REMEDIATION CHALLENGES AND OPPORTUNITIES AT THE TAR CREEK SUPERFUND SITE, OKLAHOMA[1]

by

Robert W. Nairn, Brian C. Griffin, J.D. Strong and Earl L. Hatley[2]

Abstract: The Tar Creek Superfund Site is a portion of the abandoned lead and zinc mining area known as the Tri-State Mining District (OK, KS and MO) and includes over 100 square kilometers of disturbed land surface and contaminated water resources in extreme northeastern Oklahoma. Underground mining from the 1890s through the 1960s degraded over 1000 surface hectares, and left nearly 500 km of tunnels, 165 million tons of processed mine waste materials (chat), 300 hectares of tailings impoundments and over 2600 open shafts and boreholes. Approximately 94 million cubic meters of contaminated water currently exist in underground voids. In 1979, metal-rich waters began to discharge into surface waters from natural springs, bore holes and mine shafts. Six communities are located within the boundaries of the Superfund site. Approximately 70% of the site is Native American owned. Subsidence and surface collapse hazards are of significant concern. The Tar Creek site was listed on the National Priorities List (NPL) in 1983 and currently receives a Hazard Ranking System score of 58.15, making Tar Creek the nation's number one NPL site. A 1993 Indian Health Service study demonstrated that 35% of children had blood lead levels above thresholds dangerous to human health. Recent remediation efforts have focused on excavation and replacement of contaminated residential areas. In January 2000, Governor Frank Keating's Tar Creek Task Force was created to take a "vital leadership role in identifying solutions and resources available to address" the myriad environmental problems. The principle final recommendation was the creation of a massive wetland and wildlife refuge to ecologically address health, safety, environmental, and aesthetic concerns. Additional interim measures included continuing the Task Force and subcommittees; study of mine drainage discharge and chat quality; construction of pilot treatment wetlands; mine shaft plugging; investigations of bioaccumulation issues; establishment of an authority to market and export chat, a local steering committee, and a GIS committee; and development of effective federal, state, tribal, and local partnerships.

Additional key words: hard rock mining, lead and zinc mining, ecological restoration, treatment wetlands, reclamation

[1]Paper presented at the 2001 National Meeting of the American Society for Surface Mining and Reclamation, Albuquerque, New Mexico, June 3-7, 2001. Published by ASSMR, 3134 Montavesta Rd., Lexington, KY 40502. Publication in these proceedings does not preclude authors from publishing their manuscripts, whole or in part, in other publication outlets.

[2]Robert W. Nairn is Assistant Professor of Environmental Science, University of Oklahoma, Norman, OK 73019-0631, nairn@ou.edu; Brian C. Griffin is Secretary of Environment and J.D. Strong is Director of Environmental Affairs, Office of the Secretary of Environment, State of Oklahoma, 3800 North Classen Boulevard, Oklahoma City, OK 73118; Earl L. Hatley is Director, Tribal Environmental Management Services, National Energy-Environmental Law and Policy Institute, Tulsa University, 3120 East 4th Place, Tulsa, OK 74104-3189.

Introduction

Hard rock abandoned mine reclamation (HAMR) has been identified as a major environmental issue to be addressed in the 21st century (EPA 1997). The U.S. Environmental Protection Agency (EPA) estimates that over 50 billion tons of untreated mining wastes exist across the U.S. at over 550,000 hard rock abandoned mine sites. Cleanup costs are estimated at $33-72 billion (U.S. House of Representatives, 1993). The now-defunct U.S. Bureau of Mines reported that 12,000 miles of U.S. rivers and streams are degraded below EPA standards by mining-related water pollution. In 1998, the Western Governors Association published a review of HAMR problems that identified the need to address the complex environmental policy issues associated with these problems.

Although often associated with mining operations in the Rocky Mountain west, HAMR problems exist in

Proceedings America Society of Mining and Reclamation, 2001 pp 579-584
DOI: 10.21000/JASMR01010579

other portions of the U.S., notably the Tri-State Lead and Zinc Mining District of Kansas, Missouri and Oklahoma. In this area, the ore deposit consists of lead and zinc sulfides associated with cherty carbonate host rock (McKnight and Fischer 1970). The principal host stratum is the Boone Formation, composed of fossiliferous dolomite, limestone and nodular chert (Luza 1983). Principal ore minerals are sphalerite and galena, with secondary concentrations of chalcopyrite, enargite, luzonite, marcasite, pyrite, and barite (Playton et al. 1980).

