2016 Poster Abstracts

1989 – Memories from the Sunnyside Mine

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Abstract 1 – Both Oral and Poster

In the late 1980s the Sunnyside Mine was an active underground gold mine operation. As a member of the mine engineering staff from 1987-1991, the author had the opportunity to explore many aspects of the underground and surface expression of the mine. Hired to support the underground survey crew in 1987 and later working as the mine ventilation engineer and water treatment plant operator, the author shares memories of the physical characteristics of the operating mine. The presentation uses publicly available maps and diagrams coupled with personal descriptions of the underground workings, the Lake Emma glory hole on C-Level, lime treatment plants and settling ponds constructed to treat acid mine drainage at the American and Terry Tunnels, tailings effluent water quality adjustment at the Mayflower Mill, and surface water sampling in the upper Animas River Watershed in the years just prior to the mine shutdown. The intention of the presentation will be to give the audience a first-hand account of underground mining in the Gladstone area and associated environmental activities circa 1989 and provide an opportunity to improve understanding of mining and the mine area geography affecting the Upper Animas watershed.

Rapid Assessment of Soil Metal Concentrations Along the Animas River, New Mexico

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Abstract 9 – Both Oral and Poster

On August 5th, 2015 an inadvertent breech of a mine shaft holding metal laden waters in Colorado was spilled into the Animas River and ultimately into the San Juan River confluence in Farmington, NM and beyond into the Navajo Nation. Farming communities draw irrigation water from the Animas and San Juan Rivers, raising concerns that metal-laden water in the river was spread across farm fields as irrigation water. As the pollutant plume moved down the river, a reddish sludge was deposited in the river sediment and along the riverbanks. Initially, the water containing the plume was cloudy as the sludge was suspended in the water. However, after several weeks, the initial plume ran its course downstream and the water running down the Colorado portion of the Animas River near Durango appeared quite clear in September 2015; so clear in fact that the coating of the orange sludge on the bottom of the river and adjacent banks was readily apparent. The concern now is the remaining sludge in the river will slowly be carried downstream as irrigation ditches are once again activated for the 2016 growing season.

In an effort to rapidly respond to the threat to soil health in the farm fields of the area, the Natural Resources Conservation Service (NRCS), New Mexico State University (NMSU), and Texas Tech University (TTU) partnered to use state of the art portable X-ray fluorescence spectrometry (PRXF) for rapid, on-site analysis of soil elemental composition. PXRF spectrometry is a novel, yet widely accepted means of rapid elemental assessment in soils and sediments. Reference methods for the technique have been developed both by the NRCS (Soil Survey Staff, 2014) and Environmental Protection Agency (US-EPA, 2007) (Method 6200) and NRCS referenced methods for use in soils and sediments. The operational theory, optimized uses, limitations and applications are summarized by Weindorf et al. (2014).

Materials and Methods

On-site rapid PRXF field scans were undertaken Sept. 1-3, 2015 using a Delta Premium (DP-6000) PXRF featuring a Rh X-ray tube operated at 10-40 keV with elemental quantification accomplished via integrated ultra-high resolution (<165 eV) silicon drift detector. Multiple types of land were evaluated including: irrigated lands (water taken from the Animas River), non- irrigated lands (Control), and riverbank sediment. The location of each soil scan was georeferenced with GPS. Scanning was conducted in a proprietary software configuration known as Geochem Mode which offers elemental quantification of the following elements: V, Cr, Fe, Co, Ni, Cu, Zn, W, Hg, As, Se, Pb, Bi, Rb, U, Sr, Y, Zr, Th, Mo, Ag, Cd, Sn, Sb, Ti, Mn, Mg, Al, Si, P, S, Cl, K, and Ca. Geochem mode consists of two beams; each was set to scan for 30 sec, such that one complete sample scan took 60 sec. PXRF performance was assessed via scanning of two NIST certified soil standards.

Results and Discussion

Notably, the riverbank sediment was observed to be a mix of natural alluvial sediment and Gold King Mine sludge; the two of which had substantively different elemental signatures. In total, 140 samples were scanned in three days. Summary results are provided in Table 1.

Table 1. Elemental concentration ranges and averages for soils and sediments scanned with PXRF in the Animas River Valley in Colorado and New Mexico. All units are in mg kg-1.

n	Location	Al Avg	Al Range	Fe Avg	Fe Range	Cu Avg	Cu Range	Zn Avg	Zn Range	As Avg	As Range	Pb Avg	Pb Range
29	Control	64087	25413-83540	28987	9047-50892	33	ND-94	117	25-330	7	ND-13	53	12-230
67	Irrigated	53541	7281-80325	28514	4430-48232	36	11-100	175	39-819	7	ND-13	67	5-271
35	Riverbank	37749	4218-80108	38302	5818-293194	77	ND-220	365	19-1068	11	ND-38	153	10-487
9	Riverbank-Sludge	21018	8730-38781	48355	38292-75959	137	90-176	474	277-1174	40	ND-54	637	509-859
140													

Generally, the properties of the river sludge sent down the Animas River had Pb levels of ~600-800 mg kg-1; and higher levels of Fe, Cu, and Zn. Notably, the residential screening limit for Pb in soils is 400 mg kg-1 (Brevik, 2013). These sludge materials were found both in New Mexico and Colorado, both on the stream banks and underwater. Irrigated lands along the Animas River tended to have slightly higher levels of metals than non-irrigated "control" areas, although these were below agricultural loading rates notably for Pb. Nevertheless, it is essential we monitor these areas over time as more sludge sediment washes down the river and potentially spreads out via irrigation. It is unclear whether contaminated sludge will move down into New Mexico over time in response to hydrologic pulses (snow melt, flash floods, etc). The level of metals found in sludge along the Animas River warrant careful observation and extensive spatial and temporal sampling are recommended such that the levels of metals in soils of the Animas

River Valley will be more thoroughly understood in an effort to protect and optimize soil health. If areas of accumulation are noted, phytoremediation or other remediation strategies should be undertaken to ensure that the metal laden soils do not pose a risk for metal bioaccumulation in plants or feedstocks used by humans or animals.

This technology will be put to use in two phases of the project: 1) initial, rapid, on-site assessment of metal levels in soils of the Animas River Valley, and 2) long term monitoring whereby temporal accumulations of metals can be studied and documented as irrigation with river water once again resumes.

Acknowledgements:

We thank the NRCS (Richard Strait) and NMSU Experiment Station (David Thompson) for funding.

