland, riparian, and wetland sites of USDI Bureau of Land Management’s Miles City Field Office, eastern Montana USA has great utility in the planning of ecologically successful revegetation projects on disturbed sites in eastern Montana and adjacent areas. It covers the eastern third of Montana with detailed plant species composition of vegetation communities on every kind of natural site: upland, riparian, wetland, grassland, shrubland, and forest. In planning revegetation on sites that have had their natural vegetation either severely impacted or removed by human activities, there is always the question of what plant species are appropriate to use, and in what proportions. It is no longer acceptable to simply “green-up” a site with some generic cultivar developed for its quick cover and tolerance of harsh growing conditions. Land managers and private landowners now recognize that remediation and restoration efforts need to provide as great a “jump start” to the natural integrity and ecological function on a site, as is economically feasible and practical. This document has a dichotomous key for naming the type (habitat type or community type) at a site. For each of the 92 types summarized in the document, there is a description of physical and vegetation characteristics, a species composition table, community successional information, and site management information on several topics, such as livestock grazing, timber harvest, wildlife management, rehabilitation/restoration considerations, etc. With the name of the type at the site and the corresponding information provided in this document, a restoration planner can confidently prescribe a pallet of species that will establish the foundation of an appropriate natural community on a disturbed site. This will set the recently disturbed site well on its way to becoming ecologically functional with the greatest chance for long term success.


2 Paul L. Hansen, William H. Thompson, J. Gant Massey, and Max Thompson, Ecological Solutions Group LLC, 115 West Third Street, Suite 210, Stevensville, MT 59870.
INTEGRATED EVALUATION OF ECOLOGICAL SUSTAINABILITY OF A MINING AREA IN THE WESTERN REGION OF CHINA

Yufen Hao, Zhenqi Hu and Jack R. Nawrot

Abstract: The ecological environment is extremely fragile in the western region of China, where the largest coal mining company in China is located. After mining, subsidence and massive loss of water resources occur in many areas. Plant mortality caused by lack of water, has made the fragile ecological environment deteriorate much more rapidly after 1986. Therefore, an investigation of eco-environmental sustainability in the mining area is imperative. Based on Remote Sensing (RS) and GIS, two typical mines were selected as study areas. Four types of spatial information (desertification, land use structure, water and soil erosion, and vegetation) for the ecological environment were extracted from remote sensing imagery for 5 periods (August 2, 1986, August 29, 1990, July 26, 1995, July 31, 2000, and July 24, 2006). The spatial information was used to construct an evaluation index system. Based on a grid of environmental data, the environmental index was used to develop and design an integrated evaluation model for evaluating sustainability of the ecological environment in the mining area. Four classes of ecological sustainability were identified by the model. The analyses identified variability in the environmental sustainability. The changes in loess areas were much greater than in sandy areas because subsidence in loess areas was more serious than that in sandy areas. Because most cropland occurs in loess areas, and the ecological environment of loess regions is extremely sensitive and vulnerable to desertification, negative effects of mining are a serious concern. Therefore, evaluation of the environmental sensitivity and sustainability of the mining area is indispensable. The results of this evaluation corresponded quite well with the actual environmental conditions, demonstrating that this model is scientifically sound and objective. Application of this model to other mines and mining regions within China can be used to evaluate potential impacts in environmentally sensitive areas.

Additional Keywords: coal mine, subsidence, erosion, Remote Sensing/GIS, integrated evaluation model.


2 Yufen Hao, PhD student, Institute of Land Reclamation and Ecological Reconstruction, China University of Mining and Technology, Beijing 100083, China; Visiting Scholar at SIUC CWRL, Zhenqi Hu, Professor, China University of Mining and Technology (Beijing), Beijing 100083, China, Jack R. Nawrot, Senior Scientist, Cooperative Wildlife Research Laboratory, Southern Illinois University, Carbondale, IL 62901-6504
THE ROLE OF DISSOLVED ORGANIC CARBON IN ACETATE BIORREDOCTED URANIUM ATTENUATION

Janessa Hartmann², Emily Lesher, Linda Figueroa, James Ranville, Kate Campbell³, James Davis³, Kenneth Williams⁴, Philip Long⁵

Abstract: The Integrated Field Challenge Site at Rifle, Colorado (RIFC) is home to a legacy of subsurface uranium contamination resulting from mill operations. Research at RIFC has shown that acetate amendment (as an electron donor and carbon source), and the consequential growth of iron-reducing microbial communities results in the bioreduction of uranium. As microbial communities metabolize the acetate, dissolved organic carbon (DOC) changes both concentration and composition. Subsurface OC affects the biogeochemistry of an aquifer through equilibrium metal complexation and microbially mediated electron transfer and metabolic reactions. Accordingly, an understanding of DOC composition and evolution over the course of bioremediation is useful in modeling the fate and transport of uranium.

Groundwater from the RIFC was analyzed before, during, and after acetate biostimulation for total and operationally defined fractions of uranium and organic carbon. The defined fractions of OC in the dissolved phase can give insight into the microbial and chemical reactivity of the organic carbon fractions. The DOC fractionation scheme involved XAD-8 and XAD-4 resins to isolate and measure hydrophobic, transphillic, and hydrophilic organic carbon. Fractionated DOC was further analyzed for specific UV absorbance. The unfractionated DOC was analyzed by HPLC for short change organic acids. Research findings have shown the enrichment of the transphillic organic carbon fraction in groundwater as a result of acetate stimulation. Additional data will be presented outlining the changes in uranium and OC composition from temporally and spatially varying Rifle groundwater. The evaluation of the composition of groundwater before and after biostimulation allows for a direct comparison of the extent of natural U(VI) bioreduction to acetate-stimulated bioreduction. This information will facilitate the design of a more effective bioremediation strategy for the Rifle IFC. More importantly, it will aid in the design of uranium bioremediation strategies for other sites with subsurface uranium contamination.

Additional Keywords: Acetate Biostimulation, Bioreduction of Uranium, Dissolved Organic Carbon

² Janessa Hartmann², Emily Lesher, Linda Figueroa, James Ranville are with Colorado School of Mines: Environmental Science & Engineering Division, 1500 Illinois St Golden, CO 80401;³ Kate Campbell, James Davis USGS, 345 Middlefield Rd Menlo Park, CA 94025;⁴ Kenneth Williams Lawrence Berkeley National Lab, 1 Cyclotron Rd Berkeley, CA 94720; and ⁵ Philip Long Pacific Northwest National Lab, P.O. Box 999 Richland, WA 99352
MICROBIAL AND SUBSTRATE CHARACTERIZATION OF FOUR BLM BIOCHEMICAL REACTOR SYSTEMS IN THE COEUR D’ALENE IDAHO AREA

Roberta Martínez Hernández, Linda Figueroa, David Fortier

Abstract: The Bureau of Land Management (BLM) has constructed four biochemical reactor systems (BCRs) to treat mine impacted water in the Coeur D’Alene Superfund area near Coeur D’Alene, Idaho. Passive treatment systems are especially suited to these remote locations; however, the treatment efficiencies of the BLM BCRs have declined over the last several years.

These biochemical reactor systems rely heavily on the presence of sulfate reducing bacteria (SRB), which produce hydrogen sulfide that precipitates dissolved metals out of solution. In order to insure long-term sustainability of passive treatment systems sulfate reduction levels must be sustained.

The central objective of this study is to characterize the fraction of sulfate reducing microbial species and bioavailable substrate present within the BLM BCRs to understand how to promote sustained sulfate reduction levels.

The substrate analysis includes both a chemical and biological assessment. The chemical analysis consists of an acid extraction to separate the organic substrate into two fractions: acid soluble organics (organic acids, starches and holocellulose) and acid insoluble organics (lignin). The bioassay consists of incubating the solid phase sample from the BCR in an anaerobic bottle with a buffered nutrient solution and an anaerobic inoculum in order to measure the degradation of the bioavailable fraction of the residual organic substrate.

The microbial analysis will be conducted using Quantitative PCR (Q-PCR). Primers have been established for all bacteria and subsets of SRBs, which allows for an estimate of the relative number of SRBs with respect to total bacteria present.

The analysis results will expand the understanding of the sulfate reducing capacity of the BLM BCRs., facilitating performance enhancement of both the current BLM BCRs and future passive treatment systems for mine impacted waters.

Additional Keywords: passive treatment, biochemical reactor, sulfate reducing bacteria, mine drainage

1Poster was presented at the 2009 National Meeting of the American Society of Mining and Reclamation, Billings, MT Revitalizing the Environment: Proven Solutions and Innovative Approaches May 30 – June 5, 2009. R.I. Barnhisel (Ed.) Published by ASMR, 3134 Montavesta Rd., Lexington, KY 40502

2Roberta Martínez Hernández, Research Associate, and Linda Figueroa, Associate Professor, Department of Environmental Science & Engineering, Colorado School of Mines, Golden, CO 80401, and David Fortier, Environmental Engineer, Bureau of Land Management, Coeur d’Alene Field Office, Coeur d’Alene, ID 83815
INTEGRATED RECLAMATION: APPROACHING ECOLOGICAL FUNCTION?1

Ann L. Hild2, Nancy L. Shaw, Ginger B. Paige and Mary I. Williams

Abstract. Attempts to reclaim arid and semiarid lands have traditionally targeted plant species composition. Much research attention has been directed to seeding rates, species mixes and timing of seeding. However, in order to attain functioning systems, attention to structure and process must compliment existing efforts. We ask how to use a systems approach to enhance reclamation success. Using a case study example, we discuss ways to target key drivers that return the functional and dynamic nature of western wildlands. Integration of a multitude of abiotic (soil stability, hydrology and nutrient cycling) and biotic processes (plant functional traits, species turnover and regeneration, and wildlife interactions) into reclamation planning will be crucial to unifying research with management experience. Long-term monitoring coupled with tools to unify diverse datasets will be key to future management decisions. Reclamation is constrained by our inability to unify varied experiences with documented evidence. Research should assist managers with integrating spatial and temporal variability of ecosystem processes into long-term management planning. Using an integrated approach, we can more fully comprehend reclamation within the context of ecosystem function. An integrated knowledge base should serve as a communication tool and facilitate more sustainable landscape solutions.

Additional Key Words: functional traits, plant community structure, seeding


2 Ann Hild is Professor of Shrubland Ecology, Department of Renewable Resources, University of Wyoming, Laramie, WY 82071. Nancy Shaw is Research Botanist and Team Leader, Great Basin Native Plant Selection and Increase Project, USDA Forest Service, Rocky Mountain Research Station, Boise, ID. Ginger Paige is Assistant Professor and Watershed Hydrologist, and Mary Williams is a Doctoral Student and Instructor of Restoration Ecology, Department of Renewable Resources, University of Wyoming, Laramie.
REVEGETATION OF REED CANARYGRASS INFESTED RIPARIAN AREAS: PERFORMANCE OF PRE-VEGETATED COIR AFTER 3 to 6 YEARS

Paul B. Hook, Katie M. Salsbury, and Jeffrey M. Klausmann

Abstract: Reed Canarygrass (RCG) is an exceptionally aggressive invader of wetlands and streambanks throughout much of North America and a serious challenge in many riparian restoration projects. RCG generally degrades habitat quality, can outcompete most native grasses and forbs, and can sometimes invade stream channels. Over the last six years, we have used pre-vegetated coir mats for rapid bank stabilization and native plant establishment and to thwart reinvasion by RCG. In this paper, we use field experiments, case studies, and literature to evaluate whether aggressive revegetation can defeat RCG. Our results demonstrate that: (1) successful revegetation of infested sites is possible; (2) although RCG can be excluded for several years, even sites with very successful revegetation are not immune to reinvasion and may require periodic management; and (3) major hurdles include incomplete initial RCG control and poorly understood or challenging hydrology. Factors that favor RCG over native herbaceous plants include rapid spread by seed and rhizomes, high competitive ability, strong response to nutrients and disturbance, broad hydrologic tolerances, resistance to herbicides and other control practices, presence of non-native genotypes, and historical or continuing use as a forage or for bank stabilization. Complete control and replacement of RCG is unrealistic. Decisions about goals and effort for RCG control will depend on RCG abundance in the landscape, project purpose, project sponsors’ values, regulatory context, and mandated performance criteria. Depending on the location and agency, RCG may be treated as a regulated noxious weed, an undesirable invasive plant with low value in rating biological integrity, not a concern, or a plant suitable for pastures and other uses. Where minimizing RCG is required, time and resources should be allocated to pre-project RCG control, analysis of site hydrology, intensive revegetation practices, large woody plant material, follow-up RCG control, and monitoring for at least 3 years.

Additional Key Words: invasive plants, streambank bioengineering, riparian restoration, hydrology.


2 Paul B. Hook is Wetland and Watershed Scientist, Intermountain Aquatics, Inc., 85 S. Main St., P.O. Box 1115, Driggs, ID 83422, Katie M. Salsbury is Principal and Fisheries Scientist, and Jeffrey M. Klausmann is Principal and Revegetation Ecologist.
SITE SPECIFIC RECLAMATION: RECLAMATION PRESCRIPTIONS INDIVIDUALIZE FOR SUCCESSFUL RESULTS

K.E. House, D. J. Dollhopf, and K. C. Harvey

Abstract: Land reclamation proves to be difficult throughout the arid west during oil and natural gas development due to harsh environmental and climate conditions. Site specific reclamation uses science-based reasoning and technology to develop reclamation prescriptions that are tailored to each individual site within a project area. Reclamation begins with construction through the salvage of suitable soil materials by developing a soil salvage plan. The pre-construction soil salvage plan is a tool used to delineate the location and quantity of suitable soil resources at a planned site of disturbance to ensure that unsuitable material is avoided. Next, a site-specific reclamation prescription is created based on individual site properties such as soil type, dominant vegetation, and topography. If landscape homogeneity is common across a project area, zones with similar properties are delineated and reclamation prescriptions are created for each zone, rather than individual sites, to provide guidance for determining the most appropriate reclamation procedures. However, when site specificity is necessary, individual prescriptions are created for each site. Such practices are currently being implemented under the Natural Gas Full Field Development Plan for the West Tavaputs Plateau project area in Duchesne and Carbon Counties, Utah and results are pending. This proposal aims as an introduction to the concepts of the soil salvage plan and site-specific reclamation services. Given that reclamation science is continually evolving and strictly prescribed, blanket reclamation plans could limit reclamation success. Each reclamation plan, comprised of a soil salvage plan and a reclamation prescription, is therefore a living document. Knowledge gained through monitoring reclamation performance of zone-specific or site-specific reclamation prescriptions will be used to facilitate modification and improvement of recommendations over time.

Additional Key Words: arid land reclamation, soil salvage plan, West Tavaputs Plateau, Natural Gas Full Field Development Plan

2 Kelley E. House is a Reclamation Soil Scientist with KC Harvey, Inc., Douglas J. Dollhopf, Ph.D., is Professor Emeritus Soil Science and Land Rehabilitation, Montana State University, Bozeman, MT 59715, and Kevin C. Harvey is President and Chief Scientist of KC Harvey, Inc., 376 Gallatin Park Dr., Bozeman, MT 59715.
Abstract: The Stucky Ridge test plot is located approximately two miles northeast of Anaconda, Montana. Sparse vegetation includes quaking aspen, Wood’s rose, currant species, rubber rabbitbrush, horsebrush, redtop and basin wildrye. In November 2002, 22 tons/acre lime kiln dust was disced to a 12” depth. Prior to spring seeding, 500 bulk-pounds of fertilizer were applied/incorporated to a 6” depth. Thirty-six grass, two subshrub accessions, and four seed mixtures were arranged in a Randomized Complete Block with four replications. Plots were drill-seeded in May 2003 at 50 Pure Live Seeds per linear row foot. Soil sampling for arsenic and heavy metals occurred after planting. A significant amount of new grass seedling emergence was detected during the June 2004 evaluation, particularly for Indian ricegrass, western wheatgrass, Nevada bluegrass, and basin wildrye. Following the 2004, 2005, and 2006 evaluations for cover and vigor rating, each plot was sampled for biomass production. Tissue analyses indicated heavy metal concentrations were generally within limits for livestock and wildlife use. In single-species plots, ‘local source’ plants exhibiting superior performance included Copperhead and 9081621 slender wheatgrass, Opportunity Nevada bluegrass, 9081968 western wheatgrass, 9081624 and Washoe Germplasm basin wildrye, 9081628 Indian ricegrass, 9081636 bluebunch wheatgrass and 9081635 Canbyi bluegrass. In 2003, Open Range Germplasm winterfat was the only broad-leaved entry demonstrating significant emergence. In 2007, the only broad-leaved plants surviving were Open Range winterfat and 9081632 silverleaf phacelia. Old Works fuzzytongue penstemon and silverleaf phacelia were only detected in alternating years. In the Seed Mixture Trials, the ‘Experimental’ mixes containing native ‘local source’ were far superior to the ‘Developed’ mixes consisting of native ‘nonlocal source’ (Upland Mix) and introduced cultivars (Waste Management Areas). However, it was estimated the majority of plants in the Experimental mixtures were Copperhead slender wheatgrass, the best overall performer on the test site.

Additional key words: lime kiln dust, arsenic, heavy metals, livestock, wildlife.


2 Roger M. Hybner, Manager, Elizabeth C. Graham, DATR Program Leader, Mark E. Majerus, (retired) Manager, and Shannon G. Majerus, former DATR Program Leader, USDA-NRCS Plant Materials Center, 98 S. River Road, Bridger, MT, 59014.


PILOT-SCALE TESTS OF OXIDATION AND NEUTRALIZATION FOR MINE WATER: PRECIPITATION ASPECT ASSESSMENT


Abstract: Pilot-scale tests of 30 m³/d flowrate were conducted to study on the treatment process of mine water in an abandoned coal mine. Four different processes of oxidation basin (1 m³), neutralization basin (0.4 m³), reaction basin (0.4 m³), and settling tank (1 m³) were constructed to have a continuous treatment system. For this study, ferrous oxidation, neutralization, and sequential precipitation of oxidation products were characterized with aeration at oxidation basin, pH adjustment at neutralization basin, and change of retention time. As results, the optimum aeration flowrate for 1 m³ of oxidation basin was 300 L/min in terms of oxidation efficiency. With increase of retention time, efficiencies of ferrous oxidation increased even though the increase trend was not linear. Once the pH at neutralization basin increased to 7.5, almost 100% ferrous was oxidized. The efficiencies of ferrous oxidation were closely linked with sequential precipitation efficiencies of oxidized products. The remained ferrous could increase the turbidity of mine water for a while, and then the precipitation of oxidation products took more hours to give a poor properties in the engineering aspect of settling.

Additional Key Words: oxidation, neutralization, settling, pilot-scale tests

---


2 Min Jang, Senior researcher of water treatment team, Hyun Ju Lee, Won Hyun Ji, Hyun Sung Park, Researcher of water treatment team, Yon Sik Shim, Team leader of water treatment team, and Hyun Ho Kwon, Director, Institute of Mine Reclamation Technology, Korea Mine Reclamation Corporation (MIRECO), 30 Chungjin-dong St., Jongnu-gu, Seoul 110-727, Korea

3 Byung-tae Lee, Post-doc, Department of Chemistry & Geochemistry, Colorado School of Mines, Golden, CO, USA
RAPID REMOVAL OF FINE PARTICLES IN MINE WATER BY USE OF COAGULATION AND FLOCCULATION PROCESS

M. Jang, H.J. Lee, Y.S. Shim, H.H. Kwon

Abstract: After the complete oxidation was conducted for coal mine drainage, the suspended particles had a very slow settling profile due to their small particle size distribution ($d_{50}$: 1.06 μm). It takes about 18 hrs to decrease the turbidity from 120 NTU to 5 NTU. In terms of engineering design, this property makes the settling system problematic since it needs a huge settling basin. In order to remove the fine particles with a fast speed, we applied the combined process of coagulation and flocculation. Polyamine-type of cationic coagulants and acryl type of anionic flocculants were selected for this study to optimize the turbidity removal process. Through fitting the kinetic data with the agglomeration rate model, kinetic study of turbidity reduction was conducted to optimize the mixing speed, types and concentrations of coagulant and flocculent. As results, the optimum chemicals and their concentrations were FL-2949 (coagulant, 10 mg/L) and A333E (flocculent, 12 mg/L). Zeta-potentials (ZP) were also measured to elucidate the flocculation mechanism for each step. Interestingly, the rate constants of turbidity removal for each combination of coagulant and flocculent were linearly correlated with the differences between ZP of flocculent-applied mine water and ZP of coagulant-applied mine water. When compared to the rate constant for mine water without any treatment, the optimized condition of coagulation and flocculation showed about 867 times higher removal speed of fine particles.

Additional Key Words: oxidation, neutralization, settling, pilot-scale tests

---


2 Min Jang, Hyun Ju Lee, Yon Sik Shim, and Hyun Ho Kwon, Institute of Mine Reclamation Technology, MIRECO, 30 Chungjin-dong St., Jongnu-gu, Seoul 110-727, Korea
CHARACTERIZATION AND TREATMENT OF METAL CONTAMINATED IRRIGATED MEADOWS ADJACENT TO THE ARKANSAS RIVER NEAR LEADVILLE, CO

S.R. Jennings, J. Christner, R. Merrick, D. Wall and M. Holmes

Abstract. Releases of mine waste, contaminated water and sediments with elevated levels of metals have impaired productivity of agricultural land adjacent to the Arkansas River and downgradient from the historic mine districts of Leadville, Colorado. Historically irrigated agricultural meadows outside the floodplain contaminated by low pH, metal enriched irrigation water were sampled. The resultant depositional pattern shows the influence of irrigation ditches in conveying contaminated materials as expressed by bare ground and sparse vegetation cover dominated by metal tolerant species. The co-occurrence of phytotoxicity with acidic soil was described during pre-treatment sampling.

Additional Keywords: acid sulfate soil, phytotoxicity, metal contamination

2 Stuart R. Jennings, Environmental Geologist and Principal, Reclamation Research Group, LLC., Bozeman, MT 59715.
CONSERVING AN S1/G5/T2 MUSTARD AT A SOUTHEAST MONTANA COAL MINE THROUGH NURSERY PROPAGATION AND TRANSPLANTING

G. L. Johnson and R. A. Prodgers

Abstract. An uncommon variety of perennial mustard occurred in a topsoil stripping area at a southeast Montana coal mine. Spring Creek Coal Company is attempting to reestablish Physaria didymocarpa (Hook.) A. Gray var. lanata A. Nelson, woolly twinpod, in reclamation. This recognized variety is rated S1 in Montana (at risk, imperiled); the G5 (common, secure) global designation refers to generic Physaria didymocarpa (common twinpod), whereas T2 (less imperiled than S1, it occurs also in WY) refers to the trinomial (var. lanata). It is more of a stenotopic stress-tolerator than a competitor. In the wild, fruits aren’t produced every year and empty capsules are common, hence the prospects for collecting seed appeared dim. Fifty mature plants were collected from the area permitted for mining and transplanted into five-gallon Smartpots™ with a mix of native scoria soil, manure-based compost, and commercial mycorrhizal inoculant. One year later, most were magnificent specimens bearing more and bigger fruits than seen in nature. Because seed production is naturally meager, cloning was implemented to propagate seedlings to become nursery-raised transplants. Tissue culture was easily started from seed provided by three of the original transplants. However, transplanting and acclimatizing them to commercial greenhouse conditions presented other problems. Seedling survival was just 15%. Seed collected from the initial transplants, prompted by their prodigious fruit production, yielded about 90% survival. From these two propagation methods, more than one thousand 115-ml (seven-cubic-inch) “stubby cells” were raised in 2008. An experimental population was planted in fall 2008 into suitable mine reclamation. Approximately 800 seedlings will be transplanted in spring 2009, this effort to be repeated in subsequent years. In addition to delicate clone roots/indurate agar, challenges include nursery rot due to the tendency to collect water at the rosette center, providing good root/soil contact when transplanting into appropriate coarse substrate, and possible herbivory. Flexibility and adaption are key elements of the revegetation program. Some lessons may guide others similarly engaged.

