Long-term Effect of Herbaceous Species Cover on the Development of Soil Properties on Reclaimed Mine Site¹

R. Anderson, E. Baer, J. Gillespie, M. Livas, E. Salkind, A. O. Abaye and C. E. Zipper²

Abstract: For the purpose of mine land reclamation, species selection of vegetative cover is necessary for recovering land productivity potential for ecosystem services or planned use. This study focused on the effects of vegetation on soil development at the Powell River Research and Education Center in Wise County, VA. The study site is a previously active coal mine which was overburdened by sandstone and shale and underwent gradation and compaction. The study site was established with a variety of herbaceous species in the summer of 1990, following the addition of an amendment of mixed woodchips and composted biosolids. Research was conducted to compare the effects of the following seven species on soil development: tall fescue, crown vetch, reed canarygrass, common Sericea lespedeza, AULotan Sericea lespedeza, switchgrass, switchgrass/AULotan, and a forested control. Chemical properties of the soil including nutrient content, soluble salts, cation exchange capacity, soil pH, total carbon, and organic carbon were considered. Physical properties including rooting depths, soil structure, soil texture, rock fragments, and diagnostic horizons were Also considered. There is a correlation between extensive rooting systems such as those of common Sericea lespedeza, AULotan Sericea lespedeza, and switchgrass and accelerated pedogenesis. Formation of moderate soil structure and a cambic diagnostic horizon was evident under the aforementioned herbaceous species. The limiting factor at this site was the presence of densic horizons originating from compaction during site establishment. Due to the heterogeneity and microtopography of the study site, further research is necessary to determine the individual factors' contributions to variability of this study.

Additional Keywords: soil genesis, disturbed soils

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Potential Recovery of Aluminum, Titanium, Lead, and Zinc from Fine Tailings in the Abandoned Picher Mining District of Oklahoma¹

W.J. Andrews, R.W. Nairn, and C.J.G. Moreno²

<u>Abstract:</u> The abandoned Picher mining district in northeastern Oklahoma, part of the Tri-State mining district, was the largest source of sulfide ores of lead and zinc in the U.S. in the first half of the twentieth century. After abandonment in the 1960s, numerous environmental problems caused by the abandoned mines and large tailings piles affected the district and surrounding areas with contamination of water, soils, vegetation, wildlife, and humans by lead and other metals. Current (2014) cleanup efforts in the district include separation of coarse and fine tailings particles, sales of the coarse particles (which consist mostly of dolomite and chert) for use as aggregate in asphalt, and burial of metals-rich fine tailings below ground to reduce exposure to, and transport of, toxic metals. Reprocessing of these fine tailings to extract remaining aluminum, titanium, lead, and zinc may be feasible. The value of lead and zinc in the tailings of this abandoned mining district probably are not sufficient to justify recovery of metals from the tailings may provide sufficient returns to justify the costs associated with reprocessing the fine tailings remaining in this district.

Additional Key Words: mining, metals, recovery, economic value

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Impacts of Aeration on Hydraulic Characteristics of Passive Treatment Systems¹

J. Arango, K.A. Strevett and R.W. Nairn²

<u>Abstract:</u> The purpose of this study was to evaluate the impact of off-the-grid reaeration systems powered by wind and solar energy at two passive treatment systems (Hartshorne and Mayer Ranch) that treat underground mine discharge waters. In order to evaluate the impacts of aeration on hydraulic parameters in re-aeration ponds, a series of tracer studies was conducted using Rhodamine WT, a red, stable, fluorescent dye, that allowed determination of hydrologic characteristics such as retention time (\mathbb{T}), number of completely mixed reactors flowing in series (N), dispersion number (d) and index of short-circuiting (α s). Tracer studies were conducted with solar- and windpowered re- aeration systems on and off. After completing the studies, mass recoveries were found to be greater than 70% for every tracer study. A longer hydraulic retention time was achieved with aeration systems on. At Hartshorne, a nearly 67% increase was observed, while at Mayer Ranch a 73% increase was found. Both the dispersion number and number of completely mixed reactors flowing in series with the re-aeration systems on showed that the systems approached a completely mixed flow regime. No shortcircuiting was introduced by any of the re-aerations systems.

Additional Keywords: passive treatment systems, re-aeration systems, tracer study

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Meadow Creek Restoration/ Stibnite Mine Idaho¹

L. Ballek²

Abstract: Restoration of riparian vegetation is critical for improving water quality and restoring healthy fisheries on streams impacted by mining activities. Woody riparian plants provide bank stability, shade for temperature moderation and woody debris for fish habitat. Mine impacted streams have conditions difficult for successful establishment of riparian plants. Stream banks can be dry during part of the year and most have very rocky soils with few fine types of sediment. In addition, high elevation sites have extremely short growing seasons with harsh winters. Innovative restoration techniques for application of cuttings salvaged riparian shrubs and nursery grown plants were utilized on a stream re-location project near the abandoned mining town of Stibnite, Idaho. A section of Meadow Creek was re-located and constructed to move it away from waterborne tailings and to restore salmon and trout spawning habitat. The new stream channel was replanted; the stream diverted into it, and then the original channel was backfilled and revegetated. Willow cuttings were collected on site and used to grow 10,000 containerized plants in a native plant nursery. An additional 2,000 (approx. 1.3 meters in length) willow cuttings were collected on-site just prior to installation to supplement the containerized plants. The containerized plants were installed with a mechanical planter mounted on an excavator arm. Cuttings were planted using an excavator mounted "stinger" in the stream banks at least 1 meter deep. Willow clumps were also salvaged on site and planted in areas of potential bank erosion with the use of an excavator. The container plants and cuttings were installed through fiber encapsulated soil lifts and rocky soils. Installation of plants, cuttings and willow clumps was completed in less than five days in Fall of 2005. Monitoring of vegetation has been conducted on a yearly basis by the US Forest Service and the results will be discussed.

Additional Keywords: bull trout, steelhead, salmon, high elevation, endangered species, fish habita

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Warm-Season Grass Production on Two Mine Soils Amended with Spent Mushroom Compost¹

J.S. Banfill and R.C. Stehouwer²

Abstract: Growth of the Pennsylvania mushroom industry has increased demand of hay bio-feedstock for mushroom growing substrate, while producing increasing amounts of spent mushroom compost (SMC) in need of disposal. Application of SMC to promote growth of quick-growing grass species on abandoned mine land (AML) within the nearby Anthracite coal region may provide an outlet for the nutrient-rich substance. Grass biomass can serve as an ingredient in mushroom production, thereby allowing for a tactical nutrient cycling and management program with market incentives. In order to evaluate the use of SMC as a soil amendment for grass hay production on mine soils, agronomic rates (0 Mg ha⁻¹, 34 Mg ha⁻¹, 67 Mg ha⁻¹) were applied to a pre-existing stand of warm-season swtichgrass (Panicum virgatum) on an Udorthent strip mine and switchgrass, giant miscanthus (Miscanthus x giganteus), timothy-grass (Phleum pratense), orchardgrass (Dactylis glomerata), and tall fescue (Festuca arundinacea) established on a coal refuse pile. Biomass yields and soil and tissue samples were obtained for both sites. Cool-season grasses were quick to establish, but produced low yields. In contrast, warm-season grasses established slowly, but out-produced coolseason grasses two to one on a dry mass basis by the second year of the study. By the third year of the study on the strip mine soil, SMC-applied switchgrass plots achieved yields of 9 to 11 Mg ha⁻¹, which is comparable to other studies on marginal land in the Northeastern United States. SMC application increased soil test levels of P, K, Mg, and Ca relative to controls and is capable of building soil macronutrient fertility in degraded anthracite coal mines soils. The use of SMC in coal mine reclamation has potential to address regional SMC disposal issues while producing raw ingredients for the mushroom industry by way of production of warm-season grasses on abandoned mine lands.

Additional Keywords: warm-season grass, cool-season grass, coal mine reclamation, spent mushroom compost

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Bats Associated with Inactive Mine Features in Southeastern Arizona¹

Angela M.D. Barclay²

Abstract: External pre-screening surveys of 60 inactive mine features were conducted on privately owned and Bureau of Land Management (BLM)-administered lands in southeastern Arizona in March 2012. It was determined that 23 of these features may provide roosts for bats. Passive external portal acoustic and visual surveys of these 23 features were completed using AnaBat acoustic detectors and infrared trail cameras from May through mid-October 2012. Acoustic survey data were analyzed, and 10 species of bats were identified. Bat species were acoustically detected at all 23 sites but were only visually detected at two sites. Acoustically, bat activity and species richness were highest in the spring, whereas bat activity and species richness were lowest in the fall. The two most common species, canyon bat (Parastrellus hesperus) and Mexican free-tailed bat (Tadarida brasiliensis), accounted for more than half of all the survey data. Ten sites accounted for more than 75% of all bat activity. Species richness was highest at two sites, with seven species detected at each site, and was lowest at two sites, where only one or two species were detected. Two species of concern under the Endangered Species Act (ESA), western small-footed myotis (Myotis ciliolabrum) and Yuma myotis (M. yumanensis), were acoustically detected at 15 and three sites, respectively. Two BLM-sensitive species (also identified as species of concern under the ESA), Townsend's big-eared bat (Corynorhinus townsendii) and cave myotis (M. velifer), were acoustically detected at 10 sites and seven sites, respectively. Although no bats were detected in any photos or videos, bats occasionally were seen flying in the analysis area around sunset. However, only one bat was seen exiting an inactive mine feature. Townsend's big-eared bats were seen roosting in two adits during the fall. No major bat roosts and no threatened or endangered bat species were detected through these surveys.

Additional Keywords: conservation, roosts, Sonoran desert scrub, passive external portal surveys, AnaBat, adit, shaft, bat activity, species richness

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Influence of Water Chemistry and Sediment Transport on Biological Recovery Downstream of Lime Dosers¹

H. Bedu-Mensah and N. Kruse²

Abstract: Lime doser treatment for acid mine drainage (AMD) is often used in areas with insufficient space for passive treatment systems and in rural areas where more complex treatment systems would be impractical. In the coal bearing region of Ohio, four lime dosers are currently in use treating AMD in four watersheds: Monday Creek, Sunday Creek, Raccoon Creek and Leading Creek. The dosers were installed between 2004 and 2012 and have varied results. In Raccoon Creek, previous studies support the theory that stream geomorphology and natural alkalinity sources in the watershed support recovery of fish and macroinvertebrate communities. This study assessed field parameters (pH, total dissolved solids, conductivity, temperature and Eh), velocity and settleable solids monthly for 8-11 miles downstream of each doser (distance depending on watershed) for twelve months. A full chemical analysis and flow rate measurement were performed at least twice annually since installation of each doser. The installation of each doser has led to biological improvement in the downstream reaches; however, the improvement has not been consistent between the watersheds. In Raccoon Creek and Monday Creek, biological, acidity, pH and metal targets are all met 7 miles downstream of the doser. In Sunday Creek, acidity, pH and metal targets are met 3.5 miles downstream of the doser, while biological targets are not met until 7 miles downstream of the doser. In Leading Creek, while the pH goal is met 1.5 miles downstream of the doser, the acidity, metal and biological targets are not met. pH values downstream of dosers in Raccoon and Monday Creeks currently average between 5.5 to 8.0 and that for Sunday and Leading Creeks range from 6 to 6.5. Preliminary data suggests that reduction in sediment load, precipitation of dissolved metals and additional alkalinity loads downstream of the doser treatment lead to better biological improvement.

Additional Keywords: active treatment, acid mine drainage, macroinvertebrate

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Hydrology and Geochemistry of the Palzo Surface Mine, Williamson County, Illinois – 2003-2013¹

P.T. Behum, R. Kiser and B. Johnsrud²

Abstract: The Palzo site is an abandoned surface coal mine located southeast of Marion in Williamson County, Illinois and within the Shawnee National Forest. Area-type surface mining of the Davis and De Koven coal beds of the Pennsylvanian age Spoon Formation affected the area in the 1960's. Land reclamation between the 1970's and the early 2000's has re-established vegetation throughout most of the site. However, acidic mine drainage (AMD) discharges at an average rate of about 100,000 gallons per day creating a significant aquatic impact on the adjacent Sugar Creek and the nearby South Fork of the Saline River. AMD is primarily collected in two drainage ways constructed in the backfilled spoil; both are channeled through temporary weir structures where the flow is measured by pressure sensors. The East drain way was the largest discharge (42 GPM) and had a pH = 2.75, dissolved iron = 70 mg/L, dissolved aluminum = 112 mg/L, dissolved manganese = 19 mg/L, sulfate = 2,369 mg/L, and total acidity = 1,140 mg/L calcium carbonate equivalent (CCE; median values). The West drain way (28 GPM) had a pH = 2.83, dissolved iron = 147 mg/L, dissolved aluminum = 141 mg/L, dissolved manganese = 12 mg/L, sulfate = 1,903 mg/L, and total acidity = 1,299 mg/L CCE (median values). Groundwater in the reclaimed mine spoil was impacted throughout the site. However, the chemistry was spatially variable with low pH and high acidity occurring in areas where the net neutralization potential was lower. There is an influx of net alkaline groundwater with improved quality from up-gradient bedrock that is unable to buffer acidic drainage within the spoil mass. Surface and groundwater monitoring will continue at this AML site with the goal of developing measures to reduce the off-site impact on surface water resources.

Additional Keywords: low-pH iron oxidation and acid mine drainage

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Preventing New Groundwater Pollution from Old Oilfield Areas¹

P. Billingsley and J. Harrington²

Abstract: In the past 16 years, the Oklahoma Corporation Commission (OCC) has responded to many well water pollution complaints, and has taken over 2,000 ground water samples from wells, springs, borings and monitoring wells across the state. OCC has worked with the Association of Central Oklahoma Governments and others to define and map the pollution sources, and seek solutions. OCC has found numerous groundwater pollution problems related to old (first drilled pre-1980, often abandoned) oil and gas fields. This presentation will show a few maps of where this groundwater pollution has been found and how it is occurring, but the main focus will be on legal and regulatory issues to help reduce risks from these old oilfield Brownfields and prevent additional groundwater pollution in the future. For example, one way near surface soil/perched groundwater pollution can spread down into an aquifer is via inadequately sealed domestic water wells, so OCC is working with the Oklahoma Water Resources Board to enact new state rules for safer water well construction in old oilfield areas. OCC is also making maps for and working with Oklahoma's Councils of Government and city planners to ensure that when there is new construction proposed in former oil and gas fields, the potential for pollution will be taken into consideration. Cities and towns can incorporate protective requirements into their development rules.

Additional Keywords: Brownfields, old oilfields, groundwater, pollution

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Variability in Phosphorus Sorption by Acid Mine Drainage Residuals Under Flow-Through Conditions¹

J. Bowen, C. Penn and R. Nairn²

Abstract: Excess phosphorus (P) loading from surface soils to surface waters is a major cause of poor water quality. Transported P can be initially categorized as particulate or dissolved. While current best management practices (BMPs) are effective at reducing particulate P losses, conventional BMPs do little to prevent dissolved P transport. One of the main sources of dissolved P in runoff is high P soils. Even if application of fertilizers and manure to high P soils were to cease, these soils will continue to release dissolved P in runoff for many years. Industrial by-products such as acid mine drainage residuals (AMDRs) typically have a high affinity for P and can potentially be used to filter P in runoff prior to reaching a water body using a P removal structure. This study examined the ability of several AMDRs collected from Eastern Oklahoma, to remove P under flowing conditions. The ability of the AMDRs to potentially serve as a P sorption material in a P removal structure will be discussed along with AMDR characterization that is related to P sorption under flowing conditions.

Additional Keywords: phosphorus, sorption, mine drainage residual, by-products, beneficial re-use

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Impact of Mine Drainage on the Genetic Diversity of Brook Trout¹

F.J. Brenner, G.T. Herald, L.M. McGarvey, L.Q. Rittenhouse and S.M. Rummel²

Abstract: Brook trout (*Salvelinus fontinalis*) populations have been isolated in the headwater streams of the West Branch of the Susquehanna watershed for over five decades. Over the last three years, these populations have been surveyed to determine their population densities and fin clips have been obtained from each fish and preserved in 70 percent ethanol. The DNA has been extracted and the mtDNA has been sequenced and gene scans have been completed on each sample to determine the genetic homozygosity and heterozygosity in each population. Preliminary results based on over 150 gene scans indicate that a high percentage of these trout are homozygous at several loci, which appear to be related to population densities and the amount of time these populations have been isolated. There were single nucleotide polymorphisms detected in the mitochondrial DNA among the different brook trout populations.

Additional Keywords: acid mine discharges, population size, Mitochondrial DNA

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Litter Decomposition Rates in Mine Water Wetlands and Ponds¹

J.D. Brumley and R.W. Nairn²

Abstract: Decomposition is important to energy cycling in ecosystems. Decomposition rates are related to the chemical composition of litter and environmental conditions. Six wetlands were examined for above and below ground biomass, vegetation taxa, vegetation metal concentrations and decomposition rates: three volunteer wetlands at the Tar Creek Superfund Site, Ottawa County, Oklahoma, and three passive treatment systems constructed for coal mine drainage in the Arkoma Basin of eastern Oklahoma. Litter bag decomposition experiments were completed using 5 g standing dead Typha spp. litter, dried to a constant weight, cut to 10-cm lengths and homogenized in fiberglass window screening litter bags (15cm x 15cm). Five replicate litter bags were placed in six plots each in i) flooded and ii) saturated hydrologic zones in each volunteer wetland and iii) different cells of each treatment system. Litter bags were collected at approximately 51, 90, 138, 187, and 240 days. A single exponential decay model was used to express decomposition rates and a least squares regression was used to calculate decomposition rates. One way ANOVAs were performed to assess decomposition rate differences within and between systems. All volunteer wetlands showed similar decomposition rates despite differences in hydrology, vegetation and size (F(5,30) = 0.317, p = 0.05). The three passive treatment systems showed significant differences in decomposition rates between the different process units (p < 0.05) and decomposition occurred more rapidly in litter bags closer to system outflows. Slowest decomposition rates were found in the initial oxidation cells where iron accumulation was greatest. The greatest litter mass lost was in flooded hydrologic zones. Overall, decay constants (k) were similar to values for other Typha spp. systems (k = 0.0012-0.0240 day⁻¹). This study not only showed that wetland hydrology greatly influences litter decomposition rates, but that decomposition rates vary with flow through passive treatment systems as water quality changes.

Additional Keywords: energy cycling, decomposition rates, metal accumulation

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Reflecting 50 years of Reclamation: my Career 1963-2013¹

B.A. Buchanan²

<u>Abstract:</u> The first ten years of my career were spent as a student learning the Science, hoping to be called an Ecologist. The next twenty years were spent at a University teaching, and researching the Science, hoping to be called a Professor. The next (last) twenty years were spent as a Consultant applying the Science, hoping to be called a Reclamationist. Over the years I have learned about teaching, research, committees, politics, and opinion. No question, there is more than one way to catch a mouse and it seems I have spent some of my 50 years trying to build a better trap. I will share some of my mistakes, which are many and some of my contributions which are few. I am at best an average Scientist, nothing stellar just someone who loved his career. Raised by a coal miner and a working mother, I was advised by a High School Counselor not to waste my time in college. Ten years later and a Ph.D., I became a Professor at New Mexico State University. I will share some of my philosophies about the importance of students, the value of employees and how to treat supervisors.

