THE EPA ROCKY MOUNTAIN REGIONAL HAZARDOUS SUBSTANCE RESEARCH CENTER[1]

T. R. Wildeman, D. L. Macalady, C. D. Shackelford and S. L. Woods[2]

Abstract. The Rocky Mountain Regional Hazardous Substance Research Center (RMRHSRC) for remediation of mine waste sites has recently been formed. The RMRHSRC is funded by the U. S. Environmental Protection Agency (EPA), represents EPA Region 8 states, and consists of a consortium of participants from Colorado State University, Colorado School of Mines, and several academic and non-academic participants from other regions of the U. S and Canada. The research goal of the RMRHSRC is to develop new and improve existing methods or technologies for remediation of mine waste sites that are cost effective and lead to clean ups that are protective of human health and the environment. Also, the activities of the RMRHSRC include training, technology transfer and outreach programs that will focus on the development of new technologies. A number of issues were considered in establishing an action plan and in choosing the research projects to fund. Some of these issues, such as cost, apply to every possible method of treatment. Others such as whether to concentrate on abandoned or active operations are somewhat mutually exclusive. The issues that were considered, the conclusions that were made, and how these conclusions affected the decision of which research projects to fund is the subject of this paper.

Additional Key Words: mine wastes, acid mine drainage, abandoned mine lands.

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[2]Thomas R. Wildeman and Donald Macalady, professors Department of Chemistry and Geochemistry, Colorado School of Mines, Golden, CO 80401; Charles D. Shackelford and Sandra L. Woods, professors Department of Civil Engineering, Colorado State University, Fort Collins, CO 80523

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Introduction

The Hazardous Substance Research Center (HSRC) Program of the US EPA was established in 1989 and is the longest-running competitive research program within the agency. Five centers are funded for five year periods, and these centers are geographically distributed throughout the ten regions of the EPA. In the recent renewal competition, the EPA directed that there be one center in Region VIII that focuses on the treatment of mining wastes. This paper describes the establishment of this Rocky Mountain Region Hazardous Substance Research Center (RMRHSRC) and the initial direction of its research and outreach activities.

Six states comprise the U. S. Environmental Protection Agency (EPA) Region 8: Colorado, Montana, North Dakota, South Dakota, Utah, and Wyoming. Mining has played a critical role in the socio-economic history of all of these states, and all of these states have environmental problems associated with historic or current mining operations. Of particular concern in this regard is the threat to the environment resulting from inactive or abandoned mine lands (AMLs). In the Region 8 states, 26 of the 45 active National Priority List sites are associated with AMLs.
In general, these AMLs represent hardrock and non-coal mines located on private, state, and federal lands that were actively mined over the past century and a half, but subsequently abandoned prior to the promulgation of the modern environmental regulations (e.g., Clean Water Act, RCRA, CERCLA) enacted since the 1970s.

In response to this concern, the RMRHSRC for remediation of mine waste sites recently has been established at Colorado State University (CSU), and consists of a consortium of participants from CSU, the Colorado School of Mines (CSM), and several academic and non-academic participants from other regions of the U. S and Canada. The Center is funded by the EPA in the amount of $4 million for an initial period of 5 years, with an additional $1 million in funding contributed by CSU and CSM.

Center Organization

The organizational structure for the RMRHRC is illustrated in Figure 1. The Center consists of two main activities related to research and outreach programs that pertain to remediation of mine waste sites, and a third activity related to quality assurance/quality control (QA/QC) for these programs. The research activities are separated almost equally between the two main participating universities (i.e., CSU and CSM), and the outreach activities include three main components, that is technical transfer, technical outreach to communities, and technical outreach to communities with brownfield activities. The research activities are overseen by a Science Advisory Committee (SAC), and the outreach activities are overseen by a Training and Technology Advisory Committee (TTAC).