Significant quantities of lead and zinc were produced from the Tri-State District from the 1890s through the 1960s. Peak production occurred in the early 1920s when the mines accounted for over 55% of total U.S. zinc production. By the late 1950s, depressed global markets resulted in the suspension of most mining operations. By the early 1970s when mining ceased, almost 2 million tons of lead and 9 million tons of zinc had been produced (McKnight and Fischer 1970).

Approximately 1,000 hectares are underlain by underground mine workings in 47 sections of the Picher Mining Field in Ottawa County, northeastern Oklahoma (Figure 1; Luza, 1983). During mining, large capacity dewatering operations pumped 50,000 cubic meters of water per day (Reed et al. 1955). Groundwater has now filled the voids (the Boone Formation is the superficial aquifer as well as the ore-bearing strata), which now contain approximately 94 million cubic meters of contaminated waters. In late 1979, metal-rich waters began to discharge into the major drainage, Tar Creek, from natural springs, boreholes and abandoned mine shafts. In addition, 50-75 million cubic meters of unvegetated mine waste materials (chat) litter the surface in large piles and approximately 325 hectares of tailings ponds exist. These materials are contaminated with elevated concentrations of lead, zinc, cadmium and iron (Table 1).

Table 1. Principal contaminant concentrations in water and waste materials at the Tar Creek Superfund Site (EPA 2001); data collected 1980-1985. Chat refers to unreclaimed mine waste processing materials usually left in large piles on the land surface

	Mine drainage (ug/L)	Chat (mg/kg)	Tailings (mg/kg)
Pb	80	750	3,800
Zn	154,000	8,300	21,600
Cd	80	46	124
Fe	331,000	NA*	NA*

*Not analyzed

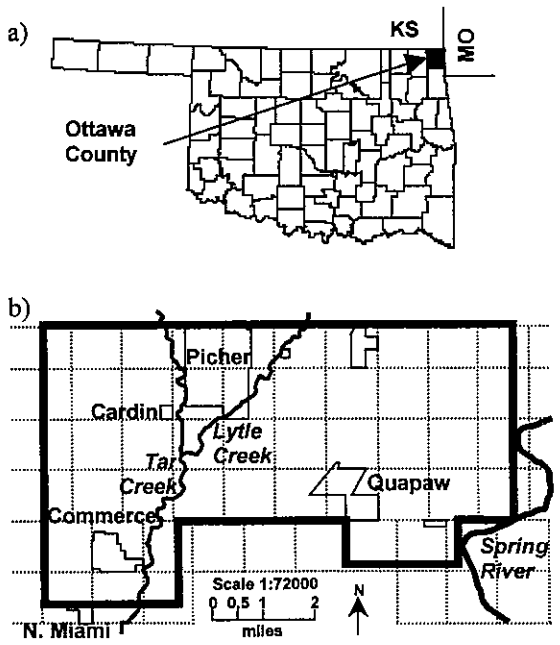

Figure 1. Maps showing a) location of Ottawa County, Oklahoma bordering the states of Kansas and Missouri and, b) the boundaries of the Tar Creek Superfund Site, location of local communities and major surface water drainages. Miami is south of the Superfund boundary. Dotted lines represent section lines.

The site was proposed for the Comprehensive Environmental Response, Compensation and Liability Act (CERCLA or Superfund) National Priorities List (NPL) in 1981 and received final listing in 1983. The Tar Creek Superfund Site receives a Hazard Ranking System (HRS) score of 58.15, giving it the undesirable distinction of being number one on the NPL (EPA 2001). The project area encompasses over 100 square kilometers and includes the incorporated communities of Miami, North Miami, Picher, Cardin, Quapaw, and Commerce. Total population in the area is approximately 30,000. Over one-half of the land is Native American owned.