Additional Keywords: retirement, philosophy, career, history

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Remediation of Tar Creek Sediments and Adjacent Mine Waste

Design Considerations¹

B. Burnett, W. Smith, C. Ferguson, M. Schelbusch and M. Scott²

Abstract: The U.S. Environmental Protection Agency, Region VII, is in the early design phase of a planned remediation for Tar Creek and its tributaries located in Kansas just north of the Oklahoma state line. The length of these water ways is approximately 3.8 miles and encompasses approximately 445 acres of wetlands and open water. The nuances of remedial design and performing remediation, on this environmentally sensitive area, include hydraulic modeling, as well as wetland inventories. The efforts encompass coordination with multiple stakeholders, organizations and other federal agencies. In order to establish clean-up goals and stakeholder buy-in, a sampling protocol is being developed. The Preliminary Remediation Goals (PRGs) will be obtained through sampling at established points and a reality based assessment that will be ascertained by a cost benefit analysis coupled with hydraulic controls and clean sediment deposition. The remediation will involve stream bed movement, flood plain benching and waste excavation and relocation out of the immediate flood plain. Reestablishment of wetlands and habitat will be a key feature of the remediation. Short term, and long term, monitoring will also serve to assess success of remedy efforts. The phasing of the entire effort, due to funding and logistics, will serve to further establish a successful approach to the methodology utilized. Contractual efforts will include performance based contracting to ensure remediation efforts enhance stream quality and establishment of vegetation is accomplished prior to downstream efforts.

Additional Keywords: sediment

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Vegetative Trends on Reclaimed Gas Well Pad Locations in the

Pinedale Anticline Gas Field, SW Wyoming¹

R.S. Carr, III and A. Davison²

Abstract: In the fall of 2004, Shell Rocky Mountain Production Company (now SWEPI LP) initiated a voluntary pilot project to reintroduce native plant species supportive of sage grouse and ungulate habitat to numerous reclaimed drill locations over the full length of the Pinedale Anticline gas field in Southwest Wyoming. Seeding was done with the intent of testing a number of variables, including seeding techniques, organic soil amendments, seed mixes and the effectiveness of fencing. Each fall thereafter, more reclaims have been seeded as pads are built, drilled, put into production and closed. All seeding efforts were carefully documented and reclaims have been monitored annually using standard qualitative and quantitative methods, resulting in a detailed record of results, which for some reclaims extends back nearly ten years. In this poster, a number of reclaimed sites of differing ages are tracked through annual monitoring results to see if they are "trending" toward successful closure criteria. Three to nine years of onsite vegetation transect data are compared with reference transects to determine trends of species diversity, shrub/forb density and grass frequency, wildlife usage, as well as the introduction of local native species from adjacent undisturbed areas. Established photo points, documented annually, are shown for each reclaim, illustrating effects of varying annual precipitation amounts and timing. The reclaim sites shown include hydro-seeded and drill-seeded locations with or without soil amendments; some were fenced to exclude cattle for a number of years, and some were left unfenced. Successful reclaim sites include both hydro-seeded and drill-seeded locations with and without soil amendments. Fencing has proved critical for establishing native plants during the first three to five years.

Additional Keywords: shell, reclamation, Wyoming, gas field

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² Di hard G. Cara III. C.M.F. increased a Cara a la construction, Julie 14-20, 2014.

² Richard S. Carr, III, C-M Environmental Group, Inc., Reno, Nevada 89509 and Aimee Davison, SWEPI LP

Challenges in Passive Treatment Design: the Future at Tar Creek¹

D. Cates and R. Nairn²

Abstract: The 40 sq. mi Tar Creek Superfund site is located in the Oklahoma portion of the abandoned Tri-State Mining District. Beginning around 1907, shallow lead and zinc sulfide ores were mined and dewatering operations pumped approximately 13 million gallons of groundwater daily. With abandonment around 1970, a 75,000 acre-feet, acidic mine pool with high concentrations of zinc, lead, cadmium, iron, and sulfate formed in the underground mine voids, and once filled (around 1980), began discharging across the site. Remedy funding was made difficult due to initial failures, the implementation of a Fund Balancing Waiver, and declaration that impacts to Tar Creek were due to "irreversible man-made damages". However, a direct congressional appropriation enabled the construction in 2008, of a full-scale passive treatment system (PTS) demonstration project at the Mayer Ranch site, where the discharges first appeared. A second, as of yet unabated, artesian discharge (380 lpm, Fe 138 mg/L, Zn 11 mg/L, Cd 37 μ g/L, and Pb 62 μ g/L) is located nearby and successful passive treatment is possible here using the Mayer Ranch blueprint with newly acquired funding. In 2006, collapse features and adjacent contaminated land surfaces were reclaimed on this site, and a French drain system was installed to move the waters downstream. Significant challenges exist for а PTS here, including design variables, land availability/access/acquisition from multiple landowners, proximity to schools and other existing infrastructure, and limited elevation changes allowing solely gravity-driven hydraulics, flow capture, operations and maintenance requirements, and long term care. Also, mine pool waters are chemically different (Fe 217 mg/L, Zn 6.4 mg/L, Cd 16 μ g/L, and Pb 80 μ g/L) than the flowing discharge. The past experience and expertise of the participants and use of the Interstate Technology Regulatory Council (ITRC) biochemical reactor (BCR) guidance will enable the successful completion of this and future PTS projects.

Additional Keywords: Tar Creek superfund site, passive treatment, BCR, mine pool, Mayer Ranch PTS

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Water Quality Impacts from Mining at the Tar Creek Superfund Site¹

D. Cates²

Abstract: The Tar Creek Superfund Site is located in far Northeast Oklahoma and encompasses approximately 40 square miles of abandoned lead and zinc mines of the Tri-State Mining District. Room and pillar mining occurred here from the early 1900's through about 1970, with extraction of lead and zinc sulfide ores from multiple levels within the shallow Boone formation. During peak periods, dewatering operations pumped approximately 13 million gallons of groundwater daily from the Boone. After abandonment, a 75,000 acre-feet mine pool with high concentrations of zinc, lead, cadmium, iron, and sulfate formed in the mine voids, and once filled, began discharging at several surface locations that flowed into Tar Creek. Milling operations left hundreds of millions of tons of mine tailings (chat) scattered in numerous piles across the site. Leachate from these chat piles and mine water discharges into area streams resulted in severe impacts to stream water quality and aquatic life for many miles downstream. The Roubidoux formation, which is the principal source of drinking water in the region, underlies the Boone and where connected through a conduit (e.g., a borehole), downward flow of contaminated mine water can occur. Early remediation efforts focused on diversion and diking to reduce inflow into the mines and plugging of abandoned deep wells to protect the Roubidoux. Recently, remediation has focused on removal of the mine waste (chat) at the surface and placement into mine shafts and subsidences, and injection of fines into mine voids. A Passive Treatment System (PTS) containing various units including an oxidation pond and a down-flow biochemical reactor has been constructed at the Mayer Ranch site where discharges first appeared in 1980. In the future, more treatment systems are expected to be constructed at other discharge sites.

Additional Keywords: Tar Creek, mine water discharges, mine pool, Roubidoux, passive treatment system

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Effects of Mushroom Compost With Limestone Granules on Metal Removal in Vertical Flow Columns¹

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Abstract: This study was carried out to determine the effect of addition of limestone granules into mushroom compost (MC) on metal removal efficiencies and clogging in columns for treating acid mine drainage (AMD). Four columns (Area 1, 2, 3 = 0.07m², Area 4 = 0.20m²; Height 1, 2, 3, 4 = 1.5m) were set up near the abandoned Wyrong coal mine, Kangwon province, South Korea. All columns contained MC (0.3m thick) placed over limestone gravel (0.7m thick). Columns 3 and 4 contained MC mixed with about 1~2mm limestone granules (1:1 wt. %). The columns were operated for 9 weeks with water samples taken weekly for chemical analysis. Average hydraulic loading rates at columns 1, 2, 3 and 4 were 5.45, 6.01, 5.20 and 2.38 m/d, respectively. Pore spaces in the limestone gravels in columns 1 and 2 were mostly filled with aluminum hydroxide over the course of the experiment, but pore spaces in columns 3 and 4 were not filled as time passed. According to pH measurements and metal concentrations over time, the first two columns showed lower pH values and worse removal efficiencies than the other two columns. Columns 3 and 4 showed better metal removal efficiencies because of the greater buffering capacity of the MC mixed with limestone granules, which maintained pH at around 6 for 9 weeks removing Al within the MC layer. In columns 1 and 2, the MC layers lost buffering capacity in a few weeks causing the pH to drop to around 4 so that AI remained dissolved and then precipitated in pore spaces and on the surface of the limestone which led to clogging. The enhanced buffering capacity of MC mixed with limestone granules led to reduced clogging and improved metal removal and would be an option to increase the longevity of vertical flow ponds for treating AI rich AMD.

Additional Keywords: acid mine drainage, clogging, metal removal efficiencies, vertical flow column

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Open Limestone Channel Treatment Dynamics: A Case Study Treating Low-pH Coal Mine Drainage PA¹

A. Conrad, K. Palmer, A.W. Rose and W. Strosnider²

Abstract: The performance of the Swank open limestone channel was monitored over two years treating a discharge of acid mine drainage averaging pH 3.3, Fe 0.6 mg/L, Mn 0.9 mg/L, Al 9.2 mg/L, and SO₄ 281 mg/L with acidity 83 mg/L CaCO3 and specific conductance 605 μ S/cm. The channel is about 300 m long, has a slope of 6 to 9% and contains limestone fragments with diameters averaging 23 cm, with a maximum diameter of 46 cm and >85% CaCO₃. The 275 m of monitored channel removes about 1/3 of the acidity and metals at a relatively low cost. The outflow pH averaged 4.4, with acidity of 50 mg/L and Al 5.5 mg/L. Metals and acidity removal was inversely proportional to flow rate, which is proportional to residence time. Acidity of the influent was directly proportional to acidity removed, indicating the importance of slight changes in influent geochemistry. No relationship was noted between temperature and treatment performance.

Additional Keywords: oxic limestone channel, acid rock drainage, passive treatment

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Dual Microcapillary Barriers in Conjunction with Water Harvesting can Increase Reclamation Success in the Wamsutter Natural Gas Production Area¹

S. Cude, J. Norton, T. Kelleners and M. Ankeny²

<u>Abstract:</u> Low annual precipitation and soil crusting due to salt content significantly impede successful reclamation of disturbed lands in the Wamsutter natural gas production area. By utilizing a microcapillary barrier of sand above and below a native topsoil seed mix, and situating this inside a water harvesting geometry, available soil moisture can be captured and retained for an extended period of time, potentially increasing vegetation emergence and establishment. The bottom sand layer would prevent the upward movement of salts into the germination zone, and the top sand layer would be largely free of salts and prevent soil crusting. HYDRUS 1D software was used to model transport, flow and evaporation of water during and after precipitation events to design the dual microcapillary barrier water harvesting structure. Column experiments will be conducted to verify HYDRUS data. 24 plots were tested on two field sites in the fall of 2013 in a randomized block design for a total of 48 test plots. Plots included one broadcast seeding (control), one water harvesting geometry, one sand mulch, one capillary barrier, one dual sand barrier and one dual sand barrier with clay wicks to consolidate water.

Additional Keywords: capillary barrier, reclamation, soil structure, soil physics, water harvesting

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Bridging the Gaps Between Policy, Practice, and Science¹

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Abstract: Reclamation and Restoration Ecology provides a unique opportunity to share knowledge between the scientific community, practitioners, and regulatory agencies. Although many isolated studies have been conducted by the scientific community, the field of restoration ecology is comprised of more practitioners than scientists and their knowledge of large-scale restoration efforts is limited. There have been multiple calls to establish conceptual bases, frameworks, intents, or definitions for Restoration Ecology, but few have incorporated comprehensive assessments to account for large-scale work of practitioners. A lack of centralized data and comprehensive assessments may limit scientific knowledge by excluding past failures and successes of restoration efforts. The Wyoming Reclamation and Restoration Center (WRRC) at the University of Wyoming has worked closely with BP America Production Company and Conservation, Seeding, and Restoration, Inc. to develop a database to track large-scale restoration efforts associated with oil and gas development in Wyoming. Since the inception of the database, the US Fish and Wildlife Service has expressed interest in considering reclamation efforts under the Policy for Evaluating Conservation Efforts When Making a Listing Decision (PECE) clause of the Endangered Species Act when deciding whether or not to list the Greater Sage-Grouse as an endangered species. Over 10 other operating companies have shared data, or have agreed in principle to share data. Analysis of the database has revealed strengths and weaknesses and has highlighted areas where the scientific community can work towards bridging gaps between on-the-ground work by practitioners and improved regulatory success standards. Function of the database will be demonstrated and areas where science should aid practitioners and regulatory agencies will be explained.

Additional Keywords: reclamation success

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Pedogenesis and Local Water Quality Effects of Upland Placement of Saline Dredge Spoils in Virginia¹

W.L. Daniels, N.W. Haus, G.R. Whittecar and C.H. Carter III²

Abstract: This study assessed the pedogenesis, salt redistribution and environmental impacts resulting from the placement of 176,000 cubic meters of marine dredged materials into a confined utilization facility (CUF) at the Weanack Land LLLP facility in eastern Virginia. The CUF was formed in compacted and smeared high clay subsoils, with very low permeability and surrounded by a low berm wall. Less than four years after placement/dewatering, all soils had ripened sufficiently to form "wet" cambic horizons. The more leached soils were Fluvaquentic Epiaquents, while the more saline soils classified as Typic Halaquepts. Large reductions in salinity (> 50% initial electrical conductivity) were evident in all horizons including unaltered Cg horizons, although most of the soils would still be classified as saline-sodic for agricultural purposes. Cation redistributions on the exchange complex with depth over time suggest the soils underwent rapid pedogenesis and achieved the composition of 30 year-old confined freshwater dredged materials in less than five years. A significant increase of total dissolved solids in one downgradient groundwater well was noted just outside of the retention berm, but not at two others. Subsequent field investigations indicated that a former gravel roadbed immediately (10 m) upgradient from the affected well and was not properly removed and sealed when the berm was constructed. Following a second deposition of saline dredge and subsequent curing, winter wheat was established on the central portion of the CUF and 2013 yields were similar to surrounding undisturbed prime farmland. This study indicates that CUFs could be a safe and practical method for beneficial use of suitable saline dredge materials, assuming time is allowed for physiochemical ripening and if salts leaching to groundwater can be contained.

Additional Keywords: soluble salts, sodic soils, dewatering, groundwater impacts

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Agricultural Impacts of Longwall Mine Subsidence: The Experience in Illinois, USA and Queensland, Australia¹

R.G. Darmody, R. Bauer, D. Barkley, S. Clarke and D. Hamilton²

Abstract: Planned mine subsidence occurs under two types of underground coal extraction. The first is referred to as High Extraction Retreat mining where the roof supporting pillars in a conventional room and pillar mine are systematically removed and the roof is allowed to collapse. The second type is known as longwall mining which employs a mining machine that extracts a continuous strip of coal from an area leaving nothing behind to support the roof. Both types result in large areas of the surface soils dropping about 70% of the mined out thickness. In Illinois, there was a concern that farm land thus subsided would be lost to productive agriculture. In the early 1980s, the Illinois Farm Bureau (IFB) and the Illinois Coal Association (ICA) began meeting to discuss their mutual concerns about subsidence, which eventually lead to the creation of the Illinois Mine Subsidence Research Program (IMSRP)IMSRP. The IMSRP was organized in 1985 to investigate the environmental and agricultural impacts of planned mine subsidence and to determine the possibility of mitigating its impacts. Its findings established the fact that planned mine subsidence was not as detrimental as was originally feared and that the impacts could be mitigated. This overall project was a successful collaboration of the state and federal governments, scientists from the local Universities and from the Illinois Geological Survey. Similarly, in Australia, longwall mining has met with opposition from the farming community. In response, Bandanna Energy Ltd. has organized the Agricultural Coexistence Research Committee to oversee research into the effective mitigation of longwall mining impacts in Queensland. This presentation will compare and contrast the impacts of longwall mining under different soils, climate, and regulatory regimes.

Additional Keywords: prime farmland, mitigation, regulations, SMCRA

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The American Society of Mining and Reclamation: The First 40 Years¹

R.G. Darmody, J. Skousen and R. Barnhisel²

Abstract: West Virginia, a mountainous state in the Appalachian Coal area of the US with extensive surface and underground coal mining, witnessed the birth of what would become The American Society of Mining and Reclamation. In 1973, it started as a small advisory council to the mining industry and regulators at a time when environmental concerns and reclamation were not routine and efficient extraction was the primary concern. At the dawn of the modern era of environmental awareness, the council was at the forefront of developing workable reclamation methodologies and procedures. The scope of the organization evolved and expanded over the years and its name changes reflected that development. Originally called the "West Virginia Mining Council" until 1983 and then becoming "The American Society for Surface Mining and Reclamation" (ASSMR), in 2001, the name was changed to its current "American Society of Mining and Reclamation" (ASMR). As the name indicates, surface mining was the original focus, and as the industry increasingly moved into planned subsidence techniques, longwall mining in particular, subsidence mitigation became another focus. The reclamation concerns in the coal mining industry were originally loosely regulated by the states, but in 1977, the federal government became more involved with the passage of the Surface Mining Control and Reclamation Act (SMCRA). Since then, ASMR has served as an information exchange medium among reclamation researchers, regulators, mining industry, and industries providing reclamation services and equipment. Currently there are about 400 members in ASMR from the US, as well as from 13 other countries. The primary goal of the society is technology transfer to make the world a better place, while allowing the mining industry and other anthropogenic land disturbances to have minimal impacts on the environment. This talk will present an overview of ASMR.

Additional Keywords: ASMR, subsidence, prime farmland

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Utilization of River Sediments as Topsoil to Reclaim Brownfields and Other Sites¹

R.G. Darmody and J.C. Marlin²

Abstract: Dredging of lakes, reservoirs, and marine ports is done to maintain and enhance their economic and environmental qualities. This activity is necessarily accompanied by the opposite activity, disposing of the dredged sediments. In the USA, dredged material was historically viewed as spoil to be disposed of by the least expensive method. The disposal site was often located in close proximity to the dredging, typically open water or adjacent wetlands. There was little official concern regarding the resuspension of contaminated sediments or loss of marshes, estuaries, and floodplain lakes until the 1970s. Concern over social and environmental issues with dredging and sediment disposal created interest in finding beneficial uses for clean dredged materials. At the same time, concern over water shortages has drawn attention to sedimentation of freshwater lakes and reservoirs, thus leading to increased dredging activity. There is a growing need to develop innovative dredging equipment and sediment placement strategies to maintain freshwater resources. Initial attempts at beneficial use of dredged sediments focused on using sediment for beach restoration and as strip mine or landfill cover. Beneficial use of sediment as topsoil is an option for uncontaminated, fine-grained material. Several studies show that freshwater sediment is a good amendment to sandy soils and that it improves degraded soil at old commercial and industrial sites or "brownfields." Due to improved handling technologies and changing perceptions, it is likely that beneficial use of dredged sediment will continue to gain acceptance. The challenge is to develop improved project designs and dredging and sediment handling technologies. In the future, sediment may become an important commodity for restoration of ecological, agricultural, and urban landscapes hundreds of kilometers from dredging sites. This presentation will include case studies from Illinois where sediments have been successfully utilized as topsoil substitute to restore disturbed areas.