References

Brevik, E.C. 2013. Soils and human health - an overview. *In:* Brevik, E.C., Burgess, L.C. (Eds.), Soils and human health. CRC Press, Boca Raton, FL, pp. 59-82.

Soil Survey Staff. 2014. Soil survey field and laboratory methods manual. Soil Survey Investigations Report No. 51. Version 2.0. USDA-NRCS National Soil Survey Center, Lincoln, NE. Available at:

http://www.nrcs.usda.gov/wps/portal/nrcs/detail/soils/research/report/?cid=nrcs142p2_053371 (verified 3 December 2013).

US Environmental Protection Agency, 1996b. Method 3052: Microwave assisted acid digestion of siliceous and organically based matrices. *In:* Test methods for evaluating solid waste. US Environmental Protection Agency, Washington, DC, USA. Available at: http://www.epa.gov/wastes/hazard/testmethods/sw846/pdfs/3052.pdf (verified 26 January 2014).

US Environmental Protection Agency. 2007. Method 6200: Field portable X-ray fluorescence spectrometry for the determination of elemental concentrations in soil and sediment. *In:* Test methods for evaluating solid waste. US Environmental Protection Agency, Washington, DC, USA. Available at: http://www.epa.gov/osw/hazard/testmethods/sw846/online/6_series.htm (verified 3 December 2013).

Weindorf, D.C., N. Bakr, and Y. Zhu. 2014. Advances in portable x-Ray fluorescence (PXRF) for environmental, pedological, and agronomic applications. Advances in Agronomy 128:1-45. doi: http://dx.doi.org/10.1016/B978-0-12-802139-2.00001-9

What are the Effects of the Gold King Mine Spill on San Juan County, NM Agricultural Irrigation Ditches and Farms?

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Abstract 10 – Both Oral and Poster

Livestock production in San Juan County, NM is an 18-million-dollar industry with over 700 producers owning livestock (NMSU San Juan County Cooperative Extension). Alfalfa and other forage hays dominate much of the irrigated agricultural landscape. There are commercial apple orchards and grape vineyards in addition to farms that grow high value specialty horticultural crops including vegetables, herbs and cut flowers. Irrigation ditches that divert water from the Animas/San Juan rivers consist of intake points directly from the Animas River which are regulated by the New Mexico (NM) Office of the State Engineers and Federal Government (on the Navajo Nation) and operated by community ditch cooperatives and farm boards. The irrigation season typically begins around late April and ends late October, at which point the main ditch intakes are closed for the winter.

Typical furrow irrigated system in San Juan County, NM.

In August 2015, three million gallons of heavy metal contaminated water were accidentally released from the Gold King Mine (GKM) into the Animas River (EPA 2015; https://www.youtube.com/watch?v=ZBlR05tDCbI). Orange colored sediment laden with heavy metals including Pb, As, and Mn was evident along the river one month after the spill. Significant amounts of river sediments accumulate in irrigation ditches, smaller laterals, and gated irrigation areas during the growing season and constitute a potential threat to agricultural lands.

As a precaution against contaminating irrigation ditches, ditch cooperatives in NM and the Navajo Nation closed main diversion points into the 20 or so irrigation canals about 48 hours before the mine spill plume arrived in NM (San Juan Agricultural Water-Users Association 2015). The majority of irrigation ditches reopened after the EPA declared the river “safe” and irrigation resumed. The Navajo Nation made the difficult decision to open some ditches, while leaving others closed. In Northwest NM, some irrigators on and off the Navajo Nation ceased irrigating crops for the 2015 growing season, just at the time most crops were maturing for harvest.

The GKM spill is hitting the region just as there is a resurgent interest in local food production among both Anglo and Indo-Hispano cultures. Contamination of the Animas and San Juan Rivers following the Gold King Mine blow-out raises a number of questions by farmers and ranchers in San Juan County who are still anxious about the safety of the water and soil. Because the ditches were dry for about 10 days during the closure of the river, this gave our team the unique opportunity to establish base-line measures of irrigation ditch sediment in dry irrigation ditches for future long-term monitoring of the river/irrigation ditch/agricultural field interface and potential contamination threats to agricultural lands.

One of the objectives of our response to the mine spill centered on the following questions:

- What was in the ditch sediment before the spill?
- What is in the ditch sediment after the spill?

Methods, Procedures and Facilities: Thirteen irrigation ditches in San Juan County from the Colorado border to Farmington, NM were sampled August 11-August 14, during the ban on irrigating crops. We sampled only non-contaminated sediments. Where possible, sample transects were made downstream of a NM Office of the State Engineer (NMOSE) gage station. These gage stations monitor flow data in real time and may provide clues to ditch sedimentation. The following week, three main ditches on the Navajo Nation were sampled. Permission to sample was obtained by ditch companies, the NMOES, Navajo EPA and Navajo community farm board members. In one main ditch, we pulled transects at six locations from various points along approximately 15 miles (24 km). Sample sites were recorded with GPS. Through repeated measures, we resampled the same irrigation ditch locations during the winter 2015-2016, once the main intakes were closed for the winter. Because ditch sedimentation during the irrigation season can vary, at each sample point, we attempted to auger to 18-24 inches (46-70 cm) deep in three separate core pulls (6-8 inches long per core). Total metals from soil was measured following USEPA method 3051A (USEPA, 1998) using inductively coupled plasma optical emission spectrometry (ICP-OES) analysis. Baseline samples are now analyzed and we are beginning to analyze time 2 ditch sediment samples.

Our goal is to help restore consumer confidence and grower trust in the region by continuing to sample ditches and fields to ascertain if soil contaminant concentrations are below or similar to pre-August 2015 levels. These evaluations are critical to reassure growers and consumers in the region that the products grown on soils in the Animas and San Juan River Watersheds are safe.

Acknowledgements: We thank the NMSU Agricultural Experiment Station for salary and material support.

Investigation of Metal Persistence in Sediments of the Animas River Watershed after the Gold King Mine Spill

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Abstract 17 – Both Oral and Poster

The concentration and speciation of major and trace elements contaminants in water and sediments of the Animas River was investigated in samples collected during August 17^{th}-18^{th}, 2015, after the Gold King Mine spill occurred on August 5, 2015. A combination of spectroscopic, microscopic and water chemistry techniques was used to better understand the short-term impact of the spill, which will contribute to elucidate the long-term consequences of recurrent mine waste contamination events.