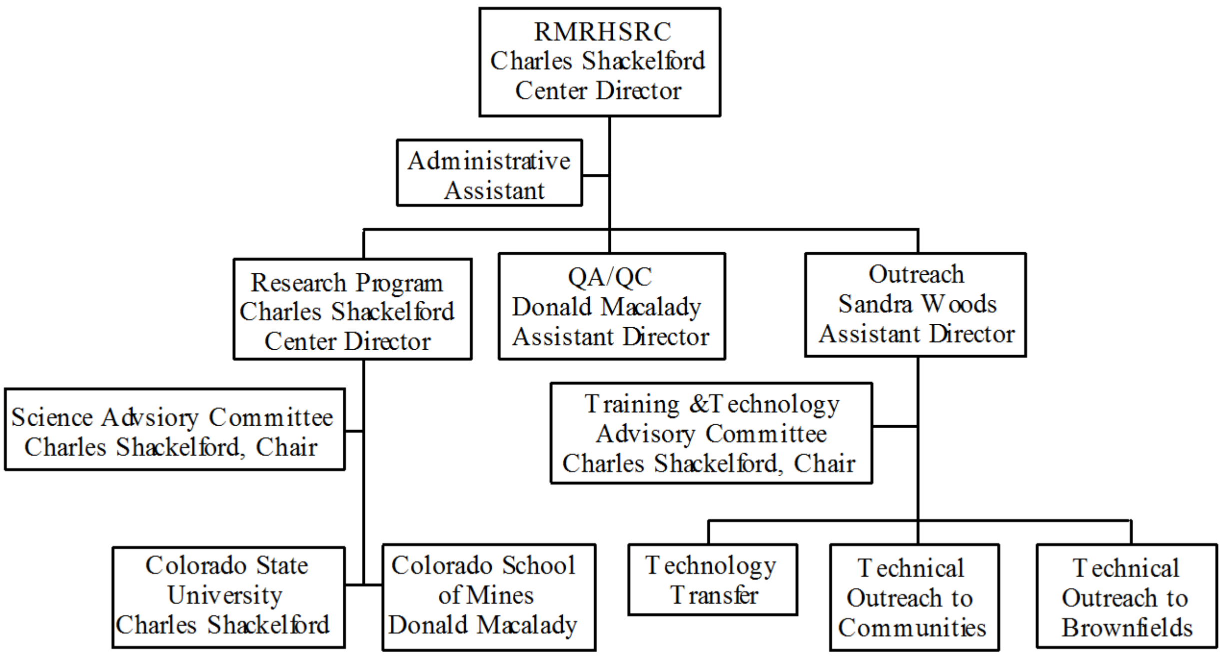


Figure 1. Organizational structure for the Rocky Mountain Regional Hazardous Substance Research Center (RMRHSRC) for remediation of mine waste sites.

The membership of the SAC consists of 6-9 technical peers drawn from the public and private sectors and academia. At least one-third of the SAC membership must consist of appropriate personnel from EPA's Regional Offices and Laboratories, and at least another one-third of the membership must be drawn from the academic community. The remaining members may come from industry or other Federal, State, or local governmental units. Appointments to this committee are subject to approval by the EPA project officer. Duties include reviewing the RMRHSRC's research plan, annual development of a list of relevant research topics, preparing recommendations regarding the relevance and technical merit of project proposals, and reviewing ongoing projects. Meetings are held twice a year. Members must be chosen from outside the institutions comprising the HSRC.

Membership of the TTAC includes representatives from relevant EPA Regional Offices, EPA's Office of Emergency Response, academia, and states or localities. Others may be added by the Center Director with approval by the EPA project officer. Duties include annual meetings to recommend outreach activity plans for the next year, review progress, and recommend changes to current year programs.

Environmental Issues Affecting Mining

Because of the proposal competition and subsequent award of funding from the EPA for a major research Center, we have had to assess those issues that concern mining and the environment and decide which ones will control the initial research and outreach activities of the Center. Certainly, our decisions on which areas of mining and the environment deserve our concentrated efforts can be modified or changed. However, at this time it is necessary to make decisions so that our projects have an appropriate focus. In the case of the outreach and community service efforts of the Center, all hazardous substances will be addressed. However, the EPA specifically requested that this Center, located in Region 8 of the 10 national EPA regions, concentrate on the environmental problems related to mining wastes. We have decided which issues are important and how they impact on the goals and operation of the RMRHSRC.

