SUSTAINABLE MINING BEST PRACTICES AND CERTIFICATION[1]

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Abstract. Sustainable mining concepts are being applied to current mining practices; however, assessment tools or criterion for best available mining and reclamation practices are needed. Environmental regulations and market incentives must align with these assessment tools before enhanced environmental performance and sustainable mining practices can be realized. This paper uses an environmental management system methodology to evaluate the sustainability of pollution prevention practices, such as in-situ mining and mineral processing circuits that produce desulfured tails, and ameliorative practices that employ mine waste covers and reclamation. This paper also discusses the conflict between the current regulatory process and the need for more innovative mining practices.

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Introduction

There is a relationship between production efficiency and environmental performance and there are also economic and environmental limitations to traditional regulations. These emerging paradigms make a case for an environmental management policy that promotes environmental management systems for implementation of best practices for metal mines. The norm in environmental regulation in the 80s and 90s was that governments set maximum permissible discharge levels or minimum levels of acceptable environmental quality. These usually consisted of prescriptive, media-specific Best Available Technologies (BATs), water quality standards, and air quality standards. However, these prescriptive BATs often neglect to consider the overall environmental footprint of a facility causing environmental improvement in one area while resulting in environmental degradation in another (Staub and Cooper, 2004). Regulations also often lack the flexibility necessary to allow for innovative technology. Furthermore, certain environmental controls may only work if incorporated into a project from the outset and integrated with the entire environmental management system (EMS).

BAT performance needs to be monitored and judged against standards. However these standards remain static until incrementally adjusted by regulation. Incremental improvements do not necessarily promote innovation in environmental practices as they tend to promote incremental upgrades in response to incremental regulation (Warhurst, 1994). Hence regulation does not necessarily promote the innovations in technology or practice that could result in higher levels of overall environmental performance and sustainability. Furthermore, environmental regulations tend to treat the symptoms of environmental impacts and prescribe end of the pipe solutions rather than pollution prevention measures that are tailored to site specific conditions. Regulations also tend to focus on technological based and media-specific solutions rather than human resource and knowledge based solutions.

Only dynamic companies with new projects are positioned to invest in the research and development required to implement environmentally and economically sound alternatives to older, less efficient technologies. They can raise the capital up front to build new state of the art systems that push the technology beyond the bounds of regulation in order to seek competitive advantage. These systems often include an environmental management system as a means to improve economic and environmental performance.

At the end of the mine life closure does not halt environmental impact and closure and decommissioning and reclamation involve significant environmental costs. The challenge for policy makers is how to keep companies dynamic during closure such that they can afford clean up and continue to generate economic wealth that can pay for closure costs.

Approach

There is a need for integrating EMSs in a sustainable development policy. Furthermore there needs to be a revamping of regulatory policies to encourage rather than prevent innovative mining approaches. Lastly, there needs to be a market incentive system for mining companies to sell certified metals at a higher price than non-certified metals. This is because certified metals are developed using best available technologies and best available mining practices. Metals produced using these practices are value-added because they were produced with a minimum of environmental impact, which also minimizes closure cost and maximizes the value of adjacent resources. Society must reward metals produced in this manner because the goal of sustainable development is to "fulfill the needs of the present without compromising the ability of future generations to fulfill their needs" (Bruntland, 1994).

Ore deposits are localized accumulations of materials that are formed by geologic processes. The concentration at which an accumulation of minerals is considered to be an ore body is dictated by economics. As reserves of high grade ores decrease we will have to rely on ore deposits that have lower and lower concentration factors and will have to expend more and more energy to refine the ore. Substantial resources of minerals exist at concentration factors that are about an order of magnitude lower than those currently considered to be ore. However larger and larger amounts of mining waste will have to be generated in order to develop these deposits using current mining practices. Environmental management systems include the tools necessary to evaluate mining methods that reduce the amount of waste generated and mitigate the potential impact from these wastes. Regulations need to be flexible to allow for these new and innovative techniques. The EMS for a sustainable mining operation will ideally encompass exploration, new technology development and environmental rehabilitation simultaneously.