Additional Key Words: rare plant conservation, tissue culture propagation, outplanting.


2 Gabe L. Johnson is a Environmental Engineer, Spring Creek Coal Mine, Decker, MT 59025, Richard A. Prodgers is a Plant Ecologist, Bighorn Environmental Sciences, Dillon, MT 59725.
SHARP-TAILED GROUSE RETURN TO MINED LAND¹

Roy Karo²

Abstract: Columbian Sharp-tailed Grouse (CSTG) were once considered among the most abundant game bird species in the United States. By the mid 1900’s, the CSTG sub-species had become so reduced in population size and distribution that it was considered the rarest of all the sharp-tailed grouse sub-species. Since early settlers often preferred CSTG habitats for farming and ranching, the CSTG suffered greatly due to agricultural expansion, over-grazing, alterations in natural fire regimes, and historical over-hunting. Today, CSTG are found in only three counties in Colorado: Moffat, Rio Blanco and Routt. In the early days of mined land reclamation science, many wildlife experts predicted the decline of CSTG numbers to be caused by mining operations.

For the past thirty years, Peabody reclamation scientists have established landscapes and vegetation communities beneficial to both wildlife habitat and livestock grazing. CSTG have, in particular, benefited from reclaimed mine land. Fitness and sustainability of the CSTG population is met by the characteristics of the reclaimed land. Reclaimed lands are dominated by dense herbaceous vegetation with inclusions of big sagebrush and snowberry. Horizontal structure or canopy cover of 75 percent is desirable while at least 30 cm of vertical structure provides good visual cover. Vegetation monitoring data shows that reclaimed areas fit these criteria well. These characteristics provide excellent nesting habitat and necessary cover from predators and weather. The herbaceous dominated reclaimed area vegetation contains important food from forbs and grass seed. Brood rearing success is greatly enhanced by the many forbs and grasses in the reclamation. During the brood rearing season, cool season vegetation produces an abundance of succulent shoots and buds high in nutrition. The increasing structure from seasonal plant growth provides cover for foraging birds. The increased natality and reduced mortality facilitated by the reclaimed lands has resulted in positive population benefits for CSTG in the region.

Additional Key Words: reclamation, wildlife, birds


² Roy A. Karo is reclamation manager for Peabody Energy in Colorado, Box 670; Hayden, CO 81639
SWITCHGRASS PRODUCTION POTENTIAL ON RECLAIMED SURFACE MINES IN WEST VIRGINIA

Travis Keene and Jeff Skousen

**Abstract:** The high cost of petroleum based transportation fuels has caused an increased interest in the development of renewable biofuels to supplement our energy needs. One energy crop that is well suited for conversion to biofuels is switchgrass because of its high biomass production on marginal lands with moderate fertility needs. West Virginia has the potential to become a center of biofuel production with its large expanses of reclaimed mine lands that are central to the U.S. energy market. Switchgrass production on surface mine land offers the unique opportunity to increase the land resources devoted to energy crops without decreasing the land resources devoted to food and livestock feed production. Our intention with this study is to identify the best varieties of switchgrass for mined lands in West Virginia, their planting and management requirements, yields, biofuel feedstock potential, capacity for carbon capture and sequestration and other revenue streams. Two sites in the southern and one in the northern part of the state were selected for this experiment. Three varieties of switchgrass were randomly assigned and planted into 0.4 ha plots, which were replicated three times for a total of nine plots at each site. Planting was conducted in May of 2008. The varieties of Carthage, Cave-in-Rock and Shawnee were chosen for their favorable growing characteristics and adaptation to West Virginia’s climate. All three sites are reclaimed surface mines and have had topsoil rolled out above the overburden material. The Coal-Mac mine site in Logan County was prepared with a disk harrow and then hydroseeded with seed and mulch. The Hobet 21 mine site in Boone County was prepared with a disk harrow and then hand broadcast with a spinner spreader and then hydromulched. The Hampshire Hill site in Mineral County had been amended previously with bio solids from a municipal waste treatment facility, and the soil was disked, harrowed and then switchgrass was broadcasted by hand with a spinner spreader, and not hydromulched. Switchgrass seed of each variety was planted at a rate of 9 to 11 kg pure live seed per plot at all sites. Germination success, percent cover, mine soil characteristics and biomass yield will be discussed.

Additional Keywords: switchgrass, biomass production, carbon sequestration.

---


2 Travis Keene, Research Assistant, West Virginia University, WV, 26506 and Jeff Skousen, Professor of Soils and Land Reclamation Specialist, West Virginia University, WV 26506
MINING RECLAMATION FOR WILDLIFE IN WEST VIRGINIA: A CONTINUING CHALLENGE

Randall L. Kelley and Roger J. Anderson

Abstract: West Virginia has historically been and continues to be one of the country’s leading coal producing states. Surface disturbance associated with mining gives managers an opportunity to practice what may be the “ultimate” in early successional stage habitat management. Not only does mining remove the existing vegetation but it also creates a new soil horizon. Prior to the passage of the Surface Mining Reclamation Control Act (SMRCA) in 1977, very little reclamation took place. Since then, however, companies have been required to reclaim mine lands. It was in this required reclamation that the West Virginia Division of Natural Resources (WVDNR) saw an opportunity to involve itself in reclamation to benefit wildlife. The WVDNR Mining Coordination Program was thus created in 1981. This program would review mining preplans for their impact to wildlife and would provide technical assistance to the coal companies to aid in reclamation for wildlife. These reclamation plans were designed to provide food and cover for targeted species on what was often being left as large expanses of open grass land. Their primary goal was to speed succession using plant species that would provide food and cover for the targeted species. Although limited in part by mining reclamation practices, some of which were required by law, these wildlife reclamation plans were quite successful. However the size of the operations and the techniques used in modern mining has produced a new set of challenges to the Mining Coordination Program. Recent strides toward improving reclamation at the newer mining operations have been made, but the future presents new and greater challenges in keeping wildlife a focal point in reclamation.


2 Randall L. Kelley, Wildlife Biologist, West Virginia Division of Natural Resources, Wildlife Section, Logan, WV, and Roger J. Anderson, Program Manager, West Virginia Division of Natural Resources, Wildlife Section, Elkins, WV.
STABILIZATION OF ARSENIC IN MINE TAILINGS WITH NANO-SIZED ZERO VALENT IRON AND MAGNETITE


Abstract. The technology using nano-sized iron particles have received considerable attentions to remediate groundwater contaminated with toxic metals or metalloids. The present study applied surface-modified and nano-sized zero valent iron (nZVI) and iron oxides (magnetite) to stabilize arsenic in mine tailings. The nZVI was prepared through the iron reduction by sodium borohydride under nitrogen. The mixture solution of iron chloride and iron sulfate (2:1 of molar ratio) was adjusted to high pH with sodium hydroxide to produce iron oxide colloids. Anionic surfactant, sodium dodecyl sulfate (SDS), was added to the parent solution to modify the surface properties of iron colloids. Transmission Electron Microscopy (TEM) measured the size of nano particles; the nZVI was 50 – 100 nm and magnetite was 10 nm in diameter. Due to its smaller size, surface-modified magnetite penetrated into the sand column deeper than surface-modified nZVI. Surface modification enhanced the mobility of magnetite through the sand column (1.46 times higher in iron concentration at the effluent of sand column when compared with the unmodified magnetite). Leachability of arsenic by TCLP in mine tailings decreased from 1.12 mg L\(^{-1}\) to 0.29 mg L\(^{-1}\) by the amendment of magnetite, while nZVI reduced arsenic concentration in the leachate (0.54 mg L\(^{-1}\)) by 52.27 %. Arsenic adsorption with surface-modified magnetite followed Langmuir adsorption isotherm.

Additional Key Words: zero valent iron, magnetite, surface modification, arsenic, stabilization

---


2. Ki-Rak Kim is graduate student of Department of Environmental Science and Engineering, Gwangju Institute of Science and Technology, Korea, Ju-Yong Kim is Research professor, and Kyoung-Woong Kim is professor. Byung-Tae Lee is Post-doc fellow of Department of Chemistry & Geochemistry, Colorado School of Mines, Golden, CO, 80401. Jin-Soo Lee is team manager of Geochemistry Division, Technology Research Center at Mine Reclamation Corp. (MIRECO), Korea, Soon-Oh Kim is associate professor of Department of Earth and Environment Science, Gyeongsang Nat. Univ., Korea
RAPID PROPAGATION OF THE SENSITIVE SPECIES PHYSARIA DIDYMOCARPA VAR. LANATA FOR RECLAMATION

Sandra M. King, Richard A. Prodgers, and Michael G. King

Abstract: In order to ensure sufficient plants for replanting threatened populations of Physaria didymocarpa var. lanata (Common Twinpod, Wooly Twinpod), in vitro propagation of this species was attempted. Seeds from three plants of Physaria didymocarpa var. lanata were cultured on a Murashige and Skoog salts base medium supplemented with 6-Benzylaminopurine. Both immature and mature seeds survived and germinated in culture. Each seedling culture produced several new shoots every four to six weeks. Each of these shoots was transferred to fresh medium to start new cultures. Roots were produced on excised shoots both in vitro on gelled medium and ex vitro on moistened coco fiber. Six months after initiating 100 seeds, 2,000 plants were ready for shipment to the nursery greenhouse and enough multiplying cultures were established to produce 1,000 new plants every two months. Though further work needs to be done on acclimatization to greenhouse conditions, survivors grew into normal robust plants, flowering in the pots.

Additional Key Words: tissue culture, micropropagation

2 Sandra M. King is with SMK Plants, LLC, Billings, MT, 59106, Richard A. Prodgers is Plant Ecologist with Bighorn Environmental Services, Dillon, MT, 59725, Michael G. King is with SMK Plants, LLC.
USING PLANT TISSUE CULTURE TO DEVELOP PLANTS WITH ACID SOIL, HEAVY METAL TOLERANCE (AHMT), POTENTIALLY USEFUL FOR HARD-ROCK MINE LAND RECLAMATION¹

Sandra King², Michael King³, Stuart Jennings, and Dennis Neuman.

Abstract. Our objective for this project was to determine if we could find, collect, and tissue culture local native plants which grow directly on acid, heavy metal contaminated (AHM) soil. These plants are potentially useful for mine land reclamation and may possess acid soil, heavy metal tolerance. Explants (small actively growing plant tissue segments) were collected from fifteen plant species growing directly on degraded sites heavily impacted from past hard rock mining activities in Western Montana. These plants, when collected were rooted, surviving and growing in soils characterized by very low soil pH (about 4.0) and high concentrations of various heavy metals. Of the 15 species collected, six were successfully propagated using plant tissue culture, also known as micro-propagation. We concentrated on three of the six species and have attained commercial rates of multiplication and rooting in-vitro. These three species have been successfully acclimated and grown under commercial greenhouse conditions. Results comparing our potentially AHMT tissue cultured plants to non-selected plants of the same species (raised from seed) in test soils under greenhouse conditions will be presented. Future plans for field tests will be described and discussed.

Additional key words: Micro-cuttings, in-vitro, site-adapted


² Sandra King and Michael King, Owners, SMK Plants LLC, Billings, MT 59106, Stuart Jennings and Dennis Neuman, Reclamation Research Group, LLC, Bozeman, MT 59771
EVALUATION OF FIRST 1.5 YEARS OF OPERATION OF A PASSIVE TREATMENT SYSTEM IN SE OKLAHOMA

J.A. LaBar and R.W. Nairn

Abstract: A 12-cell passive treatment system was constructed to treat an abandoned coal mine discharge near Hartshorne, Oklahoma. The system was designed to treat a net-acidic discharge (1400 mg/L) characterized by elevated concentrations of metals (Fe 765 mg/L; Mn 18 mg/L; Na 1800 mg/L), anions (Cl⁻ 225 mg/L; SO₄²⁻ 7800 mg/L), with pH 5.4, and flow ~40 L/min. The mine water was discharging from an existing air shaft, which was converted into a vertical anoxic limestone drain (VALD) to generate alkalinity. The VALD is followed by an alternating series of oxidation ponds and vertical flow cells, a polishing wetland, and finally an existing farm pond. System construction was completed in late 2005, but discharge from the VALD did not occur until January 2007 due to a prolonged regional drought. In the first 1.5 years of operation and monitoring, the VALD has consistently produced water with alkalinity concentrations in excess of 400 mg/L as CaCO₃. More importantly, the system has been effective in removing iron and manganese, with final concentrations of 0.67±0.62 mg/L and 4.39±4.71 mg/L, respectively. There has also been significant removal of trace metals such as cadmium and lead. The system is now discharging net-alkaline waters to the receiving stream. At current rates, the system generates ~4 tons/yr net alkalinity as CaCO₃ and retains ~12.5 tons/year iron.

Additional Key Words: acid mine drainage, coal mining, passive treatment, anoxic limestone drain

2 Julie A. LaBar, Research Scientist, and Robert W. Nairn, Associate Professor, Center for Restoration of Ecosystems and Watersheds, School of Civil Engineering and Environmental Science, University of Oklahoma, 202 West Boyd St., Norman, OK 73019
EFFECT OF VEGETATION COVER AND SEASONAL DROUGHT ON LOBLOLLY PINE SURVIVAL ON RECLAIMED MINE SOIL

David Lang, George Hawkey, Judd Sanborn, Rebecca Buell, Bill Roberson and Victor Maddox

Abstract: Step three of the Forestry Reclamation Approach is to plant tree compatible ground covers. The normal reclamation sequence at the Red Hills Lignite Mine in Ackerman, MS involves planting bermudagrass (Cynodon dactylon) followed by establishment of loblolly pine (Pinus taeda) with generally 70-80% survival. The objective of this study was to evaluate bermudagrass as a compatible species for establishment of loblolly pine. Vegetative ground cover and tree counts were conducted within randomly selected 81.4 m² circles. Seasonal droughts in 2006 and 2007 reduced ground coverage of bermudagrass in some areas, allowed encroachment of other volunteer species and had an adverse affect on loblolly pine survival. However, pine seedling survival was not related to the degree of bermudagrass coverage. A section of respread prime farmland (PFL) topsoil that had ground coverage of 100% bermudagrass in 2006 had only 30% pine seedling survival in 2007. Other areas reclaimed and seeded in 2006 that achieved only 20% coverage of bermudagrass and 50-70% bare soil also had only 30% pine seedling survival in 2007. The 20% bermudagrass areas developed a volunteer stand of giant ragweed (Ambrosia trifida L.) and marestail (Conyza canadensis L.) that had a 30% understory of volunteer white clover (Trifolium repens L.) in 2007. Marestail disappeared in 2008 and was largely replaced by volunteer stands of either white clover, sericea lespedeza (Lespedeza cuneata (Dum. Cours) or partridge pea (Chamaecrista fasciculata (Michx.). Pines replanted in 2008 had poor survival if either sericea or partridge pea was greater than 30%. There was a clear negative relationship between pine seedling survival and the presence of either sericea or partridge pea, however pine survival in bermudagrass was excellent prior to 2006 and in 2008 indicating that bermudagrass is a tree compatible species.

Additional Key Words: Competition, Volunteer Forbs, Cynodon dactylon
AN ANALYSIS OF STEEL SLAG AND ITS USE IN ACID MINE DRAINAGE (AMD) TREATMENT

Ben Mack and Brady Gutta

Abstract: Steel slag is a highly alkaline substance that is a byproduct of the steel-making process. This substance has been used in many different applications, including the remediation of mine drainage. However, some research has shown that large concentrations of possibly toxic metals may leach from the steel slag matrix when it is used in this capacity.

The National Mine Land Reclamation Center (NMLRC) has used steel slag in three Acid Mine Drainage (AMD) remediation projects. These three projects are named the McCarty Highwall site, the DeAntonis site, and the Muzzleloader Club site. Two of the three projects used steel slag in similar capacities. The DeAntonis site and the Muzzleloader Club site used steel slag in direct contact with fresh water, while the slag used at McCarty Highwall site was directly contacted by acidic water. Although project longevity between the three projects varied, leaching potential of toxic metals did not seem to be affected by the type of water the steel slag was used in. All three projects have also shown water quality improvement regardless of time since project construction.

Although both the McCarty Highwall and Muzzleloader Club projects had a few elements above EPA CCC standards, it is likely that these concentrations are not significantly high enough to greatly affect water quality. Due to a general lack of TCLP metals found in effluent waters for these projects, steel slag is recommended as a viable alkaline source for the treatment of AMD.

Additional Key Words: Alkalinity sources, limestone, trace metals


2 Ben Mack is a Research Associate, West Virginia University, Morgantown, WV 26506. Brady Gutta is a Project Manager, West Virginia University, Morgantown, WV 26506.
REVEGETATION MONITORING AT BLOCK P MILL AND TAILINGS SITE, MONTANA

J. Gant Massey, Ph.D., and William H. Thompson

Abstract. In 1929, the Block P Mill and Tailings Site (Block P) near Monarch, MT was the largest lead producer in Montana. When the mill finally closed in 1943 the site left behind a legacy of barren, phytotoxic soil and an ongoing transport of hazardous trace elements into nearby streams. Problems included areas of soil acidity as low as 1.8 pH, and zones with highly elevated concentrations of arsenic, cadmium, copper, lead, zinc and manganese in both soils and tailings materials. As a result, much of Block P, which would have been fully covered with vegetation if undisturbed, was nearly devoid of plant life. In 2001, however, it was decided to clean up and restore Block P to a functional site with natural vegetation. In 2004 and 2005, waste materials were consolidated to a centralized repository. Then, soil amendments (compost, slow-release fertilizer and lime) were added to areas from which tailings were removed, leave-area soils and imported fill materials. In 2005 and 2006, the project site was replanted with native grass and forb seeds, as well as containerized woody plant species that had been propagated from local stock.

In July 2008, scientists from ESG monitored the status of revegetation at Block P. Monitoring included assessments of containerized woody plant survival, herbaceous cover, and overall cover on the nine revegetation units at the site. The monitoring results show a continued trend toward successful revegetation. The average containerized woody plant survival, weighted for unit size, was 74 percent, which exceeds the 70 percent project goal. Average herbaceous canopy cover and average total canopy cover of all plants across the entire project site are respectively 46 and 49 percent. The canopy cover of native species far exceeds non-native canopy cover, the cover of weedy exotic species is minimal, and hundreds of woody volunteer plants are appearing. The improvements in vegetation, environmental, and aesthetic values of the Block P Mill and Tailings site are clear and palpable, and demonstrate the efficacy of using appropriate soil amendments and site-adapted native plant species to restore even the most challenging of disturbed sites.

Additional Key Words: soil amendment, mine restoration, native plant species

---


2 J. Gant Massey, Ph.D., and William H. Thompson are Founding Members and Plant Ecologists at Ecological Solutions Group, Stevensville, Montana 59870.
BIG HANAFORD CREEK FLOODPLAIN AND WETLAND RESTORATION PROJECT AS MITIGATION FOR A SURFACE COAL MINE PROJECT

Mark Matthies\(^2\) and Tony Briggs

Abstract. This paper presents the restoration design process and construction activities associated with the Big Hanaford Creek restoration project. The project was completed as part of required wetland mitigation to compensate for adjacent plant and mine activities requiring state and federal wetland permits. Big Hanaford Creek is a tributary to the Skookumchuck River in Lewis County, Washington, with its headwaters in the foothills of the Cascade Mountains, and with lower reaches in low gradient floodplain valleys. Within its lower reaches, a 4800-meter portion of the creek was straightened and deepened approximately 90 years ago when the valley was drained for agricultural purposes. Most recently, the floodplain surrounding the creek was used for grazing and mowing of pasture grasses for hay production. In an effort to rehabilitate in-stream habitat, reconnect the creek to the floodplain, and return native floodplain vegetation to the valley, a 61-hectare restoration project is underway. The project includes excavating 63,460 cubic meters of soil to relocate 2,286 linear meters of the stream back to a historical channel alignment; installing in stream wood structures for fish habitat; creating a new channel cross section with a bench at spring water surface elevations; planting willows along the reconfigured channel; creating low lying floodplain swales, and planting over 290,000 native trees, shrubs, and sedge plugs in the floodplain. Aerial photographs were used to identify a past historical meander pattern to serve as the new stream alignment and Government Land Survey Office field notes from 1867 were used to identify the historical wetland floodplain plant community. Construction occurred over an 18-month period to allow for channel excavation and included construction of approximately 150 in-stream wood structures during the dry season; and installation of plants the following spring. A 10-year monitoring program is being developed to monitor hydrologic performance and establishment of the native vegetation. This project is located immediately west of the TransAlta Centralia Generation Plant and Mine operations on land currently owned by the TransAlta Corporation.

Additional Key Words: stream relocation, fish habitat improvement, wetland restoration, floodplain connectivity, wetland mitigation.

---


\(^2\) Mark Matthies is a Wetland Biologist at ICF Jones and Stokes, Seattle, WA 98104. Tony Briggs is Permitting Manager of US Operations at TransAlta Centralia Generation, LLC, Centralia, WA 98531
AM-COLONIZED PLANT MATERIALS FOR MINED-LAND RECLAMATION¹

Tim W. Meikle² and Krystal Weilage

**Abstract:** The production of quality native plants materials is essential to large-scale reclamation efforts being undertaken at mine sites throughout the United States. Some studies have shown that nursery inoculation with arbuscular mycorrhizal (AM) fungi improved survival, growth, and drought tolerance of installed tree and shrub seedlings. The production of AM-colonized plant material, however, has proven problematic due to a lack of integration between the biotechnical firms that produce inoculums and cultural procedures at commercial nurseries. The objective of our research has been to integrate mycorrhizal inoculum successfully into a nursery program, thereby, producing plant materials with improved out planting performance. Multiple studies were conducted to investigate the efficacy of various inoculum products, the influence of growth media types, and the influence of standard fertilization techniques on the ability of AM fungi to colonize plant materials under nursery conditions. Our research has resulted in a growth media which promotes colonization of plant materials by AM inoculum in a nursery environment. Plants produced by this technique have significantly higher colonization rates than controls. This study reviews the results of greenhouse trials to increase AM-colonization rates in plant materials and out planting field trials established in Oregon, Montana, and Utah to compare traditionally grown seedlings with those grown in the AM-promoting growth media formulation.