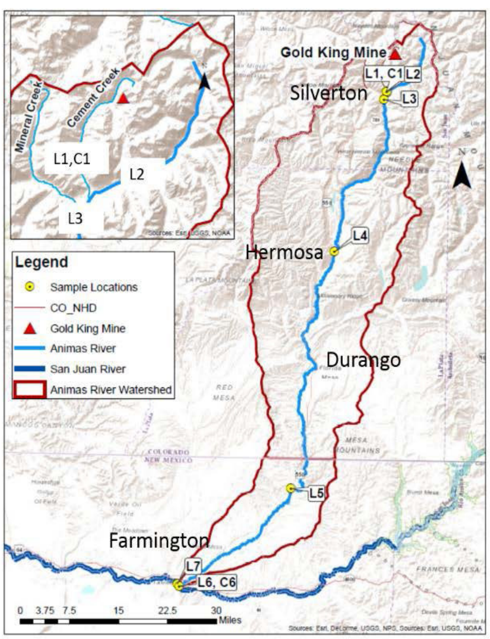

Figure 1 Map of the locations sampled during the trip on August 17^{th} and 18^{th}, 2015. Water samples were collected in all locations, and sediment samples were collected in all the locations but in L2 (Animas River upstream the Cement Creek confluence). In addition, two reference samples (C1 and C6) were collected above the river water level in Cement Creek and in the Animas River in Farmington.

For this study we took water and sediment samples in different locations across the Animas River watershed, trying to select locations similar to those sampled by EPA (Figure 1). Our selected samples include a location in Cement Creek, CO, the Animas River tributary where the spill occurred, and one in the San Juan River near Farmington, NM. The rest of the locations were selected in the Animas River from before the confluence with Cement Creek, CO, downstream to Farmington, NM.

The total concentrations of different metals in the water were within typical background levels at the time of the sampling trip. However, analyses of the data published by the EPA suggest that metals such as Pb and As exceed the drinking water standards of 15 $\mu g\ l^{-1}$ and 10 $\mu g\ l^{-1}$, respectively, at different locations of the Animas River after high flow events, as shown in Figure 2. In addition, nitrate, nitrite and phosphate were measured in water in the Farmington samples, a highly agricultural area, which suggest nutrient cycling in the river and could have implications in metal mobilization.

We detected the presence of high concentration of metals in the sediments (108.4 ±1.8 mg kg-1 Pb, 32.4 ±0.5 mg kg-1 Cu, 729.6 ±5.7 mg kg-1 Zn and 51,314.6 ±295.4 mg kg-1 Fe). The predominance of clay, jarosite, and alumino-silicate minerals was determined by XRD analyses in these

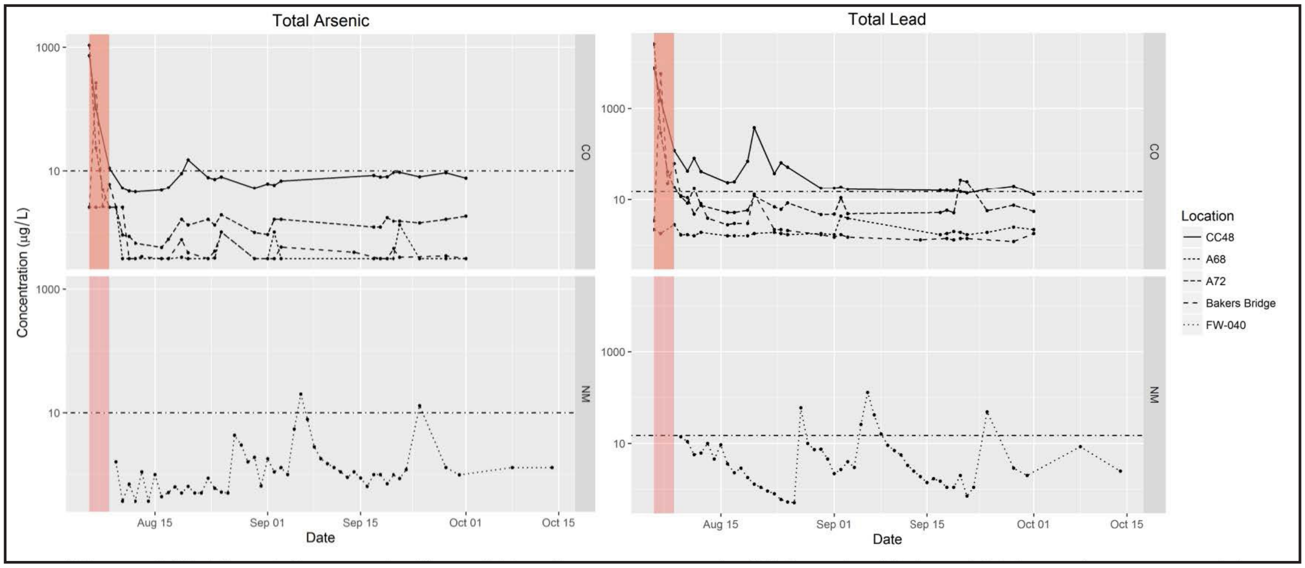

Figure 2. Total metal concentrations (https://www.epa.gov/goldkingmine/date-gold-king-mine-response) in water following the Gold King Mine Spill (marked as the red bar in the graphs). The spikes in total arsenic and lead concentration correspond with high flow events in the Animas River in Colorado (top graph) and in New Mexico (bottom graph). The dashed lines represent the drinking water standard concentration of 10 μg 1-1 for arsenic and 15 μg 1-1for lead

sediments, which are relevant primary minerals known to accumulate metals in the environment. Analyses using XPS detected the presence of sulfates, phosphates and nitrogen species in the surface of the sediments; Fe as 75% Fe(II) and 25% Fe(III) upstream the Animas River, but Fe(III) was the predominant specie in the surface of the Farmington sediments; and 100% Pb(II) in the samples from Cement Creek and Hermosa. The co-occurrence of Pb, Cu, Zn and Fe with sulfate was identified in these sediments using TEM, confirming the presence of metal-bearing jarosite ($KFe^{3+}{}_3(OH)_6(SO_4)_2$). The Mössbauer analyses of the samples from Cement Creek and Hermosa also shows the jarosite mineral in the sediments. The water at Cement Creek has a pH 3.3 but it increases into the alkaline range in the Farmington area, thus, the detection of jarosite in sediments from this location confirms the stability of this metal-bearing phase under acidic conditions.