Additional Keywords: dredging, restoration, water quality

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Tar Creek: Superfund Remedy for Mine and Mill Wastes on Operable Unit 4 Remediation¹

D.L. Datin²

Abstract: The Tar Creek Superfund Site is part of the former Tri-state Mining District that extended from northeastern Oklahoma, through southeast Kansas, and into southwest Missouri. Extensive lead and zinc mining during the early 1900's through the 1960's resulted in the contamination of the shallow ground water and surface water. Contaminated soils and large volumes of mine tailings (chat) are still present on the surface at the site. The Environmental Protection Agency (EPA) issued Records of Decision for the cleanup of residential soil in August 1997 and the cleanup of mine waste in February 2008. The cleanup of the residential soils began in 1997 and cleanup of the mine wastes began in 2010. Approximately 2,800 residential properties and approximately 1,465 acres have been cleaned up. 882 properties were bought out by the state and federal government, with 36 property owners refusing the buyout offer. Some of the methods used for cleanup include excavation of the soil and chat and hauling to a repository, selling of chat for use as aggregate in asphalt, injection of chat and fine tailings into the mine voids filled with water, and capping the chat in place. Some other possible methods are deep tilling and stabilizing of the transition zone soils in place.

Additional Keywords: chat, Tar Creek

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Reclamation in the Pinedale Anticline Gas Field, SW Wyoming: A Ten-Year Perspective¹

A. Davison and R.S. Carr, III²

Abstract: Shell Rocky Mountain Production Company (now SWEPI) has been active in the Pinedale Anticline natural gas field in Southwest Wyoming since 2002. Well-pad reclamation carried out up through 2003 utilized the then-current Bureau of Land Management standard seed mix, a grass-dominated mix which created suitable sites for grazing, but was not conducive to restoring critical sage grouse habitat. In 2004, Shell initiated a project to reintroduce native plant species supportive of sage grouse and ungulate habitat to numerous reclaimed drill locations over the full length of the Pinedale Anticline gas field. Along with newly-seeded reclaims, many of the earlier "grass" locations were over-seeded with a new "Habitat" seed mix. Each fall thereafter, more reclaims have been seeded as pads are built, drilled, put into production and closed. Various seeding methods – drill seeding and hydro-seeding, with or without soil amendments, fenced or not fenced – have been tested through above-normal to droughty precipitation years. All seeding efforts were carefully documented and reclaims have been monitored annually using standard qualitative and quantitative methods, resulting in a detailed record of results that now look back nearly ten years. The Bureau of Land Management reclamation standards for the Pinedale Anticline field were upgraded in 2008 to include seed mixes similar to those modeled by Shell; the standards are currently more stringent than most on federal lands in the Rocky Mountain region. Most of the Shell reclaims seeded prior to 2008 would meet the new standards – though not required – with the exception of forb frequency and diversity, due in part to the commercial availability of native forb seed. Factors to be discussed that have contributed to success or failure on this project include soil chemistry and structure, soil amendments, selection of native seed species and timing and amount of annual precipitation.

Additional Keywords: reclamation, natural gas, Wyoming, sage grouse

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Effects of Soil Disturbance and Packed-Box Amendment Study on Two Sodium-Affected Natural Gas Wells Pads in Wamsutter, WY¹

S. Day, J.B. Norton and C. F. Strom²

Abstract: Energy development in arid regions frequently requires disturbance of naturally salt-laden soils, which can introduce subsurface salts and clays to surface soils during reclamation. Quantifying the effects of disturbance is necessary for successful soil restoration when preventative action is no longer an option. Two reclaimed natural gas well pads in Wamsutter, WY (one sodic, one saline-sodic) were sampled in four locations from 0-15 cm in each site's disturbed and undisturbed areas. Samples were analyzed for texture, bulk density, dry and water-stable aggregate distributions, electrical conductivity (EC), ponded infiltration, soil organic carbon (SOC), total nitrogen (N), calcium carbonate, pH, root biomass, and extractable Ca, Mg, K, and Na. Analysis of variance of data from both sites indicated total N decreased by 30% (p=0.001), SOC decreased by 63% (p<0.001), and root biomass decreased by 100% (p=0.037) as a result of disturbance. Dry aggregate distributions reflected the formation of large clods after disturbance, while water-stable aggregate distributions varied. Both sites exhibited significant increases (α =0.05) in % clay, EC, and concentrations of Ca, Mg, and K. To evaluate amendment options for soil remediation on sodium-affected sites, a packedbox experiment was conducted for one year using soil from the saline-sodic well pad. Soil was packed into 0.28 m² wooden frames, 15 cm in depth, with a mesh screen bottom, and buried outdoors level with the soil surface. The amendment treatments used were gypsum, elemental sulfur, and langbeinite, each alone and in combination with compost, compost alone, and a control. Soil amendments were incorporated into the top 10 cm of soil in the boxes in October 2012. Samples were taken in January, April, July, and October 2013 at depths of 0-3, 3-8, and 8-15 cm, and analyzed for Ca, Mg, K, and Na at each depth. Results are currently being analyzed for the packed-box study.

Additional Keywords: sodic, saline-sodic, reclamation, soil structure, soil amendment

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Reclamation Success Variables on Highway Construction Projects in Colorado¹

A.J. DeJoia, A. Hirsch, B. Roeder and M. Banovich²

Abstract: Identification and testing of critical revegetation variables is an important process to determine which factors can increase revegetation rates and success on highway right-of-way revegetation projects. Although the Colorado Department of Transportation (CDOT) has defined specifications for vegetation, many of these specifications are being modified during the construction phases. Through an initial screening process, it was determined that three major research areas needed to be addressed. The first item was to determine through a construction site quality control evaluation what specifications where being modified and the reasons for these changes and the overall impact upon the revegetation process. CDOT and the research team conducted five onsite visits throughout Colorado to determine the reasoning behind modification and deletions along with the potential impacts on reclamation success. This stage was to determine if the CDOT restoration "process" was responsible for reclamation success or failure. The second part of the study was to visit historical revegetation sites to determine revegetation strategies that had positive results and those that had problems achieving reclamation success. Five sites throughout Colorado were evaluated to determine if specifications and methodologies could be identified that increased or decreased the success of reclamation sites. Finally, the third research area determined, through review of the literature and discussions with other DOTs landscape professionals, that correct topsoil salvage is likely a critical aspect of reclamation success. Proper topsoil salvage may reduce overall cost by implementing proper amendment/fertilizer applications. Four separate topsoil salvage methods were evaluated which included 1) No salvage 2) Uniform six inch salvage 3) NRCS soil survey salvage and 4) Field verified soil salvage. This presentation will discuss the results of the first year of research into these three critical revegetation variables and demonstrate the importance of each variable on reclamation success.

Additional Keywords: highway, reclamation, topsoil, quality control

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Characterization and Heavy Metals Status in Pre-mined Soils in North-East Botswana¹

O. Dikinya²

Abstract: A-Cap Resources LTD will begin uranium mining on a 70 km² tract located in Serule, North-East Botswana in 2016. Characterization of soils and establishment of heavy metal concentrations prior to mining disturbance provides an essential benchmark for post-mining reclamation. Land disturbance from uranium mining could result in metal contamination of surface soils with subsequent negative impacts on soil quality and human and ecosystem health. This soil characterization study was conducted because there is no background data of soil trace metals and radionuclides for this region. These benchmark data are essential for post-mining monitoring and possible future remediation. The planned conventional open pit mine will produce 15,000 and 50,000 tonnes (ore and waste rock) per day. The envisaged overburden and waste dumps are likely to enhance potential for heavy metal contamination of soils. To establish the baseline data and pre-mining site environmental conditions; (i) the physico-chemical properties of soils and (ii) potential heavy metal pollutants at different sites were determined. The sampling sites were selected based on the variation in soil classes in the study area. The following heavy metal concentrations were determined: Th, U, Sr, Ba, Be, Cd, Pb, V, Cr, Ni, Cu, Zn and Co. Characteristic to heavy metal pollution impacts the soil's properties including clay content, soil pH, and cation exchange capacity (CEC). The results reveal that most soils are predominantly sandy clay loam suggesting high potential for natural attenuation of heavy metals by adsorption on soil as evidenced by relatively high clay content (17.2%). Further, most heavy metals were at expected ranges for non-contaminated soils and there was no evidence of any geochemical anomalies.

Additional Keywords: heavy metals; metalloids; pollution; soil properties; uranium; Botswana

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Beneficial use of Coal-Bed Natural Gas Produced Water Through Managed Irrigation in the Powder River Basin of Wyoming¹

C. Driessen, K. House and K. Harvey²

Abstract: In the early 2000's, Coal Bed Natural Gas (CBNG) activities were flourishing in the Powder River Basin of northeastern Wyoming. Natural gas producers in the region faced the issue of managing large quantities of produced water. CBNG produced water is naturally occurring and unaltered groundwater generated when water in the coal seams is pumped to the surface to reduce hydrostatic pressure and recover the coal bed natural gas. This groundwater is rich in sodium and bicarbonate minerals from natural processes occurring as rainfall and snowmelt percolate through the soils and deeper geologic formations. Managed irrigation was developed to supply a beneficial use for the produced water. By definition, managed irrigation is the application of soil science, water chemistry, agricultural engineering, and agronomic principles to utilize CBNGproduced water in a beneficial manner to produce forage for livestock and wildlife, while protecting soil physical and chemical properties. The suitability of managed irrigation as a water management tool depended on many factors including produced water chemistry, site and soil characteristics, landowner agronomic objectives, and natural gas production company project economics. CBNG development has slowed significantly in recent years and decades-long managed irrigation projects are now reaching site closure stages. This study examined a managed irrigation program consisting of 86 fields covering over 3,000 acres through the last twelve years.

Additional Keywords: saline-sodic soil

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Analysis of Microbial Communities in Vertical Flow Bioreactors at the Tar Creek Superfund Site Water¹

K.E. Duncan, R. Nairn, K. Strevett and J.K. Choi²

Abstract: Water flowing out of abandoned underground mines at the Tar Creek Superfund site is polluted by metals including cadmium, lead, and zinc. A passive treatment system was constructed in part to promote the activity of anaerobic Sulfate-Reducing Bacteria (SRB) in order to precipitate metal sulfides. The primary organic matter was a mixture of spent mushroom compost and wood chips. Anaerobic degradation of cellulose requires the activities of several different physiological groups of microbes, viz. the primary cellulose-degraders, fermenting bacteria ("Clostridia"), SRBs, and methanogens. DNA was extracted from substrates collected from two vertical flow bioreactors after operating for 1.5 years to determine if an anaerobic cellulosedegrading community had developed. Quantitative polymerase chain reaction (qPCR) of a gene coding for dissimulatory (bi) sulfite reductase (dsr), essential for sulfate reduction, was used to estimate the abundance of SRBs. The number of bacterial 16S ribosomal RNA (rRNA) gene copies was estimated using gPCR. Clone libraries of archaea, bacteria and eukaryotes were constructed using PCR amplification of rRNA genes. Bacterial 16S rRNA gene copies estimated for subsamples within the cells ranged from 108 to 109/g substrate, dsr copies from 7x103 to 7x105/g substrate. The bacterial clone libraries were dominated by Chloroflexi, Proteobacteria, and Bacteroidetes. Many of the Chloroflexi sequences were not affiliated with described genera, but did include some genera that were anaerobic and fermented sugars, which could be utilized by SRB. Sequences of SRB comprised approximately 10% of the total. Sequences affiliated with Class "Clostridia" groups that degrade cellulose or other polymers were present but at less than 10% of the total. Nearly half of the archaeal sequences were those of methanogens. Approximately 1/3 of the eukaryote sequences were similar to those of fungi, though most were not affiliated to cellulose-degrading fungi. In conclusion, a microbial community containing members necessary for anaerobic degradation of cellulose was established.

Additional Keywords: metal pollution, sulfate-reducing bacteria, mining waste treatment, anaerobic microbial communities

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Jennings Passive Treatment System Rehabilitation¹

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Abstract: A Vertical Flow Pond (VFP) is one type of passive treatment technology utilized to treat mine drainage. The Jennings VFP located at the Jennings Environmental Education Center in Butler County, Pennsylvania was installed in 1997. At the time of construction, the hydraulic design life of the treatment media was estimated to last 7-10 years with exhaustion of the acid neutralizing capacity estimated at approximately 14 years. Occasional maintenance activities such as stirring the treatment media is believed to have extended the life of the media, but after almost 15 years of near continuous operation, the treatment media of the VFP at Jennings experienced a significant loss of permeability resulting in the inability of the VFP to treat all of the influent acid mine drainage. Neither the backflushing nor stirring events that were conducted in 2011 were able to effectively increase sufficient permeability. An extensive rehabilitation of the VFP was determined to be needed and was performed in 2012. Media from the VFP was removed and encapsulated in Harsco's Mineral CSA, an alkaline material byproduct produced as a result of recovering metals from steel slag. This is the first known use of this material in this way. Next, a new underdrain, bedding stone, and treatment media were installed. The addition of single-shredded woodchips to the treatment media recipe of spent mushroom compost and high calcium limestone is expected to increase design life and decrease maintenance. Post-rehabilitation water quality monitoring indicates that the system is functioning well. Project partners included U.S. Office of Surface Mining, Foundation for Pennsylvania Watersheds, Western Pennsylvania Coalition for Abandoned Mine Reclamation, Pennsylvania Department of Environmental Protection's Growing Greener Program, Pennsylvania Department of Conservation and Natural Resources, Harsco Mineral, Slippery Rock watershed Coalition, BioMost, Inc., and Stream Restoration Incorporated.

Additional Keywords: water treatment, mine drainage, system rehabilitation, vertical flow pond

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Biochemical Reactors for Treating Mining Influenced Water¹

P. Eger, C. Baysinger, D. Cates and S. Hill²

Abstract: Innovative approaches and technologies need to be developed and implemented that solve environmental issues and remove existing regulatory barriers. The Interstate Technology and Regulatory Council (ITRC) is a state-led, national coalition helping regulatory agencies, site owners, and technology developers and vendors achieve better environmental protection through use of innovative technologies. Through open communication among its partners, ITRC is streamlining and standardizing the regulatory approval review process for better, more cost-effective, environmental technologies through the development of consensus based Technical and Regulatory guidance documents. Funding comes from the Departments of Defense and Energy, and the US Environmental Protection Agency, as well as industry affiliate fees and is used to support teams to address state environmental priorities. The ITRC mine waste team was formed in 2008 to address mining influenced water and residual mining solids and produced a web based guidance to help select technologies that address a wide variety of mine waste issues (ITRC MW-1, 2010 at http://www.itrcweb.org/miningwaste-guidance). During the development of the first guidance, the team felt that although Biochemical Reactors (BCRs) were a promising technology to treat Mining Influenced Water (MIW), more information on their design, use and success was needed. As a result, in 2013, the team produced a second guidance on their use (http://itrcweb.org/bcr-1/). The guidance contains information on the applicability, design, construction, monitoring and maintenance of BCRs as well as discussion on the regulatory and public stakeholder issues related to their use. Fifteen case studies are included.

Additional Keywords: passive treatment, sulfate reduction

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Getting the Lead out (and Other Trace Metals) - Solving Mine Water Problems With Peat-Based Sorption Media¹

P. Eger, P. Jones and D. Green²

Abstract: American Peat Technology (APT) has developed a patented carbonization process to convert raw reed sedge peat into a granular, hardened ion exchange material (APTsorb[™]). These granules have a high internal surface area, maintain their structure when wet and can be crushed to any size, making them easily adaptable to existing active and passive treatment system technologies. The material has a high affinity for trace metals, particularly lead. In laboratory experiments, maximum lead loadings of 15% dry weight Pb were observed. A pilot test was initiated at a base metal mine in North America in October 2013. The pilot was designed to model both an active (pressurized tank) and passive (biocell) treatment system approach. The original plan was to treat the discharge from the clarification basin, but if the mine discharge could be treated directly, the basin could be eliminated. To accommodate this approach, a pressurized sand filter was installed before both systems. Input mine water had a pH greater than 7 and contained about 1500 ug/l Pb, 100 ug/l Zn and 1.5 ug/l Cd. Total metals concentrations varied with the suspended solids in the discharge. The sand filter essentially removed all suspended metals, but removal decreased as the pressure drop over the filter increased. Both pilot systems removed over 99% of the lead and reduced all metals to below permit values. A conceptual model of full scale treatment was developed for a mine discharge of 8000 gpm. Estimated capital costs were on the order of 5 million dollars, about a factor of three less than a standard chemical treatment plot. Based on 6400 bed volumes of treatment capacity, annual operating and maintenance costs would not exceed \$0.001/gallon. This cost will decrease as more bed volumes are treated.

Additional Keywords: zinc, cadmium, water treatment

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Solving Mine Drainage Problems at the Soudan Mine: The final? Answer¹

Paul Eger, Peggy Jones, Doug Green²

Abstract: Water discharging from the Soudan mine contains elevated copper and cobalt and treatment is required. Since 2009, the water has been treated with a commercial ion exchange resin system that includes flow equalization tanks, bag and cartridge filters, a break tank, a carbon tank and several ion exchange tanks. Although effective, the system's high cost, inefficient removal of suspended material and substantial maintenance have been ongoing and troublesome issues. In November 2012, a pilot test was initiated using a peat based sorption media (APTsorbTM). This media is produced from raw reed sedge peat through a patented carbonization process which produces a hardened granular ion exchange material. The granules are uniform, have a high hydraulic conductivity and maintain the high metal affinity of natural peat. Mine water was pumped through the media without any pretreatment. Copper input typically ranges from $30 - 60 \mu g/l$, but concentrations increased to a maximum value of around 300 μ g/l in the summer of 2013. Since startup, over 16 million gallons (> 30,000 bed volumes) have been treated with an average removal of around 75% for suspended copper and 60% for dissolved copper. Backwash is required at about 4000 bed volumes, but with a combination of air sparging and high flow backwash, the suspended material appears to be effectively removed from the bed. The APTsorb media produced equivalent copper removal to the existing treatment system components of the bag and cartridge filters, the break tank, the carbon tank and the first commercial ion exchange tank. By reducing the size and complexity of the system, the capital and operation and maintenance costs are substantially reduced. Based on the existing data, using a single APTsorb tank will reduce annual operating costs by about a factor of 6; from around \$130,000 to \$21,000.

Additional Keywords: copper, cobalt, ion exchange, peat

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Monitoring Experimental Valley Fills Designed for Reduction of Total Dissolved Solids in Discharged Waters¹

D. Evans and C. Zipper²

Abstract: Surface mining for coal and the use of valley fills to dispose of excess spoil often results in increased Total Dissolved Solids (TDS) concentrations in streams below the mining operations. Increased TDS concentrations in surface waters negatively impacts stream habitat and aquatic organisms. However, conventional mine reclamation, excess spoil disposal methods, and regulations in the USA have not been designed with the intent of limiting TDS generation and transport. Two experimental valley fills are being constructed in Virginia, USA, using methods intended to reduce TDS generation and transport to surface streams, including placing low TDS generated spoil in surface and subsurface drainage zones, reducing water flow through bulk fill, and isolating high TDS generating spoil away from hydrologic flowpaths. Results will be presented from ongoing water quality monitoring of multiple water quality parameters, including TDS, specific conductance, major ions, as well as stream discharge and hydrologic function metrics from three existing conventional valley fills, one experimental valley fill, and one stream that is slated for experimental valley fill construction. Preliminary results are presented with more than one year of discharge data and 1.5 years of water quality data.