Sustainable Mining Best Practices

Hydrometallurgical production alternatives can produce value-added, sustainable mineral products that are produced at the mine site. Local production avoids transportation costs and supply and distribution problems associated with smelters. However environmental regulation and market conditions have hindered certain hydrometallurgical technologies such as in-situ mining from being implemented on an industry-wide basis. In addition in-situ mining is potentially a more economically efficient technology in that it can develop resources that are too low grade or inaccessible to be developed by conventional open pit and underground mining techniques. Furthermore in-situ mining is potentially an environmentally superior technology because the overall environmental footprint of an in-situ mining operation is far smaller than that of conventional mining and smelting..

In-Situ Mining

There are several examples where in-situ mining technologies have been tested. Although these projects were promising, regulatory constraints and market conditions prevented them from reaching full production status. A brief discussion of two of these projects is provided below.

Santa Cruz Project. The Santa Cruz in-situ copper mining demonstration project conducted in the 1990s near Casa Grande Arizona provides a good example of an innovative pollution prevention technology that transcends the bounds of prescriptive BATs. In fact, a Best Available Discharge Control Technology (BADCAT) system was developed for the Santa Cruz project under the Arizona Aquifer Protection Permit (APP) program (Arizona Department of Environmental Quality, 1989). It is also a model project for industry-government joint venture that fostered technology development and technology transfer to the wider industry. Indeed several technology transfer seminars were sponsored and conducted by the U.S. Bureau of Mines and ASARCO where industry leaders from mining companies, government and academic institutions were invited to participate in the technology transfer process.

The in-situ mining technology involved the injection of a dilute sulfuric acid solution into a saturated copper oxide ore horizon several hundred feet below an alluvial aquifer (Dillard, 1995). The project demonstrated how leach solutions could be controlled using well field technology and how an innovative project of this nature could be permitted following state laws such as the

APP and federal laws including Underground Injection and Control (UIC) regulations. The technology was also demonstrated to be environmentally safe as leach solutions were effectively controlled and attenuated outside of the target ore zone. Furthermore it could produce copper from a deep and low grade resource (approximately 1 billion tons of 0.55 percent copper oxide ore) that would be uneconomic using existing surface and underground mining technology. It should be noted that traditional open pit development would have resulted in a large open pit and the construction of large waste and overburden stockpiles similar to the facilities at the nearby Sacaton Mine which is now closed.

Unfortunately due to low copper prices in the 90s, commercial development of the project was halted by ASARCO. This could have been avoided if the market for value-added, sustainable copper had existed based on certification of in-situ mining as a BAT. A justification for this market exists because copper produced by in-situ mining is potentially competitive with copper produced by a conventional mine with an estimated profitable selling price of $0.50 to $0.80 per pound (Pugliese, 1989). However the overall environmental impacts are potentially much less than an open pit mine which means that the externalized costs are much less.

<u>Mineral Park - Reduction in ARD.</u> At the Mineral Park mine Near Kingman Arizona the U.S. Bureau of Mines and Cyprus Mineral Park Corporation (now owned and operated by Mercator) jointly conducted another in-situ mining test in a copper sulfide deposit (Schmidt and Earley, 1998). The test site was located on the edge of Ithaca Pit that was excavated by Duval during the 1970's to extract molybdenum and copper (Fig. 1 and 2). Therefore, the setting at this site is one of previously dormant open pit operations surrounded by low grade copper sulfide ore in undeveloped ground.

An experimental in-situ mining well field was nestled in the juniper and cactus that covers the slopes of the adjacent mountains. This test demonstrated how acid rock drainage (ARD) can be mitigated by using in-situ mining techniques that do not disturb the sulfide bearing host rock. The conventional mining methods used previously at this test site relied upon blasting and comminution of the sulfide ores that resulted in exposure of pyrite and other sulfides to unsaturated hydrologic conditions greatly increasing the potential for long term production of ARD. In contrast the in-situ mining technology maintains the saturated conditions within the sulfide ore body which results in the return of anoxic conditions once the leaching operations are halted (Earley et al., 1996). Under these conditions the pyrite oxidation reaction is slowed to background rates. Furthermore the hydraulic gradient generated by pumping the adjacent open pit allows spent leach solutions to be contained within the pit capture zone (Fig. 2).