**Additional Key Words:** reclamation, seedling, VAM, mycorrhiza, plant material.

---


² Tim W. Meikle, Principal, Great Bear Restoration, Hamilton, MT and Krystal Weilage, Native Plant Specialist, Montana Tech-University of Montana, 1300 West Park Street, Butte, Montana 59701
INFLUENCE OF DIFFERING MINE SITE CHARACTERISTICS AND PLANTING TREATMENTS ON SURVIVAL AND BUD SET TIMING OF CASTANEA DENTATA\textsuperscript{1}

C.R. Miller, J.A. Franklin*, and D.S. Buckley\textsuperscript{2}

\textbf{Abstract:} Reforestation on mine sites requires the use of species adapted to harsh conditions experienced by those mine sites. Studies show that American chestnut (\textit{Castanea dentata}) is a suitable species due to its adaption to xeric conditions and high light intensity characterized by surface mines. Here we compare the date of budset in American chestnut planted on two sites, but differing in genetic stock, planting date, and planting method. Budset is signaled by photoperiod, but can also be influenced by temperatures and nutrient availability. Understanding the relationship between budset timing and planting treatment in the American chestnut will prove beneficial to reclamation, and the restoration of the species. Individuals that set bud late will experience longer growing periods, but risk damage due to freezing temperatures.

The study location was on a mine site reclaimed using the FRA in eastern Tennessee. Two sites, containing two plots each, had similar substrate but differed in topography and material placement. Conditions on one site are characterized by loosely dumped spoil piles, placed on a gentle slope with a northeasterly aspect. The second, steep slope, site conditions are characterized by a moderately graded surface, with a southeasterly aspect. To one lot of seed, nine treatments were applied. Treatments were in a factorial arrangement with factors of forest topsoil (sterilized and un-sterilized), Terra-Sorb (applied and not applied), and fertilizer pellets (applied and not applied). Chestnuts were directly seeded in rows with randomized treatments. A second lot of seed was planted in randomized locations within the same plots, but at a later planting date. Bud set was recorded every two weeks, starting in August, until more than 90% of the trees had set bud. The objective of this study is to determine the influence of site and planting treatments on survival and bud set. Survival in the first planting lot averaged 30% survival after 2 months. Fertilizer significantly reduced emergence and survival from 38-30%. This earlier planting group set bud sooner than the second group. Second lot survival ranged from 55-72% after 2 months.

Additional Key Words: dormancy

\textsuperscript{1} Poster was presented at the 2009 National Meeting of the American Society of Mining and Reclamation, Billings, MT, \textit{Revitalizing the Environment: Proven Solutions and Innovative Approaches} May 30 – June 5, 2009. R.I. Barnhisel (Ed.) Published by ASMR, 3134 Montavesta Rd., Lexington, KY 40502.

\textsuperscript{2} Christopher R. Miller, Research Assistant, Jennifer A. Franklin, Assistant Professor, David S. Buckley, Associate Professor and Christopher R. Miller, Research Assistant, Department of Forestry, Wildlife, and Fisheries, University of Tennessee, 274 Ellington Plant Science, Knoxville, TN, 37902.
REDUCED-IMPACT LAND DISTURBANCE TECHNIQUES FOR NATURAL GAS PRODUCTION

M. D. Mitchem\textsuperscript{2}, D. J. Dollhopf, and K. C. Harvey

Abstract: Traditional drill pad construction techniques for natural gas production involve a cut-and-fill procedure that displaces existing plant communities and results in costly soil remediation and revegetation procedures. At the Jonah natural gas field, Sublette County, Wyoming, Encana Oil and Gas (USA), Inc. is evaluating use of oak mats during drilling and completion activities to minimize disturbances to soil and plant resources. In this study, changes in vegetation and soil attributes were evaluated as a result of oak mat use. Overall, oak mats tended to protect plant resources, minimize weedy forb establishment and maintain the plant community in a condition similar to adjacent rangeland. On average when compared to native range, grass growth improved, forbs remained similar, and shrubs were negatively impacted in oak matted areas. Vegetative results suggest that the success and timeliness of reclamation following the use of oak mat drill pads is superior to that obtained at reclaimed cut and fill locations. Following mat removal, mean soil bulk density values changed -2.9, 2.2 and 3.7 percent for the 0 to 5.1, 0 to 15.3, and 0 to 30.5 cm depth increments. All soil bulk density values remained below recommended thresholds for rangeland environments. A cost-benefit discussion indicates that in this setting, construction costs associated with oak mats are similar to those incurred by traditional cut-and-fill techniques. Drilling procedures using oak mats are more costly due to the need for a closed system for treatment of drill cuttings. However, this expense may be offset by lower reclamation costs associated with oak mat use.

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

\textsuperscript{1} Paper was presented at the 2009 National Meeting of the American Society of Mining and Reclamation, Billings, MT, Revitalizing the Environment: Proven Solutions and Innovative Approaches May 30 – June 5, 2009. R.I. Barnhisel (Ed.) Published by ASMR, 3134 Montavesta Rd., Lexington, KY 40502.

\textsuperscript{2}Melissa D. Mitchem, Reclamation Specialist, Douglas J. Dollhopf, Ph.D., Professor Emeritus Soil Science and Land Rehabilitation, and Kevin C. Harvey, President and Chief Scientist, KC Harvey, Inc., 376 Gallatin Park Dr., Bozeman, MT 59715.
AN INVESTIGATION TO USE TAILING PONDS AS SOLAR PHOTOVOLTAIC FARMS\textsuperscript{1}

Moe Momayez\textsuperscript{2}, Terril Wilson, Alex Cronin, Srikant Annavarapu, Bill Conant

Abstract. Fine-grinding of ores for the liberation of metal- or other valuable concentrates most often results in acreage dedicated to tailings impoundments. A determination of the post-mining land use of such acreage is then required. Tailings impoundments can be suitably utilized as sites for installation of solar photovoltaic (PV) panels. The electrical energy produced can be used initially for mining and concentrating operations, and subsequently for the utility grid after mine closure is complete. Since the extraction, processing and transport of minerals is energy-intensive, most mines already have a substantial electrical transmission-line infrastructure. This eliminates one of the major costs associated with PV energy farms. In this paper, we analyze the long-term economic benefit (i.e. payback period) of PV installation and energy production at mine sites. We also discuss integrating PV systems with erosion control and revegetation measures.

\textsuperscript{1} Paper was presented at the 2009 National Meeting of the American Society of Mining and Reclamation, Billings, MT, Revitalizing the Environment: Proven Solutions and Innovative Approaches May 30 – June 5, 2009. R.I. Barnhisel (Ed.) Published by ASMR, 3134 Montavesta Rd., Lexington, KY 40502.

\textsuperscript{2} Moe Momayez is Associate Professor, Terril Wilson is Adjunct Professor and Srikant Annavarapu is Graduate Associate, Department of Mining & Geological Engineering, University of Arizona, Tucson AZ. Alex Cronin is Associate Professor, Department of Physics, University of Arizona. Bill Conant is Assistant Professor, Department of Atmospheric Sciences and Institute for Atmospheric Physics, University of Arizona.
ACID MINE DRAINAGE PREVENTION USING BIOLOGICAL SOURCE TREATMENT: COAL AND HARD ROCK EXPERIMENTS

J.M. Morris², P.H. Fallgren, and M.L. Sait

Abstract: Western Research Institute has developed a biological source treatment (BST) technique to address acid mine drainage (AMD) at its source. The site-specific BST system is a composition of substrate and inoculum amendments designed to grow a hydrophobic, reductive biological barrier over the AMD source material to prevent oxidation of metal sulfides. The results of 4+ years of an ongoing field study of the BST technique at a backfilled coal mine indicate that AMD generation is being prevented or controlled. For instance, in one down-gradient monitoring well the pH increased by as much as 3 units from 5.7 to 8.8, iron concentrations decreased by >99% (93 to 0.2 mg/L), conductivity decreased from 1,279 to 500 µS/cm, and sulfate decreased from 724 to as low as 174 mg/L. Electromagnetic induction surveys supported this improved water chemistry by revealing a treatment zone created around and between injection wells where the conductivity of contaminated groundwater was lower within the treatment zone than in adjacent untreated areas. Additionally, a laboratory feasibility test was performed using water and mine waste material from a historic gold mine to determine if BST could be used as a potential remediation scheme or augmentation at hard rock mine sites. Several variations of microcosms with continually saturated source material and source material undergoing wet/dry cycles with different inoculum and wet and dry substrate amendments were simulated. The pH of the treated microcosms was significantly ($P \leq 0.001$) higher than control microcosms (pH 8.0 vs 2.6, respectively) after 60 days. Finally, 16s rRNA analysis indicates a robust biological community present in treated microcosms and a lack of acidobacteria in treated microcosms compared to controls. Overall, our results indicate that the BST system effectively prevents AMD generation from coal and hard rock mine waste material using wet or dry substrates under both saturated and wet/dry conditions.

Additional Key Words: Acid rock drainage; bioremediation, source control

² Jeffrey M. Morris, Ph.D., Lead Scientist, and Paul H. Fallgren, Senior Scientist, Western Research Institute, Laramie, WY 82072, and Michelle L. Sait, Ph.D., Post Doctoral Research Associate, Department of Molecular Biology, University of Wyoming, Laramie, WY 82071.
THE USE OF LANDSCAPE FABRIC AND SUPPLEMENTAL IRRIGATION TO ENHANCE SURVIVAL AND GROWTH OF WOODY PERENNIALS PLANTED ON RECLAIMED SURFACE MINE LANDS

R.C. Musselman, F.W. Smith, W.D. Shepperd, L.A. Asherin, and B.W. Gee

Abstract: A study was initiated to determine the effectiveness of landscape fabric and supplemental irrigation in survival and growth of woody perennials planted on reclaimed surface coal mine lands. The study compared growth and survival of nursery grown potted aspen and serviceberry planted with or without landscape fabric, and with or without biweekly supplemental irrigation. First year survival and growth indicates that the landscape fabric was particularly crucial in survival and growth of aspen trees on sites with high amount of competing vegetative cover. Supplemental irrigation appears to have provided limited advantage compared to the landscape fabric. Photosynthesis and pre-dawn moisture stress measurements on the aspen indicated that aspen trees were more stressed without landscape fabric. Soil moisture was higher under the landscape fabric. The serviceberry plants did not respond to landscape fabric or irrigation treatment during the first growing season.

Additional Key Words: Amelanchier alnifolia, aspen, competition, Populus tremuloides, re-vegetation, serviceberry, soil moisture


2 Robert C. Musselman is Plant Physiologist, and Lance A. Asherin is Forester, US Forest Service, Rocky Mountain Research Station, Fort Collins, CO 80526; Frederick W. Smith is Professor, Wayne D. Shepperd is Research Scientist, and Brian W. Gee is Graduate Student, Colorado State University, Department of Forest, Rangeland, and Watershed Stewardship, Fort Collins, CO 80523.
CHALLENGES IN DESIGN AND CONSTRUCTION OF A LARGE MULTI-CELL PASSIVE TREATMENT SYSTEM FOR FERRUGINOUS LEAD-ZINC MINE WATERS


Abstract: Artesian discharges of net alkaline, ferruginous waters from abandoned underground lead-zinc mines cause considerable surface water degradation at the Tar Creek Superfund Site, part of the historic Tri-State Mining District of Oklahoma, Kansas and Missouri. Two perennial borehole discharges, identified as the lowest elevation mine water discharge points in the district, have flowed unabated for almost 30 years and considerably degraded the physical, chemical and biological integrity of a first-order tributary to Tar Creek. Based on a comprehensive water quality and quantity characterization study, a large multi-cell passive treatment system was designed to receive approximately 1000 L/minute of mine water flowing from these abandoned boreholes (pH 5.95±0.06, total alkalinity 393±18 mg/L CaCO$_3$, total acidity 364±19 mg/L CaCO$_3$, Fe 192±10 mg/L, Zn 11±0.7 mg/L, Cd 17±4 ug/L, Pb 60±13 ug/L and As 64±6 ug/L). The objectives of this project include: i) remediation of polluted mine waters to acceptable quality for maintenance of the receiving water body aquatic community, ii) demonstration of the first mine water treatment facility of any kind in the Tri-State Mining District, and iii) technology transfer to speed application of this technology to other locations. The passive treatment system includes an initial oxidation pond followed by parallel treatment trains (to facilitate research and experimentation) consisting of aerobic wetlands, vertical-flow bioreactors, re-aeration ponds (with active aeration via wind and solar power) and horizontal-flow limestone beds. Waters from the parallel trains are recombined in a polishing wetland prior to final discharge. Total design surface water elevation change in the entire system is approximately 1.8 m. Prior to system implementation, the abandoned boreholes required rotosonic over-drilling to establish hydraulic control. In addition, diversion of storm water flows from an approximately 470-ha upgradient watershed was necessary. During construction, a third mine water discharge was discovered and incorporated into the design. This system represents a state of the art ecological engineering research site for passive treatment of mine waters.

Additional key words: metal mining, acid mine drainage, natural treatment systems

2 Robert W. Nairn, Associate Professor, Julie A. LaBar, Research Scientist, Keith A. Strevett, Professor, William H. Strosnider and William J. Andrews, Graduate Research Associates, and Robert C. Knox, Professor, Center for Restoration of Ecosystems and Watersheds, School of Civil Engineering and Environmental Science, University of Oklahoma, 202 West Boyd Street, Room 334, Norman, OK 73019, Tom Beisel, Project Manager, Robert C. Thomas, Project Consultant, Daniel Fuller, Senior Construction Manager, CH2M-Hill, Atlanta, GA; and James Bays, Principal Technologist Natural Treatment Systems, CH2M-Hill, Tampa, FL.
METAL LEVELS IN VEGETATION GROWING ON IN SITU TREATED ACID METALLIFEROUS MINE WASTES IN MONTANA

Dennis R. Neuman

Abstract: The purpose of in situ or in-place treatment of metal mine wastes is to immobilize contaminants within the soil/plant complex, reduce metal and arsenic movement to groundwater, reduce metal and arsenic movement to receiving streams, stabilize the landscape from wind erosion, and to provide a functional ecosystem compatible with current and future land uses. In-place treatment includes the incorporation of chemical and biological amendments to provide a hospitable rootzone, and to select plant species that can thrive in the newly amended environment. During in-place treatment, metals are chemically precipitated, and/or sequestered by complexation and sorption mechanisms within the mine wastes/contaminated soils. Metal availability to plants is minimized, and metal leaching into groundwater is reduced. Metals and arsenic that remain in soil solution are immobilized via chemical reactions at plant root surfaces. The selection of plant species for in-place treatment is based on availability of seed or seedlings, the species’ relative lack of ability to translocate (or move) metals and arsenic from the roots into the above ground biomass of the plant, and land use and management considerations. In-place treatment does not remove contaminants from the soil. As a consequence, short-term and long-term effectiveness of in-place treatment has been and continues to be debated. One concern is the potential toxicity to livestock and wildlife from the contaminants in soils and/or plants. This paper provides vegetation metal data from several Superfund and AML sites at which in-place treatment has been used as a remedial strategy. Interpretations of these data based on plant toxicity and residual risk to terrestrial receptors including grazing animals are presented.

Additional Key Words: phytostabilization, metals, contaminated soils, Superfund


2 Dennis Neuman is Environmental Chemist, Reclamation Research Group, 202 South Black Avenue, Bozeman, MT 59715.
CHITIN AS A FRACTIONAL AMENDMENT TO COMPOST TO ENHANCE THE EFFICIENCY OF MIW TREATMENT: LONGEVITY TESTS IN CONTINUOUS FLOW COLUMNS

C. E. Newcombe and R. A. Brennan

Abstract: Previously, our laboratory has shown that crab-shell chitin, a waste product of the shellfish industry, is capable of neutralizing acidity, reducing sulfate, and thoroughly removing aluminum, iron, and manganese from acidic mine impacted waters (MIW). Despite its remarkable effectiveness, the relatively high cost of crab-shell chitin ($1.32/kg or $0.60/lb) compared to the leading substrate, spent mushroom compost ($50/ton), may preclude its use in many systems. To facilitate the development of an effective but cost-efficient approach for MIW bioremediation, crab-shell chitin was used as a fractional amendment to spent mushroom compost substrate (SMS) in this study.

Continuous-flow PVC laboratory columns were used to evaluate different chitin-SMS mixtures for their ability to support MIW treatment. The five substrate conditions evaluated were: no substrate control (column filled with inert sand); 10% limestone + 90% SMS; 5% chitin + 95% SMS; 50% chitin + 50% SMS; and 100% chitin. Before being packed into the columns, these substrates were mixed with sand at a 1:22 ratio by mass (to provide sufficient hydraulic conductivity) and 50 g benthic sediment (as a bacterial inoculum). Natural, acidic MIW containing Al, Fe, Mn, and Zn was then continuously pumped through the columns to achieve hydraulic residence times ranging from 6-24 hours. Aqueous samples were collected regularly from the columns and tested for pH, acidity, alkalinity, volatile fatty acids, total dissolved carbon, ammonium, anions, dissolved metals, and oxidation/reduction potential to assess substrate suitability for a field-scale passive treatment system. The columns were evaluated for a period of 148 days, or an average of 416 pore volumes.

The treatment capacity of each substrate was defined here as the volume of MIW treated to pH>6 and alkalinity >0 mg/L as CaCO$_3$, prior to the breakthrough of metals to influent levels. The treatment capacity (and associated substrate costs) for each substrate mixture was determined to be: 36.7 L/kg ($1.38/1000 L) for 10% limestone + 90% SMS; 40.1 L/kg ($2.95/1000 L) for 5% chitin + 95% SMS; 162 L/kg ($4.25/1000 L) for 50% chitin + 50% SMS; and 428 L/kg ($3.09/1000 L) for 100% chitin. Based on the calculated treatment capacities as well as effluent water quality data over the lifetime of the columns, it appears that a small fraction of chitin (5%) does not provide a significant benefit over traditional limestone and compost substrates. Larger fractions of chitin (50-100%) are significantly more efficient than traditional limestone substrates, especially for the removal of metals.

Additional Key Words: Acid mine drainage, bioremediation, passive treatment.

---

2 Caroline E. Newcombe is a graduate student and Rachel A. Brennan is an Assistant Professor in the Department of Civil and Environmental Engineering at The Pennsylvania State University, University Park, PA 16802.
EFFECTS OF NATURAL GAS WELL DEVELOPMENT, RECLAMATION, AND CONTROLLED LIVESTOCK IMPACT ON TOPSOIL PROPERTIES

J. B. Norton, A. M. Mason, and C. A. Hudlow

Abstract. Stripping, stockpiling, and reapplying topsoil stimulates decomposition and loss of soil organic matter (SOM) by breaking apart soil structure and eliminating inputs of plant residues. Organic matter can be further decreased by stripping too deeply and diluting with subsoil. Studies of reclaimed coal mine sites in eastern Wyoming found an average of about 59 percent less SOM compared to adjacent undisturbed sites. Mixing of clays, salts, and sodium from subsoils into topsoil further reduces the ability of the plant community to recover once a site is reclaimed. Controlled livestock impact, achieved by confining and feeding hay to cattle, sheep, or goats at high stocking rates for short time periods on reclaimed areas immediately after seeding, may support reclamation success by adding organic materials of varying composition and improving seed-soil contact. Calculations of potential contributions of organic materials based on SOM levels of reclaimed coal mine sites in eastern Wyoming suggest about 412 cattle per ha per day would be required to bring SOM to predisturbance levels. Drier sites in southern and western Wyoming, for instance, with lower SOM contents would require about half that number. Hoof impacts are also reported to be beneficial, but the mechanism of the benefit is not clear. Packing the seed bed may improve seed-soil contact, but effectiveness of hoof impact compared to other methods is unknown. The number of accounts of the success of controlled livestock impact for reclamation warrants rigorous scientific study to define effects and mechanisms. This paper reviews literature on the effects of natural gas extraction activities (including reclamation) on soil properties and the potential impact of livestock activity on soil properties of these disturbed sites.

Additional Key Words: controlled livestock impact, soil restoration, soil degradation, soil organic matter.
LAND APPLICATION OF COALBED METHANE PRODUCED WATER: CHANGES IN SOIL CHEMISTRY THROUGH TIME\textsuperscript{1}


\textbf{Abstract.} Federal and State agencies, special interest groups, energy companies, and the public debate the methods used to manage groundwater produced through coalbed natural gas (CBNG) operations. Coalbed natural gas produced water is unaltered groundwater that is typically sodium bicarbonate rich. A ten-step plan has been developed to irrigate six sites in the Powder River Basin of northeastern Wyoming with CBNG produced water for multiple irrigation seasons. A combination of techniques, referred to as managed irrigation, were used to maintain soil chemical conditions that are supportive of plant growth. To prevent excessive salinity accumulation in the plant root zone, soil water balances and irrigation scheduling were used to maintain suitable agronomic leaching fractions. Geochemical equilibrium modeling determined the quantity of soil-applied amendments, used to mitigate the sodicity hazard of CBNG produced water. Since the initiation of irrigation, soil sampling occurred in each of the six fields at least bi-annually. Results indicate that soil electrical conductivity (EC), exchangeable sodium percentage (ESP), and sodium adsorption ratio (SAR) have increased significantly since the initiation of irrigation due to the application of both produced water and soil applied amendments. Soil pH has not increased appreciably compared to adjacent non-irrigated areas. The presence of well-aggregated soil structure and stable soil infiltration rates, which do not differ significantly from adjacent non-irrigated areas, suggest sodic soil conditions are not present. Although soil EC, ESP, and SAR have increased, management strategies have prevented the formation of sodic soil conditions. Agronomic leaching has maintained root zone salinity at levels suitable for moderately tolerant plant species, which are native to northeastern Wyoming.