Additional Keywords: salinity, watersheds, streams, coal mining

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Solar-powered Irrigation System - Jewett Lignite Mine, Jewett, TX¹

D. Ezell and J. Young²

Abstract: In 2009, Texas Westmoreland Coal Company embarked on a mission to not only improve the stream restoration efforts at the Jewett Mine, but to build a process that would be recognized as a premier stream restoration program. As with all best management practices, excellence begins with planning and design. In the design phase, enhancing our revegetation efforts included several "best practice techniques" such as hydromulching with native grasses, the planting of high quality hardwood species and the use of specialized irrigation to ensure a high success rate in any condition. The revegetation component of this stream restoration process is the final measure of reclamation success. In order to promote herbaceous cover and increase survivability of woody species within these corridors, Texas Westmoreland Coal Company knew irrigation was a key component. Through the design process, these remote plantings provided the challenge of getting water to these trees. A solarpowered irrigation system has proven to increase survivability of these bottomland hardwoods in a cost-efficient manner. To enhance the timeliness of our revegetation efforts, the Jewett Mine has paved a new path forward with respect to stream restoration by studying the stream channel prior to disturbance, developing a plan that honors the original system and transitioning that plan into an effective means of success.

Additional Keywords: reclamation, hydromulching, survivability

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Tree and Ground Cover Establishment Over Seven Years as Affected by Seeding and Fertilization Rates¹

J. Franklin and D. Buckley²

Abstract: Planted ground covers can compete strongly with planted tree seedlings, hindering reforestation efforts. Fertilization may benefit both trees and ground cover, but its effects on the balance of these competitive interactions are unclear. A 3x3 factorial experiment with 3 levels of fertilizer application and 3 seeding rates was established in 2006 to test for differences in tree seedling growth and survival, and for differences in ground cover establishment and composition. Treatments were applied by hydroseeding a mixture of native warm-season grasses, annual ryegrass and Korean lespedeza at around 6, 30, or 60 kg/ha, along with 10:20:20 water soluble fertilizer at rates of 1, 224, or 448 kg/ha. Bare-root, 1-0 tree seedlings of scarlet oak, white oak, black walnut and mockernut hickory, along with mockernut hickory seed were planted on an 8x8 foot spacing. Tree growth and survival, and ground cover establishment have been monitored. After seven years, white oak survival was consistently good across plots with an overall average of 69% and hickory was consistently poor across plots with less than 5% survival. Survival of scarlet oak and black walnut was highly variable, averaging 46% and 33%, respectively. Maximum growth and survival of white oak was found at moderate levels of fertilizer application, while black walnut diameter growth increased with fertilization. Fertilization increased cover of switchgrass but decreased the cover of Indian grass when assessed seven years after planting. There was no significant influence of seeding rate or fertilization rate on total vegetative cover, or on the proportions of grass, legumes, and forbs present. On steep reclaimed coal mines in Tennessee, the establishment of native trees and ground cover may be successful using reduced rates of seed and fertilizer application.

Additional Keywords: restoration, afforestation, forestry

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Vegetation and Soil Development in Planted Pine and Naturally Regenerated Hardwood Stands 48 Years After Mining¹

J. Franklin and J. Frouz²

<u>Abstract:</u> Restoration activities at the time of stand initiation can have lasting effects on subsequent recovery of stand structure and function. Several metrics were compared, with an emphasis on soils, structure and function in forest stands that had been planted with pine or remained unplanted, and had undergone primary succession over 48 years on mine spoils. These were also compared to reference sites in the adjacent forest, to test the hypothesis that the development of forest functional processes will differ between planted and unplanted sites. Sites planted to pine had lower basal areas, and lower soil and microbial respiration rates than did unplanted sites. Basal areas of unplanted sites were comparable or higher than those of reference sites, suggesting that the natural succession of hardwood may lead to better long-term recovery than planting of pine. Differences in root biomass, along with corresponding differences in soil respiration, suggest that below-ground biomass production recovers more slowly than does above-ground productivity. Mined sites had a greater stock of phosphorous than did reference sites. The greater presence of earthworms on mined sites may speed up nutrient cycling, as indicated by faster cellulose decomposition.

Additional Keywords: reforestation, Pinus, restoration

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Biodiversity Assessment of an Ecological Engineered Treatment System for Metals-Contaminated Mine Drainage¹

B. Furneaux²

Abstract: Passive treatment of mine drainage harnesses natural ecosystem processes in an ecologically engineered system to improve water quality through retention of metals and alkalinity production. The effectiveness of passive treatment systems for water quality improvement has been well documented. As living ecosystems, passive treatment systems develop additional structure and functions which are not intentionally engineered. To examine the development of ecosystem structure in a passive treatment system, biodiversity surveys of plants, Odonata, and amphibians were conducted at the Mayer Ranch Passive Treatment System (MRPTS), a multi-cell system treating hard-rock mine drainage in the Tar Creek Superfund Site in northeast Oklahoma. Control surveys were conducted at a number of ponds, both miningimpacted and non-impacted, within the ecoregion and within 11km of MRPTS. The individual cells of MRPTS were found to be relatively species-poor for plants, but were not significantly different from the control ponds for Odonata. Because MRPTS is spatially localized and hydraulically connected, it can also be considered as a single system. Thus, aggregated MRPTS species richness is greater than that observed in control ponds for both plants and Odonata. The contrast between individual cells and the whole system is a demonstration of high biological differentiation between cells at MRPTS. Drought conditions during the summer of 2011, when the study was conducted, resulted in a small sample size which lacks statistical power, but amphibian species richness is qualitatively impaired at MRPTS, relative to references.

Additional Keywords: biodiversity, mine drainage, ecological engineering, wetlands, ponds, ecological assessment

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Sequestration of Heavy Metals on Manganese Oxide Coatings in Passive Treatment Systems¹

J. J. Gusek, L. Josselyn and D. Millsap²

Abstract: Conventional wisdom for passively sequestering heavy metals in Mining Influenced Water (MIW) suggests that sulfide precipitation in a Biochemical Reactor (BCR) is an appropriate approach. Post-BCR aerobic polishing cells have typically been viewed as an "insurance policy" for sequestering remaining trace concentrations of heavy metals via adsorption. This mechanism was recently assumed to provide a significant primary heavy metal sequestration function in a 4,740 L/min. passive treatment system treating MIW discharging from an abandoned underground gold mine in California, USA. The system design was conservatively based on a manganese removal rate of 0.9 grams per day per square meter of wetland that was observed in bench scale testing. Data from previous studies suggested manganese removal rates from 1.5 to 5 times this rate. Deposition of manganese in the downstream portion of the passive treatment system was expected to remove trace amounts of secondary contaminants that are present in the MIW including copper, lead, zinc, cadmium, and thallium via adsorption mechanisms on to freshly-formed manganese dioxide (e.g., pyrolusite). Manganese removal was documented in a comprehensive sampling event about two years after the system's startup in late 2011. The paper will reveal the manganese removal results and secondary contaminant sequestration trends in an aerobic environment.

Additional Keywords: mining influenced water, abandoned mines, pollution prevention, pyrolusite, heavy metals

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Land Application of Biochemical Reactor Effluent: An Innovative Method for Mitigating Acid Rock Drainage¹

J.J. Gusek²

Abstract: The concept of in-perpetuity is a very long time. Perpetual treatment (either actively or passively) of Acid Rock Drainage (ARD) is unsustainable; cumulative economic burdens on mining companies and/or government agencies faced with treating ARD will certainly bankrupt future society. ARD suppression at its source is the logical strategy to avoid or lessen ARD impacts. Innovative strategic concepts have been advanced in recent years; this author has contributed to this effort. The concept of land-applying Biochemical Reactor (BCR) effluent to suppress ARD is another promising strategic tool. It was introduced from the podium of the 30th Annual ASMR Meeting in Laramie. This white paper develops the idea in more detail. The concept's elegance lies with the merging of two well-developed mine remediation/processing technologies: BCRs and heap or dump leaching of metal ores. In the proposed innovative technology, organicrich effluent from a BCR would be land-applied to acid-producing mine waste (e.g., tailings, waste rock, and coal refuse) using solution application methods typically used in precious metal heap leach pads. BCR effluent is typically anoxic and contains biochemical oxygen demand, excess alkalinity, dissolved sulfide ion, and dissolved manganese. If all these characteristics can be preserved, and the BCR effluent solution can be dispersed over a large area of mine waste (which could be re-vegetated or barren), the downward percolating solution should coat the mine waste with a film of bio-solids that would suppress biological and abiotic pyrite oxidation. In deeper, moreoxidized portions of the rock/waste column, surfaces should be coated with ARDsuppressing MnO₂. It is believed that heap leach solution application techniques could accomplish this inexpensively. The mine waste ARD source would behave similar to a trickling filter in a waste water treatment plant. ARD might be suppressed for decades, perhaps longer, before a "booster shot" of BCR effluent might be required.

Additional Keywords: mining influenced water, abandoned mines, pollution prevention, BCR

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The Recovery of an AMD-Impacted Stream Treated by Steel Slag Leach Beds: A Case Study in the East Branch of Raccoon, Creek, Ohio¹

C. Hawkins, N. Kruse, A. Mackey and J. Bowman²

Abstract: The East Branch of Raccoon Creek was the highest contributor of acidity to the Raccoon Creek mainstem prior to reclamation projects. The 19.95 mi² subwatershed, which is highly impacted by preregulation coal mining, contains 11 steel slag leach beds that passively treat low pH, Fe and Al-rich waters. While acidity and metal load reductions show improved water quality, these factors do not account for biological recovery or localized stream conditions that influence sediment deposition and sediment and aqueous metal concentrations. In this study, water chemistry, aquatic macroinvertebrate richness and diversity, habitat quality, and stream gradient are examined. Macroinvertebrate richness and diversity (Macroinvertebrate Aggregated Index for Streams), and habitat quality (Qualitative Habitat Evaluation Index), are evaluated at 5 sites downstream of treatment systems. Water quality, and gradient are examined at 18 sites, 5 of which are macroinvertebrate bioassay sites. Water quality samples from mainstem sites and treatment tributaries are being taken 4 times over two years in order to examine water column chemistry in both low-flow and high-flow regimes. A model of alkalinity and acidity sources by river mile is used to determine how the steel slag bed treatment systems increase the buffering capacity of the stream. Stream gradient (the elevation between the thalwegs at riffle sites) is measured using a surveyor's level. Preliminary investigations show that macroinvertebrate richness and diversity ranges from good to very poor and may be related to habitat quality or proximity to treatment systems. Variations in macroinvertebrate score may suggest zones of recovery and impairment on the mainstem. Based on preliminary results, it appears that macroinvertebrate richness and diversity is influenced by aqueous chemistry, sediment depositions and quality, and habitat quality in a stream undergoing treatment by steel slag leach beds.

Additional Keywords: macroinvertebrate, acid mine drainage, stream recovery

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Effective Passive Treatment of Coal Mine Drainage¹

R.S. Hedin, T. Weaver, N. Wolfe and G. Watzlaf²

Abstract: Contaminated mine drainage on abandoned coal mine sites can be treated by passive or active treatment techniques. Passive treatment is less costly than active treatment, but its reliability is often questioned. This paper presents a simple design approach that has been used to design passive treatment systems in Pennsylvania for the past 20 years. Five systems that demonstrate commonly utilized passive technologies are described and long-term data are presented. The technologies described include aerobic settling ponds, aerobic constructed wetlands, anoxic limestone drains, oxic limestone beds, and vertical flow ponds. The systems have provided highly reliable and effective treatment for 3-18 years. The data demonstrate that properly designed, constructed, and maintained passive treatment systems are a reliable and highly cost-effective solution for contaminated mine discharges.

Additional Keywords: AMD, passive treatment

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Assessment of Benthic Macroinvertebrate Community Impairment from Residual Aluminum Contamination in the Confluence of Middleton Run, Ohio, USA and the Impacts of Ingested Aluminum of Crayfish Growth¹

W. Hellyer, N. Kruse and K. Johnson²

Abstract: Abandoned mines in the United States are a key source of aqueous pollution due to acid mine drainage which can leave streams heavily impacted by acidity and metals. Middleton Run in the Little Raccoon Creek watershed has a very poor biological community and impacts the biological community downstream in Little Raccoon Creek. It was hypothesized that the high aluminum concentrations of more than 30 mg/L from Middleton Run were the cause of biological impairment. Field studies were undertaken to quantify the biological community in Middleton Run and laboratory studies were performed to test the impact of aluminum on macroinvertebrates. Macroinvertebrate community assessment followed the Macroinvertebrate Aggregated Index for Streams method. Impairment to growth in crayfish from the ingestion of aluminum was the primary focus of the laboratory studies. Crayfish were separated into four groups, a control group and three treatment groups, and fed food pellets spiked with 25 mg/g, 50 mg/g, and 75 mg/g of aluminum chloride. Crayfish carapace length, total length, and mass were recorded pre-trial, at 2 weeks of treatment, 4 weeks of treatment, and 6 weeks of treatment. Analysis of the data revealed that there are no significant differences or changes in growth between the control group and those given aluminum chloride spiked pellets. It is likely that ingested aluminum is excreted in waste or accumulated in tissues without impairing growth. While the macroinvertebrate community in Middleton Run is certainly impaired by AMD, this study suggests that aluminum toxicity due to ingestion is not the mechanism of impairment.

Additional Keywords: acid mine drainage, biological recovery

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Dolese Bros. Co., Davis Quarry, Mining, Water Management and Stream Enhancement¹

M. Helm and T. Dupuis²

Abstract: Dolese Bros. Co.'s Davis Quarry is a limestone quarry in south central Oklahoma. The guarry has been in existence for more than 40 years and supplies central Oklahoma with construction materials from rip rap size material down to mineral filler. The plant has had more than \$35 million spent in large capital improvements in the last 10 years. This includes improvements from the processing face to final crushing, screening and classification. The site is located in the Arbuckle Simpson Aguifer. This aquifer has been under scrutiny for the last 12 years and led to a major groundwater study and new legislation and regulatory rules impacting how water use is tracked, managed and reported. An offsite stream and wetland mitigation and restoration project was also conducted under the guidance of the Corp of Engineers in order to fulfill 404 permit requirements. This paper and presentation will be an overview of the following four areas; 1) summarize the company's more than 110 year history of operating in Oklahoma 2) review processes used in mining limestone at this guarry and some of the unique features of the company's processes, 3) give an overview of the quarry's water management and reporting program, and 4) review of the stream and wetland mitigation and restoration project. This presentation will include slides, video and photos for the four areas listed above.

Additional Keywords: mining, water management

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²Mark Helm, Oklahoma City, Dolese Bros. Co., OK 73101-0677, and Tom Dupuis, Dolese Bros. Co.

Tar Creek: Early History and Legacy of Mining in the Tri-State Mining District¹

A. Hughes²

Abstract: The Tri-State Mining District has a long and colorful history. Oklahoma's part, specifically, includes labor disputes that shaped national policy, enough lead and zinc mined to armor two world wars, and boasts being the birth place of Mickey Mantle. It is also the home to the Tar Creek Superfund Site, one of the first and still largest Superfund sites in America. For over 30 years, local, state, federal and tribal governments have struggled with how to solve the many problems associated with the mining legacy. Tucked away in far northeast Oklahoma, polluted groundwater, soil contamination, and mountains of chat, continue to pose challenges with no easy answers. Hundreds of millions of dollars spent and three communities shut down, the social, cultural, and financial aspects of the Tar Creek Superfund Site continue to intrigue.

Additional Keywords: Tar Creek, mining, history, lead and zinc, superfund

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²Angela Hughes, Oklahoma Department of Environmental Quality, Oklahoma City, OK

Case Study: Shullsburg (WI) Lead/Zinc Mine Reclamation¹

T. Hunt²

Abstract: The zinc-lead deposits of the Upper Mississippi Valley fueled one of the earliest mineral rushes in the United States. Historically, the mining district, which intersects Wisconsin, Illinois, and Iowa, has produced lead since the French explorers visited the region in the seventeenth century. The area remains of interest because of base metal resources and ongoing environmental issues, including reclamation and water quality issues related to the widespread metallic mineralization that occurs throughout the region. The district probably contains as much undiscovered ore in the ground as has been mined in the past, though the area has not been thoroughly explored using modern geophysical methods. Waste piles including flotation tailings, jig tailings, waste rock piles, demolition piles, and junk piles are of concern to local residents and environmental regulators. In 1981, Inspiration Development Company gained ownership of four mines in southwestern Wisconsin. Only the Shullsburg and the nearby Bear Hole mines were put into production after they were permitted. The Shullsburg mine and mill site still remains under an active permit with the Wisconsin Department of Natural Resources (WDNR) pending final certification that reclamation is successful and complete. The original permit application for the Shullsburg mine designated the post-mining land use for the site as wildlife habitat. All post-mining activities to-date have been directed to that end. Today, the majority of the mine site (~75 acres), excluding access and maintenance roads, has been reclaimed to wildlife habitat and for minimal non-consumptive uses such as educational purposes. In order to issue a Certificate of Completion (COC), site performance standards for vegetation, soils, and other reclamation-related habitat factors must meet compliance criteria. This case study describes the journey necessary to attain a fully reclaimed mine site that provides a secure, aesthetically compatible, ecologically functional, and hydrologically and mechanically stable wildlife habitat area.

Additional Keywords: reclamation, wildlife, habitat, lead, zinc, Shullsburg

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²Tom Hunt, Applied Ecological Services / Professor Emeritus University of Wisconsin-Platteville, Brodhead, Wisconsin 53520

The Lionkol Project, Practical Application of Geomorphic Mine Land Reclamation Methods¹

H.H. Hutson and B. Thoman²

Abstract: The Natural RegradeTM (NR) design concept was first pioneered in 2007 by the Wyoming Abandoned Mine Land Division for surface mine reclamation in the Gas Hills. Following that success, NR was applied to the Lionkol project north of Rock Springs, Wyoming. The reclamation project was constructed in four phases over a six year period ending in 2013. The project reclaimed 320 acres of intensely disturbed mine lands, including four open pit complexes, associated mine spoils, numerous underground mine portals, shafts, and subsidence features, and restored over five miles of degraded ephemeral stream channels. New methods in geomorphic mine land reclamation were implemented to achieve a sustainable, stable reclaimed landscape which blended with the native topography. As the project evolved, so did the geomorphic design and construction methods. The first phases employed a mix of traditional and geomorphic reclamation techniques, where subsequent phases came to incorporate more NR design elements. Empirical methods were used to more accurately estimate native channel and surface water runoff characteristics. Modifications were made to the NR design input data based on the performance of the previous phases. Field adjustments in re-vegetation and monitoring contributed to the success of the project. The conclusions presented are the result of the evolution of the mine reclamation design process and are useful for ensuring future reclamation successes.

Additional Keywords: natural regrade, geomorphic, mine land reclamation

¹Oral paper presented at the 2014 National Meeting of the American Society of Mining and Reclamation, Oklahoma City, OK, *Exploring New Frontiers in Reclamation,* June 14-20, 2014. ² Harold H. Hutson, BRS Inc., Riverton, Wyoming 82501 and Bobby Thoman, BRS Inc.