The Issues Affecting the Center

Cost is a dominant issue particularly because of the physical size of some mining wastes. Because many of the sites that have been impacted by organic wastes are U. S. Department of Defense and Department of Energy sites, development of innovative and low cost methods of treatment at these sites has been supported by significant Federal funding initiatives. However, the Federal government is not involved in any of the priority pollutant mining sites found in Colorado, Utah, Montana, Wyoming, South Dakota, and North Dakota, the states that make up Region 8. So, state and local governments are going to be required to some extent to initiate treatment efforts, and these entities demand a low-cost solution. Also, the record so far shows that high costs paralyze most current attempts at remediation. Consequently, cost limits both the scientific questions that can be answered with respect to a given problem as well as the level of technology that can be implemented to solve the problem. In other words, cost drives feasibility.

Although this is a regional center, treatment of environmental problems related to mining is obviously a global issue. Also, some academic, governmental, and private agencies beyond this region and nation have a great track record on working on the treatment of mining wastes. The MEND Program of Canada and the Acid Drainage Technology Institute of the University of West Virginia are two examples. Also, political restrictions, such as the Good Samaritan problem within Colorado, sometimes create hurdles that must be overcome when attempting pilot-scale and full-scale treatment projects within the region. Consequently, in preparing our proposal and now in carrying out the objectives of the RMRHSRC, our approach has to be beyond Region VIII. At least two of the four research projects have investigators outside of the region and the University of Waterloo in Canada is a participant. The EPA dictates that outreach activities be coordinated across the EPA Regions. However, for the technology transfer and outreach of this Center to be successful, the Center also must conduct research with other entities outside of Colorado and Region 8 that have already been concentrating on the treatment of mining wastes.

In the case of mining wastes, social and political issues will eventually drive most treatment efforts. However, this Center will concentrate research on the scientific and engineering aspects of the problem. The objective will be to make the answers to all the scientific and engineering questions to be clear and complete enough that the social and political questions can be played out on a well-defined scientific and engineering field.

With respect to concentrating on active versus abandoned mining operations, the plan will be to start studies on abandoned operations and then work with the mining industry to transfer solutions developed through the research activities to active operations. Since the Summitville disaster of December 1992, the permitting procedures for all states appear to be so extensive that all contingencies are taken into consideration. In particular, a complete closure plan has to be included in any new mining permit, and companies understand that their liability extends through the closure of the operation. Currently, opening and operating a mine depends on environmental regulations that are based on reasonably good science and engineering. Thus, the Center will begin operations concentrating on AMLs. There are some issues related to current operations that certainly deserve study, such as whether the models used to predict pit water chemistry are accurate, and how to bring a continuing operation that was started in the 1970's or 80's into compliance with the current regulations that relate to new operations. However, AMLs comprise the majority of the problems in Region 8 and appear to be a more fruitful area for the application of science and engineering for developing inexpensive and innovative treatment strategies. Also, bringing a current operation into compliance with more modern regulations means that treatment is done after contamination has occurred. Consequently, this can be considered to be similar to the treatment of an abandoned operation.

When considering whether the most important problem is contamination of the air, water, or earth, the water and the earth command the most attention. The question of what to do with abandoned tailings and waste rock piles represents the largest physical problem in any of the national priority pollutant sites that are on the EPA list. The problem of acid mine drainage (AMD) contaminates more miles of surface streams than any other type of contamination by hazardous substances. Consequently, these materials will command the research attention of the RMRHSRC.