\textbf{Additional Key Words:} land management, low quality irrigation water, and northeastern Wyoming


\textsuperscript{2} Kate L. Norvell is a Soil Scientist, KC Harvey, Inc., KC Harvey, Inc., Kevin C. Harvey, President and Chief Scientist, KC Harvey, Inc., Dina E. Brown, Certified Professional Soil Scientist, KC Harvey, Inc., Aaron J. DeJoia, Certified Professional Soil Scientist, KC Harvey, Inc., 376 Gallatin Park Dr., Bozeman, MT 59715.
APPLICATION OF A SATURATED-UNSATURATED GROUNDWATER FLOW MODEL TO SIMULATING THE PROBABLE HYDROLOGIC CONSEQUENCES OF MINING AT THE NAVAJO MINE EXTENSION PROJECT, NEW MEXICO

Art O’Hayre, Rick Reinke, Brent Musslewhite and Daphne Place

Abstract: This presentation describes the numerical groundwater flow model developed in support of the baseline hydrogeologic characterization and the probable hydrologic consequences assessment of the BHP Billiton Navajo Coal Company (BNCC) proposed Navajo Mine Extension Project (NMEP) near Farmington, New Mexico. Groundwater models are conceptual descriptions or approximations that describe physical systems using mathematical equations. Although the hydraulic conductivities of the coal beds at the NMEP are relatively low, they are still considerably higher than the interbedded shales, resulting in large vertical potentiometric gradients and perched groundwater zones. One of the primary hydrogeologic changes to occur as a result of mining is the removal of the coal and the interbedded shales and sandstone strata resulting in more homogeneous and isotropic conditions within the mine backfill. In order to meet the modeling objectives, a multi-layer numerical groundwater flow model of the NMEP mine area and adjacent area has been developed using FEFLOW, a finite element analysis technique that simulates groundwater flow and chemical transport for both saturated and unsaturated conditions.

The set-up and calibration of the model is briefly described followed by a summary of the application of the model to simulate the results for the proposed mining and reclamation plans. Re-saturation of spoil backfill results from recharge from precipitation, lateral inflow from the coals and interburden of the Fruitland Formation, and upward flow from the Pictured Cliffs Sandstone. Recharge from precipitation will be higher during active mining due to surface depressions and lack of vegetation in the mine spoils prior to reclamation. The results show that the rate of groundwater recovery in the mine backfill and the rate of groundwater flow once post-mine steady state conditions are reached are both extremely slow. FEFLOW has also been applied to simulate the spatial and temporal distribution of TDS and selected trace constituents from mine spoils and Coal Combustion Byproduct (CCB) materials that are planned for selective placement in mine backfill.

2 Art O’Hayre, Vice President, and Rick Reinke, Senior Hydrogeologist, Norwest Corporation; Brent Musslewhite, Environmental Coordinator and Daphne Place, Environmental Engineer, BHP Billiton Navajo Coal Company
COMPARISON OF A NEUTRON PROBE WITH A PR-2 SOIL MOISTURE METER

Mick O’Neill, Dan Smeal, Bruce A. Buchanan, Terry Brown and Steven R. Perkins

Abstract: In 2006, a project was initiated at Navajo Mine in northwest New Mexico to study the redistribution of soluble salts in a newly reclaimed area. As part of the project, soil moisture was monitored at 34 sites on a monthly basis from September 2006 to September 2008 and weekly during the growing season (May – September). Soil moisture readings were collected with two instruments, a Troxler neutron probe and a Delta-T PR-2/6 moisture meter. Both instruments were calibrated using gravimetric samples. A part of the study was to determine if the PR-2/6 probe would provide reliable soil moisture readings, compared to the neutron probe in spoil material having various levels of soluble salt. In general, the PR-2/6 probe gave similar results and was determined to be a useful instrument to measure soil moisture in these spoil materials.

Additional Key Words: soil water measurement, water measurements


2 Mick O’Neill, Associate Professor and Superintendent, Dan Smeal, College Professor, Agricultural Science Center, New Mexico State University, Farmington, NM 87499, Bruce A. Buchanan, President, Terry Brown, environmental scientist, Buchanan Consultants, Ltd., Farmington, NM 87499, Steven R. Perkins, Environmental Specialist, BHP Billiton, New Mexico Coal, Fruitland, NM 87416
ASSESSING THE USE OF HIGH RESOLUTION SATELLITE IMAGERY TO INVENTORY ABANDONED MINE LAND FEATURES IN VIRGINIA

Dianne Osborne, Jason San Souci, Daniel Kestner, Richard Davis, Ann McDavid, Kim Britton

Abstract: The State of Virginia (VA) Division of Mined Land Reclamation (DMLR) and the Office of Surface Mining (OSM) used high resolution satellite imagery along with other Geographic Information System (GIS) tools to assist in the inventory of abandoned mine land (AML) sites and identification of re-mined areas in southwestern VA. Inventory of AML sites was conducted through feature extraction of QuickBird-2 satellite imagery to identify new AML sites and more precisely locate existing AML sites. The AML features identified as priority for mapping by VA DMLR were dangerous highwalls, apple cores, gob piles, clogged streams, clogged stream lands, portals, subsidence, acid mine drainage, hazardous equipment and facilities, spoil piles containing high coal content for re-mining consideration, and re-mined areas.

The initial results of the image feature extraction included locating acid mine drainage areas, determining linear feet of dangerous highwalls, location of gob piles and spoil piles containing high coal content and areas identified for re-mining consideration, clogged streams and clogged stream lands required acquisition of summer imagery to conduct feature extraction. Additional field data collection is planned to classify portals and subsidence features as well as complete an accuracy assessment of the final classification.

Additional Key Words: DMLR, OSM, AML, remote sensing, classification, QuickBird-2, GIS


2 Dianne Osborne is a Remote Sensing Specialist, U.S. Office of Surface Mining Reclamation and Enforcement, TIPS Technology Transfer and Training Branch, Denver, Colorado, Jason San Souci is President & CEO of AFE Advisor, LLC, Colorado Springs, Colorado, Daniel Kestner is a Mapping Supervisor, Richard Davis is a Minerals Specialist, Ann McDavid is an AML Specialist and Kim Britton is a GIS Analyst with the Virginia Division of Mined Land Reclamation, Big Stone Gap, Virginia.
USE OF RECENT AND HISTORICAL AERIAL PHOTOGRAPHY INTERPRETATION TECHNIQUES TO QUANTIFY POST-MINING REFORESTATION CHANGE AND ASSOCIATED CARBON SEQUESTRATION IN SOUTHWESTERN VIRGINIA

Dianne Osborne\textsuperscript{2}, James Ward, Richard Davis, Daniel Kestner

\textbf{Abstract:} The State of Virginia (VA), Division of Mined Land Reclamation (DMLR), and the Office of Surface Mining (OSM), used recent and historical aerial photography to classify reforestation change over time over a pilot study area in southwestern VA.

To quantify change in reforestation over time, recent aerial photography dated 2007, and aerial photography dated prior to passage of the Surface Mining Control and Reclamation Act (SMCRA) in 1977 were interpreted into forest type and percent cover categories. Geographic Information System (GIS) analysis was conducted to quantify change in post-mining forest type and percent cover.

The amount of carbon sequestered over this time period has been quantified along with predicted modeling of maximum loading on the site. Results of these efforts will be presented.

\textbf{Additional Key Words:} DMLR, OSM, QuickBird-2, classification, SMCRA, GIS


\textsuperscript{2} Dianne Osborne, Remote Sensing Specialist, U.S. Office of Surface Mining Reclamation and Enforcement, TIPS Technology Transfer and Training Branch, Denver, Colorado, James F. Ward is President of James F. Ward and Associates, Inc., Nacogdoches, Texas and Daniel Kestner is a Mapping Supervisor and Richard Davis is a Minerals Specialist with the Virginia Division of Mined Land Reclamation, Big Stone Gap, Virginia
CHARACTERIZATION OF SLUDGE IN SAPS SYSTEM


Abstract: Sludge characterization was performed to evaluate the impact on the treatment of passive system located at Yahryong 5 pit mine. This system is in Gangneung city, Northeast part of South Korea and is being operated with the sequence of SAPS - oxidation pond - aerobic wetland. Sludge accumulation of 26 cm deep was observed on the surface of SAPS and has started since the system was constructed in Oct. 2003. The chemical analysis results of the mine water showed not only low pH (3.4) and DO (1.6 mg/L) but also high ratio of Fe^{2+} / total Fe. Although sludge accumulation could not occur in the above conditions with the basis of chemistry aspects, there are 415 m^3 of sludge resulting in low permeability for SAPS system. According to the XRD, XRF and size distribution analysis of sludge, it showed amorphous phase of Fe, S, and Al oxy/hydroxides. Sludge also had a homogenous distribution size of 4 ~ 10 µm. Loss on ignition (LOI) showed about 57 % of organic matter content in sludge. Those results revealed that sludge has been produced by rapid Fe oxidation and it is possible to suggest there might be some medium for rapid Fe oxidation. Isolation results of sludge showed Fe-oxidizing bacteria (Acidithiobacillus spp., Thiomonas spp.) dominated to lead the rapid oxidation and precipitation of Fe.

Additional key words: sludge, SAPS, Fe-oxidizing bacteria

---


2 Hyun-Sung Park, Won-Hyun Ji, Hyun-Ju Lee, Researcher of water treatment team, Min Jang, Senior researcher of water treatment team, Yon-Sik Shim, Team leader of water treatment team, Hyun-Ho Kwon, Director, Institute of Mine Reclamation Technology, Korea Mine Reclamation Corporation (MIRECO), 30 Chungjin-dong St., Jongnu-gu, Seoul 110-727, Korea

3 Byung-tae Lee, Post-doc, Department of Chemistry & Geochemistry, Colorado School of Mines, Golden, CO, USA
SPOIL QUALITY EFFECTS ON VEGETATION ESTABLISHMENT AND SPECIES COMPOSITION FOLLOWING RECLAMATION OF MINED LANDS IN ARID NEW MEXICO

Steven R. Perkins, Bruce Buchanan, C. Kent Applegate, Joshua Voss, and Leland Roberts

Abstract: In 1992 at the Navajo Mine in New Mexico, reclamation was completed in an area that had been topsoiled and where there was a wide range in measured EC and SAR values of the underlying spoil at the time of seed planting. The objective of this study was to examine the influence of spoil EC and SAR on subsequent vegetation establishment and species composition. In September 2008, vegetation cover and production were measured at 40 locations with spoil EC and SAR values that met current (2008) root-zone suitability criteria at the time of planting (suitable spoil) and 40 locations that did not meet the current criteria (unsuitable spoil). Results indicate that most vegetation parameters were not significantly different between suitable and unsuitable spoil. Galleta grass cover was higher in suitable (4.2±0.8%) than unsuitable (2.2±0.6%) spoil. Conversely, fourwing saltbush cover was higher in unsuitable (3.3±0.9%) than in suitable (1.0±0.3%) spoil. Shrub cover was higher in unsuitable than suitable spoil (3.7±1.0% and 1.0±0.3%, respectively) while annual forb cover (excluding weedy species) was higher in suitable than unsuitable spoil (1.7±0.2% and 1.0±0.2%, respectively). There were no significant differences between suitable and unsuitable spoil in cover of 5 of the 7 most common species, total vegetation cover, vegetation production, or shrub density. Regression models were developed to correlate vegetation properties with spoil characteristics. None of the spoil characteristics included in the models consistently influenced vegetation cover or production. Results of the study indicate that EC and SAR values in suitable and unsuitable spoil had little influence on overall revegetation success, although spoil properties may have had a limited effect on species composition by affecting the relative proportion of shrub and herbaceous species.

Additional Key Words: coal mine reclamation, electrical conductivity, sodium adsorption ratio, revegetation, Atriplex canescens, Pleuraphis jamesii.


2 Steven R. Perkins, Environmental Specialist, and C. Kent Applegate, Environmental Coordinator, BHP Billiton – New Mexico Coal, Fruitland, NM 87416, and Bruce Buchanan, President, Joshua Voss, Reclamation Scientist, and Leland Roberts, Reclamation Scientist, Buchanan Consultants, Ltd., Farmington, NM 87401.
THE EFFECT OF A SOIL COVER ON DUMP RESPIRATION AND SEEPAGE QUANTITY AND QUALITY

M. Phillip, M. O’Kane, B. Dawson, W. Kuit

Abstract: During May 15 – 17, 2006, four fatalities occurred at a partially reclaimed waste rock dump at the closed Teck Cominco Sullivan Mine near Kimberley, British Columbia, Canada. The fatalities occurred at the toe of the dump in a seepage monitoring station that is connected hydraulically, via a pipe and dump toe drain, to the acid generating waste rock capped with a 1-meter till cover. Following standard reclamation practices for the site, the cover system was placed to foster revegetation and limit infiltration. Since August 2006, the dump has been heavily instrumented in stages to test the initial hypothesis that changes in ambient meteorological parameters controlled respiration. The data collected also provides the opportunity to examine cover effectiveness. Automated and manual measurements gather a variety of data, including air velocity and seepage flow in the pipe connecting the toe drain and monitoring station; site meteorology; cover moisture content and temperature; and, internal temperature, gas composition, and pressure potential at 34 locations. Seepage quality results have been obtained at least monthly since May 2006. Vent locations have been discovered on the covered surface with depressed oxygen levels. Monitoring has shown that from fall to spring approximately 1.2 M m$^3$ of air, or nearly four times the estimated void space, enters the dump through the drainage pipe and exits through the cover. This paper evaluates the inability of the cover, even at high saturation conditions, to limit airflow and examines the changes in seepage quantity and quality.


2 M. Phillip, O’Kane Consultants USA, 3510 Hwy 1 West, Anaconda, MT, USA 59711; M. O’Kane, O’Kane Consultants Inc., Calgary, Alberta T3H 3C8, Canada; B. Dawson, Teck Cominco Metals Ltd., Kimberley, British Columbia V1A 1C7, Canada; W. Kuit Teck Cominco Metals Ltd., Vancouver, British Columbia V6C 3L9, Canada,
NOTHING BUT BORROW – REVEGETATION WITHOUT TOPSOIL

R. A. Prodgers

Abstract: This project has been a grand field experiment in revegetating biologically inert coversoils with and without organic amendment. Seven years after seeding, the condition of revegetation in the area first seeded was evaluated, passing performance standards. Salvaged topsoil is generally considered the optimal revegetation substrate, but it is sometimes unsuitable or unavailable. This riparian Superfund project relied upon coversoils originating as deep, biologically inert borrow. Revegetation can be initiated on such substrates; the issue is permanence. To promote primary succession at an advanced stage, a variety of commercial compost products have been used as a coversoil amendment in the hope of establishing a soil food web and nutrient cycling. Compost provides a microbial community and a source of carbon and nutrients to sustain them until revegetation provides new substrates such as root exudates. Seven-year-old revegetation exceeded success criteria based upon perennial plant cover. The trend in plant cover from 2004-2007 has been slightly upward but dynamically constant despite declining legumes, suggesting a relatively smooth transition from legumes to other perennials. In a comparison limited in power by the small number of un-composted samples, plant cover did not differ significantly between composted and un-composted coversoils, although composted areas had greater mean cover. Applying too much wood-based compost induced in a few years severe infertility after the labile constituents were immobilized. Native species are not immune to the negative effects of reverse fertilization.

Additional Key Words: biologically inert coversoil, soil microbiology, compost, nutrient cycling, reverse fertilization, canopy coverage.

2 Richard A. Prodgers is a Plant Ecologist, Bighorn Environmental Sciences, Dillon, MT 59725.
REVEGETATING TOPSOIL, SCORIA, AND SPOIL IN MONTANA

R. A. Prodgers

Abstract. A mining stipulation required a southeast Montana coal mine to compare plant performance throughout one decade where suitable coversoil (suitable spoil + surface substrate) was 1.2 meters (four feet) vs. 2.4 meters (eight feet) thick over sodic spoil. Execution did not faithfully implement design, leading to unexpected but useful findings that bear upon the value of biologically inert soil substitutes in revegetation. Three substrates comprised the top 4.5 dm of coversoil: stockpiled topsoil, “suitable” spoil, and scoria. Revegetation performance on these near-surface substrates and inclusion in the root zone of material adjudged “unsuitable” by regulators in Montana revealed that:

- For the first four years, topsoil treatments had far more plant cover than suitable spoil and scoria treatments, but in the dry year of 2006 (year 10), suitable spoil had the greatest plant cover and scoria had more plant cover than topsoil. By the conclusion of the study, the amount of plant cover and especially perennial cover among treatments had converged notably.
- Spoil was the least weedy substrate and particularly poor habitat for annual bromes. Topsoil consistently had the most annual bromes. Both soil substitutes, spoil and scoria, were colonized variably by sweetclover.
- Scoria was the premier species diversity substrate. After 10 years, topsoil had about the same number of species seeded and suitable spoil just a few more, whereas scoria had about 2.5 times as many species as were seeded.
- Scoria exhibited the greatest diversity and cover of forbs, potentially making it the best substrate for sage grouse habitat. Generic topsoil seeded with two seed mixes had the fewest forbs and native volunteers.
- Different seedings make shrub comparisons complicated, but while one topsoil seeding had the greatest shrub density in 2006 and 2007, suitable spoil had twice the shrub cover in 2007 by virtue of much bigger shrubs. Shrub density in all treatments declined sharply from the early years.
- “Unsuitably” heavy soil textures below 4.5 decimeters had no perceptible effect on plant performance. Neither did plant performance differ where SARs below 1.2 meters were in the 5-7 range vs. the mid-teens.

Additional Key Words: soil substitutes, substrate suitability, plant performance, plant cover, shrub density, species diversity.

2 Richard A. Prodgers is a Plant Ecologist, Bighorn Environmental Sciences, Dillon, MT 59725.
RESPONSE AND RECOVERY OF SULFATE-REDUCING BIOCHEMICAL REACTORS FROM AEROBIC STRESS EVENTS

E.M. Perrault, L.P. Pereyra, S. Hiibel, A. Pruden, K.F. Reardon, and D.J. Reisman

Abstract. Microbially-mediated treatment of mining-influenced water (MIW) through the implementation of sulfate-reducing biochemical reactors (BCRs) is an attractive option for passive, in situ remediation with low operating costs and reduced maintenance requirements. However, BCRs can be unpredictable in terms of how they recover from environmental stresses such as oxygen exposure. Previous studies have demonstrated that the inoculum can impact performance positively, suggesting that engineered control of the microbial community structure could improve the resilience of BCRs to stress. The purpose of this study was to determine the effect of bioaugmentation and biostimulation on performance and recovery from oxygen stress. Twelve columns (six conditions in duplicate) were packed with a complex organic substrate (wood chips, etc.), inoculated with dairy manure, and fed simulated acid mine drainage containing Fe, Cd, and Zn at pH 5.5. The conditions tested were: 1.) bioaugmentation with cellulose degraders (CD); 2.) bioaugmentation with sulfate reducers (SRB); 3.) biostimulation with ethanol (EtOH); 4.) biostimulation with carboxymethyl cellulose (CMC); 5.) dairy manure only control (DM); 6.) un-inoculated control (CR). Once the columns reached steady state anaerobic performance, they were exposed to oxygen, allowed to reach steady state again, and then oxygen-exposed for a second, longer time. The results indicate that all columns performed well in terms of pH neutralization and removal of sulfate and heavy metals. However, the cellulose and ethanol biostimulated columns appeared to be the most resilient to oxygen exposure and performed best by the end of the experiment (171 days), while the bioaugmented columns performed similarly to the controls. The microbial communities were evaluated at each steady state using a suite of biomolecular tools, including active community profiling (ACP) and quantitative real-time PCR (Q-PCR) targeting key functional groups of sulfate-reducers, cellulose-degraders, fermenters, and methanogens. It was found that the active microbial community structure was distinct among the six column conditions and that bioaugmentation significantly impacted the kinds and diversity of bacteria present following stress events. Functional gene analysis supported these observations, but provided finer resolution regarding the response of each functional group to stress.

Additional Key Words: sulfate-reducing biochemical reactors, oxygen stress, functional genes, column studies


2 Elizabeth M. Perrault, Graduate Research Assistant, Department of Cellular and Molecular Biology, Colorado State University, CO 80523; Amy Pruden, Associate Professor, Civil & Environmental Engineering, Virginia Tech, Blacksburg, VA 24061; David J. Reisman, Director, Eng. Tech. Support Ctr., Office of Research & Development, U.S. EPA, Cincinnati, Ohio 45268; Luciana Pereyra, Post Doctoral Researcher, Department of Chemical and Biological Engineering, Colorado State University, CO 80523; Sage Hiibel, Post Doctoral Researcher, Department of Chemical Engineering, Texas A&M University, TX 77843; Kenneth F Reardon, Professor, Department of Chemical and Biological Engineering, Colorado State University, CO 80523.
ASSESSMENT FOR TREATMENT OPTIONS AT THE YOUNG DONG COAL MINE SITE, SOUTH KOREA


Abstract: The Young Dong Coal Mine site in northeastern South Korea was closed in the early 1990s and initial reclamation was finished in 1995. Even though the adit was filled with limestone, there is still significant acid rock drainage (ARD) flowing from the site. An assessment that was started in March 2008 revealed that there were three types of water flowing from various sources on the site. ARD still flowed from the adit; which carried an average of 500 mg CaCO₃ / L of mineral acidity primarily in the form of Fe(II) with a flow that reached 2.8 m³ / min in spring runoff. This water is the focus of this paper. The hydrology is complex because there are at least two periods of high surface flow during the year, one in the spring and one during monsoon season. The water issuing from the adit is from a diffuse aquifer where concentrations increase when flow increases. In addition, the terrain is quite steep with few level spots. One other factor in the assessment of treatment is that a limestone quarry is only a few kilometers from the site. All of these factors have led to the conclusion that none of the traditional methods of passive treatment can be applied to this site. Instead, it is proposed to use an upgrade of a diversion well that is called a pulsed passive limestone reactor (PPLR). With maximizing all of the parameters that can be changed on a PPLR, it is anticipated that a one stage PPLR system could generate up to 250 mg CaCO₃ / L and so there would be a set of reactors needed to treat the complete flow.

Additional Key Words: Coal mine ARD, limestone reactors, metals contamination.

---

2James Ranville, Thomas Wildeman, and Byung Tae Lee, Department of Chemistry and Geochemistry, Colorado School of Mines, Golden, CO, 80401, 3Philip Sibrell, Engineer, USGS – Leetown Science Center, 11649 Leetown Rd., Kearneyville, WV 25430, 4Min Jang, Yon Sik Shim, Won Hyun Ji, Hyun Sung Park, and Hyun Ju Lee, Technology Research Center, MIRECO, 30 Chungjin-dong St., Jongnugu, Seoul 110-727, Korea.
COALBED METHANE NATURAL GAS (CBNG) PRODUCED WATER: OUTFALLS AND DISPOSAL PONDS

K.J. Reddy and R.E. Jackson

Abstract. Coalbed methane (CBNG) extraction is facilitated by pumping water from the aquifer. The majority of CBNG produced water is discharged into disposal ponds. The objective of this study was to examine the geochemistry of CBNG produced water in the Powder River Basin, Wyoming. Water samples from outfalls and corresponding disposal ponds in Cheyenne River (CHR), Belle Fourche River (BFR), Little Powder River (LPR), Powder River (PR), and Tongue River (TR) within the Powder River Basin (PRB) were collected over a period of three years. CBNG produced samples were monitored pH, electrical conductivity (EC), major elements [e.g., calcium (Ca), magnesium (Mg), sodium (Na), alkalinity], trace elements [e.g., iron (Fe), aluminum (Al), barium (Ba), arsenic (As), selenium (Se)]. From Na, Ca, and Mg measurements, sodium adsorption ratios (SAR) were calculated. Results suggest that Na, alkalinity, and pH all tend to increase, possibly due to environmental factors such as evaporation, while Ca decreased from outfalls to corresponding disposal ponds due to calcite precipitation. Trace elements concentrations in both outfalls and disposal ponds were below the discharge limit, however an increasing trend was observed in disposal ponds. Overall, these results are useful to develop management approaches for CBNG produced water and reclamation of disposal ponds.