Stabilization of the Pensacola Dam West Abutment¹

S.R. Jacoby, C. Landrum and S. Walker²

Abstract: The Pensacola Dam West Abutment was established during the 1939-40 construction of the historic multiple arch dam in Northeastern Oklahoma, near Langley, Oklahoma. The geology of the abutment consists of Mississippian age rock of the Osagean Series. The Keokuk or Boone formation outcrops along the Grand River and is generally referred to as the Boone Chert or Cherty Limestone. The limestone is subject to significant weathering and fracturing which is progressive in nature and results in rock falls that cause hazards for power plant personnel, loss of access to plant facilities and damage to plant facilities. The issue was identified as a safety concern in several 5year Federal Energy Regulatory Commission safety inspections dating back into the mid-1990s and resulted in temporary access improvements and a study of alternatives for long term stabilization. Temporary stabilization included critical rock scaling, installation of protective chain link mesh, removal of talus deposits restricting access to critical plant features and installation of an access bridge. Permanent solutions studied included Shotcrete Facing or an Anchored Mesh rock retention system. The retention system was selected and is under construction at the time of this abstract development. It is likely that a tour of the completed project and the Pensacola Dam will be included in the American Society of Mining and Reclamation 31st National Meeting agenda. This paper discusses the history, the conditions, the evaluation of the geology and the alternative selection process. A review of the construction and finished work and its challenges will be developed.

Additional Keywords: rock anchors, scaling, rock stabilization

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Biogenic Hydrogen Sulfide Production for Metal Recovery Dissolved in Acid Mine Drainage¹

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Abstract: Indigenous sulfate reducing bacteria were used to produce biogenic hydrogen sulfide from acid mine drainage to precipitate metal sulfide for metal recovery. Two bioreactors were applied and observed for biogenic hydrogen sulfide production. Bioreactor 1 was operated using a pure sulfate reducing bacterium Desulfovibrio vulgaris (DSM 644) culture in the customized 775 Postgate's culture medium B. In contrast, bioreactor 2 used the native sulfate reducing bacteria mixed culture collected from the spent mushroom compost from passive treatment system located in Mungyeong, Korea. The Gapjeong coal mine drainage (pH 6.5, Sulfate 410±26 mg/L) was amended as the sulfate source to bioreactor 2. To monitor produced biogenic hydrogen sulfide, ZnS gas traps with 5% Zn-acetate were installed at each bioreactor. The results revealed that the biogenic hydrogen sulfide was produced after a week lag phase and the pH (6.9 ± 0.2) and ORP (-980 ± 30 mV) values were maintained for the period in the bioreactor 1. In the same manner, bioreactor 2 parameters pH (6.9±0.3 and ORP -900±50mV) were continuously sustained. In addition, milky white ZnS precipitates were observed in the bioreactor 2 gas trap due to successful biogenic hydrogen sulfide production after 20 days of incubation. These results imply that biogenic hydrogen sulfide can lead to metal recovery as metal sulfide. Further studies should be performed to elucidate whether these conditions are effectively imitating those of metal recovery in acid mine drainage, which are complicated chemical and physical phenomena.

Additional Keywords: biogenic hydrogen sulfide, acid mine drainage, sulfate reducing bacteria, desulfovibrio vulgaris, spent mushroom compost

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Current State of Frac Sand Mine Reclamation Techniques in Wisconsin¹

Y.B. Johnson, S.M. Alvarez and A.L. Delyea-Petska²

Abstract: In the past five years, industrial sand mining has expanded rapidly in western Wisconsin, driven largely by the use of sand in hydraulic fracturing. There are currently 105 proposed, permitted, or operational "frac sand" mines in the state encompassing roughly 25,000 acres in total area. Yet, there is no available published research on the reclamation of frac sand mines. As a preliminary step to understanding reclamation methods and success, this study analyzed reclamation plans for all frac sand mines in the state. The study focused on revegetation techniques, topsoil handling, and plans for future use of the land post-mining. It was found that most mines planned to revegetate with nonnative grasses, followed by native grass/prairie mixes, oak savanna species, other forest community types, and cranberry bogs. Success criteria for prairies and oak savannas generally required a minimum of two native grasses and two native forbs per 100 sq. ft. with an overall cover of 70% after two or more growing seasons. The success criteria for forested communities required a minimum of 250 live trees and shrubs per acre three years after initial planting. Topsoil handling procedures were only mentioned in 37% of the plans. The most common procedure was to direct haul topsoil from current stripping operations or stockpiles and respreads. Future long-term research is needed to determine whether reclamation success criteria are being met.

Additional Keywords: frac sand mining, reclamation, Wisconsin

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Creating Anaerobic Environments to Control Acid Generation in Pyritic Material¹

R.L. Kleinmann²

Abstract: The early passive mine water treatment technologies that were developed in the 1980s and 1990s have evolved into a nice toolbox of passive treatment options. Logical progression of the technology's evolution leads to anaerobic water treatment, moving from an external bioreactor to within the acid-producing pyritic waste. The simplest variation of this will be to create a sulfate-reducing environment at the toe of the tailings pile, simply by limiting options for oxygen to enter and adding inexpensive, non-toxic, organic waste to generate a sulfate-reducing environment. Metals will be precipitated as sulfides in situ and alkalinity will be generated, greatly reducing the down-gradient surface area required for passive treatment. This concept can, theoretically at least, be expanded to greatly reduce pyrite oxidation and acid generation by making the oxidative near-surface environment anaerobic. This should be relatively easily accomplished in tailings and fine coal refuse, where the oxidative zone is usually limited to a near-surface layer, by adding organic carbon. This has already been done on a pilot-scale basis, greatly reducing contaminant concentrations, though the tailings in this case were not acid-producing. Applying this approach to acid-producing tailings and coal refuse should be possible, but it must be remembered that metal sulfides will be precipitated and that these could subsequently oxidize and generate acidity if not permanently protected from atmospheric oxygen by a generous layer of organic substrate and very effective re-vegetation. Other potential concerns would be remobilization of contaminants that are soluble in reduced form, such as manganese and arsenic. At-site tests of the concept and locally available organic waste options should be standard practice before this approach is undertaken at a mine site.

Additional Keywords: At-source control, acid rock drainage, in situ water treatment

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Remediation and Redevelopment of Historical Smelters in Oklahoma¹

R.R. Kottke²

<u>Abstract</u>: The Oklahoma Department of Environmental Quality (ODEQ) has investigated all the historical lead and zinc smelters in the state, and has worked diligently to ensure that these former facilities are properly remediated. The agency has utilized both enforcement and voluntary programs to ensure that the sites were properly addressed. ODEQ has successfully cleaned up smelter sites under Superfund, RCRA, Brownfields and Voluntary Cleanup. This presentation will highlight several of these cleanups and will specifically highlight the successful redevelopment of some of these sites. It will also discuss the challenges of remediating these sites.

Additional Keywords: zinc, Brownfields

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The History of Zinc Smelting in Oklahoma¹

R.R. Kottke²

Abstract: In the early 1900's, Oklahoma had a thriving smelter industry. The reason for this was the Tri-State Mining District and Oklahoma's abundant stores of natural gas, which was needed to fire the smelter furnaces. At the time, zinc and other metals were recovered from ore by a process of distillation. This process required a vast supply of cheap fuel, and the smelters would drill natural gas wells on site to provide the needed fuel. Zinc smelters were especially prevalent. Zinc was in high demand during WWI due to its use as a coating for armaments. The zinc smelters it Oklahoma were horizontal retort smelters. This type of smelting operation was labor intensive, and one smelter could employ 600 men to operate it. The operations produced huge amounts of wastes consisting of slag, broken retorts and condensers. The smelter also spewed vast amounts of acidic smoke containing heavy metals into the atmosphere, spreading contamination for miles around. As, new, more efficient methods of metal recovery became available, the horizontal retort smelter became obsolete. The demand for zinc weakened as WWI ended and many of the metal's former uses were replaced as technology advanced. The old smelters closed, leaving vast amounts of wastes behind. Over the years, communities reused the wastes as backfill and as "gravel" on roads, driveways, and bridges. Unfortunately, the "gravel" was contaminated with highly toxic heavy metals. Heavy metals commonly found at smelter sites in Oklahoma include lead, cadmium, arsenic, and zinc. There were 17 zinc smelters in Oklahoma and most had closed by the 1930s. Two operated into the 1970s. This presentation will inform the audience of the history of zinc smelting in Oklahoma and the remediation challenges facing the state.

Additional Keywords: remediation

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Tribal-Led Remedial Action at the Tar Creek Superfund Site - Catholic 40¹

C. Kreman and T. Kent²

Abstract: The Quapaw Tribe Environmental Office, along with Quapaw Services Authority conducted the first ever tribal-led cleanup of a Superfund site in the nation at the Catholic 40 within the Tar Creek Superfund Site. The Catholic 40 site is of cultural and historical significance to the Quapaw Tribe, as it contains evidence of important events in the history of the tribe. Several historical structures were identified within the site, which were associated with a Catholic church and school that provided educational opportunities to the Quapaw Tribe, surrounding tribes, and the community. After funding was discontinued and the school closed in 1927, mining began at the site around 1936 and mine waste existed over remnants of the historic buildings and other features associated with the church and school. The rest is history as they say, until the Tar Creek Superfund Site was added to the National Priorities Listing in 1983. The Catholic 40 was included in the Record of Decision, Operable Unit 4 in 2008 for remedial action. After initial plans of tasking cleanup activities to the primary contractor at the Tar Creek Superfund Site, the Quapaw Tribe requested that EPA fund the Tribe, through a Superfund Cooperative Agreement, to manage the remedial action activities at the site. In early 2013, after a successful negotiation process, the EPA approved the Tribe's Superfund Cooperative Agreement application. Following review and approval of preremedial action activities (including required site-specific plans); the Quapaw Tribe Environmental Office and Quapaw Services Authority began remedial action activities in late 2013. This presentation will provide the audience with the experiences acquired during the remedial activities at the Catholic 40 and provide insight to the Quapaw Tribe's hopes of managing more remedial activities at the Tar Creek Superfund site on Tribal Lands.

Additional Keywords: Tar Creek superfund site, tribal-led remedial action, Quapaw Tribe of Oklahoma

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Steel Slag Leach Bed Longevity Analysis¹

S. Landers, S. Maj, A. Mackey and N. Kruse²

Abstract: The Raccoon Creek watershed, located in southeastern Ohio, utilizes a mixture of source control, passive, and active treatment projects to remediate Acid Mine Drainage (AMD) polluted waters within the 684 square mile watershed. Fifteen steel slag leach beds (SSLBs) are utilized as a passive treatment strategy throughout the watershed. The oldest steel slag leach beds were installed in 2004 and the most recent in 2011. Each bed is designed differently to account for individual site variation, however each consists of a liner, PVC piping, and steel slag bed material. Newer project designs allow for discharge rates to be manually adjusted by valves which control the quantity of water entering the bed. With the ability to regulate the amount of water flowing through the bed comes the opportunity to fine tune the level of treatment to meet project goals without over treating and prematurely exhausting the alkalinity in the beds. The objective of this work was to estimate the useful lifespan of the slag and evaluate treatment targets by determining target alkalinity loads for SSLB discharges based on the acid loads of the AMD receiving tributaries targeted for treatment. Current and past alkalinity loads from each SSLB were used to estimate the alkalinity generating potential of each bed related to the flow rate through the bed. The acid load of the receiving tributary being treated was calculated based on multiple years of long term monitoring data. This information was applied to the treatment goal of each bed to determine a target operational flow rate. The capability to better estimate the useful lifespan of a SSLB will enable agencies to better estimate long term project maintenance costs and enable those individuals maintaining systems to choose appropriate flow rates to meet treatment goals without prematurely exhausting the alkalinity of the bed.

Additional Keywords: acid mine drainage, passive treatment, alkalinity, acidity

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Comparison of Long-Term Recovery Between Managed and Unmanaged Reclaimed Mine Lands¹

T. Macy and N. Kruse²

Abstract: Reclaimed mine lands account for high portions of land within southeastern Ohio, and fully restoring these lands to their original state requires much time and effort. The legal requirements for reclamation are minimal, and restoration and land management after reclamation may promote further recovery when financially possible. Reclamation aims to promote drainage, prevent acid production and establish vegetative cover, while post-reclamation restoration and management aims to control invasive plants, prevent erosion, and aid in returning a disturbed habitat to its original condition. The objective of this study is to compare species richness, vegetation diversity, proportion of native to invasive plants, and percent organic matter between reclaimed mine lands that have experienced post-reclamation management, including further plantings, invasive removal, grazing, or burning, and reclaimed mine lands that have not been managed after an initial vegetative cover established. Vegetation composition was assessed at 42 sites (21 managed and 21 unmanaged sites) using the North Carolina Vegetation Survey method. The results found that cover of native plants was not significantly different between managed and unmanaged sites, but the cover of invasive plants was significantly larger in unmanaged sites. The occurrence of invasive species is indicative of the success of a site because invasive plants benefit from disturbance. The vegetation diversity and species richness was higher in managed sites. There was a significant difference between organic matter between managed and unmanaged sites. Post-reclamation management allows a site to be more successful by creating higher diversity and therefore a better ability to adapt to change or disturbance.

Additional Keywords: coal mine, surface mine, organic matter

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Rehabilitation of Pennsylvania Passive Treatment Systems¹

R.M. Mahony, B.J. Page, C.F. Denholm, T.P. Danehy, C.A. Neely, S.L. Busler and M.H. Dunn²

Abstract: Passive treatment systems have been successfully treating abandoned mine drainage since the technology was developed in the late 1980's. Since that time, over three hundred publicly funded passive treatment systems have been installed throughout the Bituminous and Anthracite coal fields of Pennsylvania. However, for various reasons, a portion of these systems are not as effective as when they were first installed. Many of the organizations responsible for maintaining these systems are grassroots watershed groups who often have little to no funding, minimal technical knowledge, and lack manpower and/or equipment necessary to restore passive treatment system function. In 2010, the Pennsylvania Department of Environmental Protection issued grant funds to Stream Restoration Incorporated for a Passive Treatment O&M Technical Assistance Program to provide watershed organizations, nonprofit organizations, and government agencies with technical assistance related to the monitoring, operation, and maintenance of passive systems across Pennsylvania. To date, approximately 30 systems have been evaluated with work being performed on many of them to improve functionality. Select sites will be presented to demonstrate the improvements in performance after maintenance activities were conducted, including Lutherlyn (Butler County) and McCaslin Road (Allegheny County). Data obtained from multiple systems will be utilized in future maintenance activities to improve effluent water quality.

Additional Keywords: water treatment, mine drainage, operation & maintenance, passive system rehabilitation, vertical flow pond

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Mobility of Arsenic in Sediments of Coalbed Natural Gas (CBNG)¹

K.C. McNicholas and K.J. Reddy²

Abstract: Coalbed Natural Gas (CBNG) development has occurred on all five sub-basin watersheds in the Powder River Basin (PRB). This type of natural gas production involves an extensive amount of water removal to acquire the energy resource. The most common option to handle the large amount of produced water is impounding the water to discharge ponds. Over time, as the gas production ceases, the CBNG discharge ponds no longer receive outfall water and have transitioned to playas. The objective of this study is to assess the potential mobilization of arsenic in the sediments of the now dry detention ponds and how those processes might affect shallow ground water aquifers. Sediment samples were collected at 0-10 cm and 10-20 cm depths, in duplicate, from seven representative playas of CBNG discharge ponds in the PRB. Samples were analyzed for texture, pH, Electrical Conductivity (EC), calcium carbonate (CaCO₃) content, Total Organic Carbon (TOC), and Total Arsenic (As) concentrations. A five step sequential extraction procedure was used to assess the solid-phase partitioning and potential mobility of arsenic in the sediments. This procedure differentiates arsenic into the following phases: water soluble As, surface-absorbed As, Fe⁻ and Al⁻ associated As, carbonate-bound As, and residual As. Having a better understanding of the geochemical processes of trace elements, such as arsenic, in these sediments will likely benefit State and Federal government environmental offices, as well as, regional land owners, land managers, industry and the scientific community. The arsenic fate and transport information obtained by this study will also assist the listed stakeholders with the development of effective reclamation strategies that can be applied to the CBNG playas in the PRB. Geochemical data analysis in progress, results will be presented.

Additional Keywords: trace elements, fractionation, sequential extraction

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Investigations of Bioavailability, Toxicity and Accumulation of Trace Metals from Shallow Sediments in Grand Lake Following Simulated Disturbance Events¹

S. Morrison, S. Nikolai, D. Townsend and J. Belden²

Abstract: The abandoned Tri-State Mining District (TSMD) is a historic superfund site that covers 6,500 km² and three states (Kansas, Missouri, and Oklahoma) and is the source for trace metal loading in Grand Lake sediments. Despite elevated concentrations of cadmium, lead, and zinc, no evidence of sediment toxicity has been observed during previous investigations; however, these investigations were limited to just a few lake transects with mostly deep water sediments. The lack of toxicity is likely due to specific water chemistry of the lake including high hardness and frequent anoxic sediments. The current project aims to develop a more complete metal distribution map with emphasis on shallow water areas (\leq 20ft depth) located in the northern reaches of Grand Lake where chances of sediment deposition from the TSMD are greatest. Distribution information is important because shallow areas are subject to disturbance events (e.g., boat traffic, wave action, and dock construction) and have a higher chance of becoming dry during low water periods. Changes in water chemistry and oxidation state of trace sediments during these disturbance events could cause greater availability of trace metals; resulting in toxicity, bioaccumulation, and greater lake impacts. Therefore, total sediment concentrations, amphipod (Hyalella azteca) sediment toxicity tests, bioaccumulation in pond snails (Helisoma trivolvis), and accumulation in passive samplers will also be used to investigate the influence of highly oxygenated versus anoxic sediments. The results of this research will demonstrate how changes in oxidation of sediments collected from Grand Lake affect trace metal release, bio (availability), and ultimately toxicity to aquatic organisms.

Additional Keywords: trace metals, bioavailability, passive samplers, disturbance events

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Implementation of Passive Treatment for Irreversibly Damaged Waters¹

R.W. Nairn²

Abstract: In the Tar Creek (Oklahoma) watershed of the abandoned Tri-State Lead-Zinc Mining District, impacts to surface waters were once deemed to be due to "irreversible man-made damages", resulting in minimal effort to address ecological and human health risks from legacy mine waters for over 30 years. However, completion and evaluation of a full-scale passive treatment demonstration project, coupled with recent watershed-scale environmental monitoring efforts, indicate that ecological engineering solutions exist. For the targeted mine water discharges, a large multi-cell passive treatment system (~2 ha), designed to receive 1000 L/minute of abandoned mine water (pH 5.95±0.06, 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), includes an initial oxidation pond followed by parallel treatment trains of aerobic wetlands, vertical flow bioreactors, re-aeration ponds, and horizontal-flow limestone beds, followed by a single final polishing wetland. In five years of operation, final effluent waters had pH >7, were net alkaline and contained <0.5 mg/L total Fe and <0.1 mg/L Zn, with concentrations of Cd, Pb and As below detectable limits. Conceptual designs for watershed-scale passive treatment have been developed. Ecological engineering techniques (i.e., the design and construction of sustainable ecosystems that integrate human society with the natural environment for the benefit of both) may provide cost-effective and environmentally relevant solutions in this watershed, incorporating an appreciation of the unique industrial heritage of the region as well as the cultural and social needs of Native American tribes.