The presence of nutrients in the sediments and water in the Farmington samples and the accumulation of metals in clays and precipitation as metal-bearing minerals highlight the relevance of understanding biogeochemical interactions to further asses the long-term stability of the contamination in the sediments of the Animas River watershed.

Examination of Sediment Microbial Communities in the Animas River Watershed Following the Gold King Mine Spill

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Abstract 18 – Both Oral and Poster

On August 5th, 2015 the EPA conducted an investigation of the Gold King Mine near Silverton, Colorado in order to assess the on-going water releases from the mine, treat mine water, and assess the feasibility of further mine waste remediation. While excavating near the entrance of the mine, pressurized water began to leak from the adit of the mine, spilling approximately 3 million gallons of heavy metal contaminated mine waste into Cement Creek, a tributary of the Animas River. (epa.gov)

On August 17th-18th, 2015 The University of New Mexico visited sites shown in Figure 1 along Cement Creek, Animas River, and San Juan River. At these sites, sediment samples were taken to determine metals composition, and microbial communities associated with the sediment. Basic water quality parameters were also measured such as water temperature, dissolved oxygen, conductivity, pH and oxidation-reduction potential. Sediment samples were sent to Research and Testing Laboratory for DNA extraction and Illumina Next Generation Sequencing.

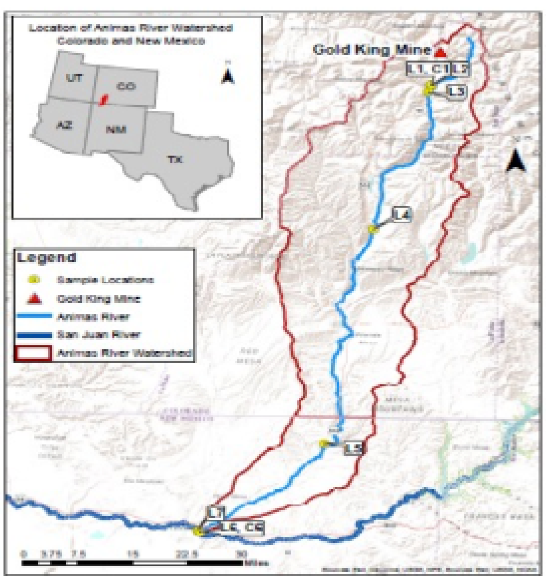

Figure 1: 8/17/15 – 8/18/15 Sample Locations in Animas River Colorado and New Mexico.

L1	Cement Creek 14th St Bridge
L2	EPA A68 Silverton Animas upstream
L3	EPA A72 Downstream of Cement Creek
L4	Animas at Bakers Bridge
L5	Animas Cedar Creek
L6	Animas at Farmington
L7	San Juan River downstream

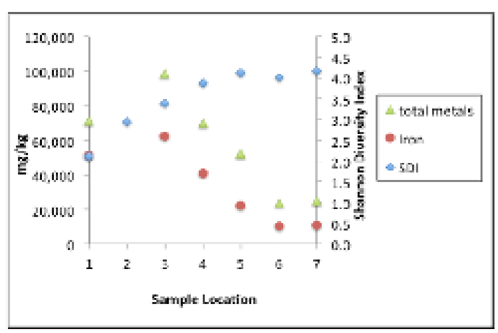

Figure 2: Total Metals, Iron concentrations and Shannon Diversity Index for sediment samples

As shown in Figure 2, Iron and Total metals concentrations are highest in sediment at sample locations closest to Cement Creek where the Gold King Mine discharged. Further downstream, concentrations of metals decrease and level off near the confluence of The Animas and San Juan rivers. The diversity of microbial samples collected at each site has been determined by calculating the Shannon Diversity Index (SDI) (Lande 1996). By this measure, microbial diversity appears to be generally lower at upstream sites with sediment containing high metals concentration. As metal concentrations decrease downstream, microbial diversity appears to recover by the steady increase in the SDI.

Figure 3 shows a dramatic change in sediment bacteria family communities observed in the Animas River upstream and downstream of the Cement Creek confluence. Upstream of the confluence, Cement Creek is rich in Gallionellacae (60.4% relative abundance), where the Animas River upstream of the confluence is all but missing this family (0.07% relative abundance). The family Gallionellacae is well document to consist of Iron oxidizing bacteria (FeOB) that mineralize dissolved Fe(II) to a precipitated Fe(III) in the form of extracellular bio-mineral structures (Krepski et al 2012). This process is important at acid mine draingage impacted sites because iron is usually the most abundant metallic element, and other heavy metals may co-precipitate or adsorb to Fe(III) precipitates formed by FeOB such as Gallionellacae (Stumm et al.1996, Fabisch et al. 2013).

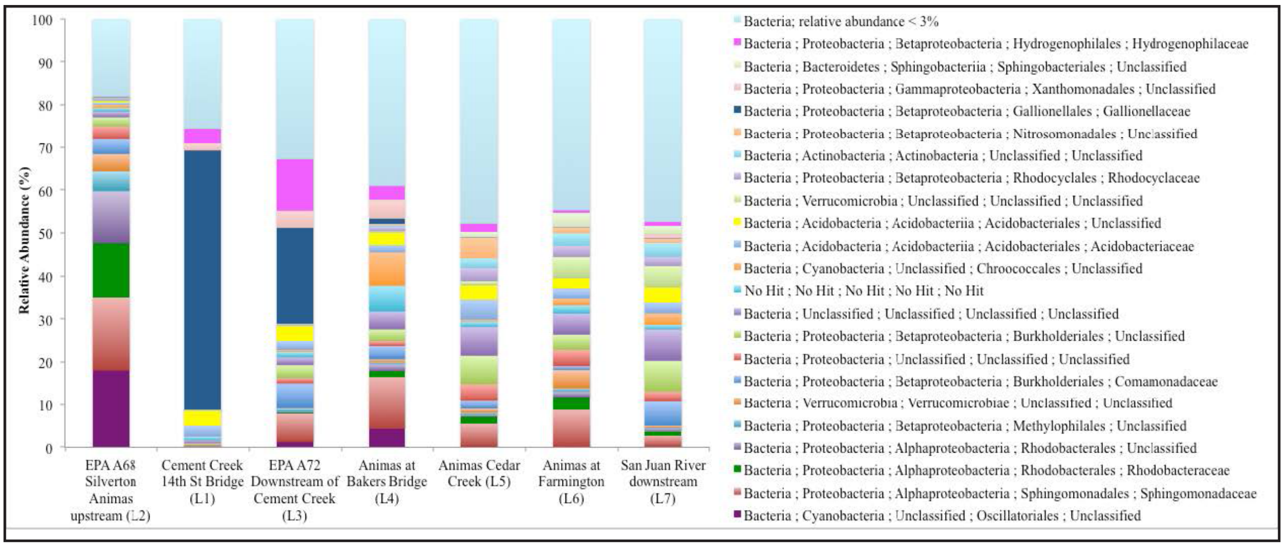

Figure 3. Illumina next generation DNA sequencing results for sediment samples in the Animas River watershed sorted by familiar. Bacteria familiae observed at less than 3% relative abundance across all locations were grouped together for visual simplicity