The Tar Creek Superfund Site is one of the most challenging HAMR sites in the U.S. and on the NPL. The areal extent of disturbance and contamination is considerable. The volumes of contaminated waters, sediments, waste materials, and soil are large by any mining industry standard. These materials are in close proximity to several communities and their residential inhabitants, thus further complicating many remediation efforts. Extensive use of chat as aggregate in road and driveway construction, concrete foundations, buildings, and even recreational facilities (i.e., sandboxes and playing fields) helped to spread contamination

problems outside the mining area. Complex jurisdictional issues regarding Native American sovereignty and land rights also make matters complicated.

Remediation Efforts and Possibilities

Past Remediation Efforts

In the early 1980s, initial remediation efforts focused on ground and surface water contamination (Operable Unit 1). The Boone Formation aquifer was mined and is contaminated. The Roubidoux Formation, the primary drinking water aquifer approximately 325 m below the surface, demonstrated limited contamination due to boreholes and wells connecting the two strata. Initial actions included the provision of emergency water supplies (1985) and plugging of boreholes and improperly sealed wells (1986). Large-scale attempts were made to halt surface water from entering the mine voids via diversion and diking of three inflows. These attempts failed to decrease impacts to the receiving waters. In the Five Year Review for this site, EPA cites an Oklahoma Water Resources Board memorandum that takes the arguably pessimistic view that Tar Creek has incurred "irreversible man-made damages" (EPA 1994).

In 1993, Indian Health Service (IHS) data indicated approximately 35% of children tested in the Superfund area had elevated blood lead levels (BLLs) dangerous to human health. Since then (under Operable Unit 2), a residential remediation effort has been conducted to clean up lead contaminated yards, driveways, etc. with soils testing over the trigger limit of 500 mg/kg lead. Over 1,500 residences were remediated in the first phase, with approximately 600 scheduled for the second phase in 2001 at a total cost of approximately $57.5 million.

Despite these efforts, several concerns of the local communities and tribes have yet to be addressed. Prior to the human health studies and subsequent residential remediation efforts, environmental data collection, especially for water and chat quality had practically ceased. Due to lack of adequate progress in addressing human health, safety, and environmental threats at the site, Oklahoma Governor Frank Keating established the Tar Creek Superfund Task Force in January 2000.

Efforts of the 2000 Governor's Task Force

The Governor's Task Force was created to take a "vital leadership role in identifying solutions and resources available to address" the myriad problems at this site, and was charged to submit recommendations to the Governor by October 2000. Eight subcommittees, composed of volunteer technical experts, were created to address distinct concerns at the site: Health Effects, Mine Shafts, Subsidence, Chat Use, Drainage and Flooding, Water Quality, Native American Issues, and Natural Resource Damage Assessment (NRDA). The task force compiled and reviewed the recommendations of the subcommittees and attempted to formulate a holistic proposal for sustainable solutions to the problems at the Tar Creek Superfund Site. In this paper, the subcommittee recommendations are briefly summarized and the task force comprehensive proposal is presented and assessed.

Human Health. This subcommittee reported that past studies had determined that nearly 40% of area children had elevated BLLs, compared to a national average of 4.4% (Lynch and Nichols 2000). However, residential remediation, lead-based paint removal and educational efforts have had a significant impact on BLLs. The subcommittee provided the following recommendations: 1) intensify efforts to track and reduce BLLs, 2) institute regular blood screening for children, 3) track exposed children over time, 4) initiate long-term health outcomes studies, 5) study effects of metals on adult and adolescent health, 6) continue residential remediation efforts, 7) study health effects from gathering and consuming wild foods, 8) continue and expand lead-based paint remediation efforts, and 9) consider health first in any efforts to remove chat from the mining area (Lynch and Nichols 2000). Total cost estimates were $34,475,000, including $27,500,000 for Phase II contaminated yard remediation.

Mine Shafts. Approximately 2,600 shafts exist in the Tri-State Mining District, in addition to thousands of boreholes and other openings (including 1,320 shafts in the Superfund Site). These shafts contribute to larger subsidence problems and mine drainage discharges (Graves and Kastl 2000). The following recommendations were offered: 1) develop a Geographic Information System (GIS) of shafts and boreholes, 2) prioritize closure projects, 3) identify Bureau of Indian Affairs (BIA) lands to expedite closure, 4) identify underground features to select closure methods, 5) plug open drill holes, and 6) continue talks with EPA to approve closure under CERCLA (Graves and Kastl 2000). Estimated costs for identification, mapping and closure were $10,250,000.