Additional Key Words: Energy Demand, Clean Energy, Coalbed Methane, Produced Water, Reclamation of CBNG Disposal Ponds


2 K.J. Reddy is Professor and Associate Director of Academics, Department of Renewable Resources and School of Energy Resources, University of Wyoming, Laramie, Wyoming 82071 and R.E. Jackson is a Natural Resource Specialist, Bureau of Reclamation, Marsing, Idaho.
DIRECT REVEGETATION OF ACIDIC MINE TAILINGS AT THE IDARADO MINE SITE IN SOUTHWEST COLORADO\textsuperscript{1}

E. F. Redente\textsuperscript{2}

\textbf{Abstract:} The Idarado Mining Company (Idarado) mined gold, silver, copper, lead and zinc in the Red Mountain and Telluride mining districts in southwest Colorado between the 1940s and 1978. In 1983, the State of Colorado filed a natural resource damage claim against Idarado to address historic environmental impacts linked to past mining and milling activities. After prolonged negotiation and litigation, Idarado and the State of Colorado agreed on a comprehensive plan to improve water quality in local streams and reclaim historic mining sites. Six tailing storage facilities that were constructed during 65 years of ore processing were reclaimed between 1993 and 1995. The elevation of the tailing facilities range from 2,709 to 3,208 m. A direct reclamation approach was implemented by using the tailings as the primary plant growth media and amending the upper 45 cm of the tailings with lime, limestone, manure, and straw. Plant cover was monitored annually for the past 12 years (1997-2008), along with metal uptake by the dominant plant species. Plant cover was determined using permanent and random point-line transects on both the top surface and side slopes of each tailing facility. The four most dominant grasses and two most dominant forbs on each tailing facility were collected for metal analysis, using both washed and unwashed samples. The State of Colorado established specific standards associated with plant cover and species diversity that will be applied after 15 growing seasons to determine reclamation success. Plant cover and species diversity exceed the State standards in all years where precipitation is average or above average, based on long-term climate records. However, in years where precipitation is below average, plant cover falls below expectations. Plant metal concentrations (i.e. Cd, Cr, Cu, Pb, and Zn) are consistently below levels considered to be phytotoxic, regardless of the year and species tested.

\textbf{Additional Key Words:} organic amendment, liming, high elevation, heavy metals.

\textsuperscript{1}Paper was presented at the 2009 National Meeting of the American Society of Mining and Reclamation, Billings, MT \textit{Revitalizing the Environment: Proven Solutions and Innovative Approaches} May 30—June 5, 2009. R.I. Barnhisel (Ed.) Published by ASMR, 3134 Montavesta Rd., Lexington, KY 40502.

\textsuperscript{2}Edward F. Redente is Vice President and Principal Ecologist, MWH Americas, Inc., 3665 JFK Parkway, Suite 206, Fort Collins, CO 80525
PASSIVE TREATMENT AND MONITORING AT THE STANDARD MINE SUPERFUND SITE, CRESTED BUTTE, CO

David Reisman, Thomas Rutkowski, Pat Smart, James Gusek, and Michael Sieczkowski

Abstract. At the 2008 ASMR conference, data from the initial two months of operation of a U.S. EPA pilot biochemical reactor (BCR) was reported. The BCR was designed and constructed in August, 2007 to treat mining influenced water (MIW) emanating from an adit at a remote site in southern Colorado. The original objective of the study was to operate and monitor a BCR on a year-round basis in a harsh mountain environment. In the second year, a pilot chitin reactor was constructed for manganese removal. The treatment results from 13 months of BCR operation and 2 months of chitin reactor operation are presented. The treatment goal for the two pilot reactors was to determine compliance with the applicable surface water quality standards for the State of Colorado. Several attributes of the treatment and monitoring system were unique. It was constructed at an elevation of 11,000 feet a.m.s.l. (3,353 meters), was designed to operate year-round, and was totally passive, using solar energy for the monitoring system and pump power. Due to the site being inaccessible during winter months, this remote monitoring system was designed to collect samples and monitor field variables through the winter months. Field variables were measured and stored by HydroLab™ sondes. Influent and effluent water quality samples were collected and stored in Teledyne™ ISCO™ 6712 samplers. For the first year of operation, the field variable data were transmitted via Stratolink™ satellite communicators. Due to operational issues, the Stratolink™ units were replaced with satellite phones in September 2008. The contaminants of concern (COCs) in the MIW are cadmium, copper, iron, lead, manganese, and zinc. BCR metal removal rates averaged approximately 98% over the first year of operation for cadmium, copper, lead, and zinc. Despite these high removal rates, the BCR effluent exceeded the applicable water quality standards for cadmium, lead, and zinc. Iron and manganese removal rates varied over the first year of BCR operation and were not sufficient to achieve the applicable water quality standards. The removal of manganese by the chitin reactor was inconsistent with an average percent removal rate of 23% over the first two months of operation. Since data are limited on biochemical and chitin reactors operating in elevated and harsh winter locations, the acquired data are unique for MIW remediation.

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


2 David Reisman ETSC, Office of Research and Development, US EPA, Cincinnati, OH 45268, Thomas Rutkowski Golder Associates Inc., 44 Union Blvd #300, Lakewood, CO 80228 Pat Smart and James Gusek Golder Associates Inc., 44 Union Blvd #300, Lakewood, CO 80228 Michael Sieczkowski, CHMM, Technical Sales Director, JRW Bioremediation, L.L.C., Lenexa, KS,
LAND RECLAMATION PERFORMANCE EVALUATION PROCESS AND STANDARDS USED AT THE ANACONDA SMELTER SITE, MONTANA

Robert Rennick, Gunnar Emilsson, and Charlie Coleman

Abstract: Land reclamation is a vital component of remedial response actions used at historic mining and smelting sites throughout the west. In Montana, data-predicated decision tools have been developed to assist state and federal agency personnel in evaluating the success of reclamation efforts implemented on these impacted lands. This paper describes the process developed by EPA to evaluate whether land reclamation practices implemented at the Anaconda Smelter NPL site are meeting agency goals and numeric criteria. The tool is also being used to monitor vegetation condition and erosion stability so that effective maintenance can be performed as these plant communities develop over time. This paper provides an overview of land reclamation practices at this site, describes how the post-reclamation evaluation tool was developed, and discusses the established vegetation management process from seeding to assessing the performance of the reclaimed areas.


2Robert Rennick is a Senior Environmental Scientist, Camp Dresser & McKee (CDM) Inc. Helena, MT 59601, Gunnar Emilsson is Senior Environmental Engineer, CDM, Charlie Coleman is Remedial Project Manager, US EPA Helena, MT 59601.
RAPID ALKALINITY GENERATION AND METAL REMOVAL FROM MINE IMPACTED WATER USING CRAB-SHELL CHITIN UNDER ABIOTIC CONDITIONS

M. A. Robinson-Lora\(^2\), and R. A. Brennan

**Abstract.** Crab-shell chitin has proven to be an efficient multifunctional substrate for the biological treatment of mine impacted waters (MIW). Beyond its capacity as an electron donor source, this material has shown high efficiency in the neutralization of acidic water and in the removal of metals, especially Mn. In this study, the performance of crab-shell chitin as a substrate for abiotic and anoxic MIW treatment was assessed to isolate its chemical and physical treatment mechanisms.

Alkalinity generation and metal (Mn, Fe, Al) removal with crab-shell chitin were evaluated and compared to those obtained using limestone in closed-system and kinetic tests. Raw (R-SC20) and deproteinized (DP-SC20) crab-shell chitin were tested and compared to evaluate the effect of chitin-associated proteins. Anoxic, synthetic MIW (SMIW), with individual metal concentrations of 10 mg/L, was used in all tests. Systems for all tests were prepared and operated inside an anaerobic chamber by mixing crab-shell chitin or limestone with SMIW at predetermined ratios.

In closed systems, 5 g/L of R- or DP-SC20 completely removed (≥95%) both Mn and Fe from single-metal SMIW. After 72 h, pH increased from 3 to 9.2-10.2, while 83-187 mg CaCO\(_3\)/L of alkalinity was generated. In contrast, 5-125 g-limestone/L only raised the pH to 7.8-8.3, leading to lower alkalinity levels (56-63 mg CaCO\(_3\)/L) and poor metal removal efficiencies (≤85%). In kinetic tests with 5 g-DP-SC20/L, removal of ≥95% of the initial metal load was achieved after 0.5, 6, and 48 h for Al, Fe, and Mn, respectively. Geochemical calculations (PHREEQC) indicate that precipitation of Al-hydroxides and rhodochrosite (MnCO\(_3\)) and/or MnHPO\(_4\) are the probable mechanisms for Al and Mn removal. In the case of iron, geochemical calculations point to hydroxides precipitation; however, visual observations suggest the formation of green rust, a precursor of other more stable phases like goethite or lepidocrocite. The faster changes observed with DP-SC20 compared to limestone could be attributed to its significantly larger surface area. These results are the first to verify and quantify the capacity of crab-shell chitin to treat MIW abiotically.

**Additional keywords:** Manganese removal, passive treatment

---


\(^2\) Mary Ann Robinson-Lora, PhD candidate, Rachel A. Brennan, Assistant Professor, Department of Civil and Environmental Engineering, The Pennsylvania State University, University Park, PA, 16802.
A CASE HISTORY: LIMESTONE QUARRY RECLAMATION USING FLUVIAL GEOMORPHIC DESIGN TECHNIQUES

Melissa Robson, Richard Spotts, Ryan Wade, and Wayne Erickson

Abstract: Geomorphology is the study of landforms and development of an understanding of the processes that shape them. Reclamation of mined land, including drainage system reconstruction, is evolving through increased use of geomorphic principals and site specific environmental conditions to design and construct surface topography that is geomorphically and hydrologically stable, aesthetically pleasing, and suitable for and capable of supporting post-disturbance land uses. A case study that exemplifies the benefits of using this fluvial geomorphic design and construction approach is reclamation of a surface quarry at GCC Rio Grande, Inc.’s Tijeras Cement Plant and Limestone Mine, Tijeras, New Mexico; a semi-arid region of the United States.

Surface quarrying removes burden and mineral resources that normally results in the mined area becoming significantly lower in elevation than surrounding undisturbed land. Typically, backfill materials are limited in availability at the conclusion of mining; backfilling frequently requires earthen materials to be hauled into the reclamation area. Fluvial geomorphic post-mining topography (“PMT”) designs should: 1) Incorporate mined-out quarry features; 2) Aesthetically blend reclaimed surfaces into adjacent undisturbed lands; 3) Optimize the use of in situ with imported backfill materials; 4) Establish reconstructed soil depths adequate to support growth of desired vegetation communities; 5) Produce a stable landform; 6) Reconstruct adequate drainage features; and consider post mine land use goals.

This case study compares the latest fluvial geomorphic PMT design method with conventional terrace and drain PMT methods. Potential fluvial geomorphic method cost advantages are identified in design, permitting, construction and reclamation liability period maintenance activities. This project is a 2008 Portland Cement Association award finalist which recognizes leaders in the industry for use of innovative technologies relevant to environmental preservation.


2 Melissa Robson is a project engineer for Water and Earth Technologies, Fort Collins, CO, 80525; Richard Spotts is a Professional Engineer for Water and Earth Technologies Inc., Fort Collins, CO, 80525; Ryan Wade is a project engineer for Water and Earth Technologies Inc., and Wayne Erickson is a Principle Environmental Scientist for Habitat Management Inc., Englewood, CO 80112
CLEAN COAL BIOTECHNOLOGY FOR MONTANA

Tom Rossetto

Abstract: Coal Black Liquids LLC ("CBL") is advancing a project to construct a commercial plant in Montana based on a patented CO$_2$-neutral bioconversion technology that uses naturally occurring microorganisms (derived from wood-eating and humus-eating termites) to convert coal into methane gas as well as humic acid products for agriculture and environmental remediation. CBL is conducting applied research, including lab and field trials, to investigate the benefits of the organic humic acid fertilizer product on plant growth, nutrient availability, yield response and other plant production characteristics. CBL is also conducting research on the effectiveness of the environmental remediation products in the removal of organic and inorganic pollutants from environmental, industrial, and municipal waste/production streams.

Lab and field research currently under way is investigating the efficacy of the organic fertilizer for Montana wheat and alfalfa crops, as well as in the reclamation of acid metalliferous mine tailing. Further research is planned on its effects in establishing growth on nutrient poor soils on cut and fill slopes, increasing plant nutrient availability over time, and in preventing the accumulation of toxic heavy metal soil contaminants by plants.

Additional research is also planned in the treatment of industrial and environmental waste streams with the environmental remediation product. This research will evaluate product effectiveness in comparative side by side evaluations with competing sorbent and ion exchange technologies. Tests will evaluate complete life cycle of the product from treatment through regeneration/disposal. These test results will allow a comparative economic evaluation of the proposed technology.

Preliminary design and cost analysis of a commercial plant are underway. Three Montana coals (leonardite, lignite, and sub-bituminous) are undergoing lab scale bio-conversion analysis to establish plant design parameters. Scale up issues from current lab and pilot scale production will be clearly analyzed in the commercialization plan.


2 Tom Rossetto Senior Engineer, Coal Black Liquids, LLC, 2702 Montana Ave., Suite 201, Billings Montana 59101.406-238 0155.
PRELIMINARY EVALUATION OF LOCALLY AVAILABLE ORGANIC SUBSTRATES FOR VERTICAL FLOW PASSIVE TREATMENT CELLS IN POTOSÍ, BOLIVIA


Abstract: Vertical flow cells (VFCs) are key components of passive acid mine drainage (AMD) treatment systems and require organic substrates that create anaerobic conditions and encourage bacterial sulfate reduction. Sustainable and economical substrate options are often locally available organic waste materials. In the high elevation desert of Potosí, Bolivia, the low productivity landscape limits their availability. In this study, several locally available organic wastes were identified and evaluated as potential VFC substrates in a preliminary laboratory batch study to assist in passive treatment system design. Brewery waste, llama manure and cow manure were collected from three nearby locations. Two abandoned mine water discharges with different properties were collected near Cerro Rico de Potosí. Discharge water A had an initial pH of 2.96, a specific conductivity of 3.310 mS/cm and acidity of 1350 mg/L as CaCO₃ equivalent. Discharge water B had an initial pH of 3.85, specific conductivity of 1.867 mS/cm and acidity of 1000 mg/L. Triplicate batch reactors were set up in 1-L cubitainers with each potential substrate exposed to each AMD, yielding a total of 18 bioreactors which were exposed for 9 days and sampled two times for analysis of anions and dissolved metals. Substrate samples were collected for microbial analysis including iron reducing bacteria (IRB), sulfate reducing bacteria (SRB), fermenters and nitrifiers. Cow manure reactors exhibited the greatest pH, alkalinity and specific conductance increases. Brewery waste reactors did not show any increase in pH. However, sulfate concentrations only decreased in brewery waste reactors, from 2595 mg/L in discharge water A and 1105 mg/L discharge water B to 1350±202 mg/L and 669±31 mg/L respectively. Discharge water A had a minimal impact on microbial groups tested. SRB populations were higher for brewery and cow manure reactors. Fermentative bacteria were higher in llama and cow manure reactors. Results from this short-term experiment suggest that llama and cow manure may be appropriate locally available substrates. Additional longer-term studies are needed to determine the best mix of substrates to be used in a VFC in Potosí, Bolivia.


2Beatriz E. Santamaria, Graduate Research Associate, William H. Strosnider, 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, 202 West Boyd St. Room 334 Norman, OK 73019 Maria R. Apoza Q., Laboratory Technician, Centro de Investigacion Minero Ambiental (CIMA-JICA), Potosí, Bolivia.
COMPARISON OF RECLAMATION OF COAL MINES UNDER THE SURFACE MINING CONTROL AND RECLAMATION ACT OF 1977 AND OIL AND GAS SITES IN WYOMING

Brenda K. Schladweiler

Abstract. The current art of reclamation and the science surrounding it generally had its beginnings in the environmental movement of the late 1960’s and early 1970’s and culminated in the Surface Mining Control and Reclamation Act (SMCRA) of 1977 and subsequent advancement in knowledge since that time. Within current energy industries in the western United States, much can be learned from almost 30 years of coal mine reclamation practices and research. Reclamation regulations vary significantly between coal mines and all other mining (such as uranium), as well as oil and gas (O&G) operations. However, knowledge obtained from one industry may promote land stabilization in a time effective manner within another industry’s disturbance and bonding requirements.

Land disturbances due to O&G are different in that the majority of the disturbance is linear rather than large blocks. The proximity to native areas in O&G development is generally a positive factor, in that significant edge effect (reinvasion of plant species) may come into play during reclamation. The depth and volume of material movement in a coal mining operation are much greater than in traditional O&G or coalbed natural gas (CBNG) operations when an equal sized area is compared. However, total surface disturbance in O&G or CBNG has the potential to be much greater than in a single coal mining operation.

There is not a one-size-fits-all reclamation solution across all industries due to the type of disturbance, varying regulations and site-specific circumstances. Within a given O&G development, the contact between various landscape features makes a one-size-fits-all approach particularly problematic. Each development area for O&G should be evaluated individually to determine what techniques might be appropriate. However, well pads, facilities, and pipelines with similar topography, soil, and precipitation patterns should be treated in the same way, wherever possible, to reduce the complexity of reclamation operations.


2 Brenda K. Schladweiler is President and owner of BKS Environmental Associates, Inc., Gillette and Rock Springs, WY 82717 and 82902.
CLIMATIC ADJUSTMENTS ON RECLAIMED CROPLAND YIELDS FOR FINAL BOND RELEASE

Dr. Stephan A. Schroeder

**Abstract:** Determining a cropland yield standard to be met for final bond release purposes can be accomplished by either trying to use actual average yield data over several years or using USDA Natural Resources Conservation Service (USDA-NRCS) productivity indices (PI) if field data is unavailable or unreliable. However, both cases are subject to variability in growing season conditions from one cropping year to the next and thus methodologies must be developed to try to account for this yearly variation. Several methods have been developed and are currently being used by the North Dakota Public Service Commission to try to “adjust” the yield standards necessary for final bond release caused by these yearly climatic variations. These methods include: 1. Developing a climatic correction factor ratio using a county-wide average yield based upon USDA-NRCS PI data and dividing that yield into the yearly average county yield reported by the USDA-North Dakota Agricultural Statistical Service (USDA-NDASS) or yield data from an area of similar soils where the actual yield was measured. This correction factor is then multiplied times the reclaimed area yield standard calculated using USDA-NRCS PI values to develop an adjusted yield standard; 2. Developing a Productivity Ratio between the reclaimed yield standard for the reclaimed tract based on USDA-NRCS PI values divided by the long-term average county yield from USDA-NRCS which is then multiplied times the annual county yield data supplied by the USDA-NDASS to develop an adjusted yield standard; or 3. Developing a crop-based weighted production ratio factor taking into consideration one of the above climatic adjustments and the acreage of all crops within the reclamation tract. Each of these methods have their own advantages and disadvantages which will be discussed and have been used successfully by several mining companies to adjust reclaimed cropland yield standards for final bond releases in North Dakota.

**Additional Key Words:** Weather, growing season, small grains, haylands, yields

---


2 Stephan A. Schroeder, Environmental Scientist, Reclamation Division, North Dakota Public Service Commission, Bismarck, ND 58505. USA.
EFFECTS OF SUB-IRRIGATION TUBES AND COVER TYPE ON WOODY PLANT ESTABLISHMENT

Joseph D. Scianna, Elizabeth C. Graham, Robert W. Kilian, Darren P. Zentner, and Roger M. Hybner

Abstract. The survival and growth of trees and shrubs in arid regions of the western U.S. is often limited by inadequate soil moisture availability during establishment. This four year study investigated plant growth and water conservation benefits associated with subsurface water delivery via PVC pipes (sub-irrigation tubes) on two sites. The first test site was maintained fallow, and the second site with a cover of thickspike wheatgrass *Elymus lanceolatus*. Four species of woody plants (bur oak *Quercus macrocarpa*; green ash *Fraxinus pennsylvanica*; ponderosa pine *Pinus ponderosa*; and Rocky Mountain juniper *Juniperus scopulorum*) were tested in randomized complete block designs. The effects of water delivery method (surface-applied versus sub-irrigation tube) and herbaceous competition (fallow versus vegetated) on plant survival, height growth, and vigor rating were compared. In year one, sub-irrigation tubes did not result in significant improvements (ANOVA, LSD Separation, p=0.05) in survival or height growth of any species on either site, but did result in significantly better vigor rating in bur oak on the vegetated site. In year two of the study, only green ash on the fallow site demonstrated significantly better height growth and vigor rating where sub-irrigation tubes were used. In year three on the fallow site, bur oak had significantly greater height growth and green ash had significantly better vigor rating where sub-irrigation tubes were used. Additionally in year three, ponderosa pine on the vegetated site had significantly better height growth where tubes were used. In year four on the fallow site, green ash had significantly better vigor rating where tubes were used. There were no significant differences in survival of any species on either site as a result of water delivery method. With the exception of ponderosa pine in year one, each species by treatment had equal or greater survival, height growth, and vigor rating on the fallow versus the vegetated site. Results strongly support clean cultivation to increase the functional success of tree and shrub conservation plantings. In addition, sub-irrigation tubes may prove effective for some species depending on proximity to the seedling’s root system, severity of drought, and other management practices.

Additional Key Words: fallow; vegetated; soil moisture; competing vegetation; PVC pipe; survival; height growth; vigor rating.


2 Joseph D. Scianna, Research Horticulturist, USDA-NRCS, Bridger, MT 59014, Elizabeth C. Graham, Environmental Engineer & DATR Project Leader, Deer Lodge Valley CD, Bridger, MT 59014, Robert W. Kilian, Area Rangeland Specialist, USDA-NRCS, Miles City, MT, Darren P. Zentner, Biological Technician, USDA-NRCS, Bridger, MT 59014, and Roger M. Hybner, Manager, USDA-NRCS, Bridger, MT 59014.
MAPPING VEGETATION CHANGE ON A RECLAIMED SURFACE MINE USING QUICKBIRD

Michael Shank

Abstract. This paper looks at two methods for visualizing and mapping vegetation change on a large surface mining complex in southern West Virginia. Two Quickbird image sets, acquired in 2003 and 2007, were used to identify vegetation trends and to map significant change events manifested during the four year interval. Vegetation trends were visualized using Normalized Difference Vegetation Index (NDVI) difference images, which proved to be a simple and effective means of identifying vegetation change events for further investigation. The study then evaluated Feature Analyst—a commercial analysis package—for its ability to map and quantify two of the most significant change events identified in the study area.