Research Activities

Applying the focus issues to research activities uncovers the following problems concerning the remediation of AMLs: (1) an inadequate ability to rapidly and cost effectively characterize the extent and impacts of the effects of contamination resulting from mining activities; (2) an inadequate ability to accurately characterize the fate and transport of metals and other toxic chemicals from mining sites; (3) a paucity of cost-effective technologies that can clean up mine waste sites; and (4) a need to develop less costly and more rational clean-up strategies. Based on these problems, the goal of RMRHSRC research activities will be to extend our knowledge of the geochemical, biological, hydrological/ mineralogical and engineering aspects of environmental questions associated with mining and mine wastes and, based on this knowledge, develop new or improved methods or technologies that are cost effective and lead to clean ups that protect human health and the environment. The specific research objectives that will be addressed to accomplish the goal of the Center are:

(1) to more rapidly and effectively characterize the extent and impacts of the effects of contamination resulting from mining activities;

(2) to more accurately characterize the fate and transport of metals and other toxic chemicals from mining activities;

(3) to develop cost-effective treatment processes and associated technologies that can effectively clean up mine waste sites; and

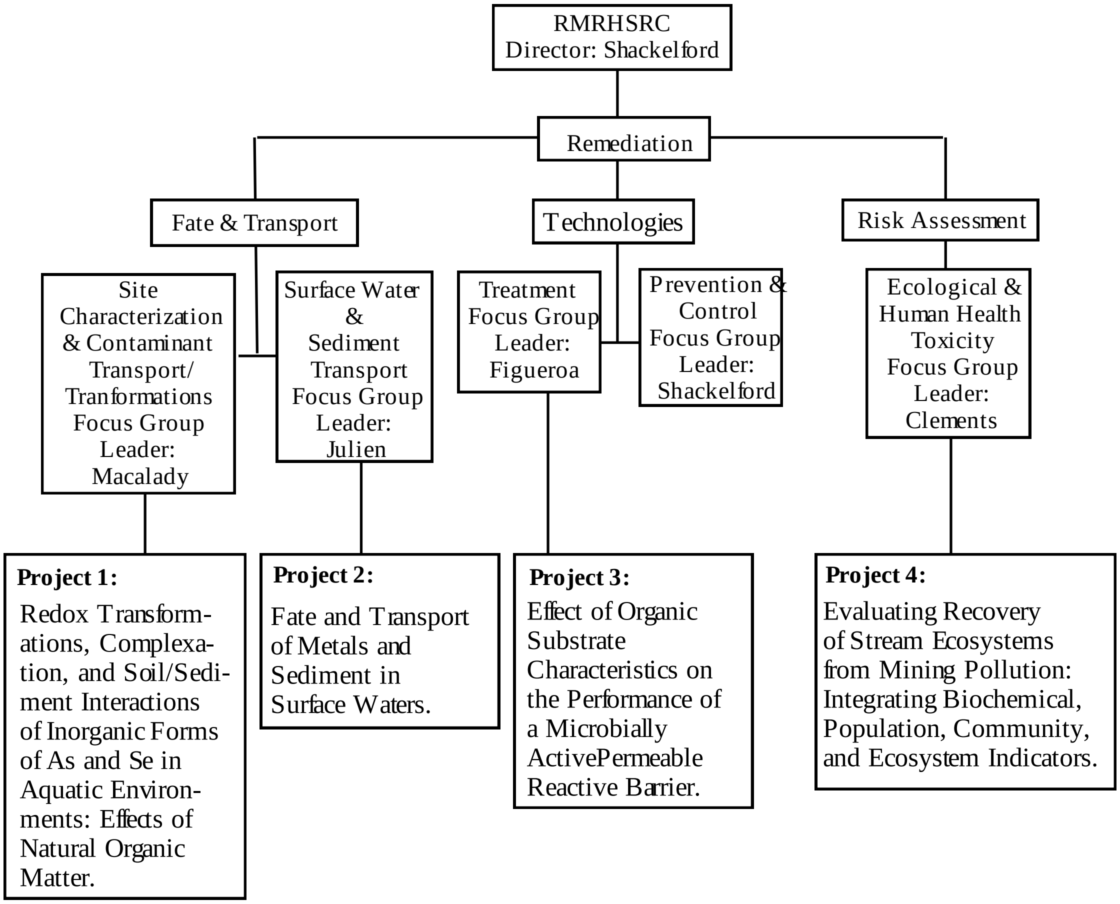
(4) to improve our ability to evaluate risk assessments for developing rational clean-up strategies.