References:

Emergency Response to August 2015 Release from Gold King Mine. https://www.epa.gov/goldkingmine

Fabisch, M., Beulig, F., Akob, D., Kusel, K. Surprising abundance of Gallionella-related iron oxidizers in creek sediments at pH 4.4 or at high heavy metal concentrations. Frontiers in

Microbiology (2013) Volume 4 Article 390

Krepski, S., Hanson, T., Chan, C. 2012. Isolation and characterization of a novel biomineral

stalk-forming iron-oxidizing bacterium from a circumneutral groundwater seep. Environmental Microbiology (2012) 14(7), 1671–1680

Lande, Russell. Statistics and Partitioning of Species Diversity, and Similarity among Multiple Communities. Oikos, Vol. 76, No. 1 (May, 1996), pp. 5-13

Stumm, W., Morgan, J., (1996). Aquatic Chemistry: Chemical Equilibria and Rates in Natural

Waters. New York, NY: John Wiley and Sons.

Surface-Water Quality in Northwestern New Mexico after the Gold King Mine Release

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Abstract 26

The Gold King Mine Release of August 5, 2015 mobilized three million gallons of water and sediment into a tributary of the Animas River, which flows south from Colorado into New Mexico. The Animas enters the San Juan River at Farmington, New Mexico, the sixth largest city in the state and one of several communities that rely on the Animas and San Juan rivers for drinking water and (or) crop irrigation. Mines such as the Gold King are sources of metals and acidity to streams of the area, leading to concerns regarding the effects of the release on water quality. Potential problem constituents such as lead and arsenic (among others) were analyzed in surface water and sediment samples collected by the U.S. Geological Survey (USGS) in August 2015. Surface-water samples collected from the San Juan River at Farmington on August 8, 2015 (a time when the orange color indicative of the release was observed) had concentrations in whole water (unfiltered) samples of 552 µg/L lead and 26.3 µg/L arsenic. The concentrations of lead and arsenic were above the lead action level of 15 µg/L and the maximum contaminant level of 10 µg/L for arsenic, as set by the U.S. Environmental Protection Agency for drinking water. In contrast, the dissolved concentrations (0.45 µm filter) of these elements at the same site and time (lead <0.04 µg/L and arsenic 0.23 µg/L) were about two to three orders of magnitude below drinking-water standards and three to 5 orders of magnitude below the whole water sample concentrations. At the San Juan River at Farmington streamgage, located approximately two river miles downstream from the Animas River at Farmington streamgage, concentrations measured in whole water samples collected 4 hours after the samples on the Animas River ranged from 122 µg/L for lead, and 7.89 µg/L for arsenic. These concentrations were likely affected by dilution from the San Juan River which had discharge on August 8, 2015 of about 1,300 cfs, whereas discharge on the Animas River at Farmington was about 800 cfs.

Based on the results for total and dissolved water samples, constituents of concern generally were associated with particulates in the water. Bed sediment samples collected from the Animas River at Farmington on August 12, 2015 had lead concentrations ranging from 33.0 to 179 mg/kg and arsenic concentrations ranging from 3 to 11 mg/kg (n =4). Concentrations of these constituents in bed sediments were generally lower at the San Juan River at Farmington, similar to the trend in water-quality data for the same sites. Concern related to suspended particulates and bed sediment in these rivers continues months after the release. Continuous monitoring of pH, temperature, specific conductance, and turbidity is expected to help to understand the current geochemical interactions in the rivers. Additionally, water-quality sampling during snowmelt and storm events will provide valuable information about sediment and metal mobility during high-discharge events in the Animas and San Juan Rivers.

The Legacy Uranium Mining and Milling Cleanup Plan: Evacuation of the EPA Five-Year Plan, Grants Mining District, New Mexico

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Abstract 27

Uranium mining and milling in northwestern New Mexico (NM) impacted soils, stream sediments, surface water, and ground water with elevated levels of radioactivity and toxic heavy metals. Uranium and its radioactive decay products such as radium and radon gas present a significant public health and safety hazard and environmental health risk. The exposure of people and the environment to heavy metals and radionuclides in soil, air, and water in the vicinity of legacy uranium operations in the Grants District requires mitigation through the systematic assessment and cleanup of materials and sites bearing these hazardous contaminants. In August 2010 EPA released the Five-Year Plan Grants Mining District, New Mexico to assess and cleanup hazards from legacy uranium in northwestern NM. An evaluation of the activities in the first five years (2010-2014) of such a large-scale project was performed to determine if there has been measurable progress toward major goals and specific tasks in the Plan. The Six Objectives of the Plan address the following areas: 1. ground water; 2. mines; 3. mills; 4. structures; 5. Jackpile Mine, and 6. biomonitoring. The Plan accomplishments and progress during 2010-2014 toward completion of these six Objectives indicates that Jackpile Mine and Biomonitoring (Objectives 5 and 6, respectively) were achieved. Objectives 3 and 4 (mill sites and residential structures, respectively) show accomplishments and continuing work. Objectives relating to ground water and mine cleanup (Objective 1 and 2) show some progress but these two objectives were not fully achieved. Constraints and complexities related to regulatory practices, uncertainties, financial burden, and health impacts were identified as hindrance to full completion of the Six Objectives. Recommendations to support future work include development of an implementation plan for ground water, full enforcement of state ground water protection regulations, enhanced public involvement, and better collaboration among five-year plan agencies.