Additional Keywords: ecological engineering, off the grid power, sustainability

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Soil Metal Concentrations in Proposed Wetland Development Areas Near the Tri-State Lead-Zinc Mining District¹

R.W. Nairn and D.E. Townsend II²

Abstract: The Neosho River Bottoms includes approximately 9,700 ha of floodplain and upland areas in Craig and Ottawa Counties, Oklahoma. The Grand River Dam Authority (GRDA) has acquired approximately 1,400 ha within this area, as part of offsite mitigation for fish and wildlife impacts under the Federal Energy Regulatory Commission (FERC) Pensacola hydroelectric project license, including portions of the Elm Creek watershed. The eastern portion of the Elm Creek drainage basin is disturbed by historic mining activities of the Tri-State Lead-Zinc Mining District (TSMD) and is part of the Tar Creek Superfund Site. Plans call for establishment of wildlife habitat, specifically creation and restoration of large areas of wetland for waterfowl use, on soils potentially contaminated by mining residuals. The objective of this study was to evaluate selected metals concentrations, including the contaminants of primary concern (i.e., lead, zinc and cadmium), in targeted soils of the Elm Creek watershed, focusing on likely areas of wetland development. Creation and/or restoration of wildlife habitat on metalscontaminated soils may merit special consideration and require unique management, or may impact overall project viability if sufficient risks were found. Evaluation of soil metal concentrations was conducted via field portable x-ray fluorescence spectroscopy, coupled with verification via standard laboratory analyses. Approximately 175 soil samples were obtained in those areas determined to be part of the wetted portions of the proposed wetland development units, in reference (e.g., background) locations, and in riparian locations likely influenced by overbank flooding of Elm Creek and/or the Neosho River. Overall, concentrations of the contaminants of primary concern were at or near background values, indicating minimal increased local risk. Remediation of mining waste residuals in the Elm Creek watershed is continuing and development of large swaths of marsh, scrub-shrub wetland and bottomland hardwood forest habitat in the area appears to be an appropriate and viable land use.

Additional Keywords: bottomland hardwood forests, mining residuals, ecological risk

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Dredging Management in Grand Lake O' the Cherokees, Oklahoma: Developing Permitting Strategies Using Shoreline Classifications, Substrate Characteristics and Contaminant Concentrations.¹

S. Nikolai and D. Townsend²

<u>Abstract:</u> With the approval of the Grand River Dam Authority's (GRDA) shoreline management plan for Grand Lake O' the Cherokees (Grand Lake), the Federal Energy Regulatory Commission requires the GRDA to revise the agency's dredging management plan. Previous studies have documented elevated concentrations of cadmium, lead, and zinc from sediments originating from tributaries draining throughout the Tri-State Mining District located immediately upstream of Grand Lake. Thus, GRDA proposes to establish shoreline dredging classifications to be used as a guide for implementing dredging management policy on Grand Lake. Lakewide shoreline classifications will be established by 1) assessing substrate characteristics and sediment depth located between elevations 735' and 745' Pensacola datum (PD), 2) assessing the spatial variability of cadmium, lead, and zinc concentrations in sediment within our target elevations, and 3) comparing those concentrations to appropriate sediment quality guidelines that assess risks to aquatic organisms.

Additional Keywords: metals contamination; dredging; lake management

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Prime Farmland Crop Yields From Four Soil Reconstruction Treatments Following Mineral Sands Mining: A 9 Year Summary¹

Z. W. Orndorff, W. L. Daniels, M.S. Reiter and A.F. Wick²

Abstract: Significant areas of prime farmland in the upper Coastal Plain of Virginia have been disturbed by heavy mineral sands (Ti/Zr-bearing ilmenite, rutile, zircon) mining. Mine soils created by deposition of tailings and slimes into dewatering pits exhibit physical and chemical properties that limit productivity due to abrupt textural changes, heavy compaction from grading, low pH, and inherent infertility. In 2004, the Carraway-Winn Reclamation Research Farm (CWRRF) was developed at Iluka Resources Inc. (Dinwiddie Co. VA) to evaluate reconstruction strategies for returning mined land to agricultural production. In 2004, row crop plots were established in a randomized complete block design with four replications of four treatments: 1) LBS-CT - limestabilized biosolids (78 dry Mg ha⁻¹) with conventional tillage, 2) LBS-NT – lime-stabilized biosolids (78 dry Mg ha⁻¹) with no tillage, 3) TS – 15 cm of topsoil replacement, and 4) CON – control. All treatments were ripped, limed, and fertilized. Additionally, a nearby undisturbed prime farmland soil served as an Unmined control (UM). From 2005 through 2013, the plots were managed with corn-wheat/double crop soybean rotations; however, in 2009 a cotton crop was planted instead of corn. In the first four years, the two LBS treatments produced significantly higher yields than the TS or CON treatments. Since 2009, the four reclamation treatments produced similar yields with only one exception; in 2012 the CON treatment produced a lower soybean yield. The CWRRF reclamation treatments typically exceeded long-term county averages, but were typically ~20 – 25% lower than UM yields. However, in 2012 soybean yields from the CWRRF were comparable to UM yields. This work has demonstrated that intensive soil reconstruction will allow for the return of these mine soils to economically viable agriculture, although in comparison to adjacent undisturbed highly productive farmlands, some reduction in average yields over time should be expected.

Additional Keywords: biosolids, compaction, titanium mining, topsoil replacement

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Total Dissolved Solids Related Leaching Potentials of Coal Spoil and Refuse From Tennessee and Virginia¹

Z.W. Orndorff, W.L. Daniels, C.E. Zipper and M.J. Eick²

Abstract: Overburden weathering in the Appalachian coalfields affects water quality via direct surface water runoff impacts and as drainage percolates through Valley Fills (VFs). Recently, significant concerns have emerged about the biological effects of elevated long-term total dissolved solids (TDS) emissions on headwater streams. The objective of this study was to evaluate leaching potentials, including elemental composition and temporal release patterns, for five mine spoils (from TN) and four refuse materials (from TN and VA) using laboratory leaching columns. Raw spoil materials were typically nearneutral to alkaline (saturated paste pH = 4.7 - 8.8), and saturated paste electrical conductivity ranged from 882 - 2820 uS cm-1. The samples contained little or no identifiable calcium carbonate. Spoil materials were low in total-S (< 0.15%), while the refuse materials contained higher total-S (0.76 - 1.25%). Samples were leached for 20 weeks (2x per week) under unsaturated conditions; two spoil materials and all refuse materials also were leached saturated. Leachate samples were analyzed for pH, EC, and ions of concern. Four spoils generated alkaline leachate, while one spoil produced slightly acidic leachate. Spoil leachate EC initially ranged from 900 – 2850 uS cm-1, then quickly dropped after several pore volumes and stabilized at <500 uS cm-1. Saturation effects were minimal on spoil leachate pH and EC. Refuse leachate pH and EC were more variable, reflecting total-S reactivity and saturation effects. Unsaturated refuse leachate EC remained elevated, equilibrating at 600 - 3000 uS cm-1, while the three saturated refuse samples all equilibrated to <500 uS cm-1. For all samples, the release of major cations and sulfate closely mimicked EC patterns. Bicarbonate release reflected saturation effects, with more bicarbonate leached under saturated conditions. Trace and minor element release varied widely among the samples, but was typically much higher from the more reactive refuse samples.

Additional Keywords: electrical conductivity, leachate, overburden, sulfate

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Storm Event-Driven Metal Transport Dynamics Between the Initial Oxidation Cells of a Passive Treatment System¹

L.R. Oxenford and R. Nairn²

Abstract: Iron oxidation, hydrolysis and settling are key processes promoted in passive treatment systems to remove iron from influent Acid Mine Drainage (AMD). For net alkaline mine waters, an initial oxidation cell is typically used to remove and store large amounts of precipitated iron oxyhydroxides prior to water flowing through additional wetland treatment cells. Intense storm events have been observed to resuspend precipitated iron oxyhydroxide solids, thus favoring transport of sequestered iron oxides between treatment cells. The purpose of this study was to investigate effluent total metals transport between the preliminary oxidative treatment cells and for the entire treatment system as a whole with respect to rainfall intensity at the Tar Creek Superfund Site from 2012-2013. The oxidation pond had a mean iron mass loading of 106 kg/day and an average removal rate of 25 g m⁻² day⁻¹ based on one year of system operation. Autosamplers were installed at the effluent of the preliminary oxidation cell, at the effluent of the secondary aerobic wetlands, and at the effluent of the treatment system to collect total metals samples when the rainfall intensity exceeded 1.000 cm/hour for 35 hours. Laboratory determination of total metals (EPA methods 3050 and 6010), produced a series of transport curves for events and the total amount of iron transport was approximated for (1) during the storm event, and (2) following the storm event. Preliminary results indicate that there is a significant increase in total metals transport between cells during storm events with greater amounts of material transported during high intensity, long duration events and for up to 10 hours after the rain event. The passive treatment system effluent experiences a spike in iron transport only during the most intense storm events, with an average concentration of less than 10 ppm for a less than hour duration.

Additional Keywords: iron oxidation, solids transport, Tar Creek, Passive Treatment, AMD

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Preliminary Greenhouse Investigation of Selenium Removal From Soil by Phytoremediation¹

R.G. Paudel, P.D. Stahl and C.F. Strom²

<u>Abstract:</u> Selenium toxicity in soil and aquatic systems is a common problem associated with uranium mining. Excess Se in the ecosystem may have negative influences on plants, animals and humans (through its involvement in the food chain). Serious health issues associated with Se toxicity emphasize the need for environment friendly, sustainable and cost effective methods for its removal from environment. Use of plants and their associated microbes for Se detoxification is one of the viable options. A greenhouse study was conducted to evaluate the efficiency of plants in Se removal from soil. Se contaminated soil was collected from a uranium mine for this study. The Greenhouse study consisted of seven treatments with twelve replications arranged in completely randomized design. Initial analysis suggests that application of organic matter at the rate of 10% by weight of soil along with Se hyperaccumulator plant Stannleya pinnata significantly lowered (2.6 mg/kg) Se from soil compared to control treatments (3.27 mg/kg). For Se accumulation in plant biomass, Brassica napus showed significantly higher amounts (11.8 mg/kg) of Se in their biomass. These results emphasize the potential of plants to detoxify Se toxicity from soil.

Additional Keywords: selenium, phytoremediation, hyperaccumulators, organic matter

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Passive Co-Treatment of Polymetallic Acid Mine Drainage at Cerro Rico de Potosí, Bolivia¹

R. Peer, J. LaBar, B. Winfrey, R. Nairn, F.L. López and W. Strosnider²

Abstract: Zn-rich Acid Mine Drainage (AMD) from an abandoned adit on Cerro Rico de Potosí and raw municipal wastewater (MWW) from Potosí, Bolivia were combined at a 5:1 ratio in a three-unit microcosm batch reactor passive co-treatment system. AMD was characterized with pH 3.58, acidity 1080 mg/L as CaCO3 equivalent, and 12, 0.44, 0.13, 68, 17, 0.13, 0.090, and 550 mg/L of dissolved Al, Cd, Cu, Fe, Mn, Ni, Pb, and Zn, respectively, among other metals/metalloids. Nitrate and phosphate levels in the MWW were 5.6 and 38 mg/L, respectively. Treatment efficiency was promising, with a decrease in dissolved concentrations of Al, Cd, Cu, Fe, Mn, Ni, Pb, and Zn by 99.7%, 78.5%, 18.3%, 99.9%, 4.5%, 25.5%, 45.9%, and 33.9%, respectively, as well as an increase in pH to 7.06 and a decrease of phosphate concentrations below detection limits. The treated effluent had alkalinity of 201 mg/L and net acidity of 273 mg/L. This treatment option presents a promising treatment alternative in both developing and developed regions globally.

Additional Keywords: acid mine drainage, wastewater, passive co-treatment

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Land Application of Drill Cuttings¹

C. Penn and A. Whitacker²

<u>Abstract:</u> With an increase in oil and gas exploration, by-products such as drilling "mud" are often disposed of by land application to agricultural land. Drilling mud is necessary during the drilling process for bit lubrication and cooling, sealing formations, and removing cuttings. Spent drilling fluids composed of water as the lubricating fluid are known as "water-based" drilling mud (i.e., contains little petroleum based hydrocarbons), while those composed of diesel are referred to as "oil based" drilling mud. Disposal of drilling mud in Oklahoma is regulated by the Oklahoma Corporation Commission (OCC). Current guidelines dictate that water-based mud be applied to a single site only once every 3 years. Oil-based mud can only be applied one time to a single site. In addition, the OCC requires that all oil-based mud be mixed with a stabilizer prior to land application. This presentation will discuss the typical composition of drilling mud, land application processes, current Oklahoma regulations, and potential negative agronomic and environmental risks associated with the land application of drilling muds.

Additional Keywords: drilling mud, drill cuttings, drilling fluids, land application, remediation

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Towards Closure of the Fire Road AMD Mine in New Brunswick, Canada¹

K. Phinney, M. Coleman, K. Butler and S. Pelkey²

Abstract: The approximately 120 ha backfilled Fire Road Mine strip coal mine in eastern Canada has been a source of acid mine drainage since the mid 1980's. The strip mine had depths to approximately 20m in interbedded shales with high aluminum concentrations (chlorites) and sandstones containing iron sulphides, typically pyrite, in the range of 1-2%. Many other treatment and closure options have been evaluated over the years but always tabled due to numerous impediments. Lime neutralization treatment of drainage has been continuously ongoing. Site water chemistry has been intensively monitored over the years using a series of groundwater wells within and bordering the disturbed areas. This has provided a considerable inventory of water chemistry data which has enabled interpretation of the characteristics of acid generation at the site; the effectiveness of "in situ" neutralization in reducing the ultimate acidity of the drainage, and trends in acidity over the years. This in situ neutralization has benefited from the placement of the treatment sludge back onto and into the backfilled mine site. The locations of the highly conductive mine water and the treatment sludge has been tracked with apparent conductivity mapping. The weathering of the waste rock and the prolific growth of vegetation has also reduced the acid generation rate at the site by reducing the volume and rate of precipitation percolation. During the past number of years, a definite trend of decreasing acidity has been observed leading to the conclusion that the site should exhibit "zero lime demand" within the next 10 years. At present, plans are being developed for final closure of the site.

Additional Keywords: acid mine drainage, ground water monitoring, mine closure, mine water chemistry

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Patterns of Tree and Plant Community Development Across Different Soil Types on a Reclaimed oil Sands Mine Site¹

B. Pinno, A. Lewis and R. Errington²

Abstract: The re-establishment of native plant communities is a key priority for oil sands mine reclamation in northern Alberta, Canada. The two main soil types used in oil sands reclamation are Forest Floor – Mineral Mix (FFMM) derived from upland forests and Peat – Mineral Mix (PMM) derived from wetland ecosystems. These soils are generally placed in large, discreet patches across reclamation landforms, but it may be possible to change the pattern of soil placement to benefit natural plant communities. This study examined natural deciduous tree regeneration and plant community development across both of these soil types. Tree regeneration was significantly greater on PMM (median 4,800 seedlings per ha) than FFMM (median 1,000) and was less variable across the PMM landform, while for understory plants there were significantly more species present in FFMM (median 9.5 species per quadrat) compared to PMM (median 5 species). To examine the potential linkages between soil types, species compositions we measured along transects spanning the interface between soil types. For understory plant species, plots in the PMM but within 10 m of the FFMM had a greater number of species than the rest of the PMM, suggesting that plant species are spreading from the FFMM to the PMM. There were no apparent trends for trees or woody plants indicating a different mechanism for seedling establishment for these species. Overall, FFMM and PMM offer distinct advantages for native plant establishment and integrating these soil treatments spatially into landform design could help to maximize the potential benefits of both across the landscape.

Additional Keywords: forest land reclamation, oil sands

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Regional Variance in Site Selection for Land Disturbing Activities in Oklahoma¹

C.M. Porter²

Abstract: Preliminary site reconnaissance and subsequent delineation of natural resources is necessary for evaluating the possible adverse effects associated with any land disturbing activities. Permitted activities require strict adherence to regulations supported by legislation protecting natural resources. In addition, delineating and classifying natural resources are critical for successful mitigation and/or reclamation projects. Oklahoma supports unique and different natural resources. Regional variances between eastern and western Oklahoma provide site selection challenges for industry. Significant differences in precipitation across the state support unique terrestrial and aquatic ecosystems. A limited number of these unique systems provide protected habitat for protected species. Protected habitat generalists provide a different and more frequent challenge for industry. The challenges of avoiding protected species and other natural resources across Oklahoma will be presented along with a limited discussion of permitting.

Additional Keywords: protected species, Oklahoma, site selection

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Pine Plantations on Reclaimed Minelands: Growth Rates Versus Unmined Lands¹

J. Priest, J. Stovall, D. Coble, B. Oswald and H. Williams²

Abstract: Strip-mining is a common practice in the Gulf Coastal Plain, with some individual mines spanning over 5,000 hectares. Loblolly pine (Pinus taeda) plantations are a widespread reclamation land-use in east Texas, although the productivity of these plantations compared to those on unmined lands is not well-documented. The objective of this study is to quantify current site quality of loblolly pine plantations on two mines as compared to stands on unmined soils. The two mines differ in the method of overburden replacement. Substituting mixed overburden for topsoil generally results in no distinction of original soil layers following reclamation (Beckville Mine, BM), while removing and mixing the pre-mining upper, oxidized soil layers for topsoil in the postmining reclamation areas creates some stratification (Oak Hill Mine, OHM). Stand structure was quantified for 72 stands across both mines ranging from 3 to 30 years since establishment. All trees in a one tenth-hectare plot in each stand were measured. Above and belowground destructive harvests were completed in winter and spring of 2014 to create site index curves and estimate productivity based on biomass and carbon sequestration. These sampling methods have resulted in more precise estimations of growth of loblolly pine on these reclaimed mine lands than has been previously available. Preliminary results indicate the site indices are 15.8 and 18.0 m at 25 years for BM (mixed overburden) and OHM (mixed oxidized material), respectively. The replacement of topsoil appears to result in a height gain of 2.5 m over 25 years compared to using mixed overburden alone, although these site indices are both substantially lower than east Texas' average site index of 21 m at 25 years. Pre-mining site indices were approximated from soil surveys at 21.3 m (BM) and 20.1 m (OHM), indicating that prior to mining both sites were of average productivity for the region.

Additional Keywords: site index, loblolly, reclamation

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Soil Test and Bermudagrass Forage Yield Responses to Animal Waste and FGD Gypsum Amendments¹

J.J. Read, A. Adeli, D.J. Lang, K.K. Crouse, N.R. McGrew and J.D. Friedlander²

Abstract: Knowledge of soil and plant responses to animal or industrial byproducts is needed for effective use of these potential amendments on reclaimed mine soil. This study compared seven treatments of 11.2 Mg ha⁻¹ Flue Gas Desulfurized (FGD) gypsum, 896 kg ha⁻¹ NPK fertilizer (13-13-13), 22.4 Mg ha⁻¹ poultry litter; 22.4 Mg ha⁻¹ swine compost, fertilizer + gypsum, litter + gypsum, and compost + gypsum at a surface lignite mine in northeast Mississippi. Individual plots were 3.7 x 12.2 m and experimental design was a randomized complete block with three replicates. In May 2011, treatments were incorporated to 15-cm depth using a tandem disc, and bermudagrass (Cynodon dactylon L.) was sown using a Brillion cultipaker. In 2012 and 2013, treatments were split-applied without incorporation in May and August. Treatment effects were determined for soil chemical characteristics (0-15 and 15-30 cm depths), plant vigor, and forage Dry Matter (DM) yield. In the analysis across years, the year by treatment interaction was significant for DM yield (P < 0.01), but ranking of treatments was similar each year and values averaged greater in litter than compost treatment (6.47 vs. 3.37 Mg ha⁻¹). Improved DM yield was associated with greater N concentration in litter than compost (~30 vs. 22 g kg⁻¹), as well as increased P, K and Na in the surface soil in autumn 2013. Applying FGD gypsum with litter reduced soil bulk density by 9% and increased cation exchange capacity by 9%, organic C by 25%, and soluble salts from 0.25 to 0.83 mmhos cm⁻¹, as compared to litter alone. The co-application of gypsum was associated with a 21% decrease in soil organic matter (P < 0.05). These data indicate applying 22.4 Mg poultry litter ha⁻¹ yr⁻¹ can improve soil quality and forage yield performance during reclamation of a respread area.