A field investigation used handheld GPS receivers equipped with ArcPad software and GPS-equipped cameras to verify the cause of the two events—1) the defoliation of stands of black locust, and 2) a significant increase in area dominated by deciduous shrub vegetation, caused by rapid growth in autumn olive. Feature Analyst was able to delineate the extent of black locust defoliation, estimated at over 152 acres on several reclaimed permits. In the second case, the analysis estimated that deciduous shrub cover expanded from 32 acres to over 81 acres on one permit, representing an increase from 6.5% to 16.5% of the total permit area.

Feature Analyst showed significant promise for extracting vegetation features from the source images, including individual trees. Feature Analyst’s ability to effectively utilize panchromatic and multispectral image sets suggests it is an effective tool for use with increasingly high resolution data available from commercial vendors.

Additional Key Words: Remote Sensing, feature extraction, object recognition, landcover classification.


2 Michael Shank is a geographer with the Technical Applications and Geographical Information Systems (TAGIS) unit, West Virginia Department of Environmental Protection, Charleston, West Virginia 25304.
A MODEL FOR EVALUATING AND COMPARING SOIL AND SITE FACTORS AFFECTING PRODUCTIVITY OF DISTURBED AND UNDISTURBED SIMILAR AND DISSIMILAR SOILS

H. Raymond Sinclair, Jr., Robert R. Dobos, Sharon W. Waltman, Karl W. Hipple, and Joseph V. Chiaretti

Abstract. The National Commodity Crop Productivity Index (NCCPI) is a model that generates soil productivity indices and allows the evaluation of arrayed similar soils or different soils. The NCCPI user guide explains three major environmental factors (soil properties, landscape features, and climate factors) and many subfactors and their relationships to each other and soil productivity. A cropland tillage system or any mechanical manipulation of the soil that, for example makes hydraulic conductivity (Ksat) slower than medium usually results in a lower crop index than the original soil. Physical soil properties, e.g., bulk density, Ksat, rock fragments within the soil, and other physical soil properties are more difficult to change by farming practices to a more favorable soil condition than chemical soil properties such as pH. Reconstructed soils after surface mining for coal generally have higher soil bulk density, lower soil root zone available water capacity, and slower hydraulic conductivity. These conditions tend to limit crop root growth and lower crop yields as compared to the pre-mined soils. The NCCPI model is a tool that demonstrates that lowering any of the three crop growth factors of a reclaimed soil will result in a lower index. Individual sub-factors can be compared to determine the reason(s) for index being lower for a reconstructed soil than for the pre-mined soil. NCCPI can be used to decide about disposing of undesirable subsurface soil horizons for plant growth and substitution of more favorable soil parent material as subsurface soil rooting media. After surface mining, the reconstructed prime farmland soils should have a positive value for the “water-gathering surface” subrule described in the NCCPI.

Additional Key Words: 7CFR657, SMCRA law, 30CFR823, State Regulatory Authority (SRA), and Office of Surface Mining (OSM), Root Zone Available Water Capacity (RZAWC).

2H. Raymond Sinclair, Jr. and Robert R. Dobos are Soil Scientists, NSSC-NRCS, Lincoln, NE 68508. Sharon W. Waltman is Soil Scientist - Spatial Data Specialist, USDA-NRCS, Morgantown, West Virginia 26505. Karl W. Hipple is National Leader, Soil Survey Interpretations and Joseph V. Chiaretti is Soil Scientist, USSA-NRCS, Lincoln, NE.
SURVIVAL AND GROWTH OF FIVE CHESTNUT SEED TYPES ON A MOUNTAINTOP SURFACE MINE IN WEST VIRGINIA

Jeff Skousen, Travis Keene, Curtis DeLong, Eugenia Pena-Yewtukhiw and Thomas Cook

Abstract: Reforestation of mined lands has become a preferred post-mining land use in some parts of Appalachia since the Appalachian Regional Reforestation Initiative began. With this new emphasis, attention has been focused on replanting the American chestnut on these areas, which was decimated by Chestnut blight during the last century. The American Chestnut Foundation has developed potential blight-resistant hybrids through a series of backcrosses between American and Chinese chestnut. Therefore, the objective of this study was to evaluate the survival and growth of five seed types of chestnut (100% American, 100% Chinese, and three hybrids [B1F3, B2F3, and B3F2]) into loosely-graded minesoils at the Glory surface mine in Boone County, West Virginia. The five seed types were randomly planted in eight blocks (four with tree shelters and four without shelters) and each block was split into randomly assigned peat or no peat treatments. Average seedling survival from seeds after the first growing season was 72% across all treatments, with survival of Chinese 82%, American 67%, and the hybrids at between 69 and 74%. Seeds with tree shelters showed a significantly higher survival at 81% compared to non-sheltered seeds at 63%. Peat treatment generally reduced seed survival but especially so on the non-sheltered seeds. Height growth of trees showed similar results as that of survival, with Chinese seeds and sheltered trees being greatest in height. Additional plantings of seeds and seedlings will be conducted in spring 2009 in West Virginia.

Additional Keywords: chestnut hybrids, Forestry Reclamation Approach, minesoils, tree seedlings, tree seeds


2 Jeff Skousen is Professor and Reclamation Specialist, Travis Keene and Curtis DeLong are Research Assistants, Eugenia Pena-Yewtukhiw is Assistant Professor, West Virginia University, 1106 Agric. Sci. Bldg. Morgantown, WV 26506-6108. Thomas Cook is Vice President, Environmental Affairs, Massey Coal Services, Inc., Julian, WV 25529.
ROTATING CYLINDER TREATMENT SYSTEM DEMONSTRATION\textsuperscript{1}

Patrick Smart\textsuperscript{2}, David Reisman, Stephanie Odell, Sabrina Forrest, Karl Ford, Tim Tsukamoto

**Abstract.** In August 2008, a rotating cylinder treatment system (RCTSTM) demonstration was conducted near Gladstone, CO. The RCTSTM is a novel technology developed to replace the aeration/oxidation and mixing components of a conventional lime precipitation treatment system for mining influenced water (MIW). The RCTSTM realizes several operational benefits, including enhanced lime utilization by the treatment system, reduced maintenance requirements, and reduced power consumption by the aeration/mixing components of the treatment process.

Gladstone is located in the upper Animas River watershed, near Silverton, CO, at an elevation of about 10,500 ft. Approximately 1,500 abandoned mine sites exist in the region. Cement Creek, a tributary to the Animas River, is characterized by elevated metals concentrations and has a typical pH of 3.3. Aluminum, cadmium, copper, iron, manganese, and zinc are the primary mining-related contaminants of concern for Cement Creek. The American Tunnel drainage is a significant source of MIW entering Cement Creek, characterized as a reduced water with elevated concentrations of aluminum, cadmium, copper, iron, manganese, and zinc, and acidic pH.

During the two-week demonstration, the RCTSTM treated surface water from Cement Creek and MIW discharged from the American Tunnel. The RCTSTM was operated at flow rates ranging from 30 to 400 gallons per minute during this demonstration. Monitoring activities included logging field parameters including lime consumption, pH, temperature, dissolved oxygen, and oxidation-reduction potential, and collection of 50 samples for laboratory analysis.

This paper presents the results of the RCTSTM demonstration, with an emphasis on evaluating RCTSTM effluent water quality, and comparing the RCTSTM lime consumption to conventional MIW treatment systems.

**Additional Keywords:** ARD, MIW, water treatment, rotating cylinder treatment system, RCTSTM, heavy metals remediation, Green Remediation, lime precipitation, lime neutralization, economics


\textsuperscript{2} Patrick Smart, Golder Associates, Inc., 44 Union Blvd #300, Lakewood, CO 80228; David Reisman, ETSC, Office of Research and Development, US EPA, Cincinnati, OH 45268; Stephanie Odell, Bureau of Land Management San Juan Public Lands Center, 15 Bennett Court, Durango, CO 91301; Sabrina Forrest, US Environmental protection Agency 1595 Wynkoop Street Denver, CO 80202; Karl Ford, Bureau of Land Management, Lakewood, Colorado 80228; Tim Tsukamoto, Ionic Water Technologies Inc, 9468 Double R Boulevard #A Reno, NV 89505
WATER QUALITY AND THE FATE AND TRANSPORT OF ARSENIC IN A COALBED NATURAL GAS PRODUCED WATER IMPOUNDMENT

Jonathan T. Sowder, Thijs Kelleners, K.J. Reddy

Abstract. A study was conducted to determine whether a Coal Bed Natural Gas (CBNG) produced water impoundment transports contaminates such as arsenic into a shallow groundwater table. CBNG produced waters contain small amounts of trace metals which can accumulate over time in impoundments. An impoundment with a maximum historic arsenic concentration of 146 ug/L (2004) was chosen for this study as it represents a worst case scenario from a water quality perspective (~15 times higher than EPA drinking water limit). Well head and impoundment water quality, subsurface hydrology, infiltration, isotope signatures, and computer modeling were examined to assess the hydrology of the impoundment. Modeling studies included geochemistry (Minteq), subsurface hydrology (Hydrus2D), and contaminant transport (Hydrus2D). Preliminary data indicates high SAR CBNG produced water causes a hydrologic disconnect between the impoundment and the shallow groundwater before the high arsenic concentration occurred in 2004. Minimum water and contaminant transport into the groundwater is predicted. Arsenic and other trace metals are predicted to adsorb to the top several cm of the soil and sediment under the impoundment. The contaminated sediments/topsoil from the impoundment will need to be reclaimed at the end of the impoundments life.

Additional Key Words: Coal Bed Methane, CBM, CBNG, Trace metals, Contaminant Transport, Sediment

---


2 Jonathan T. Sowder is a Graduate Student, University of Wyoming, 1000 E. University Ave. Laramie, WY 82071, Thijs Kelleners is an Assistant Professor, Department of Renewable Resources, K.J. Reddy is a Professor, Department of Renewable Resources and School of Energy Resources
REDEVELOPMENT OF SOIL CARBON POOLS ON RECLAIMED SURFACE MINE LANDS


Abstract. Soils play a crucial role in the global carbon cycle; they represent a carbon reservoir larger than the atmosphere, they are the site of a number of key carbon transformations (e.g. mineralization and humification), and contain a number of unique carbon pools (e.g. plant litter, humic substances, dissolved organic matter, etc.). Land disturbance associated with surface coal mining results in complete disruption of the soil system, loss of a significant portion of soil carbon content, and disturbance of many of the organisms that play critical roles in the carbon cycle (primary producers and decomposers). One of the challenges of surface mine reclamation is reconstruction of a soil system which functions properly in the impacted ecosystem. The objective of this paper is to report our research findings on the recovery of soil carbon pools in reclaimed surface mined lands. Data from our studies indicate 2 mechanisms are important in the rapid accumulation of C from plant litter into soil: physical protection by soil aggregates and biochemical protection of high lignin content. Examination of chronosequences of reclaimed soils indicates plant litter is rapidly incorporated into soil aggregate structure in most of these soils. Lignin content of reclaimed soils we analyzed were higher than that of nearby undisturbed soils, indicating the recalcitrant nature of soil C in reclaimed soils and/or possibly the slow recovery of lignin degrading organisms, primarily fungi. Assays of potentially mineralizable C indicate concentrations of labile C in reclaimed soils reach amounts similar to those in undisturbed soil within 5 or 6 years after revegetation.

Additional Key Words: Ecosystem Recovery, Soil Organic Matter, Mineralizable Carbon, chronosequences. Soil Aggregates

2 Peter D. Stahl, Associate Professor, Department of Renewable Resources, University of Wyoming, Laramie, WY, 82071; Abbey F. Wick, Postdoctoral Research Associate, Dept. of Crop and Soil Environmental Sciences, Virginia Polytechnic Institute and State University, Blacksburg, VA, 24061; Girisha Ganjegunte, Assistant Professor, Dept. of Crop and Soil Sciences, Texas A&M University, EL Paso, TX 79927; Lachlan J. Ingram, Postdoctoral Fellow, Dept. of Biology, Idaho State University, Pocatello, ID, 83201; Urszula Norton, Research Scientist, Dept. of Renewable Resources, University of Wyoming, Laramie, WY, 82071.
ECOSYSTEM RECOVERY ON RECLAIMED SURFACE MINELANDS

P.D. Stahl, A.F. Wick, S. Dangi, V. Regula, L.J. Ingram, and D.L. Mummey

Abstract: The ultimate goal of mineland reclamation is reestablishment of a productive, functional, and sustainable ecosystem suitable for postmining land use. Evaluation of reclamation success for bond release, however, is limited to examination of the reestablished plant community with emphasis also placed on soil erosion protection and landscape hydrologic function. Most ecosystem components and processes of the reclaimed site are not examined but are crucial to ecosystem function and sustainability. The objective of this paper is to present data from our work on recovery of ecosystem structure (e.g. organisms, soils, mycorrhiza) and function (e.g. biomass production, carbon cycling, nitrogen cycling) on reclaimed surface coal mines in Wyoming. Our studies of chronosequences of reclaimed sites indicate increasing productivity through time in all groups of organisms monitored (plants, bacteria, fungi, nematodes and arthropods) as well as increasing concentrations of soil organic matter, rapid incorporation of organic carbon into soil aggregates, redevelopment of mycorrhizae, and reformation of carbon and nitrogen pools. Although the precise trajectory of the restored ecosystems are very difficult to predict because of changing control variables such as potential biota (invasive species) and climate, our data indicates ecosystem structure and function is recovering on reclaimed surface minelands.

Additional Key Words: Reclamation, Restoration, Soil Organisms, Ecological Processes


2 Peter D. Stahl, Professor, Department of Renewable Resources, University of Wyoming, Laramie, WY, 82071; Abbey F. Wick, Postdoctoral Research Associate, Dept. of Crop and Soil Environmental Sciences, Virginia Polytechnic Institute and State University, Blacksburg, VA, 24061; Sadikshya Dangi, Adjunct Assistant Professor, Dept. of Biology, Towson State University, Towson, MD, 21252; Vicki Regula, Bozeman, MT; Lachlan J. Ingram, Research Scientist, Dept. of Biology, Idaho State University, Pocatello, ID, 83201; D.L. Mummey, Research Associate Professor, Dept. of Biology, University of Montana, Missoula, MT, 59812.
ASSESSMENT OF ENVIRONMENTAL IMPACTS NEAR ABANDONED URANIUM MINES WITHIN THE CAVE HILLS AND SLIM BUTTES COMPLEXES, CUSTER NATIONAL FOREST, SOUTH DAKOTA

J.J. Stone and L.D. Stetler

Abstract: Prospecting and mining of uraniferous lignite in the Tertiary Fort Union formation occurred from 1954 through 1967 in northwestern South Dakota. Activity was centered on US Forest Service land and abandoned mine sites received limited reclamation. Subsequent erosion and transport of mine waste has resulted in environmental impacts to soil and water resources down gradient of the mine sites. Through US-EPA Region 8 funding, a Joint Venture Agreement between the USDA-Forest Service Northern Region and the South Dakota School of Mines and Technology (SDSM&T) has been established to evaluate environmental impacts from uranium mining to soil, water, and air resources occurring on private lands surrounding the Cave Hills and Slim Buttes complexes within Custer National Forest. Results from this impact study indicate historical mining activities have caused degradation of regional ecological and environmental resources through the transport and deposition of sediments and spoils containing elevated concentrations of arsenic and uranium. Within the watershed downgradient of the North Cave Hills, surface water concentrations of arsenic and uranium exceeded established background concentrations within 27 km of stream length below the abandoned mines. Sediment results suggest secondary arsenic and uranium mineral phases were typically limited to the upper depths of drainage sediments. Results show that 14 watersheds were potentially impacted by sediment transport from previous mining activity. The most impacted area was the Upper Pete’s Creek drainage below Bluff B where two U samples were 3× and 4× established background. Groundwater results indicate that metals and radionuclides were natural components of the groundwater systems. Results of the surface dust study indicate the general ubiquity of target analytes in the soils around the North Cave Hills. All metals concentrations in the surface dust were decreasing or below background levels within 15 km from the mine sites.

Additional Key Words: uranium mining impacts, wind dust transport, groundwater, surface water, sediments


2 Dr. James Stone, PE, Associate Professor, Department of Civil and Environmental Engineering, South Dakota School of Mines and Technology, Rapid City, SD 57701, Dr. Larry Stetler, Associate Professor, Department of Geology and Geological Engineering, South Dakota School of Mines and Technology, Rapid City, SD 57701.
PERFORMANCE OF AN ECOLOGICALLY-ENGINEERED MULTI-STAGE ACID MINE DRAINAGE AND MUNICIPAL WASTEWATER PASSIVE CO-TREATMENT SYSTEM

W.H. Strosnider, B.K. Winfrey and R.W. Nairn

Abstract: A laboratory-scale, four-stage continuous flow reactor system was constructed to test the viability of high-strength acid mine drainage (AMD) and municipal wastewater (MWW) passive co-treatment. Synthetic AMD of pH 2.6 and acidity of 1870 mg/L as CaCO$_3$ equivalent containing a mean 46, 0.25, 2.0, 290, 55, 1.2 and 390 mg/L of Al, As, Cd, Fe, Mn, Pb and Zn, respectively, was mixed at a 1:2 ratio with raw MWW from the City of Norman, Oklahoma and introduced to the system which had a total residence time of 6.6 days. During the 135-d experiment, dissolved Al, As, Cd, Fe, Mn, Pb and Zn concentrations were consistently decreased by 99.8, 87.8, 97.7, 99.8, 13.9, 87.9 and 73.4 %, respectively, pH increased to 6.8 ±0.1, and net-alkaline effluent produced. At a wasting rate of 0.69 % of total influent flow, the system produced sludge with Al, As, Cd, Cr, Cu, Fe, Pb and Zn at least an order of magnitude greater than the theoretical influent mix, which presents a possible environmental liability if not sustainably recovered or disposed. These results indicate that passive co-treatment is a promising approach that can be optimized and applied to improve water quality with minimal use of fossil fuels and refined materials.

Additional Key Words: arsenic, aluminum, iron, lead, zinc, cadmium, nickel, chromium, aqueous geochemistry, water quality, and sewage


2 William H. Strosnider, 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, 202 West Boyd St. Norman, OK 73019, Brandon K. Winfrey, Graduate Research Assistant, Environmental Science and Technology Department, University of Maryland, 1109 H.J. Patterson Hall, College Park, MD 20742.
EVALUATION OF VARIOUS ION EXCHANGE RESINS FOR DETERMINING URANIUM GROUNDWATER FLUX\(^1\)

Valerie Stucker\(^2\), James F. Ranville, Steven Cabaniss, and Kirk Hatfield

**Abstract:** Ion exchange resins were evaluated for use in passive flux meters (PFM). The PFMs will be installed in uranium-containing aquifers to measure groundwater flow by the use of a displaced tracer, as well as the uranium flux through the meter. Resins were tested in the laboratory for maximum adsorption of uranium in various solution compositions and also in contaminated Rifle, CO groundwater using a fixed amount of resin. After a 24-hour equilibration time the solution and resins were separated. Percent sorption was determined by difference following analysis of the original solution and the solution exposed to the resin. In order to examine recovery, which is essential to determining uranium flux, uranium was desorbed from the resin using 1% nitric acid. Uranium analyses were performed by inductively coupled plasma-mass spectrometry. At a pH of 7.3 in synthetic waters, Dowex 21K, Lewatit S6328 A, and Purolite A500 anion exchange resins adsorbed over 99%, 95% and 94% of the uranium, respectively. These resins performed equally at 99% in natural waters. Effect of pH on the aqueous uranium speciation has some influence on the adsorption of uranium, but these effects are complicated by the presence of nitrate in the system. A solution acidified by hydrochloric acid showed little to no sorption by anion exchange, which is expected due to the dominance of \(\text{UO}_2^{2+}\) at the pH examined (3.8). However, pH adjustment to 3.8 with nitric acid showed a similar or reduced amount of sorption when compared to pH 7.3. Acid treatment showed 100% recovery of the adsorbed uranium from both resins. Tracer capacity and cost analysis will be done on these resins to determine the material used in the PFMs. These PFMs will be useful in studying the flow of uranium in the groundwater during ISR operations as well as in post-ISR monitoring.

Additional Key Words: adsorption, ICP-MS, ISR, monitoring

---


\(^2\) Valerie Stucker, Graduate Student, and James Ranville, Associate Professor, Department of Chemistry and Geochemistry, Colorado School of Mines, Golden, CO 80401, Steve Cabaniss, Professor, Department of Chemistry and Chemical Biology, University of New Mexico, Albuquerque, NM 87131, and Kirk Hatfield, Associate Professor, Civil and Coastal Engineering, University of Florida, Gainesville, FL 32611.
APPLYING RS AND GIS TO THE MONITORING OF SOIL EROSION IN DEEP COAL MINES

Shilu Tang

Abstract. Soil erosion has been a problem in Chinese agriculture since cultivation began, which absolutely poses a threat to the sustainability of Chinese agriculture today. Meanwhile, China is one of the few countries that have a vast amount of coal mineral resource and a wide range of coal mining industries. The extraction and utilization of coal mineral resource inevitably causes a series of serious environmental damages, which worsens soil erosion problem in coal mines. This study intends to combine soil erosion monitoring and deep coal mining impact, in accordance with the technique support from Remote Sensing (RS) and Geographic Information System (GIS), for the purpose of providing fundamental information for environment evaluation and ecological restoration projects in deep coal mines, through spatial data analysis of erosion controlling factors, and eventually conducts the generation of soil erosion risk map. On the basis of RS and GIS techniques, the monitoring of soil erosion affected by deep coal mining is conducted based on empirical relations among erosion controlling factors. Four types of data resource are involved in this study, namely remote sensing (RS) data, digital elevation model (DEM) data, mining surveying data and soil surveying data. RS data is mainly used to extract vegetation information and land use information, while DEM data is applied in topography analysis to obtain slope information. Furthermore, based on mining surveying data, mining subsidence analysis is carried on, where subsidence map is derived. Similarly, soil information is obtained from soil surveying, where soil property is analyzed and generated. As a result, soil erosion risk map is obtained, which serves as the basic but essential information for further environment evaluation and ecological restoration. The overall objective of this study is to operate qualitative soil erosion monitoring in deep coal mining area. Although this approach might be fundamental in nature, the ultimate goal is to create a tool that is useful for deep coal mining soil erosion monitoring.