Before the River Turned Orange: Bacteria and Nutrient Pollution in the Animas and San Juan Rivers

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Abstract 28 – Both Oral and Poster

While pollution from legacy mining and the mineralized San Juan Mountains has always been of concern on the Upper Animas River, local watershed groups downstream of Silverton have been focused on other water pollution issues over the last 15 years. The orange color of the Animas River following the Gold King Mine spill captured the attention of people nationwide in August 2015, but it was a different color that catalyzed local groups to take action in 2002. Excessive growth of filamentous green algae in the Animas River spawned the development of the Animas Watershed Partnership and numerous studies investigating nutrient pollution in the watershed. Similarly, high levels of bacteria and sediment loading have been a long-term concern on the San Juan River. The San Juan Watershed Group has been working to identify and address sources of bacteria loading to the rivers since 2001, and has recently completed a Microbial Source Tracking (MST) study that investigated sources of fecal pollution on both the Animas and San Juan Rivers in 2013 and 2014.

This study measured E.coli, total phosphorus (TP), nitrate+nitrite (NO3/NO2), total Kjeldahl nitrogen (TKN), turbidity, conductivity, pH, temperature, and optical brighteners, as well as a set of PCR analyses testing for the presence/absence of specific DNA markers that represent different host organisms. By testing for these Bacteroides markers, we were able to detect the presence of bacteria originating from humans, birds, horses, dogs, cows, and ruminants (cows, sheep, goats, deer & elk).

Ruminant source bacteria were the most prevalent; this marker was detected in 94% of all samples, and was found in similar concentrations across all sites (cattle sources could not be distinguished from other ruminants). Bird sources were present about a third of the time, while human sources were detected in 77% of all samples. The San Juan River showed a more consistent bacteria problem than the Animas, with 94% of samples testing positive for human bacteria, and 46% of E.coli samples exceeding the single sample maximum criteria for primary contact (ie: swimming). The San Juan site at Hogback exhibited the most serious human bacteria problem: 99% of samples were positive for Human Bacterioides, and concentrations of this marker were significantly higher than all other sampling sites ($p<0.001$).

Animas River sites had 60% of samples test positive for human bacteria, with 13.5% exceeding the single sample E.coli maximum. Maximum concentrations of E.coli, total nitrogen, and total phosphorus were all seen between July and October, and are likely influenced by monsoon storm events. Primary contact standards for E.coli were exceeded at all four NM sampling sites, and Colorado standards were exceeded on the Florida River site.

Nutrient concentrations followed a trend similar to the bacteria, with the San Juan exhibiting consistently higher concentrations than the Animas. While no nutrient criteria currently apply to large rivers like the San Juan, sites on the Animas River exceeded the target criteria set forth in its Total Maximum Daily Loads (TMDLs) for nutrients and total phosphorus, which are set to avoid eutrophication and algae blooms. TKN and TP both correlated positively with E.coli and with turbidity, lending evidence to the conclusion that if bacteria and stormwater erosion problems are addressed, these could also reduce inputs of nutrients to the rivers.

The average water sample tested positive for 2.2 bacteria source markers, meaning that addressing a single pollutant source will not fully address the bacteria problem in the Animas and San Juan Rivers. That said, while pollution from legacy mining remains a problem that must be addressed far upstream, expanding wastewater infrastructure, improving sewage handling practices, restoring riparian buffers, and addressing stormwater runoff from pastures and uplands within San Juan County are all ways to reduce some of New Mexico's "homegrown" water pollution problems.

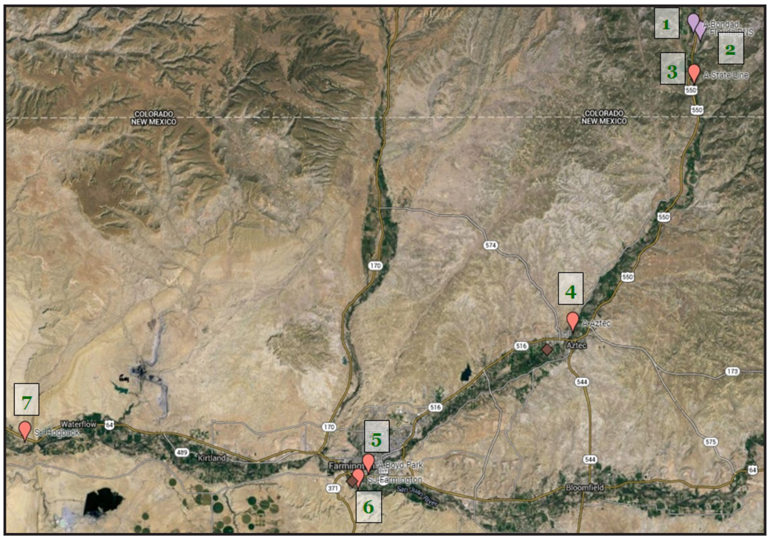
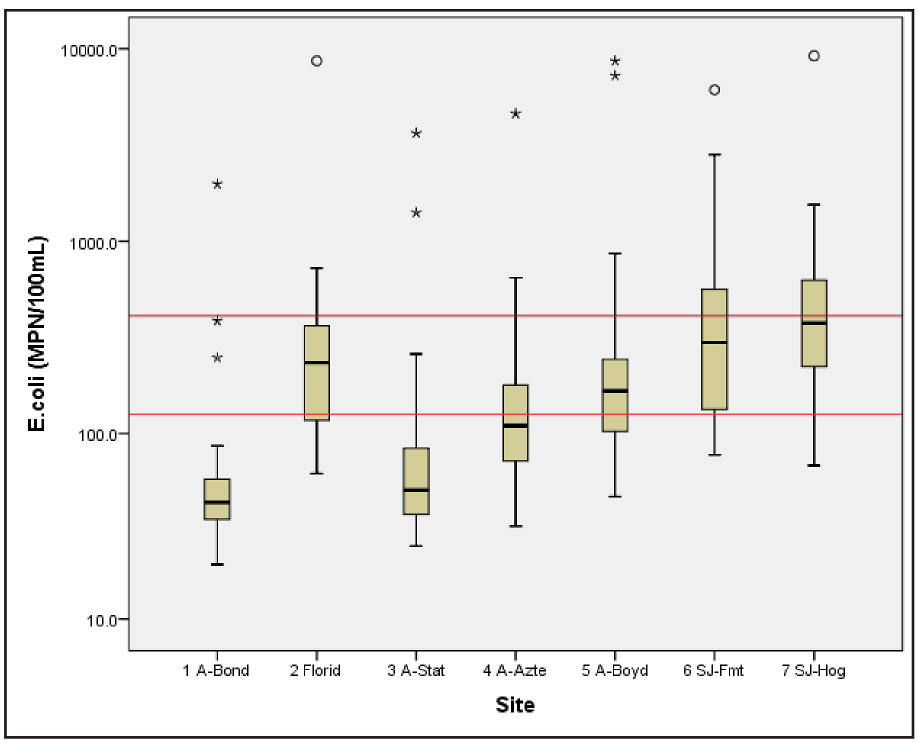


Figure 1. Map of 2014 sampling sites

Figure 2. Boxplot of E.coli concentrations at 7 sites sampled in 2014. Light red line is 126 cfu/100mL monthly geometric mean criteria, dark red line is single sample 410 cfu/100mL criteria.