Additional Keywords: composted pig mortalities, calcium sulfate, fertilizer, nitrogen, poultry litter, soil cation exchange capacity (CEC), soil organic matter (OM)

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The use of Sewage Sludge and Crocodile Manure for Treating Acidic Metalliferous Mine Drainage¹

J. Robinson²

Abstract: Biogeochemical treatment of Acid Mine Drainage (AMD) can be effectively applied through the use of constructed anaerobic wetland (biochemical cells) and Successive (or Reducing) Alkalinity Production Systems (SAPS or RAPS). These systems comprise mixtures of organic material such as wood waste, composted manures, hay, and limestone. They are designed to encourage sulfide precipitation through sulfate reduction (bacteria). Sulfate Reducing Bacteria use the decay products of organic substrates (e.g., CH2O) and sulfate as nutrients which then enable precipitation of heavy metal sulfides and alkalinity generation. This research used biosolids as the organic material alone or in combination with other naturally occurring material to assess if they could be candidate substrates for a BCR or RAPS/SAPS systems to treat acidic metalliferous mine drainage (AMD). The study was undertaken with a local mining company in Darwin and has involved 'proof of principal' static testing. Such testing is the first stage of a tiered assessment of potential organic material candidate substrates. The study has shown excellent removal rates of metals and increased pH associated with biosolids and crocodile manure. The results show up to 99% removal of heavy metals and the next stage will be the development of flow through cells with the mining company to test the dynamic removal using the selected substrates.

Additional Keywords: acid mine drainage, anaerobic treatment, sulfate reduction

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An Evaluation of Passive Treatment Systems Treating Oxic Acidic Mine Drainage¹

A.W. Rose²

Abstract: In recent years, it is evident that many Vertical Flow Ponds (VFPs) and related passive treatment systems release effluent that is still acidic and/or contains metals, as was shown by a study of about 150 Pennsylvania systems in 2009-10. In the current study, 20 post-2003 Pennsylvania systems of a range of sizes releasing net acidic water plus five successful large systems releasing net alkaline water were investigated to find the reasons for incomplete treatment. The design at five systems with poor performance was inadequate or inappropriate based on accepted concepts at the time of design. At two other sites, construction problems degraded system performance. At eight sites, the sampling in 2009-10 did not represent the actual performance of the systems. Several systems lacked maintenance that would greatly improve their performance. However, at 11 of the poorly performing sites, the treatment systems removed 89% or more of the influent acidity, which in some cases was very high. Much of the remaining acidity was Mn acidity. At five of the sites with slightly net acidic effluent, the receiving streams have recovered and have fish, and at two others the stream is largely recovered. Several recent large systems treating very acidic water have been successful. Key aspects appear to be addition of fine limestone to the compost, automatic flushing systems, and continuing maintenance. The cost of acidity removal by passive systems is generally less than \$1000/ton, median \$700/ton, compared to more than \$1200/ton for active systems. Therefore, passive systems are economically advantageous, and efforts should be directed toward ensuring good design, construction, and maintenance.

Additional Keywords: vertical flow systems

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Phytoremediation on Lead and AMD Soils¹

L. Sakiah, M. Makgae and S. Tlowana²

Abstract: The mining industry played a central role in the country's economic, political and social environment. Currently, most of the old mining sites are no longer operational and they have contaminated soils and water bodies in the surrounding areas. These polluted materials need to be rehabilitated to environmentally acceptable levels as required by the National Environmental Management Act. This paper looks at phytoremediation which is an emerging technique in which different plants are used to degrade, extract, contain or immobilize contaminants from soil and water. The technique is cost effective and environmentally friendly. The objective of the study is to determine how the two grass species, namely Vetiver and Eragrotis Curvula, perform in terms of extracting and growing on different polluted soils. Characterization of these soils was performed using X- ray fluorescence (XRF). The Vetiver grass was chosen based on the fact that it is tolerant to a wide range of soil pH (3.0 to 10.5) and regrows quickly after being affected by drought, frost, salinity and other unfavorable conditions. The rationale for using Eragrotis grass was because it grows easily and is good for erosion control. The species were planted in soils contaminated with Pb, Zn, acid mine drainage and potting soil acting as a control. The grasses were placed in the Environmental Geosciences Laboratory with a controlled continuous dripping system to provide water to the grasses. The weekly observations were recorded for the plants' growth rates under the different soil conditions. The Vetiver grass successfully demonstrated that it can withstand the harsh chemical soils conditions compared to Eragrotis Curvula.

Additional Keywords: mining, phytoremediation, lead, AMD, vetiver, eragrotis curvula

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Bench Scale Biochemical Reactor Treatment of Uranium, Radium, and Selenium¹

R. Schipper, E. Blumenstein, T. Rutkowski and B. Nielsen²

Abstract: Two bench scale biochemical reactors (BCRs) were operated over a period of three months for the removal of uranium, radium, and selenium from mining influenced water (MIW). A BCR is an anaerobic reactor comprised of organic and inorganic substrates including woodchips, straw, sawdust, and limestone. Uranium and selenium are removed in a BCR by biological reduction of oxidized species (i.e., selenite, selenate) to less soluble forms (Pahler et al. 2007, Blumenstein et al. 2008, Rutkowski et al. 2013). It is believed that radium may be removed through sorption to the biomass in the BCR. The bench scale BCRs were constructed of six inch PVC columns with a top to bottom flow configuration. The bench influent water consisted of three different water ratios from two adit seeps. BCR hydraulic retention times of 24 to 36 hours were targeted during the study. Influent concentrations ranged from 19 ug/L to 1.86 mg/L for dissolved uranium, 12 ug/L to 270 ug/L for dissolved selenium, and 4.9 pCi/L to 24 pCi/L for radium 226. The average and maximum dissolved uranium removal was 93.6% and 98.5% respectively, the average and maximum dissolved selenium removal was 93.3% and 98.9% respectively, and the average and maximum radium 226 removal was 89.5% and 100% respectively.

Additional Keywords: passive treatment

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Reclamation in Southeastern Wyoming: Beauty is in the eye of the Beholder¹

B. Schladweiler and C. Adams²

Abstract: Southeastern Wyoming contains considerable agricultural cropland acreage, as well as native rangeland. However, industrial disturbances are also present. Historically, the types and extents of industrial disturbances in southeastern Wyoming have varied. Types of industrial disturbances include, but are not limited to, abandoned mine lands, military facilities, wind development, and transportation corridors. The extent of disturbance on the landscape varies by industry type. Regulations governing reclamation for each industrial disturbance also vary by type of industry and regulating authority. For example, mining disturbances associated with small and large, non-coal and coal mines are regulated by the Wyoming Department of Environmental Quality, Land Quality Division, while disturbances associated with Wyoming state transportation corridors are regulated by the Wyoming Department of Transportation. Southeastern Wyoming geology, climate, and ecological sites provide for unique and sometimes challenging reclamation needs in order to meet the various regulations implemented by a multiple number of regulating authorities. Selected industrial disturbances and the regulations outlining reclamation needs and requirements based on the regulating authority will be discussed. In addition, the factors that contribute to "reclamation success" will also be addressed in a broad scale discussion.

Additional Keywords: success standards, regulations, regulatory authority

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Upper He Creek Water Balance Evaluation¹

T.W. Schmidt and K.L. Milmine²

Abstract: The Upper He Creek Water Balance Evaluation studies a mining impacted watershed of He Creek (2,750 acres) in east central Tennessee. A monitoring plan was developed to collect data over an extended period of time, including atmospheric and precipitation monitoring, surface water flow monitoring, groundwater level monitoring, and a lysimeter to measure evapotranspiration. Developing a "water balance" is an important step to define the sources and quantities of water introduced to a site, determine how water moves through the site, and provide insight regarding how water may be managed to meet a particular goal. This data will be subsequently used to maximize treatment efficiency to successfully meet long term Acid Rock Drainage (ARD) mitigation strategies. The water balance is intended to define the interrelationship between precipitation that falls within the drainage basin and the fate of the precipitation as it relates to evapotranspiration, groundwater recharge, and runoff that contributes stream flows to the He Creek watershed. This water balance is based on data collected at the site and values and concepts obtained from research. In addition to the field data and weather station information collected, this water balance also utilized a review of available atmospheric and climatological data, most specifically related to monthly and annual precipitation and evapotranspiration studies with deference given to areas near the site within the general Tennessee region. The information obtained in combination with an understanding of hydrology within the watershed collectively provided the framework and foundation for the water balance.

Additional Keywords: acid mine drainage, acid rock drainage, AMD, ARD, Sequatchie Valley Coal, hydrology, hydrogeology, mitigation

¹Oral paper presented at the 2014 National Meeting of the American Society of Mining and Reclamation, Oklahoma City, OK, *Exploring New Frontiers in Reclamation,* June 14-20, 2014. ²Terry W. Schmidt, Skelly and Loy, Inc. Harrisburg, PA 17111 and Kenneth L. Milmine, Cloud Peak Energy

Geochemical Modeling to Assess Impact of Chat Fine Injections on Aquifer Quality at the Tar Creek Superfund Site, Oklahoma¹

B. Schroth, R.C. Thomas and S. Irving²

<u>Abstract:</u> CH2M HILL assisted the EPA in a pilot study in northeastern Oklahoma where a 40 square mile area has been affected by lead and zinc mining. Large piles of mine tailings (locally known as chat) are scattered over this region and present potential dust hazards. The pilot study involved reinjection of the fine fraction of the chat into the original mine rooms. A groundwater flow model was developed for the region, and geochemical modeling was performed to assess the potential impacts of the reinjected chat on groundwater quality. Previous and current pilot study data were incorporated into the USGS Geochemical program PHREEQC to evaluate geochemical conditions produced by the reinjection. PHAST, a finite difference flow model coupled with PHREEQC, was used to simulate transport of mine pool water and injected water into the unaffected local aquifer over a 65-year period. Use of geochemical modeling can provide more realistic predictions of transport (utilizing precipitation and adsorption reaction databases) than the oversimplified Kd approach used by common transport models.

Additional Keywords: PHREEQC modeling, PHAST modeling

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Influence of Spoil Type on Discharged Water Quality and Hydrologic Function of Experimental Reforestation Plots in Pike County, Kentucky¹

K. Sena, C. Barton, C. Agouridis, P. Angel and R.Warner²

Abstract: Mountaintop removal mining has altered a vast land area in Appalachia. This controversial mining practice eliminates highly biodiverse native forest cover and permanently alters topography. In addition to terrestrial impacts, exposure of unweathered overburden is associated with increased dissolved solids and altered flow regimes (e.g., lower evapotranspiration and reduced infiltration) in surface waters. Because of these impacts, improved reclamation techniques need to be developed. An important but poorly understood step of the reclamation process is selecting the best available soil substitute when native soil is unavailable. A series of experimental plots was installed in 2005 on a reclaimed mine site in eastern Kentucky to examine the suitability of three spoil types (unweathered gray sandstone, weathered brown sandstone, mixed sandstone/shale) for reforestation. Two years after installation, researchers concluded that brown spoil provided the best medium for tree growth and also discharged higher quality water. Hydrological function did not differ significantly among spoil types. In 2013, tree volume on brown spoil was nearly fifty times greater than tree volume on gray spoil. As a result, brown plots discharge less than 5% of incident rainfall during the growing season compared to 21% of incident rainfall during the dormant season. In contrast, gray and mixed plots behave similarly from growing to dormant seasons (discharging 18 to 25% of incident rainfall), suggesting a strong evapotranspiration effect. Also, preliminary analysis suggests that overall water chemistry has stabilized across plots. According to these observations, when topsoil substitutes must be used, selecting brown weathered sandstone may minimize negative water quality and quantity effects associated with surface mining in Appalachia.

Additional Keywords: electrical conductivity, spoil segregation, soil substitution, forestry reclamation approach

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Fishes of a Contented Stream After Operation of Passive Treatment System¹

N. Shepherd, W. J. Matthews, R. Nairn, J. Barkstedt and N. Franssen²

<u>Abstract:</u> For a study of a passive treatment system for contaminated mine water, fish were collected in the Tar Creek watershed and reference streams in Ottawa County to assess fish assemblages in areas contaminated by heavy metals from the former Tri-State Mining District. Fish were sampled from an unnamed tributary to Tar Creek that was heavily impacted by artesian flow of metal-contaminated water, the Tar Creek mainstem, and reference stream sites, monthly from spring to autumn 2005 - 2007. No samples were taken in 2008 during construction of the passive treatment ponds. Samples taken in 2009 - 2012, after pond operations began and water quality improved, showed that numbers of fish species were present and their densities increased in the Tar Creek tributary that previously had been heavily contaminated. Important new or markedly increased species in the tributary after the ponds began operation included, among others, Largemouth Bass, five species of sunfish, and Slough Darter. Future monitoring of the fish assemblages is needed as the ponds continue to operate.

Additional Keywords: stream restoration, ecological recovery, fish assemblages

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Establishment and Growth of Switchgrass and Other Biomass Crops on Surface Mines¹

J. Skousen, C. Brown and D. McMichael²

Abstract: Biomass crops are being grown on agricultural and marginal lands to provide feedstock for co-firing in power plants and conversion to transportation fuels. Switchgrass (Panicum virgatum L.), Miscanthus (Miscanthus x giganteus), and giant cane (Arundo donax L.) are three potential biofuel feedstocks that have been planted on reclaimed surface mined land to determine their establishment and potential for biomass production. This study reports on the establishment and yield of biomass crops on several mined sites in West Virginia. The Alton site has all three species planted and biomass production after the fourth growing season averaged 5,200 kg ha⁻¹ for switchgrass (Kanlow and Bomaster varieties), 26,000 kg ha⁻¹ for two varieties of Miscanthus, and 12,000 kg ha⁻¹ for Arundo. At the Coal Mac site, an average of 12,500 kg ha⁻¹ of Arundo was produced after the third growing season. At The Wilds, an 8-ha site was planted with Cave-In-Rock switchgrass in 2013, and after the first growing season switchgrass production was 1,045 kg ha⁻¹. The MWV site was also planted with Cave-In-Rock on 8 ha of land, and average switchgrass production was 752 kg ha⁻¹. *Miscanthus* was also planted on these two latter sites and biomass production after one year was 600 and 200 kg ha⁻¹, respectively. These biomass averages at The Wilds and MWV were lower than averages produced at Alton after the first growing season. As has been demonstrated in other studies, two to three years are required for these plants to establish and expand to produce suitable amounts of biomass.

Additional Keywords: reclamation, revegetation, biofuel

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Column Study Treatability Testing for In Situ Remediation of Mining-Influenced Water¹

N.T. Smith, N. Anton, D. Reisman, A. Frandsen, R. Olsen, M. Sieczkowski and D. Smith²

Abstract: CDM Smith continued bench-scale treatability testing for remediation of Mining-Influenced Water (MIW), with the eventual goal of completing in situ treatment of MIW within abandoned mine workings and groundwater systems. The use of passive treatment methods for remediation of MIW continues to grow. However, while these methods are sometimes more cost-effective than active treatment, they may have limited applicability due to space requirements, flow rates, and seasonality of MIW discharge. In situ MIW treatment has the potential to significantly decrease the amount of space required, treats the contaminant source, and alleviates the issue of fluctuating flow that can cause issues in ex situ systems. In 2013, CDM Smith completed the second year of internal research to determine whether in situ remediation is a viable option for treating MIW. CDM Smith completed column studies using a strongly-acidic, high-metal content MIW. Phase 1 evaluated injection of treatment substrates into columns packed with acidic waste rock and pea gravel. Substrates included a guar gum / ChitoRem® suspension, and a mixture of propylene glycol, sodium hydroxide, and inoculum. Several injections were conducted, with continuous pumping of MIW through the columns. Samples were collected and evaluated. Phase 2 consisted of two columns, each loaded with inert gravel, and saturated with MIW. The first column contained ChitoRem® for MIW treatment, and the second column contained acidic waste rock to mimic the natural mine environment. The columns were recycled continuously, and MIW was periodically pumped into the columns for sample collection and to maintain saturated conditions. Periodically, flushing events were simulated by transferring a portion of the water from the ChitoRem[®] column into the waste rock column. Samples were collected and evaluated. Initial testing indicates substantial buffering and metal removal were achieved within the ChitoRem® columns, and apparent passivation of the acidic waste rock.

Additional Keywords: SRB

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GIS Analysis of Changes in Volume and Mass of Chat Piles in the Picher Mining District, Ottawa County, Okla., 2005–10¹

J. Smith²

Abstract: From the 1890s through the 1970s the Picher mining district in northeastern Ottawa County, Oklahoma, was the site of mining and processing of lead and zinc ore. When mining ceased in about 1979, as much as 165–300 million tons of mine tailings, locally referred to as "chat," remained in the Picher mining district. Since 1979, some chat piles have been mined for aggregate materials and have decreased in volume and mass. Currently (2013), the land surface in the Picher mining district is covered by thousands of acres of chat, much of which remains on Indian trust land. The Bureau of Indian Affairs manages these allotted lands and oversees the sale and removal of chat from these properties. To help the Bureau better manage the sale and removal of chat, the U.S. Geological Survey used GIS analysis of lidar data to estimate the 2005 and 2010 volumes and masses of selected chat piles remaining on allotted lands in the Picher mining district and to estimate the changes in volume and mass of these chat piles for the period 2005 through 2010. The 2005 and 2010 chat-pile volume and mass estimates were computed for 34 selected chat piles on 16 properties in the study area. The total volume of all selected chat piles was estimated to be 18.073 million cubic yards in 2005 and 16.171 million cubic yards in 2010. The total mass of all selected chat piles was estimated to be 20.445 million tons in 2005 and 18.294 million tons in 2010. All of the selected chat piles decreased in volume and mass for the period 2005 through 2010. The total volume and mass removed from all selected chat piles for the period 2005 through 2010 were estimated to be 1.902 million cubic yards and 2.151 million tons, respectively.

Additional Keywords: Picher, chat, lidar, volume, mass

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An Update and Overview of the Oklahoma Energy Resources¹

S. Sowers²

Abstract: The Oklahoma Energy Resources Board (OERB) was formed in 1993 by the State of Oklahoma's Legislature at the request of Oklahoma's Petroleum Industry for the purpose of "coordinating a program to demonstrate to the general public the importance of the Oklahoma oil and natural gas industry, to encourage the wise and efficient use of energy and to cause remediation of historical oilfield problems". The OERB is unique in that it's funding is provided by a 1/10th of 1% voluntary assessment on the sale of oil and natural gas within Oklahoma. In March of each year, Producers and Royalty Owners may request a refund of their respective assessments. Thanks to the continued and ongoing support of Oklahoma's Oil and Natural Gas Producers and Royalty Owners, the OERB has become one of the largest voluntary check-off programs in existence. By Statute, at least fifty (50) percent of its funding is allocated toward addressing historical orphaned and abandoned exploration and production sites (i.e., sites for which there is no responsible party). The remainder of OERB's budget is allocated for the purpose of educating students and the public on the continued importance of Oklahoma's Oil and Natural Gas Industry. The OERB's typical restoration activities include addressing historical hydrocarbon/produced water spills, abandoned equipment, miscellaneous concrete, trash and debris, lease roads, location pads, erosional issues and abandoned pits. As a result of OERB's voluntary restoration efforts, over 13,000 such orphaned and abandoned exploration and production sites have been restored at no cost to property owners across Oklahoma. The OERB will provide a more comprehensive overview and update of this program and the positive impact it is making to the citizens of Oklahoma.