Key words: soil erosion monitoring, deep coal mine, remote sensing, geographic information system

2 Shilu Tang, Master student, Institute of Land Reclamation & Ecological Restoration, China University of Mining & Technology (Beijing), D11 Xueyuan Road, Beijing, 100083, China.
THE APPLICATION OF 3S TECHNIQUES TO THE TECHNIQUES TO THE RECLAMATION OF CHINESE COAL REFUSE DISPOSAL PILE

Shilu Tang, Zhenqi Hu

Abstract. Coal refuse or coal waste is an incidental production of coal exploitation and processing, which roughly account for 10%-20% of the raw coal production. In China, there is a large amount of coal refuse owing to enormous amount of coal mining operation. In most cases, coal refuse is disposed continuously along with the coal exploitation and processing and consequently piled into anthropogenic hill, which is called “coal refuse disposal pile” or “coal waste pile”. It not only pollutes the nearby environment, but also the pollutes air flows to the residential area about 0.8 km from the coal refuse disposal pile. Therefore, the control of coal waste pile is urgently needed. The intention of this paper is to take a typical long-term abandoned coal refuse disposal pile as a study site, monitor both spatial information and chemical information, and estimate the reclamation cost. 3S (GPS, GIS and RS) integrated technique is applied at the monitoring for spatial information extraction, where the basic spatial information refers to plan area, surface area and volume. Due to the long-term emission of coal refuse pile, it is estimated that the sulfur content is extremely low. Further sampling and testing were conducted to prove this estimation. Based on spatial information extracted from remote sensing image and topography map using 3S techniques, as well as the estimated acidity information, the land reclamation project cost calculation of coal refuse disposal pile is operated in accordance with the cost of neutralization, regrading and revegetation. Neutraliation for coal refuse pile is eliminated, for the low sulfur content, while local plant species are selected for indigenous benefit. In general, this paper conducts the monitoring of typical long-term abandoned coal refuse pile, and generally estimates the total cost for land reclamation project.

Key words: coal refuse pile, reclamation, monitoring, spatial information, cost estimation
NATIVE PLANT MATERIAL SELECTION FOR WATER TREATMENT WETLANDS

C. R. Taylor, P. B. Hook, C. A. Zabinski, and O. R. Stein

Abstract: Treatment wetlands (TWs) are widely used for treating domestic, agricultural, and industrial wastewater, stormwater runoff, and acid mine drainage; natural wetlands are also exposed to these pollutant sources. Currently, few plant species are used in the majority of TWs, and these are often non-native and/or weedy. We are working to identify native species for year-round use in cold-region TWs, particularly the Rocky Mountain region, and explore the basis of differences in performance. In studies presented here, we evaluated chemical oxygen demand (COD) removal from simulated wastewater in microcosms planted with monocultures of 19 species. Experiments were conducted over one year at seasonal temperatures of 4-24°C. With some species and in unplanted controls, COD removal declined at cold temperatures during dormancy, as expected with normal temperature dependence of microbial processes. However, COD removal was constant across seasons with the majority of species. Average COD removal exceeded 90% for Carex aquatilis, C. bebbii, C. praegracilis, C. utriculata, Schoenoplectus acutus, Juncus arcticus, J. torreyi, and Deschampsia cespitosa; of these, only S. acutus is widely used. In contrast, the widely used (and frequently invasive) species T. latifolia, P. australis, and P. arundinacea were somewhat less effective, with average COD removals of 84%, 74%, and 83%, respectively. Redox, sulfate, and root oxygen loss measurements suggest that plant-mediated oxygen transfer may explain the ability of some species to offset the effect of temperature on microbial processes and maintain high COD removal in all seasons. Results indicate that many non-weedy, regionally native species may be candidates for use in TWs or for rehabilitation of natural wetlands exposed to certain pollutants. In addition to the species we studied, other Obligate Wetland and Facultative Wetland species of the Cyperaceae and Juncaceae merit investigation.

Additional Key Words: wastewater treatment, sedges, rushes, wetland indicator status, root oxygen loss, chemical oxygen demand, COD, biological oxygen demand, BOD.

2 Carrie R. Taylor, Department of Land Resources and Environmental Sciences and Center for Biofilm Engineering, Montana State University, Bozeman, MT 59717; Paul B. Hook, Wetland and Watershed Scientist, Intermountain Aquatics, Inc., Driggs, ID 83422; Cathy A. Zabinski, Department of Land Resources and Environmental Sciences, Montana State University; Otto R. Stein, Department of Civil Engineering and Center for Biofilm Engineering Montana State University.
MULTIPLE SITE EVALUATION OF RCTS™ ACID MINE DRAINAGE TREATMENT, EMERGENCY MOBILIZATION AND LIME UTILIZATION

Timothy Tsukamoto and Vance Weems

Abstract. Thorough oxidation and mixing is required for treatment of acid mine drainage on many sites. This is accomplished in the rotating cylinder treatment system (RCTSTM) by passing acid mine drainage and a neutralizing agent through a containment cell in which a perforated cylinder rotates. As the cylinder rotates, a thin film of water adheres to the inner and outer surfaces and water bridges across the perforations for additional gas exchange. The agitation is provided primarily by the impact of the perforations with the water flowing through the containment cell. The turbulence that is produced provides efficient mixing, which reduces chemical consumption due to more efficient use of the available alkalinity, and less sludge produced.

Metals removal effectiveness, energy requirements, and chemical consumption were characterized in four field tests. In all of these, the RCTS™ effectively precipitated metals and increased pH and did so at a lower cost than conventional systems. At sites that compared the RCTS™ with conventional treatment, the RCTS™ system required substantially less energy, chemical, labor and residence time. A direct comparison with a conventional system at the Leviathan Mine demonstrated that the RCTS system used 69% less power for aeration and mixing and was more effective at oxidizing metals. The system used 41% less lime to achieve a similar discharge pH. In addition, the RCTS™ systems can be mobilized quickly to remote locations where conventional systems cannot easily be installed. System installation time was typically less than one day.

Additional Key Words: ARD, MIW, AMD, mining impacted water, acid rock drainage, acid mine drainage, water treatment, rotating cylinder treatment system, metals remediation, green remediation, lime precipitation, lime neutralization, lime efficiency, mining economics

2 Timothy Tsukamoto, Ph.D., is the Director of Technology, Ionic Water Technologies Inc, 9468 Double R Boulevard #A Reno, NV 89505 , Vance Weems is the Operations Manager at Ionic Water Technologies Inc.
USING REFERENCE AREAS VS. TECHNICAL STANDARDS IN ASSESSING REVEGETATION SUCCESS: A QUANTITATIVE CASE STUDY

Carla L. Vik

Abstract. Two options exist under Montana law for use in determining whether revegetation criteria have been successfully met following reclamation of coal mined lands – reference area comparisons and specific technical standards. Reference areas are communities used as models to which reclaimed areas are compared to evaluate revegetation success. Technical standards are usually numeric or descriptive performance standards derived from a variety of sources such as historical data and USDA range management information. Problems exist with both options. Reference areas are often not used as a reference because of the misconception that they set unattainable standards. Many mines prefer technical standards because they can provide a known standard, reduce costs, and avoid management problems associated with reference areas. Setting suitable performance standards in arid to semiarid environments is often problematic due to substantial climactic variation. In this study, the use of reference areas and technical standards are explored using 16 years of cover and production vegetation data collected from the Big Sky Mine in Rosebud County, Montana. These long-term data allow an exploration of the relationship between vegetation data and climatic variability, i.e., precipitation, and the effect of this relationship on revegetation success as measured by reference areas or technical standards. The technical standards used in this analysis were based on NRCS rangeland ecological site descriptions, a proposed technical standard from another Montana mine in the same region, and simple linear regression models based on precipitation and Big Sky reference area plant cover and biomass production averages. Results show that revegetation criteria are less likely to be achieved when technical standards are used than when reference areas are used.

Additional Key Words: Montana, reclamation, Ecological Site Description, climatic variability, precipitation, regression model, cover, production, semiarid environment

---


2 Carla L. Vik, M.A., Plant Ecologist/GIS Specialist, ESCO Associates Inc., 5360 Manhattan Circle, Suite 200, Boulder, CO 80303
INFLUENCE OF TOPSOIL DEPTH ON VEGETATION
ESTABLISHMENT FOLLOWING MINE LAND RECLAMATION

Joshua Voss, Steven R. Perkins, Bruce A. Buchanan and C. Kent Applegate

Abstract: In 1993, a wedge plot study was initiated at Navajo Mine near Kirtland, NM. The objective of the study was to ascertain the influence of topsoil depth over spoil on vegetation establishment. Ten wedge plots were constructed with topsoil depths in each plot ranging from 0 to 24 inches. The wedge plots were seeded in May 1993 and irrigated for the first growing season. In August 2008, annual species cover data and perennial species cover and density data were collected from the plots. Data were analyzed using a Kruskal-Wallis test to determine differences in species cover and density among topsoil depths of 0 to 4 inches, 4 to 8 inches, 8 to 12 inches, 12 to 16 inches, 16 to 20 inches, and 20 to 24 inches. The most common species included galleta grass (Pleuraphis jamesii), alkali sacaton (Sporobolus airoides), Russian thistle (Salsola tragus), and fourwing saltbush (Atriplex canescens). Fourwing saltbush was the only species significantly (p<0.05) influenced by topsoil depth, and both cover and density of fourwing saltbush were greater on shallow topsoil than deep topsoil. Total cover of perennial grass species was also significantly (p<0.05) influenced by topsoil depth, and grass cover was greater on deep topsoil than shallow topsoil. The results indicate that topsoil depth can influence species composition and that variation in topsoil depth may be a management tool to increase species diversity.

Additional Key Words: mineland reclamation, plant establishment, arid environment, topsoil depth


Joshua Voss, Reclamation Scientist, Buchanan Consultants, Ltd., Farmington, NM 87499, Steven R. Perkins, Environmental Specialist, BHP Billiton – New Mexico Coal, Fruitland, NM 87416, Bruce A. Buchanan, President, Buchanan Consultants, Ltd., Farmington, NM 87499, C. Kent Applegate, Environmental Coordinator, BHP Navajo Coal company, Farmington, NM 87402.
FIFTH YEAR TRANSPLANT SURVIVAL ON CONSTRUCTED TEST PLOTS, QUESTA MINE, QUESTA, NEW MEXICO

Anne Wagner, Jeff Sanders, Bruce Buchanan, Edward Redente, Joshua Voss and Bryce Young

Abstract: Chevron Mining Inc. established a revegetation test plot program to evaluate the potential cover depth, soil amendment, and planting treatments for reclamation of the Questa Mine rock piles. The Questa Mine is located near the Village of Questa, New Mexico at an elevation of approximately 2438 m. The test plot program consisted of constructing multiple test plots on 3 slope gradients: 3 horizontal units to 1 vertical unit (3h:1v slope gradient), 2h:1v slope gradient, and flat gradient (platform) test plots. Each test plot was constructed with 3 cover soil depth treatments over the existing rock pile material. These cover soil depth treatments included: no cover, 30 cm, and 90 cm of cover soil material. Soil amendment treatments varied between the sloped and flat gradient test plots. The sloped gradient test plots received treatments of forest soil mycorrhizal inoculant or no inoculant. The flat gradient test plots received treatments of phosphate fertilizer, forest soil mycorrhizal inoculant, or no amendment. After construction, each test plot was seeded, hydromulched, and planted with transplant tree and shrub seedlings. The transplanted tree seedlings consisted of 2 categories: nurse species and crop species. The nurse species consisted of fast establishing, short-lived species, which will shade and protect the crop species. The crop species consisted of multiple conifer species, which represent the post-mining land use plant community. The crop and shrub species were planted at a constant density, while the nurse species were planted at 2 different densities. Overall survival of all seedlings (2008) for platforms, 3h:1v, and 2h:1v slopes was 47%, 44%, and 46% respectively. Of all the treatments applied to the test plots, the one that consistently made a significant difference in survival was the depth of cover soil. The overall survival of all seedlings in 2008 for 0, 30, and 90 cm covers was 22%, 59%, and 58% respectively.

Additional Key Words: Revegetation, reforestation, high altitude reclamation, transplant establishment, soil amendments, inoculant, and cover soil depth.


2 Anne Wagner, Chevron Mining Inc., Questa, NM 87556; Jeff Sanders, Chevron Mining Inc., Questa, NM 87556; Bruce Buchanan, Buchanan Consultants, Ltd., Farmington, NM 87499; Edward Redente, MWH Americas, Inc., Fort Collins, CO 80525; Joshua Voss and Bryce Young, Buchanan Consultants, Ltd., Farmington, NM 87499.
FIVE YEARS OF PLANT COMMUNITY ESTABLISHMENT ON INTERIM RECLAMATION ON MOLYBDENUM TAILING

Anne Wagner, Bruce A. Buchanan, Jeff Sanders, Joshua Voss and Bryce J. Young

Abstract: Chevron Mining Inc. owns and operates the Questa Tailing Facility, near the Village of Questa, New Mexico. The facility receives molybdenum tailing from the Questa Mine, located 9 miles east of the tailings facility. Interim reclamation has been implemented on four areas within the facility. These four areas represent reclamation activities ranging in age from 1980 to 2004. Sampling was conducted for five consecutive years in these areas to evaluate re-established plant communities and to discern if the depth of soil cover material had any effect on plant community composition. The components of the plant communities sampled included; total plant cover, perennial plant cover, shrub density, and species diversity. The results of the plant community study were analyzed to determine the relationships, if any, of plant community components and soil cover depths. In most years there is little or no relationship of plant composition and soil cover depths.

Additional Key Words: Tailings basin revegetation, cover soil depth, and reclamation.

2 Anne Wagner, Ph.D., Manager, Environmental & Public Policy, Chevron Mining Inc., Questa, NM, 87556; Bruce A. Buchanan, President, Buchanan Consultants, Ltd., Farmington, NM, 87499. Jeff Sanders, PG, Chevron Mining Inc., Questa, NM 87556, Joshua Voss, Reclamation Scientist and Bryce J. Young Reclamation Scientist, Buchanan Consultants, Ltd., Farmington, NM 87499.
NEWSOME CREEK, IDAHO: REVEGETATION PLAN FOR A FLOODPLAIN IMPACTED BY HISTORIC DREDGE MINING¹

Susan Wall² and Leonard Ballek

Abstract. Restoration of riparian vegetation is critical for improving water quality and healthy fisheries on streams that have been impacted by mining activities. Woody riparian plants provide bank stability, shade for temperature moderation and woody debris for fish habitat. Mining wastes (dredge piles) that are distributed across the valley floor along Newsome Creek confine the stream to a narrow, drastically disturbed channel which limits the potential for natural channel migration and reduces areas of productive aquatic habitat. The Nez Perce National Forest and the Nez Perce Tribe are undertaking a watershed rehabilitation project involving road decommissioning and stream restoration. Ecosystem Research Group and Herrera were hired to design the channel and floodplain restoration for a 3.5-mile section of Newsome Creek. Geomorphologists, engineers, fisheries biologists, and riparian ecologists collaborated to design channel and floodplain improvements and fish habitat structures. Goals of the restoration project are to design a self-sustaining channel that will neither aggrade nor degrade, restore native riparian vegetation, and reestablish connectivity between the channel and floodplain. Channel design focuses on opportunities to restore natural channel migration processes. Revegetation design includes site specific prescriptions for the streambank, re-graded floodplain, and relocated tailings piles. Challenges for revegetation included coarse-grained soils lacking in organic matter and a very short growing season. The planting plan incorporates detailed prescriptions for container sizes, plant species, seed mixes, and seeding methods as well as specific methods for salvaging existing native vegetation. Container depths are specified to ensure that plant roots will have access to the water table. Plant and seed mix selections are based on site adapted species, taking into account plant availability to avoid last-minute problems with supply. Planting is scheduled to occur over a two to three year period starting in 2011. Following construction, the project includes extensive long-term monitoring to determine revegetation success.

Additional key words: revegetation, reseeding, dredge tailings, riparian, floodplain, fish habitat, stream restoration

² Susan Wall, is a project scientist with Herrera Environmental Consultants, Missoula, MT, 59802 and a Master’s Degree candidate at the University of Montana School of Forestry and Conservation. Leonard Ballek is a senior ecologist with Herrera Environmental Consultants, Missoula, MT.
LANDSCAPE RESTORATION REGIONALIZATION FOR RESOURCE-EXHAUSTED COAL MINE AREAS BASED ON GIS

Linlin Wang and Zhenqi Hu

Abstract: Landscape restoration regionalization is to ascertain the restoration unit from landscape point based on the theory of landscape ecology, ecological economy and some other subjects. This paper discussed the aim and meaning of landscape restoration regionalization, ascertained the process for it. Then taking the abandoned mining areas of MTG of Beijing as an example, this paper built the index system of landscape restoration regionalization on the basis of existing research and on-the-spot investigation, which contains 8 indexes, and 11 factors. Based on GIS, every index was analyzed, partitioned the action scope by its own information and the corresponding criterion. Then according to the service function of research area, the suitable degree of any action scope of each index was determined by Delphi, and valued to 0-10. By using of GIS and database techniques, the spatial data and attribute data were managed, by overlapped the natural indexes and social economy indexes, the multi factors were analyzed synthetically, then by the fuzzy comprehensive assessment model and the principle of maximum degree of membership, the suitable degree of each research unit was calculated, and the suitable using of each unit was confirmed. In this research, there are three kinds of landscapes were confirmed. With the results of landscape suitable assessment and based on the land use, the landscape units and structure to be restored was determined, then the landscape restoration plan were made. In this paper, 16 landscape restoration regions were classified, and the restoration suitability and land-use for each unit were also determined.

Additional Key words: resource-exhausted coal mining area, landscape restoration regionalization, GIS


2 Linlin Wang City College, Capital University of Economics and Business, Beijing, 100070, China, Zhenqi Hu. Institute of Land Reclamation & Ecological Reconstruction, China, University of Mining and Technology (Beijing), Beijing, 100083 China.
THE POTENTIAL FOR CARBON SEQUESTRATION ON DEGRADED LANDS WITHIN NORTH CENTRAL MONTANA

Jennifer D. Watts

Abstract. Terrestrial carbon sequestration, using land management adjustments to increase soil carbon levels within degraded lands, has been advocated as a practical and immediate approach for carbon mitigation. Carbon sequestration and credit programs have recently been established within north central Montana; carbon storage potential within this region, however, had not been assessed previously. This study consisted of a two-part approach. A combination of satellite-image analyses and field survey was first used to obtain regional land use data. Literature-based carbon rate data were then applied to the land use data to generate a regional estimate of carbon sequestration potential given specific land use adjustments. An object-oriented approach was used in conjunction with the Random Forest algorithm to classify agricultural practices set forth in carbon contract agreements associated with the Chicago Climate Exchange and included tillage type, vegetation intensity, and conservation reserve practices. Random Forest is an advanced classification algorithm that avoids data over-fitting and incorporates an internal accuracy assessment. An object-oriented approach allowed for per-field classifications and the incorporation of contextual elements such as shape, texture, area, and neighborhood relationships in addition to spectral features. Landsat satellite imagery was chosen for its continuous coverage, cost effectiveness, and image accessibility. Results from this study found that in most cases satellite image analysis allowed for an effective way to classify land use types within the region. Results from this study estimated that approximately 77,049 t organic carbon yr\(^{-1}\) might be sequestered through the universal adoption of no-till management and the maintaining of land currently under grassland-based conservation reserve. Land use analyses via satellite monitoring and carbon sequestration efforts illustrated within this study can easily be applied to many types of situations involving degraded lands, included mined lands, and need not be restricted to an agricultural setting.


2 Jennifer D. Watts, Land Use Specialist, 508 East Lamme, Bozeman, MT 59715
IN-SITU URANIUM MINING WELL FIELD DESIGN CONSIDERATIONS

S.C. Way

Abstract: Production from uranium mines supplies 64 percent of the current nuclear power utility requirements (World Nuclear Association, July 2008). To sustain current and future uranium demands, world mine production must expand. While increasing mine production will feed the requirements of civil and industrial sectors, the potential for contaminating groundwater supplies and local ecosystems must be addressed.

In 1990, 55 percent of world’s uranium production came from conventional mining operations, but by 1999 the volume had decreased significantly to 33 percent (WNA, July 2008). Conventional mining methods produce tailings, run-off, and significant land disturbance—all requiring significant rehabilitation. With in-situ leach mining methods, disturbance is reduced because only multiple boreholes are drilled for recovery. Rehabilitation is much simpler, resulting in the steady increase of in-situ uranium mining operations.

Other than a site’s uranium reserves, hydrologic characterization of the formation is probably the most important consideration in studying the economic feasibility of an in-situ uranium mining operation. Once characterization is complete, engineers need to address three major aspects in order to increase the economic feasibility of the operation and minimize the associated environmental effects. These key steps include recovery process design, well field design, and monitoring program. The recovery process design influences how efficiently the minerals can be recovered and minimizes the time and cost to complete the recovery. A proper well field pattern with the optimum areal sweep efficiency reduces costs and duration of the operation, provides better control of lixiviant flow, and minimizes the area of potential leakage. Lastly, a groundwater monitoring program provides baseline data and detects potential leakage from the site. This paper will discuss these topics in detail.


2 Shao-Chih (Ted) Way, Ph.D., P.E. – Chief Consultant, In-Situ, Inc., 221 E. Lincoln Avenue, Fort Collins, CO 80524
ZINC INCREASED ROOTING BY 280% IN TRANSPLANTS\textsuperscript{1}

Jerald Wheeler, Joseph Paternoster\textsuperscript{2}, Kyle Peterson, Harold Jensen

Abstract: Zinc is the most common deficient micronutrient in soil. Zinc is essential to many enzyme systems in plants with three main functions including catalytic, co-catalytic, and structural integrity. Zinc contributes to the production of important growth regulators, which affect photosynthesis, new growth, and development of roots. Quick root development is key to the survival of new plants. Zinc promotes the cell growth needed for increasing root development, formation of new leaves and vigorous shoot growth. Zinc improves stress tolerance. If zinc is in short supply, plant utilization of other essential plant nutrients such as nitrogen will decrease. In the plant growth hormone, indole-3-acetic acid (IAA), is a naturally occurring auxin. It also occurs in many bacteria, fungi, and algae. To maintain plants normal growth, IAA must be produced and regulated by the plant. Zinc is the co-factor in the transformation of the amino acid tryptophan to the auxin IAA. Zinc will help maintain IAA levels in the plant and promote growth, rooting, and health. The selection of zinc sulfate as the source of zinc was based on it being the most readily available form for plants. Zinc sulfate also contains a sulfate ion. The sulfate ion (SO\textsubscript{4}\textsuperscript{2-}) is a beneficial nutrient and occurs naturally in soils. Sulfur is used to bind amino acids together by sulfide bridging to create enzymes and proteins, the building blocks of life. Research indicates that the presence of acetic acid will improve uptake minerals. Greenhouse tests show transplants watered with slow release water containing zinc acetate increase root mass by up to 284\% in 30 days. Delivering water and the zinc acetate over 90 days enables the plant to uptake this vital micronutrient.

\textsuperscript{1}Poster was presented at the 2009 National Meeting of the American Society of Mining and Reclamation, Billings, MT Revitalizing the Environment: Proven Solutions and Innovative Approaches May 30 – June 5, 2009. R.I. Barnhisel (Ed.) Published by ASMR, 3134 Montavesta Rd., Lexington, KY 40502.