Subsidence. The Subsidence Subcommittee identified 59 major collapses as of 1986 and eight more since 1986. They surmised that continued subsidence is likely (Keheley and Pritchard 2000). They recommended that the following be done: 1) develop

and maintain a GIS to identify high-risk areas, 2) use infrared technology to update extant information, 3) prioritize subsidence areas, 4) implement an immediate investigation and remediation effort on an ongoing subsidence, 5) identify and exploit funding opportunities, 6) fill selected mine shafts to reduce subsidence possibilities and 7) consider chat as a backfill material (Keheley and Pritchard 2000). Total cost estimates ranged from $200,670,000 to over $61 billion (if the subsidence risk area is equated to the entire acreage overlying the mining voids).

Chat Use. The approximately 75 million tons of chat on site provide an attractive nuisance to local residents, but regulatory guidelines on the beneficial reuse of this material are conflicting (especially the BIA moratorium on the sale of Native American chat). Also, at this time, no effective method exists for moving large volumes of chat, nor does a central marketing contact exist (McCaleb and Rodgers 2000). The subcommittee recommended the following: 1) establish chat use guidelines, 2) establish reasonable-cost testing processes, 3) remove the discriminatory BIA moratorium, 4) recognize that health and environmental problems cannot be mitigated until chat is removed, 5) establish a local marketing authority and 6) develop several projects examining the beneficial use of chat in asphalt production and road projects (McCaleb and Rodgers 2000). Total costs were estimated at $1,814,000.

Drainage and Flooding. As a result of mining activity, the Tar Creek watershed is characterized by poorly draining streams often at bankfull discharge (Crawford and Roberts 2000). Frequent flooding will most likely continue; primary concerns identified were stream aggradation, inadequate community drainage, flow obstructions, and backwater flooding problems with receiving streams. The subcommittee recommended the following 1) conduct channel improvements and buyouts of repetitive loss structures, 2) construct wetlands and conduct riparian enhancement to restore ecosystems, and 3) use the Remedial Investigation / Feasibility Study (RI/FS) to address drainage and flooding concerns (Crawford and Roberts 2000). Total costs were estimated at $48,465,000.

Water Quality. Tar Creek and its tributaries do not meet beneficial uses. However, contaminant concentrations in mine discharges and acidity in Tar Creek have improved over the last twenty years. The Boone aquifer is contaminated and threatens the Roubidoux aquifer (Hatley and Jones 2000). The subcommittee recommended the following: 1) conduct comprehensive monitoring of mine drainage discharges, chat pile runoff, and tailings pond runoff, 2) strengthen and coordinate monitoring efforts to better characterize water quality and trends, 3) analyze fish flesh to determine human health threats, 4) implement pilot-scale demonstrations of passive treatment wetland systems under the RI/FS, and 5) once appropriate system designs are identified, implement full-scale passive treatment wetland systems to comprehensively address water quality concerns (Hatley and Jones 2000). The mine drainage discharges now demonstrate a net alkaline nature (total alkalinity > mineral and proton acidity), but still contain elevated concentrations of iron, lead, zinc, and cadmium. These waters are amenable to successful remediation in treatment wetlands (e.g., Hedin et al. 1994; Nairn and Mercer 2001), and passive treatment was identified as the most promising remediation technology. Total costs were estimated at $25,311,190, including preliminary surface water and groundwater monitoring efforts, and $18,000,000 for subsequent full-scale treatment system implementation.

Native American Issues. Although Native Americans own approximately 70% of land and 80% of chat, federal and state remediation efforts rarely involve Tribal representation or concerns (Hatley 2000). Therefore, this subcommittee recommended the following: 1) lift the discriminatory BIA moratorium on chat sales, 2) accomplish better coordination with Tribal governments by the state, 3) conduct comprehensive air quality and transport studies, 4) institute a Native American hiring preference for all work at the Superfund site, 5) conduct cultural resource damage assessments, 6) provide blood sampling and analysis equipment to the Tribes and Indian Health Service, 7) complete research on impacts to cultural plant, aquatic, and animal food resources, and 8) conduct research on downstream impacts to tribes below the Quapaw jurisdiction and along Tar Creek, Neosho River, and Spring River (Hatley 2000).