To achieve these objectives, Center research will address three main areas of activity with respect to the remediation of mine waste sites: (1) fate and transport; (2) treatment and technologies; and (3) risk assessment. Each of these research activities represents an essential component of the remediation process. For example, fate-and-transport analyses using an appropriate modeling approach typically are required as an integral part of a risk assessment in order to estimate exposure-point concentrations of a given contaminant. Based on these concentrations, a toxicity and risk assessment is performed to determine the cleanup goals that ultimately affect the technology that is implemented for the remediation. Within each of these three research activity areas, both basic and applied research will be included. Mathematical and physical models will be used to better understand the processes being studied and to help extend the results of the basic research to field demonstrations.

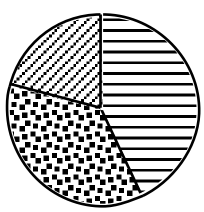
Research focus areas and approach

In order to address the three main areas of research activity, the Center research program is divided into five research focus areas, each with a focus group leader, as shown in Figure 2. The focus areas include: (1) site characterization and contaminant transport/transformation; (2) surface water and sediment transport; (3) treatment processes; (4) technologies; and (5) ecological and human health toxicity. The types of contaminant problems and the specific processes to address these problems are identified within this structure. Mathematical and physical modeling will be key components of each of the focus areas. In addition to the research focus areas of the Center, the first-year research projects of the Center also are identified in Figure 2.

To meet the goals of the Center, a multidisciplinary group of researchers has been assembled, as shown in Table 1. These people have a history of working on complex environmental processes, and taking these processes from the "laboratory to the field". Also shown in Table 1 are the principal investigators (PIs) and Co-PIs for the first year projects. A broad range of multidisciplinary expertise and experience is represented in this group and in their research proposals. A particular strength of this research group is the excellent distribution of Center investigators among the three categories, with 12 investigators from CSU, 11 investigators from CSM, and 11 participating investigators from other states within Region 8 and other EPA Regions, and Canada. Also, two of the first year projects (Projects 3 and 4) have investigators from both partnering universities (CSU & CSM) as PIs/Co-PIs.



Percent of Research Budget (1st Yr, Total Costs) within Research Activity Area



Percent of Research Budget (1st Yr, Total Costs) within Research Focus Area

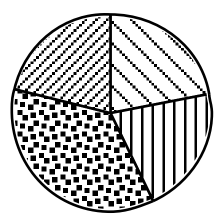


Figure 2. Research focus areas of the Rocky Mountain Regional Hazardous Substance Research Center (RMRHSRC), and first-year research projects.

Table 1. Investigators and participants of the Rocky Mountain Regional Hazardous Substance Research Center.

Investigator/Participant	Discipline and/or Expertise Areas
Colorado State University:	
Rajiv Bhadra	Chemical & Bioresource Engineering
Brian Bledsoe (Co-PI)	Sediment transport
Kenneth Carlson (Co-PI)	Environmental Engineering
William Clements (PI)	Fish and Wildlife Biology
Nancy DuTeau (Co-PI)	Microbiology
Pierre Julien (PI)	Sediment transport
Kenneth Reardon (Co-PI)	Chemical & Bioresource Engineering
Elizabeth Pilon-Smits	Biology
Charles Shackelford (Co-PI)	Geoenvironmental Engineering
Chester Watson (Co-PI)	Sediment transport
Sandra Woods (Co-PI)	Environmental Engineering, outreach
Ray Yang	Environmental Health Sciences
Colorado School of Mines:	
Dianne Ahmann (Co-PI)	Environmental microbiology, arsenic geochemistry
Ronald Cohen	Zoology, outreach
Linda Figueroa (PI)	Environmental engineering microbiology
Bruce Honeyman	Environmental geochemistry, surface interactions
Tissa Illangansekare	Meso-scale environmental testing, remediation
Junko Munkata Marr	Environmental microbiological engineering
Donald Macalady (PI)	Aquatic chemistry, metal/organic interactions, AMD
Harold Olsen	Geotechnical Engineering
James Ranville (Co-PI)	Particle size effects, AMD, surface chemistry
Robert Siegrist	Environmental Engineering, remediation technology
Thomas Wildeman (Co-PI)	Constructed wetlands for AMD, outreach
Other Investigators/Participants:	
George Aiken (USGS)	Natural organic matter, analytical geochemistry
Katherine Banks (Purdue U.)	Phytoremediation, bioremediation, wastewater treatment
Craig Benson (U. of Wisconsin)	Geoenvironmental Engineering
David Blowes (U. of Waterloo (Co-PI))	Geochemistry, permeable reactive barriers
John Garbarino (USGS) (Co-PI)	Analytical chemistry
Joe Meyer (U. of Wyoming) (Co-PI)	Environmental toxicology, zoology
Danny Reible (Louisiana State U.)	Environmental transport and mechanics, turbulence
Paul Schwab (Purdue U.)	Chemistry of heavy metals in soil
Otto Stein (Montana State U.)	Environmental Engineering (wetlands)
Richard Wanty (USGS)	Environmental geochemistry, AMD remediation
John Westall (Oregon State U. (Co-PI))	Geochemical models, inorganic and redox chemistry