\textsuperscript{2}Jerald Wheeler, Ph.D, Kyle Peterson, Chemist ACRE Inc. PO Box 36927 Tucson AZ 85740 Joseph Paternoster-President CEO, Harold Jensen-Research & Development DriWater, Inc. 1042 Hopper Ave, Santa Rosa CA 95403
MOBILITY AND BIOAVAILABILITY OF ARSENIC, LEAD, COPPER, AND ZINC AT THE AVOC A MINE SITE, COUNTY WICKLOW, IRELAND

Kent S. Whiting 2, Roger L. Olsen, Eibhlin Doyle, and Gerry Stanley

Abstract: The Avoca Mine in County Wicklow, Ireland is a volcanogenic massive sulfide deposit which has been mined for copper intermittently over the past 300 years using both underground and open pit methods. As a result of the mining activities, large areas of the site are covered with mine spoils, and the Avoca River has been impacted by ARD containing metals concentrations which have made the stream habitat unsuitable for native trout and salmon.

An evaluation of the bioavailability of lead and arsenic within the spoils material was performed using a bioassay technique developed by the University of Colorado, ICP, and electron microprobe (EMP) analyses, while the leach ability of zinc and copper within the spoils was evaluated using ICP, and EMP techniques. While the spoils contained on average 900 mg/kg arsenic and 15,000 mg/kg lead, only 0-28% of the lead (average of 6%) and 0-8% of the arsenic (average of 0.5%) was bioavailable. EMP results showed the lead and arsenic to be present mainly within plumbojarosite and other hydroxysulfate phases, which are stable under the low pH conditions within the spoils pore water. The copper and zinc concentrations within the spoils averaged 1750 mg/kg and 420 mg/kg, respectively. EMP results showed that copper and zinc was present in the spoils mainly as primary sulfide minerals. Copper and zinc concentrations were low within the secondary minerals such as plumbojarosite and other hydroxysulfate, reflecting their higher mobility in the system and explaining why copper and zinc are present in much higher concentrations in the ARD and the Avoca River than arsenic and lead.


COALBED NATURAL GAS (CBNG) WATER QUALITY TRENDS IN
THE POWDER RIVER BASIN, WYOMING

Ashley J. Whitman\(^2\) and K.J. Reddy

**Abstract:** Due to the growing demand for energy resources, the Powder Basin is booming with Coalbed Natural Gas production (CBNG). In the process of extracting the methane from coal seams, a large amount of ground water is brought to the surface. The produced water can be very useful in the water-limited region of Wyoming, but beneficial use may be hindered by potential water quality problems. To assess these problems a water quality monitoring study began in the Powder River Basin in 1999. Ten years of data will be compiled to identify trends in the water quality over time to determine the potential beneficial uses of CBNG water.

The study took water samples of CBNG produced water outfalls and the corresponding discharge ponds. Measurements taken at the site included dissolved oxygen, pH, electrical conductivity, oxidation-reduction potential, and temperature. The water samples were later analyzed for Ca, Na, Mg, K, Fe, Al, Cr, Mn, Pb, Cu, Zn, As, Se, Mo, Cd, Ba, B, SO\(_4\), Cl, F, NO\(_3\), and PO\(_4\). The water was also titrated with HNO\(_3\) in order to determine alkalinity. Subsequently, MINTEQ2 was used to determine the elemental species present in the water samples. A trend analysis of repeated measures will be used to identify water quality trends.

**Additional Key words:** Water Quality Monitoring, Produced Water, Discharge Ponds, Outfalls

---


\(^2\) Ashley J. Whitman is a Graduate Student of Renewable Resources, University of Wyoming, Laramie, WY 82071, and K.J. Reddy is a Professor of Renewable Resources and School of Energy Resources, University of Wyoming, Laramie, WY 82071.
PHYSICAL PROTECTION OF ORGANIC MATTER IN RECLAIMED
COAL MINE SOILS OF SW VIRGINIA

A.F. Wick and W.L. Daniels

Abstract: Particulate organic matter (POM) and aggregate recovery following mining disturbances are important for soil biogeochemical properties and ecosystem function. The objective of this study was to track POM accumulation and aggregation in reclaimed soils following coal mining in southwestern Virginia. A chronosequence of sites was selected based on shifts in vegetation communities with succession, typically occurring between 0-2, 5-7, 16-20, and 38-42 years since reclamation. Undisturbed adjacent forested sites were also sampled. The 0-2 yr old sites were covered with grasses and forbs, the 5-7 yr sites by thick stands of Lespedeza cuneata, the 16-20 yr sites predominately with Festuca arundinacea and patches of deciduous trees (Acer rubrum, Oxydendrum arboreum, etc.) and the 38-42 yr old sites with a mix of Pinus taeda and deciduous forest with a grass understory. Undisturbed sites predominantly supported mixed Appalachian deciduous forest. Available POM (inter-aggregate) and physically protected (intra-aggregate) forms were determined using a density flotation technique and aggregate size distribution with wet sieving. Inter-aggregate POM did not change across site ages; however, intra-aggregate POM increased significantly between the 5-7 and 16-20 yr old sites and remained unchanged through the 38-42 yr old reclaimed site. Inter-aggregate POM reached levels similar to undisturbed sites, while intra-aggregate POM weights were almost threefold that of undisturbed sites after 16-20 years. By observing just the available POM, we would conclude that reclaimed systems recover to an undisturbed condition after a period of 16-20 years, but by quantifying the protected POM, reclaimed system POM storage greatly exceeded undisturbed soil conditions. A positive relationship was observed between small macroaggregates (250-2000 μm) and intra-aggregate POM, suggesting that protection of POM by small macroaggregates in reclaimed systems is extremely important for POM accumulation and subsequently ecosystem function within a period of 20 years. We can also argue the greatest rates of POM accumulation and aggregate formation occur under early succession communities with grasses and forbs rather than under late succession forested communities.

Additional Key Words: microaggregate, organic matter, Appalachian hardwoods, soil quality, sodium polytungstate.

ZORSTM-LANDUSKY: CHALLENGES IN A DECADE OF CLOSURE

R. David Williams², Joan Gabelman, Shannon Shaw, Wayne Jepson, Chris Gammons, and John Kill Eagle

Abstract. The Zortman Landusky mines in Montana, USA, produced gold and silver from a mineralized syenite intrusion. Although mining in the area began over 100 years ago, the most extensive production was from open pit mining and heap leach cyanide processing that occurred from 1977 until 1998. Zortman Landusky is where valley-fill-heap-leach cyanide processing was first used for gold production and is the first large-scale gold mine where unexpected consequences of acid rock drainage occurred. Neither the mining industry nor the agencies anticipated the problems, which developed at the mine. Subsequently Zortman/Landusky is where many of the best management practices for mining and new reclamation techniques were developed. In 1998, the operator declared bankruptcy and the site was taken over by the U.S. Bureau of Land Management and the Montana Department of Environmental Quality. This paper details the history of acid rock drainage issues at the site from the first recognition that acidic drainage was a problem, through initial characterization and prediction work, to final reclamation and water treatment. Closure costs to date include approximately US$42M for site reclamation and approximately US$15M for water treatment facilities. Work continues on residual impacts many of which were not fully recognized until well into the closure phase. These include characterization and treatment strategies for acid mine drainage in Swift Gulch, a small stream whose headwaters originate on the mine property and which eventually flows onto adjacent tribal lands.

Some of the lessons that Zortman/Landusky are that detailed characterization and closure planning before and throughout the mine life are critical. This project also highlights the importance of having adequate financial guarantee mechanisms available to support both the anticipated reclamation throughout the project life and any potential water treatment.

Additional Key Words: Acid drainage, reclamation, water treatment

ACTIVITIES OF THE WYOMING RECLAMATION AND RESTORATION CENTER

Stephen E. Williams and Robin E. Long

Abstract. A half-day session at the 2009 ASMR/BLRS meetings showcased research activities, and some outreach/extension issues associated with the Wyoming Reclamation and Restoration Center (WRRC). Research activities associated with the WRRC are diverse and include plant and plant resources, soil issues, water and water quality, wildlife and wildlife habitat, economics of reclamation and others. Reclamation and Restoration related research and instruction have been on-going at the University of Wyoming since the 1960s. However, it was only in 2002 that a Center initiative was approved by UW’s central administration. Early in 2007 activity of the Center increased with the selection of a new director and the creation of the School of Energy Resources (SER) at the University of Wyoming. TheWRRC (http://uwadmnweb.uwyo.edu/WRRC/), administratively placed under the director of SER and the Dean of the College of Agriculture, has educational options offering of an undergraduate minor, as well as a graduate certificate both in Reclamation and Ecology. An outreach aspect of the school has will begin offering a regularly offered reclamation school for practitioners. Also, through Wyoming Cooperative Extension. The Sustainable Management of Rangeland Resources (SMRR), a fundamental Extension Initiative (composed of a team of nearly a dozen individuals from around the state) is involved with a diversity of issues regarding rangeland productivity including reclamation and restoration (see web site: http://www.wyorange.net/).

Additional Key Words: School of Energy Resources, College of Agriculture, outreach, cooperative extension, research.


2 Stephen E. Williams is the Director of the Wyoming Reclamation and Restoration Center and is Professor of Soil Biology and Biochemistry, University of Wyoming, Laramie, WY 82071. Robin E. Long is the Office Manager for the Wyoming Reclamation and Restoration Center, University of Wyoming, Laramie, WY 82071
REDUCTION OF FECAL INDICATOR BACTERIA COUNTS IN AN ECOLOGICALLY-ENGINEERED ACID MINE DRAINAGE AND MUNICIPAL WASTEWATER PASSIVE CO-TREATMENT SYSTEM

B.K. Winfrey, W.H. Strosnider and R.W. Nairn

Abstract: Passive co-treatment of municipal wastewater and synthetic acid mine drainage in a laboratory-scale, four-stage continuous flow reactor system was examined for changes in fecal indicator bacteria counts. Synthetic acid mine drainage was mixed at a 1:2 ratio with raw municipal wastewater from the City of Norman, Oklahoma and introduced to the system. The municipal wastewater contained varying concentrations of total coliforms (TC), fecal coliforms (FC), E. coli (EC), and fecal streptococci (FS). Initial concentrations ranged from 6-13, 0.6-6, 3-5, and 0.1-0.7 million cfu/100 mL, for TC, FC, EC, and FS, respectively. During the 6.6-day system residence time, a 100% reduction of all indicator bacteria was observed. However, indicator bacteria exhibited evidence of sub-lethal injury with slower colony formation rates on standard growth media. Extending standard incubation periods resulted in higher concentrations of all indicator bacteria in each treatment stage, except the final stage where only EC and TC counts increased. Although this co-treatment regime effectively reduced indicator bacteria concentrations, much remains unknown about the potential for sub-lethal injury to indicator bacteria and its impact on the viability of co-treatment for pathogen removal.

Additional Key Words: acid mine drainage, wastewater, passive treatment, co-treatment, aqueous geochemistry, water quality, pathogen, coliform, pathogen removal, and sewage


2 Brandon K. Winfrey, Graduate Research Assistant, Environmental Science and Technology Department, University of Maryland, 1109 H.J. Patterson Hall, College Park, MD 20742, email: winfrey@gmail.com (will present the paper). William H. Strosnider, 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, 202 West Boyd St. Norman, OK 73019.
Abstract. Critical wildlife habitat supporting mule deer, antelope, and sage grouse in high elevation rangeland and sagebrush ecosystems of southwest Wyoming is threatened by energy development and residential sprawl, resulting in a declining forage base. Restoring disturbances with diverse plant communities is needed. Our objectives were to assess establishment and persistence of native grass, forb, and shrubs, and to test seed mixtures and seeding techniques. In October 2005, 72 entries of 50 native species were drill-seeded on a reclaimed well-pad site, in single-species plots in a randomized complete block design with four replications. Also, two seed mixtures were broadcast- and drill-seeded, and one seed mixture was hydroseeded on disturbed areas adjacent to the plots. In replicated plots, density of seeded species was recorded in each of the 3 years post-seeding, and biomass was clipped from grass plots in 2008. Density by species was counted in mixture plots. In replicated plots, ANOVA showed plant counts depended on seeded species. Of the grasses, densities of L-46 basin wildrye (72 plants/m²), ‘Sodar’ streambank wheatgrass (47 plants/m²), and ‘Critana’ thickspike wheatgrass (37 plants/m²) were greater than other grasses; ‘Appar’ blue flax (11 plants/m²), Richfield Eaton’s and Old Works fuzzytongue penstemon (5 plants/m²) were greater than other forbs; and ‘Wytana’ fourwing saltbush (7 plants/m²), Snake River Plains fourwing saltbush (4 plants/m²), and 9016134 Gardner’s saltbush (1.4 plants/m²) were greater than other shrubs. The most biomass was produced by L-46, Washoe, and ‘Trailhead’ basin wildries, and Critana thickspike wheatgrass. Establishment of the broadcast-seeded Shell and Bridger mixtures were 140,923 and 78,309 plants/ha, respectively. Establishment of the drill-seeded Bridger and Shell mixtures were 45,865 and 34,706 plants/ha, respectively. The Shell mixture hydro-seeding was unsuccessful. Short-term results provide recommendations for native plant restoration. Relatively low establishment of forbs and shrubs indicate more work is needed to develop these plant materials and technologies.

Additional Key Words: Reclamation, native plants, wildlife habitat
ACID NEUTRALIZING CAPACITY AND LEACHATE RESULTS FOR IGNEOUS ROCKS, WITH ASSOCIATED CARBON CONTENTS OF DERIVED SOILS, ANIMAS RIVER AML SITE, SILVERTON, COLORADO

Douglas B. Yager, Mark R. Stanton, LaDonna M. Choate, and Alison Burchell

Abstract. Mine planning efforts have historically overlooked the possible acid neutralizing capacity (ANC) that local igneous rocks can provide to help neutralize acid-mine drainage. As a result, limestone has been traditionally hauled to mine sites for use in neutralizing acid drainage. Local igneous rocks, when used as part of mine life-cycle planning and acid mitigation strategy, may reduce the need to transport limestone to mine sites because these rocks can contain acid neutralizing minerals. Igneous hydrothermal events often introduce moderately altered mineral assemblages peripheral to more intensely altered rocks that host metal-bearing veins and ore bodies. These less altered rocks can contain ANC minerals (calcite-chlorite-epidote) and are referred to as a propylitic assemblage. In addition, the carbon contents of soils in areas of new mining or those areas undergoing restoration have been historically unknown. Soil organic carbon is an important constituent to characterize as a soil recovery benchmark that can be referred to during mine cycle planning and restoration.

This study addresses the mineralogy, ANC, and leachate chemistry of propylitic volcanic rocks that host polymetallic mineralization in the Animas River watershed near the historical Silverton, Colorado, mining area. Acid titration tests on volcanic rocks containing calcite (2–20 wt %) and chlorite (6–25 wt %), have ANC ranging from 4–146 kg/ton CaCO$_3$ equivalence. Results from a 6-month duration, kinetic reaction vessel test containing layered pyritic mine waste and underlying ANC volcanic rock (saturated with deionized water) indicate that acid generating mine waste (pH 2.4) has not overwhelmed the ANC of propylitic volcanic rocks (pH 5.8). Sequential leachate laboratory experiments evaluated the concentration of metals liberated during leaching. Leachate concentrations of Cu-Zn-As-Pb for ANC volcanic rock are one-to-three orders of magnitude lower when compared to leached solution from mine waste used in the kinetic reaction vessel test. This finding suggests that mine waste and not ANC rock may generate the majority of leachable metals in a field scenario.

The organic carbon content of naturally reclaimed soils derived from weathering of propylitically-altered andesite was determined in catchments where ANC studies were initiated. Soils were found to have total carbon concentrations (TOC) that exceed global average soil TOC abundances by as much as 1.5–5 times. These data support an environmental management system involving use of ANC rocks as part of life-cycle mine planning to reduce post-mine closure acid mitigation measures. Carbon contents of undisturbed soils in mined catchments can possibly be used to validate post-reclamation success and help quantify carbon sequestration for CO$_2$ emission offset trading as carbon markets mature.

Additional Key Words: Acid neutralizing capacity, leachate, carbon sequestration, propylitic rocks, volcanic soils

SHORT- AND LONG-TERM TRANSPLANT PERFORMANCE ON MINE ROCK MATERIAL, QUESTA MINE, NEW MEXICO

Bryce J. Young, John T. Harrington, Mark W. Loveall, Anne Wagner, Jeff Sanders and Bruce A. Buchanan

Abstract: Past open pit mining operations at the Chevron Mining Inc. (CMI) Questa Mine in Questa, New Mexico, resulted in several large overburden rock piles. The rock piles are generally steep, angle of repose (2:1 and steeper), acidic (pH 2.5 – 7.0) and composed of a variety of igneous rock types. Pre-mining and currently undisturbed vegetation in the area of the mine site is dominated by mixed conifer forests. Forestry is the approved post-mining land use for this mine. Since the early 1990’s studies have been conducted examining the potential for establishing the forest vegetation directly on the overburden rock piles. In the fall of 1996 and spring of 1997 two operational scale plantings at two locations on the mine rock piles were conducted to examine both the logistics associated with planting trees and shrubs directly on angle of repose slopes and the subsequent survival and growth performance of the transplanted vegetation. Short-term (three year) overall survival averaged 81%. There were survival differences between the two planting sites and among the three types of plants being transplanted with crop trees (conifers) averaging 87%, nurse trees (deciduous) averaging 63% and shrubs averaging 92%. Long-term (twelve year) survival averaged 43% and differed between planting sites with the lower elevation (2,500 m) planting site averaging 45% and the higher elevation (3,000 m) site averaging 41% overall survival. The resulting vegetative communities differed between the two planting sites with the higher elevation site having a higher proportion of crop trees compared to the lower site that had comparatively a higher proportion of shrub species. Implications of the results relative to future reclamation plantings are discussed.

Additional Key Words: reforestation, conifer survival, acid rock


2 Bryce Young, Reclamation Scientist, Buchanan Consultants, Ltd., Farmington, NM 87499, John T. Harrington, Professor of Tree Physiology, New Mexico State University – Mora Research Center, Mora, NM 87732, Mark W. Loveall, Senior Research Assistant, New Mexico State University – Mora Research Center, Mora, NM 87732, Anne Wagner, PhD., Manager, Environmental & Public Policy, Chevron Mining Inc., Questa Mine, Questa, NM 87556, Jeff Sanders, PG, Environmental Engineer, Chevron Mining Inc., Questa, NM 87556, and Bruce A. Buchanan, President, Buchanan Consultants, Ltd., Farmington, NM 87499
DEVELOPING ADAPTIVE BIOLOGICAL STRATEGIES WITHIN CURRENT MONITORING PLANS TO BENEFIT SENSITIVE SPECIES AND FACILITATE MINING OPERATIONS ON TRIBAL LANDS

Jennifer L. Zahratka, Mike Fitzgerald, Matt Owens

Abstract: Activities associated with coal mining can have multiple direct and indirect impacts to sensitive species over the short- and long-term depending on the type, duration, and proximity of the activity. As the natural environment changes with surface disturbance due to coal mining activities, so too will the response of species to their changing environment. In the United States, mining operators must comply with the Endangered Species Act (ESA) of 1973 (7 U.S.C. § 136, 16 U.S.C. § 1531 et seq.) as administered by the US Fish and Wildlife Service (USFWS), the Surface Mining Control and Reclamation Act of 1977 (SMCRA) (30 USC § 1201 et seq) as administered by the Office of Surface Mining Reclamation and Enforcement (OSM), as well as any regulations established by the land management agency administering the mine lease – in our case, the Navajo Nation Department of Fish and Wildlife (NNDFW). This approach typically applies a prescriptive mitigation and monitoring approach, often requiring a halt in mining activities, with results that are not always effective in protecting sensitive species and their habitats. We suggest long-term monitoring coupled with an adaptive and proactive approach using a suite of adaptive biological strategies such as translocation of species, creation of alternative or improved habitats, and encouraging avoidance of habitat subject to immediate disturbance, as well as other measures to minimize mitigation for sensitive species into the planning of mining operations. This approach allows mining activities to continue uninterrupted, while simultaneously protecting sensitive species.

Additional Key Words: coal extraction, mining, strategies, tribal


2 Jennifer L. Zahratka is a senior wildlife biologist for Ecosphere Environmental Services, Durango, CO 81301, Mike Fitzgerald is the owner/principal investigator for Ecosphere Environmental Services, Farmington, NM, and Matt Owens is an Environmental Specialist for BHP Navajo Coal Company, Farmington, NM 87401.
TOXICITY AND GENOTOXICITY EVALUATION OF ACID MINE DRAINAGE TREATMENT USING Artemia sp. AND Geophagus brasiliensis AS BIOINDICATORS

Fernanda Z. da Silveira2, Tamires M. Defaveri, Cláudio Ricken, Jairo J. Zocche and Claus T. Pich

Abstract. Coal mining produces amounts of residues containing high levels of chemical elements that contaminate surface and ground water. In the last several decades, constructed wetlands systems have been used to improve the quality of coal mine drainage. Although the impact of coal mining-related toxic substances on fauna community is an important conservation concern, it has not been studied intensively. The objective of this study was to evaluate the possibility of use a microcrustacean (Artemia sp.) and pearl cichlid (Geophagus brasiliensis Quoy & Gaimard, 1824) to assess the toxicity and the genotoxicity, in a constructed wetland at biopolishing acid mine drainage (AMD) previously treated by conventional physical and chemical processes. Effluent samples were collected at four stations along the treatment system: 1 - pH control and precipitation, 2 - second damping pond output, 3 - wetland input and, 4 - wetland output. Acute toxicity analysis using Artemia sp. was performed at AMD concentrations of 0%, 25%, 50%, 80%, 90% (diluted with mineral water) and 100% (not diluted). Genotoxicity analysis was performed using the comet assay on peripheral blood and hepatic cells of G. Brasiliensis. The Artemia sp. test results indicated lethality of 30% at station1 and 0% at station 4 at 100% AMD concentration, indicating that the constructed wetland is effective at reducing the toxicity for this organism. The comet assay indicated that the effluent is genotoxic, with an increase in the DNA damage index from station 1 to 3 and a significant reduction at station 4, in both blood, and hepatic cells. This increase could be due to the presence of oxidated reactive species that are in between station 3 and 4 partially captivated by the living forms present in the wetland, reducing the genotoxic potential of the effluent. The results suggest that the treatment is efficient at removing toxicity and reducing genotoxicity but further improvements are required.

Additional Key Words: Coal, Constructed Wetland, Fish, Passive Treatment, DNA Damage.

---

2 Fernanda Z. da Silveira and Tamires M. Defaveri are students of Biological Sciences Curse, Cláudio Ricken is a Professor, Jairo J. Zocche is a Ph.D. and Claus T. Pich is a Ph.D. Candidate of Dept. of Biological Sciences of Extremo Sul Catarinense University – UNESC. 1105, University Avenue, CEP: 88806-000, Criciúma, Santa Catarina State, Brazil.