NRDA. This subcommittee found that extensive natural resource damages have occurred to many species and ecosystems at the site. These damages likely exceed several hundred million dollars (Hunter-Burch and Landreth 2000). Recommendations of the subcommittee included the following: 1) continuation of the Tri-State NRDA partnership, 2) completion of pre-assessments to determine probability of NRD claims, 3) initiation of an assessment plan, 4) presentation of written demand for damages and costs to the potentially responsible parties after assessment, 5) contracting with professional consultants to integrate information into a GIS and 6) integration of NRDA and remedial activities. Total estimated costs for these tasks were $200,000. Restoration of damaged natural resources was estimated to cost $200,000,000.

Subcommittee Summary and Task Force Proposal. Common themes that emerged from the subcommittee recommendations included the use of wetlands, the need for a steering committee and the need for a GIS group to coordinate efforts. However, total cost estimates ranging from $540 million to $61 billion indicated the possible need for a comprehensive plan of action that would address the myriad problems at a realistic economic cost, and potentially provide benefit to the local community.

Therefore, the task force enlisted the assistance of the U.S. Army Corps of Engineers to develop a holistic solution involving the creation of a massive wetland and wildlife refuge to ecologically address the health, safety, environmental, and aesthetic concerns. This Wetland Concept Plan called for the removal of the towns of Picher and Cardin and the creation of a 546 acre reservoir, almost 1,700 acres of restored and created wetland habitat, and 318 acres of treatment wetlands at a total cost (including land acquisition and relocation assistance) of $250,000,000. It was theorized that the creation of this complex of deepwater aquatic habitat, created wetlands, and restored uplands would not only address human health, environmental, and aesthetic concerns, but would provide positive economic benefits to Ottawa County through increased tourism (hunting, wildlife watching, etc.) and ancillary benefits (Governor's Task Force 2000).

Several technical questions regarding the Wetland Concept Plan remain unanswered. Of prime importance are the possible detrimental effects of impounding such a massive load of water (and increased hydraulic head) over the mining voids. Comprehensive hydrogeologic studies are warranted to accurately determine the effects of this plan on the piezometric surface and the potential for down gradient detrimental impacts. The necessary areas for flood abatement and treatment wetlands are only crudely estimated in the plan. Sufficient flood hydrograph information, treatment wetland effectiveness results, and mine drainage quality and quantity data are unavailable at this time. These data are all exceedingly important to accurately determine needed designs and sizes and the potential for sufficient risk abatement. In addition, questions on the potential for bioaccumulation concerns in such large wetland areas need to be adequately and accurately answered. Operation and maintenance costs (and sources of funds) for such a large project also need to be determined.

Unanswered social questions regarding the acquisition of tribal lands and development of an acceptable relocation proposal must also be addressed. Adequate risk assessments and calculations of resultant risk reduction were not completed. Prior to implementation, sufficient technical information, in which the concept plan is particularly deficient, must first be gathered and shared with local stakeholders.

Conclusions

The Tar Creek Superfund Site is one of the most challenging HAMR sites in the U.S. and on the NPL. Due to the massive areal extent of disturbance and contamination; volumes of contaminated waters, sediments, waste materials, and soil; proximity to several communities; and inclusion of sovereign Native American lands, comprehensive remediation efforts will require innovative solutions. These remediation challenges should be viewed as opportunities to launch sustainable and forward-thinking strategies for remediation of mined lands. Perhaps most promising were the innovative ideas submitted to the Task Force in April 2000 by the Environmental Science and Engineering Capstone class at the University of Oklahoma. This report detailed a comprehensive field and laboratory study examining water quality, chat, and soil remediation possibilities for a small section of the Superfund site (University of Oklahoma 2000). Many of the remediation ideas proffered by the students were incorporated, whole or in part, in the Task Force and subcommittee recommendations.

Although listed on the NPL for nearly 20 years, it appears that the recommendations of the Governor's Task Force may result in a holistic remediation strategy for this environmentally and economically challenged area. However, cooperation is required among state and federal agencies, local communities, and Native American Tribes. The long-term success of any remediation solution will depend on a solid foundation of quality science and engineering, coupled with local cooperation.