Relation Of The Issues To The Research Projects

In the initial year of the Center, four research projects shown in Figure 2 were chosen for funding. How do these research projects relate to the examination of the issues presented above? All the projects concentrate on science and engineering rather than politics and sociology. Also, none of the projects are tied to a particular mining site, so the results could be transferred to any specific project. In the respect that the transfer of the technology can be to any other site, the issue of focusing on abandoned sites is not obvious. However, all of the projects deal with questions that have to be answered at any abandoned site-or also any active mining site. An examination of how other issues are involved in each specific project follows.

The first research project deals with the availability and transformations of arsenic and selenium in natural environments where organic matter is an important component. At first glance, this project seems unrelated to mining problems. However, this is a key area where the science is lacking to make the proper decisions on how treatment should proceed. For the heavy metals such as Cu, Zn, Pb, and Cd, principles of geochemistry and microbiology can be applied to treatment situations with a good degree of certainty. For the most part, the metals remain in one positive oxidation state and the precipitation sequence for carbonates, hydroxides, and sulfides is well known. However, for As and Se there are multiple oxidation states. In some of these oxidation states, removal is quite difficult. Furthermore, both these elements can occur in volatile compounds and their fate and transport in a removal system confuse the issue. So, for these two contaminants, fundamental scientific questions about speciation, transformation, and fate in biogeochemical systems have to be answered. Currently, we are designing treatment systems for arsenic and selenium. However, if pressed, we cannot answer questions about the ultimate fate of arsenic and selenium in these systems. This project hopes to answer those questions.

There are thousands of tailings and waste rock piles throughout the Western United States that are the relics of earlier mining operations. The questions that even the casual observer asks are: How are all those piles going to be treated, does every one of those piles have to be treated, and are there really contaminants moving from those piles into the surface and ground water? At present, the answers to the questions of which piles are contributing the most to the contaminant load in a watershed and which contaminants are coming from which pile are not known. In addition, material may move from the pile only during severe storms, and the material that moves may not dissolve but rather travel to a stream as suspended solids. However, upon reaching and entering the stream, the continuous contact of the material with the water may result in dissolution and thereby contribute to the contaminant load in a watershed. The answers to these questions are also unknown. Project 2 on the fate and transport of metals and sediment in surface water addresses these questions. The objective of the project is to develop and test a model that will provide meaningful estimates of the transport of particulates from a mine waste pile. Estimates for severe storm events will be included. Ultimately, because the cost is so great, treatment of waste piles will only be accomplished when there is a sufficient scientific basis to justify the cost. That basis can only developed when good models for the fate and transport of contaminants in waste pile are developed.