The Use of Geochemical Data to Model Diffuse Leakage from a Mine's Tailings and Settling Ponds, with an Emphasis on Subsurface Flow, Malmberget/Vitåfors Iron Mine, Norrbotten County, Sweden

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Abstract 30

The Malmberget/Vitåfors mining facility, located in Norrbotten County, Sweden, is the world's second largest underground iron ore mine, comprised of roughly 20 steeply dipping magnetite-hematite ore lenses, with an underground area of approximately 5 x 2.5km. Since its' opening in 1892, over 350Mt of ore have been removed from Malberget, and another 350Mt of iron reserves have been declared proven and probable.

The state-owned Swedish mining company, Luossavaara-Kiirunavaara Aktiebolag (LKAB), owns and operates the facility. They have seen an increase in production in the past years, effectively doubling the amount of ore processed at the Vitåfors facility, from 8Mton/year in 1998 to 16Mton/year in 2013, and they intend to maintain this steady increase into the future. Despite these changes, the amount of water used within the system has not increased proportionally, and is not predicted to do so in the future. This is due to increases in process-water recycling, which adds to the demands placed on this water. As the water is reused, the conservative and trace element concentrations grow, affecting the overall water quality.

Some portion of the spent process water is released on a daily basis into the nearby Lina River. This discharge is generated in two ways: (1) By means of monitored release via outlet pipes, and (2) through diffuse leakage and subsurface flow originating at the facility's tailings and settling ponds. As yet, the volume, flow rate, and composition of this second discharge source have not been quantified. These characteristics can be estimated, however, by means of inverse geochemical modeling that utilizes historical water quality records from various sampling points throughout the Malmberget facility. Similarly, groundwater flow modeling takes advantage of local topographic and stratigraphic information generated almost entirely by the Geological Survey of Sweden (SGU).

The combined model generated by geochemical and groundwater flow modeling software (PREEQ-C and MODFLOW, respectively) that will answer questions of leakage quantity and quality is constructed broadly, by means of a three-part process. Initially, a rough three-dimensional model of groundwater flow within the local watershed is created in MODFLOW, employing geologic and topographic data collected by the SGU, as well as meteorological records from the Swedish Meteorological and Hydrological Institute. This is used to determine the relative path that groundwater will travel from the tailings and settling ponds to the Lina River. A second two-dimensional flow model illustrates this cross-section in greater detail. Inverse modeling with PHREEQC finally generates a one-dimensional model of the path between initial and final sampling locations (i.e., the tailings and settling pond, and the Lina River). The goal is to generate a plausible chain of mineral and gaseous phases that is both appropriate to the geology and chemistry of the site, and accounts for the changes in composition between initial and final water quality analyses.

The Characterization of Abandoned Uranium Mines in New Mexico

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Abstract 34

Not only has mining played a significant role in the United States, but for hundreds of years mining has aided in the economic and social development of New Mexico as early as the 1500s. One of the earliest gold rushes in the West was in the Ortiz Mountains (Old Placers district) in 1828, 21 years before the California Gold Rush in 1849. At the time the U.S. General Mining Law of 1872 was written, there was no recognition of the environmental consequences of direct discharge of mine and mill wastes into the nation's rivers and streams or the impact of this activity on the availability of drinking water supplies, and riparian and aquatic habitats. Miners operating on federal lands had little to no requirement for environmental protection until the 1960s and 1970s, although the dumping of mine wastes and mill tailings directly into the nation's rivers was halted by an Executive Order in 1935. It is important to recognize that these early miners were not breaking any laws, because there were no laws to break.

In New Mexico, there are tens of thousands of inactive or abandoned mine features in 273 mining districts and prospect areas (including coal, uranium, metals, and industrial minerals districts and prospect areas; McLemore et al., 2005a, b). The New Mexico Abandoned Mine Lands Bureau (NMAMLB) of the New Mexico Energy, Minerals and Natural Resources Department estimates that there are more than 15,000 abandoned mine features in the state (http://www.emnrd.state.nm.us/MMD/AML/amlmain.html). NMAMLB has safeguarded more than 2,300 mine openings in about 250 separate construction projects. The U.S. Bureau of Land Management recently estimated that more than 10,000 mine features are on BLM land in New Mexico and only 705 sites have been reclaimed (http://www.blm.gov/wo/st/en/prog/more/Abandoned_Mine_Lands/abandoned_mine_site.html). The New Mexico Bureau of Geology and Mineral Resources has collected published and unpublished data on the districts, mines, deposits, occurrences, and mills since it was created in 1927 and is slowly converting historical data into a relational database, the New Mexico Mines Database (McLemore et al., 2005a,b). More than 8,000 mines are recorded in the New Mexico Mines Database and more than 7,000 are inactive or abandoned. These mines often include two or more actual mine features.

Many of these mine features do not pose any physical or environmental hazard and many more, pose only a physical hazard, which is easily but costly to remediate. However, a complete inventory and prioritization for reclamation has not been accomplished in New Mexico. Some of these inactive or abandoned mine features can pose serious health, safety and/or environmental hazards, such as open shafts and adits (some concealed by deterioration or vegetative growth), tunnels that contain deadly gases, highwalls, encounters with wild animals, radon and metal-laden waters. Some sites have the potential to contaminate surface water, groundwater and air quality. Heavy metals in mine waste or tailings and acid mine drainage can potentially impact water quality and human health.

A recent example is the Gold King mine 'blowout' incident in Colorado where approximately 3 million gallons of acid mine water eroded soil and rock debris from the mine portal, pyritic rock and soil from adjoining waste rock dump, and were deposited in Cement Creek, and ultimately, flowing downstream to contaminate the Animas and San Juan Rivers (Gobla et al., 2015). Environmental accidents also have occurred at some New Mexico mine sites, mostly before the 1980s. In July 1979, 370,000 cubic meters of radioactive water containing 1,000 tons of contaminated sediment from a failure of the United Nuclear uranium tailings

dam traveled 110 km downstream in the Rio Puerco in western New Mexico. Evidence of slope instability at the Goathill North waste rock pile at Questa molybdenum mine was observed as early as 1974, but was not stabilized until 2004.