Acknowledgements

The authors acknowledge the hard work and dedication of the 10 Task Force members and approximately 100 subcommittee members who provided thousands of hours of service in the search for sustainable and realistic remediation options for the Tar Creek Superfund Site from January-October 2000. Electronic versions of Governor Frank Keating's Tar Creek Task Force Final Report and the final reports of all eight subcommittees are available at: http://www.deq.state.ok.us/waste/Tarcreek/index.html.

Literature Cited

Crawford, J. and J. Roberts (Co-Chairs) 2000.

Governor Frank Keating's Tar Creek Task Force Drainage and Flooding Subcommittee Final Report, 87 pp.

EPA. 1994. Five Year Review, Tar Creek Superfund Site, Ottawa County, Oklahoma.

EPA. 1997. Record of Decision, Residential Areas Operable Unit 2, Tar Creek Superfund Site, Ottawa County, Oklahoma. U.S. EPA, Region VI, Dallas, TX. 59 pp.

EPA. 2001. EPA National Priorities List Narrative: Tar Creek (Ottawa County), OK U.S. EPA, Office of Emergency and Remedial Response, 8 pp.

Governor Frank Keating's Tar Creek Superfund Task Force. 2000. Governor Frank Keating's Tar Creek Task Force Final Report, 26 pp.

Graves, J. and M. Kastl (Co-Chairs). 2000. Governor Frank Keating's Tar Creek Task Force Mine Shafts Subcommittee Final Report, 70 pp.

Hatley, E. (Coordinator). 2000. Governor Frank Keating's Tar Creek Task Force Native American Issues Subcommittee Final Report, 12 pp.

Hatley, E. and G. Jones (Co-Chairs). 2000. Governor Frank Keating's Tar Creek Task Force Water Quality Subcommittee Final Report, Task 1, 56 pp. and Task 2, 35 pp.

Hedin, R.S., R.W. Nairn and R.L.P. Kleinmann. 1994. Passive Treatment of Coal Mine Drainage. U.S. Bureau of Mines Information Circular 9389. 37 pp.

Hunter-Burch, K. and L. Landreth (Co-Chairs). 2000. Governor Frank Keating's Tar Creek Task Force Natural Resources Damage Assessment Subcommittee Final Report, 11 pp.

Keheley, E. and M.A. Pritchard. (Co-Chairs). 2000. Governor Frank Keating's Tar Creek Task Force Subsidence Subcommittee Final Report, 75 pp.

Luza, K.V. 1983. A Study of Stability Problems and Hazard Evaluation of the Oklahoma Portion of the Tri-State Mining Area, U.S. Bureau of Mines Mining Research Contract Report J0100133, 147 pp.

Lynch, R. and J.A. Nichols (Co-Chairs). 2000. Governor Frank Keating's Tar Creek Task Force Health Effects Subcommittee Final Report, 3 pp.

McCaleb, N. and E. Rodgers (Co-Chairs). 2000. Governor Frank Keating's Tar Creek Task Force Chat Use Subcommittee Final Report, 29 pp.

McKnight. E.T. and R.P. Fischer. 1970. Geology and ore deposits of the Picher field, Oklahoma and Kansas, U.S. Geological Survey Professional Paper 588, 165 pp.

Nairn, R.W. and M.N. Mercer. 2001. Alkalinity generation and metals retention in a successive alkalinity producing system. *Mine Water and the Environment.* 19(2): 124-133.
https://doi.org/10.1007/BF02687260

Playton, S.J., R.E. Davis, and R.G. McClaflin. 1980. Chemical Quality of Water in Abandoned Zinc Mines in Northeastern Oklahoma and Southeast Kansas. Oklahoma Geological Survey Circular 82, 49 pp.

Reed, E.W., S.L. Schoff, C.C. Branson. 1955. Ground-water resources of Ottawa County, Oklahoma. Oklahoma Geological Survey Bulletin 72, 203 pp.

University of Oklahoma. 2000. Development of Holistic Remediation Alternatives for the Catholic 40 and Beaver Creek. Spring 2000 Environmental Science and Engineering Capstone Project Final Report. School of Civil Engineering and Environmental Science. 109 pp.

U.S. House of Representatives. 1993. Unreclaimed hard rock mines. Committee on Natural Resources, Subcommittee on Oversight and Investigations, Washington, DC.