Over the past decade, passive treatment is one method for the removal of contaminants from AMD that has been extensively investigated. Passive treatment meets the criteria of being an innovative and low-cost solution. Because they require no utilities and do not need constant attention, passive treatment systems are especially attractive for treating contaminants in mine drainage at abandoned sites. Because the objective in treatment is to fix the problems at the lowest possible cost, the criteria that are used in the design of these systems have never been thoroughly investigated. Because designs are made using incomplete criteria, failure sometimes occurs and the reasons for failure are not understood. However, enough is understood so that the weak points in the design are known. These areas need to be investigated so that passive treatment systems can be made more reliable and efficient. These systems rely on the activity of microbes to produce products such as sulfide and carbonate that form precipitates with the metal contaminants. A key question is just what can be added to the system to increase the activity of the microbes? Another key question is whether some of the contaminants are toxic to the microbes? Also, there is a nagging question of whether the organic material that is used in these systems causes the dissolution of the contaminants through complexation. In Project 3, these and other questions concerning passive bioreactor systems will be answered so that this promising method of water treatment can be made to be more reliable and efficient. Initially, laboratory studies will use batch tests to attempt to answer the question of how much contaminant can be removed. Then column experiments will be conducted to maximize the microbial kinetics. Then hopefully armed with new insights into how to improve passive treatment systems, bench-scale reactors will be tested in the field.

Finally, there are the skeptics on both sides of a mine treatment project. One side says, "How do you know that you really have to carry out this expensive remediation?" This side especially focuses on waste rock piles, and sometimes argues that removal means destruction of part of our mining heritage. The other side says that, if you don't remove all the piles and clean all the sediment from the stream, then achieving a natural ecological condition is impossible. Obviously, a middle ground exists and both parties need a good scientific basis for achieving a common decision on which mine waste piles require priority treatment. Project 4 addresses these issues concerning sediment particles in a stream originating from a mine waste pile. The objective of the study is to decide whether a contaminant in a stream is really toxic to the aquatic ecosystem and then determine under what conditions that toxicity is more or less severe. If these questions can be answered, then using these results along with the fate and transport-modeling program developed in Project 2, waste rock piles that should be removed to provide the greatest benefit to watershed restoration can be designated.

Outreach Programs

Technology Transfer

The primary goal of the RMRHSRC Training and Technology Transfer Program is to provide effective training and technology transfer resulting in the progression of ideas from the laboratory to application.

The purpose of the Training and Technology Transfer Program is to support the mission of the Center by: (1) promoting organizational linkages, (2) ensuring outreach to industry, communities, and states, (3) facilitating the use of innovative means of information transfer, (4) supporting investigations at the interface of disciplines, (5) exploiting opportunities in science, engineering, and technology where the complexity of the research needs requires the advantages of scope, scale, duration, equipment, and facilities, and (6) capitalizing on diversity through involvement of under-represented groups. The Center will facilitate the progression of laboratory research to field applications by supporting activities that result in idea generation, information transfer, laboratory and pilot-scale testing, field demonstrations and applications.

Technical Outreach and Service for Communities (TOSC)

The goal of the TOSC program is to provide educational resources to help citizens gain a better understanding of the environmental problem, allowing them to make informed decisions and participate more fully in activities affecting their communities. This project will meet the following program objectives: (1) creating technical assistance materials tailored to the identified needs of a community, (2) informing community members about existing technical assistance materials, such as publications, videos, and Web sites, (3) providing technical information to help community members become active participants in cleanup and environmental development activities, (4) providing independent and credible technical assistance to communities affected by hazardous substance problems, (5) reviewing and interpreting technical documents and other materials for affected communities, and (6) sponsoring workshops, short courses, and other learning experiences to explain basic science and environmental policy related to hazardous substances.

Technical Assistance to Brownfields (TAB)

Brownfields are defined by the Environmental Protection Agency as "abandoned, idled, or under-used industrial and commercial facilities where expansion or redevelopment is complicated by real or perceived environmental contamination." The TAB Program provides technical assistance to communities and other stakeholders with an ultimate goal of redeveloping brownfields sites. The objectives of this program are the same as for the TOSC program. For TOSC activities, the hazards and contamination are more clearly defined. In TAB activities, the contamination may not be clearly defined, however, these is real concern within the community.

Summary

Hopefully, the above exposition helps to inform how RMRHSRC will go about solving the problems associated with the remediation of mining waste sites. Also, the people associated with the Center have a strong desire for people to understand the issues that were considered in formulating the initial action plan. To the extent that important issues have been overlooked, the intent of this paper is to solicit responses from our clients so that such issues can be addressed and included with the Center activities in the future.