Many state and federal agencies have mitigated the physical safety hazards by closing these mine features, but very few of these reclamation efforts have examined the long-term chemical effects from these mine sites. There is still potential for environmental effects long after remediation of the physical hazards, as found in several areas in New Mexico (for example Terrero and Questa mines; McLemore et al., 2001, 2009, 2010). Some of these observations only come from detailed electron microprobe studies that are not part of a government remediation effort (McLemore et al., 2009, 2010).

The objective of our research is to develop a better procedure to inventory and characterize inactive or abandoned mine features in New Mexico, using the Lucky Don and Little Davie uranium mines in the Churapedero mining district, Socorro County, New Mexico as an example. Hazard ranking of mine openings and features, using BLM ranking methodology will be utilized for most sites (Bureau of Land Management, 2014). Also we want to suggest remedial activities that would manage or mitigate dangers to the environment and public health, while taking into consideration historical, cultural and wildlife issues and mineral resource potential.

REFERENCES

Bureau of Land Management, 2014, Abandoned Mine Land Inventory Study for BLM-Managed Lands in California, Nevada, and Utah: Site and Feature Analysis. Department of the Interior, Bureau of Land Management, National Operations Center, Denver, CO., 24 p., http://www.blm.gov/pgdata/etc/medialib/blm/wo/blm_library/BLM_pubs.Par.79469.File.dat/BLM-AML-Inventory-CA-NV-UT_Nov2014.pdf

Gobla, M.J., Gemperline, C.M., Stone, L.W., Gillette, D.R., Jibson, R.W., Olsen, R.S., 2015, Technical evaluation of the Gold king mine incident, san Juan County, Colorado: U.S. Bureau of Reclamation, Technical Service Center report, 132 p., http://www.usbr.gov/docs/goldkingminereport.pdf

McLemore, V.T., Hoffman, G., Smith, M., Mansell, M., and Wilks, M., 2005a, Mining districts of New Mexico: New Mexico Bureau of Mines and Mineral Resources, OF-494, CD-ROM.

McLemore, V.T., Krueger, C.B., Johnson, P., Raugust, J.S., Jones, G.E., Hoffman, G.K. and Wilks, M., 2005b, New Mexico Mines Database: Mining Engineering, February, p. 42-47.

McLemore, V.T., Dunbar, N., Tachie-Menson, S., and Donahue, K., 2010, The Effect of Weathering on the Acid-Producing Potential of the Goathill North Rock Pile, Questa mine, NM: CRC Press, Taylor and Francis Group, London, Tailings and Mine Waste '10, p. 213-227.

McLemore, V., Heizler, L., Donahue, K., and Dunbar, N., 2009a, Characterization of Weathering of Mine Rock Piles: Example from the Questa Mine, New Mexico, USA: Securing the Future and 8th ICARD, June 23-26 2009, Skelleftea, Sweden, conference proceedings, 10 p., http://www.proceedings-stfandicard-2009.com/pdfer/Virginia_McLemore_P_T2_Characterization-of-weathering-of-mine-rock-piles-example-from-the-Questa-mine-New-Mexico-USA.pdf

McLemore, V. T., Brandvold, L. A., and Carey, E. A., 2001, Long-term monitoring of the geochemistry of water and stream-sediment samples from the upper Pecos River, from the southern Pecos Wilderness to Brantley Dam, north of Carlsbad, eastern New Mexico: year nine; in Ulmer-Scholle, D. S. and Lucas, S. G., ed., Geology of the Llano Estacado, 2001: New Mexico Geological Society Guidebook 52, pp. 321-332.

Aeolian Transport of Dust-Borne Uranium Contamination

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Abstract 35

Closed mines pose significant risks to environmental and human health. While some work has been done on uranium mine waste contamination of surface water, ground water, and soil, little has been done to investigate the health risks to humans and wildlife from the aeolian transport of contaminated dust particles. In arid environments this is of particular concern due to the frequency of dust storms. At the Jackpile mine in Laguna Pueblo, NM, 15 sets of dust traps have been installed on vertical posts at heights of 0.25 m, 0.5 m, 1.0 m. and 1.5 m above the ground surface. The dust traps were installed at a range of distances from the source, from within the mine pit to approximately 4 km away. Soil samples have been collected at each site and dust samples were collected every other month as well as collected after individual windstorm events. Soil and dust samples were sieved into different size classes using 2 mm, 1.5 mm, 1.00 mm, 0.5 mm, 0.25 mm, 0.125 mm, 0.09 mm and 0.063 mm sieves. The samples were digested and uranium content analyzed using Inductively Coupled Plasma Mass Spectrometry (ICP-MS). We analyzed our samples for correlation between dust and soil contamination to 1) evaluate if soil contamination can be used as an indicator for the risk of airborne contamination, and 2) gain insight into the possibility that dust is the source of soil contamination. Secondly, we will investigate whether uranium has an affinity for a particular size class of dust. Of special interest are the particles small enough to be completely inhaled by humans. Results show that surface concentrations of uranium vary substantially across the landscape. Distance from the pit shows no correlation with concentration of uranium in the upper 5 cm of soil. Thus other factors besides distance may be controlling accumulation. Vegetation height and density is known to have a significant impact on wind speeds and related soil erosion and dust deposition. A confounding factor is topographic relief. At our study site there is 153 m difference in elevation between the highest site and lowest site. Furthermore the mesa cliffs and mine walls can constrict wind, increasing speeds at some sites and decreasing it at others. I have collected dust and soil samples from 15 sites in the area around the Jackpile mine and analyzed them for uranium concentration. The soil uranium content has been compared to site elevation and vegetation height. Preliminary analysis suggest that elevation and vegetation height may impact local erosion and deposition of uranium.

Standard Addition Method in Analysis of Animas River Samples

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Abstract 37

On August 5, 2015, approximately 3 Million gallons of mine waste containing various heavy metals was released into the Animas River from the Gold King Mine in Silverton, Colorado. This spill severely impacted the four corners area. Samples from Farmington, NM, and Silverton, CO, were analyzed for uranium, mercury, and cadmium using ICP-MS via standard addition. Results suggested an incredibly different concentration than what would be found via a normal calibration curve due to the complex nature of the river causing a matrix affect. Additionally, we exposed the river water to montmorillonite clays and observed a qualitative abatement of uranium and mercury.