Additional Keywords: restoration activities; oil and gas importance; wise and efficient use of energy

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Effects of Hydromulch Products on Rapid Vegetative Establishment on Mississippi Roadsides¹

B. Stewart, T. J. Bradford, G. Munshaw and W. Philley²

Abstract: A hydroseeding/hydromulching experiment was performed to determine its effectiveness in relation to time of establishment and germination. The experimental site was located in the northwest corner of the R.R. Foil Plant Science Research Facility (North Farm) at Mississippi State University. According to Web Soil Survey, the experimental area was mapped as a Leeper series (fine, smectitic, nonacid, thermic Vertic Epiaquepts). Eleven different hydromulch products were evaluated along with a control plot that consisted of a bare soil with no mulch and hand applied heat treated straw. The hydromulch products used consisted of heat treated straw, wood chips, wood fibers, and cellulose. Each of these fibers were used alone and blended with proprietary tackifiers. A blend of bermudagrass, (Cynodon dactylon (L.) Pers., 22.7 kg ha-1), crimson clover (Trifolium incarnatum L., 22.7 kg ha-1) and tall fescue, (Festuca arundinacea Schreb., 28.4 kg ha-1) was planted on Sept 26-30, 2011. The experimental design was a randomized complete block, replicated four times. The plot size was 3.65 m x 3.65 m. The hydroseeder was calibrated by timing the volume of material that was sprayed over a set amount of time. Over the first 48 days after planting, the site only received 13 mm of rainfall and little germination was observed. After 48 days, rainfall began to be more abundant and by 62 days after planting the heat treated straw spread by hand and the cellulose hydromulch treatments had achieved 70% cover. It was noted that the straw treatment was mainly desired species, while the cellulose treatment was mostly weedy species. Also at this time, several other treatments were getting very close to 70% cover. At 90 days, all treatments looked very similar and consisted of stands of crimson clover and tall fescue.

Additional Keywords: straw, mulch, cellulose, fiber

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Application of FPXRF Technology and Field Expedient Sample Preparation Techniques¹

M. Stinnett, R.C. Thomas and J. Ynfante²

Abstract: A field expedient procedure for processing soil samples for hand held X-Ray Fluorescence (XRF) analysis was developed for soil samples from the Tar Creek Superfund site near Miami, OK. Correlation and regression analyses were used to compare XRF and laboratory ICP data for lead and zinc using surface soil and subsurface soil XRF-Lab pairs. These analyses were performed on log10-transformed data per 'EPA SW-846 method 6200' to promote a more stable variance across the relatively broad concentration ranges for these constituents. Although the log transformation typically reduces the impact of such elevated values on the regression analyses, some data pairs typically exist that impart unusual influence (relative to the other data pairs) on the regression. This presentation covers the expedited procedure and the comparative data analysis.

Additional Keywords: Niton XL3t, Innov-X FP-XRF instrument

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Streamlining Reclamation Monitoring in the Sagebrush Steppe¹

C. Strom²

Abstract: Monitoring well pads to measure reclamation success is time consuming and often not performed at the optimum time to capture all of the species present on the site. Changing from the line point intercept or Daubenmire method to a photo point based system would reduce time required per pad and increase the number of sites monitored per day. It also may allow contractors/regulators to capture monitoring data at the appropriate time to capture forb species. Timing of monitoring is crucial. To capture forbs present with monitoring in SW Wyoming, it has to occur early in the growing season, which varies from gas fields across the state. There is a large number of sites that require monitoring, and to capture forbs in the monitoring data there is a short window of opportunity in the spring. Utilizing line point intercept and quadrats is time consuming and requires a number of crews to cover the sites in a timely manner. SamplePoint (SamplefFeq) is a photo point-monitoring program available from the Agricultural Research Service. It has the potential to replace line point intercept and quadrats for collecting data on reclaimed sites. Cagney et al. (2010) conclude that image analysis (SamplePoint) has several advantages over the point-line method: images are a permanent record of the resource that can be reanalyzed if data are questioned, if software improves, or if management objectives change; image analysis is quicker and less subject to biases from moving vegetation, moving pointer devices, and bright vegetation color. SamplePoint reduces time spent and the number of field crews. The number of sites monitored per day would increase by a magnitude of 8; it takes approximately 20 minutes to capture twenty photos along a 100 meter transect.

Additional Keywords: monitoring reclamation success

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Performance of the Swank Open Limestone Channel, Cambria County, PA¹

W. Strosnider, A. Conrad and A.W. Rose²

Abstract: The Swank open limestone channel was constructed in 2011 to treat a discharge of acid mine drainage averaging pH 3.3, Fe 0.6 mg/L, Mn 0.9 mg/L, Al 9.2 mg/L, and SO4 281 mg/L with acidity 83 mg/L CaCO3 and specific conductance 605 μ S/cm. The flow varies widely, from 60 to 3800 L/min, averaging 1200 L/min. The channel is about 300 m long, has a slope of 6 to 9% and contains limestone fragments with diameters averaging 23 cm, with a maximum diameter of 46 cm and >85% CaCO3. Dissolved solute concentrations vary inversely with the flow. The 275 m of monitored channel removes about 1/3 of the acidity and metals at a low cost. The outflow pH averages 4.4, with acidity of 50 mg/L and Al 5.5 mg/L. The main reason for incomplete removal appears to be the short retention time, which was determined to be 37 minutes during a relatively representative flow. Coatings of Fe precipitate and algae also decrease the treatment rate.

Additional Keywords: oxic limestone channel, acid rock drainage

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The Five Fundamentals of Successful Mined Land Rehabilitation¹

M.S. Theisen and L.G. Girard²

Abstract: Successful rehabilitation of massive soil and vegetation disturbances from surface mining requires a comprehensive and holistic approach. Those overseeing rehabilitation efforts must integrate and stage several considerations into a working relationship that entails proper planning and execution. "Soil poor" sites associated with mining activities offer considerable challenges when topsoil sources are scarce. This paper will discuss, "The Five Fundamentals of Successful Mined Land Rehabilitation." The first fundamental is employing creative methodologies to develop suitable growing media from less than desirable soils or substrates. This can only be accomplished by first understanding the make-up of the soil or substrate through comprehensive soil testing for agronomic potential and limitations. The second fundamental requires an assessment of suitable plant species for achieving sustainable growth and effective erosion control while meeting the collective post-reclamation needs of regulatory agencies and mine owners. Once soil and agronomic considerations have been addressed, it is appropriate to begin analyzing site conditions or characteristics to assess necessary erosion and sediment control measures. Site conditions, such as slope lengths, gradients and aspects, ditch and channel flow hydraulics, pond and stream banks, wetlands and more must be examined and proper controls selected. Proper installation practices are critical to the success of the rehabilitation program. Detailed guidelines must be developed and combined with onsite supervision to assure proper installation. Finally, once the rehabilitation measures have been installed, all active sites should be routinely inspected and maintained after each significant precipitation or other potentially damaging climatic event. This paper will offer case histories where the "Five Fundamentals" have been successfully integrated in mined land reclamation projects. In addition, the paper will provide an overview of a software program developed to facilitate execution and implementation of the five fundamental practices.

Additional Keywords: rehabilitation, soil testing, species selection, installation practices, inspection, maintenance, software program

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The use of Waste Mussel Shells to Treat Acid Mine Drainage in Upward-Flow Sulfate-Reducing Bioreactors¹

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Abstract: The efficiency of eight upward-flow sulphate-reducing (mesocosm-scale) bioreactors treating Acid Mine Drainage (AMD) from an active coal mine was assessed over a 40-week period. The effects of two different hydraulic retention times (3 and 9 days) and two different reactive substrates containing a mixture of organic materials (bark, compost and bark mulch) and either mussel shells or limestone as a source of alkalinity were evaluated. To evaluate the efficacy of the different systems to increase the pH and to remove metals and sulphate, numerous geochemical analyses were performed on influent, effluent and pore-water samples. These analyses include pH, Oxidation Reduction Potential (ORP), Electrical Conductivity (EC), alkalinity, Total Organic Carbon (TOC), Chemical Oxygen Demand (COD), metals, sulphate, sulfide, nitrate and phosphate concentrations. Up to week 30, all reactors were highly effective, at both Hydraulic Retention Times (HRT), at increasing effluent pH (>6.5) and removing metals (>80% removal). Systems containing mussel shells produced more alkalinity compared to those containing limestone, regardless of the HRT, and in general, systems operating at a longer HRT removed greater metals and sulfate and produced more alkalinity. After week 30, the reactor containing limestone operating at a shorter HRT showed declining efficiency, as both effluent pH and alkalinity concentration were very low (pH < 4.5, <30 mg/L CaCO3). Although all other reactors continued to treat the AMD until 40 weeks, reactors containing mussel shells were more efficient than reactors containing limestone. Overall, sulfate reduction was lower than expected (median removal <20%), which might be explained by poor bacterial establishment and/or a fast depletion of readily-available carbon sources. Overall, this study showed that mussel shells are an inexpensive and sustainable alternative to mined limestone in AMD passive treatment.

Additional Keywords: passive treatment, organic substrate, alkalinity generation, metal removal

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Common Sense Solutions for Management of Global Warming¹

K.C. Vories and J. Vories²

Abstract: The paper focuses on the facts that are publically available from the U.S. Energy Information Administration, concerning fossil fuel utilization and its impacts upon global climate, the global economy, and the world population. It contrasts the impacts of current popular notions in the media and the regulations that govern our nation, that fossil fuels are an evil that must be stopped, versus the utilization of common sense to assess how to best use available science and technology. It highlights best available control technology that could reduce the man-made contribution of carbon dioxide in the atmosphere in a way that does not bankrupt the global economy and jeopardize the global population. It will assess the growth of renewable energy and project the number of generations that would be required to have them replace fossil fuel as an energy source. The paper will compare the historical relevance of the impacts of the prohibition of alcohol in the U.S. from 1920-1933 that contributed to the rise of organized crime to the probable result of government actions that seek to prohibit the production and use of fossil fuels. It will conclude that if existing proven technologies such as those that are currently available for improving the efficiency and environmental performance of coal fired power plants were utilized worldwide they would reduce the consumption of coal by 40% and the production of carbon dioxide by the remaining coal that is burned by another 40%. A far greater benefit to global climate than could be achieved by the total prohibition of the use of coal in the U.S (currently 14% of the world production of coal).

Additional Keywords: fossil fuels, utilization efficiency, environmental protection

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Environmental Considerations of Proppant Frac Sand Mining and Processing¹

K. Ware²

Abstract: Developments in horizontal drilling and hydraulic fracturing have created an oil/gas boom in numerous parts of the United States. Energy companies are utilizing new technology and materials to complete wells and recover higher levels of crude oil and natural gas. One of the key components in the process is the utilization of a proppant, which is a solid material that is designed to open and maintain pore spaces within oil and gas reservoirs. The most commonly used type of proppant is silica sand, which is referred to as fractionation sand or 'frac sand.' Frac sand has unique structural and chemical characteristics and is generally located in deposits within the Midwest. Traditional mining techniques, such as excavation and dredging, are typically used to remove frac sand material from deposits. However, frac sand is processed utilizing special washing systems and drying plants that present new challenges for environmental concerns. Frac sand washing systems rely on large quantities of clean water to process material and the drying plants emit combustion emissions from the high temperature drying systems. These issues, combined with environmental concerns with sand mining, have resulted in greater public exposure and more protests during the permitting process. This discussion will focus on the appropriate methods for locating and designing frac sand processing plants and mining operations. Forecasts indicate that the oil and gas industry will continue to require large quantities of sand proppant for completion operations. Proper due diligence and planning for these mining sites can result in economically viable projects, while not stressing local fresh water resources and negatively affecting local residents.

Additional Keywords: frac sand

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Active Alkaline Addition Schemes for Removal of Diverse Contaminants from ARD¹

T.Wildema, K. Vatterrodt, L. Figueroa and C. Bucknam²

<u>Abstract:</u> For Acid Rock Drainage (ARD) with high mineral acidity, addition of lime in active treatment is known to remove AI, Fe, and Mn, but how well are other contaminants removed and how does the removal of one contaminant affect the removal of other contaminants? Two samples of ARD with high mineral acidity were used in a series of two stage lime-dosing experiments. Besides AI, Fe, and Mn, As, Cd, Cu, Ni, TI, and Zn are significantly above domestic or aquatic standards. A two-stage alkaline addition strategy of adjustment to pH of 7-8 and pH 10-11 was used. All of the constituents of concern except AI, As, and TI were consistently removed to below the standards. Removal of AI and As is best effected at the pH 7-8 step. Removal of Mn and TI are closely related. They are not removed at pH 7-8, and the pH 10-11 step is needed. In this step, the precipitation of manganese hydroxide and subsequent oxidation promotes the removal of thallium. At the pH 10-11 stage, Mn is removed to below the standard, and the final TI concentration hovers around the domestic standard of 2 μ g/L.

Additional Keywords: Al, Fe, Mn, Tl, lime addition

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Gray Sandstone as a Topsoil Substitute on Surface Coal Mines in Appalachia¹

L. Wilson-Kokes and J. Skousen²

Abstract: Steep topography and thin native soils characterize the coal mining regions of southern West Virginia. State and federal regulations require replacement of native topsoil during reclamation for reestablishment of a vegetative cover. Due to hazards associated with collecting this thin layer of soil before mining, regulators have allowed mine operators to use substitute topsoil materials, including weathered (brown) and unweathered (gray) geologic materials for growth media. For pasture and hayland post-mining land uses, substitute topsoil materials provide suitable physical and chemical properties for establishment and growth of forages with fertilization and liming. When reforestation is the post-mining land use, regulations in West Virginia require a 1.2-m layer of native topsoil and brown weathered sandstone, but unweathered materials may be used if native topsoil quantities are insufficient. This study examined tree growth on areas where brown and gray sandstone materials were applied to the surface as growth media at the Samples Mine in West Virginia. Four experimental sites were developed: brown sandstone compacted; gray sandstone slightly compacted; gray sandstone compacted; and gray sandstone compacted and then ripped. Average pH ranged from 7.3 to 7.9 on the gray plots compared to 5.4 on the brown plot. Tree growth on brown sandstone was more than triple that on gray sandstone. Mean tree volume index on brown sandstone was 3108 cm³ while mean tree volume index was significantly lower on the gray compacted plot, 909 cm³, and the gray ripped plot, 885 cm³. Mean tree volume index on the slightly compacted gray plot was only 407 cm³. Eight years after reclamation, gray sandstone, whether slightly compacted, compacted or ripped, has shown poor tree growth and has proven to be an inferior topsoil substitute for reforestation on this site.

Additional Keywords: tree volume index, reclamation, reforestation

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New Progresses of Land Reclamation in China¹

W. Xiao, Z. Hu and Y. Fu²

<u>Abstract:</u> Coal mining disturbed lands are the main sources of land reclamation in China. With the rapid increase of the economy and coal production, more and more land has been disturbed by construction and coal mining, thus, land reclamation has become important over the past 10 years. China is boosting land reclamation in mining areas. According to natural and geological conditions, the mining region was divided into eastern and western districts. Reclamation strategies are focused on prime farmland protection in the eastern district and ecological restoration in western district, respectively. Several innovative reclamation technologies and theories will be introduced in this paper, including concurrent mining and reclamation, Yellow River sediment backfilling, self-reclamation, and topsoil alternatives in opencast mines. Several important laws and regulations have been issued and implemented over the past 5 years, which promote land reclamation management. Land reclamation will still be one of the most important issues for the coal industry in the future.

Additional Keywords: land reclamation, new progress, concurrent mining and reclamation, Yellow River sediments, self-reclamation, land reclamation regulation

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Sediment Metal Concentrations in Selected Coves of

Grand Lake O' the Cherokees¹

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Abstract: Since completion of Pensacola Dam in 1940, Grand Lake O' the Cherokees, Oklahoma, has served as the ultimate repository for metal contaminants from the historic Tri-State Lead-Zinc Mining District. The purpose of this study was to assess metals concentrations in Grand Lake sediments at 10 sites in two coves where development practices may require dredging and management of sediments. One cove was already significantly developed (e.g., lakeshore homes and boat docks) and the other was much less developed. Sediment cores were incremented with depth and analyzed for total metals concentrations. Sediment metals concentrations in individual increments (n = 65) were compared to both generalized and site-specific Sediment Quality Guidelines (SQGs) including the Threshold Effects Concentrations (TECs, contaminant concentrations below which adverse effects are not expected) or Probable Effects Concentrations (PECs, contaminant concentrations above which adverse effects are likely). For generalized SQGs, concentrations for Cd, Pb and Zn, exceeded the TEC in 65 (100%), 53 (82%) and 62 (95%) sediment increments, respectively. Zn concentrations also exceeded the generalized PEC in 21 (32%) sediment increments (Cd and Pb were below generalized PECs). For site-specific SQGs, none of the sediment increments exceeded the PEC values, indicating the importance of site-specific criteria. In the more developed cove (n = 56), concentrations of Cd, Pb and Zn exceeded the generalized TEC in 56 (100%), 51 (91%) and 56 (100%) sediment increments, respectively. Zn concentrations also exceeded the generalized PEC in 21 (38%) sediment increments. For the less developed cove (n = 9), concentrations of Cd, Pb and Zn exceeded the generalized TEC in 9 (100%), 2 (22%) and 6 (67%) of sediment increments, respectively. The data generated by this study indicate the need for effective management of dredged sediments in one of the premier recreational reservoirs in Oklahoma.

Additional Keywords: Sediment Quality Guidelines, toxicity, dredging

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Dissolution Variability in Open Limestone Channel Substrate: Simple Lab Trials¹

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Abstract: Open Limestone Channels (OLCs) are commonly applied to treat Acid Mine Drainage (AMD) throughout Pennsylvania and the world. However, there is relatively little information on their performance and design. In order to better understand the performance of these systems, a simple laboratory trial was conducted with limestone from the 2-yr old Swank 13 mine OLC, which treats AMD from an abandoned updip coal mine located in Reade Township, PA. There were five limestone samples tested and two controls. The limestone tested included stone from the top and middle sections of the OLC that was coated with iron and aluminum hydroxide to different extents; algaecoated limestone from the top of the OLC; and raw and crushed limestone directly adjacent to the OLC that had not been in contact with AMD. In addition, sandstone in the channel from just below the end of the OLC was tested. 20 ± 0.5 lb of stone was placed in 50-gt HDPE containers with 15 L of a weak sulfuric acid solution (pH 3.0). After initial readings, seven more readings were taken over a 118 hr period. Alkalinity increased the most for the limestone from outside the channel (to 80 mg/L as CaCO3 equivalent for raw and 50 mg/L for the crushed), followed by the algae-coated limestone (to 63 mg/L). Alkalinity increase was less (to 33 and 35 mg/L for the top and middle section limestone) for the limestone taken from the channel. Overall, the results reinforced previous studies indicating negative impacts from iron and aluminum hydroxide coatings and decreased surface area, while suggesting that even thick algal coatings may have relatively little impact on treatment.

Additional Keywords: acid rock drainage, oxic limestone channels

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