Unfortunately owing to the low price of copper at the time the test was conducted it was not possible to develop this system into a commercial operation owing to the relatively high cost of production with an estimated selling price of $0.70 to $1.00 U.S. per pound (Schmidt and Earley, 1998). The economic model of in-situ leaching is built on the reserves analysis of Turquoise Mountain done in March 1993 which indicated 41 million tons of chalcocite ore with average grade 0.24 pct. However, the resource of chalcopyrite ore is more than an order of magnitude larger if in situ technology can be developed for that target. Environmental certification of copper produced using in-situ mining or regulatory incentives to use this technology could result in a market that would sustain this practice. Furthermore, in situ mining uses much less energy per pound of copper produced than other types of mining and operating costs are not as sensitive to energy prices.

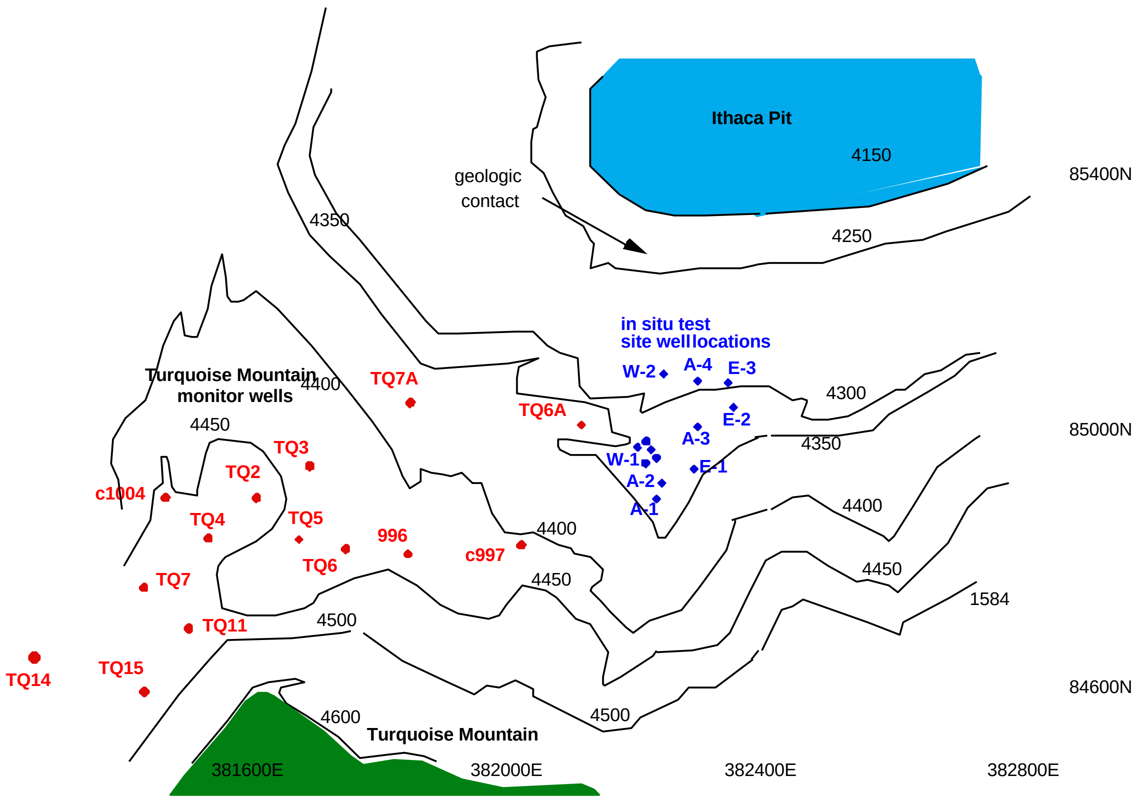

Figure 1. Mineral Park in situ leaching test site layout.

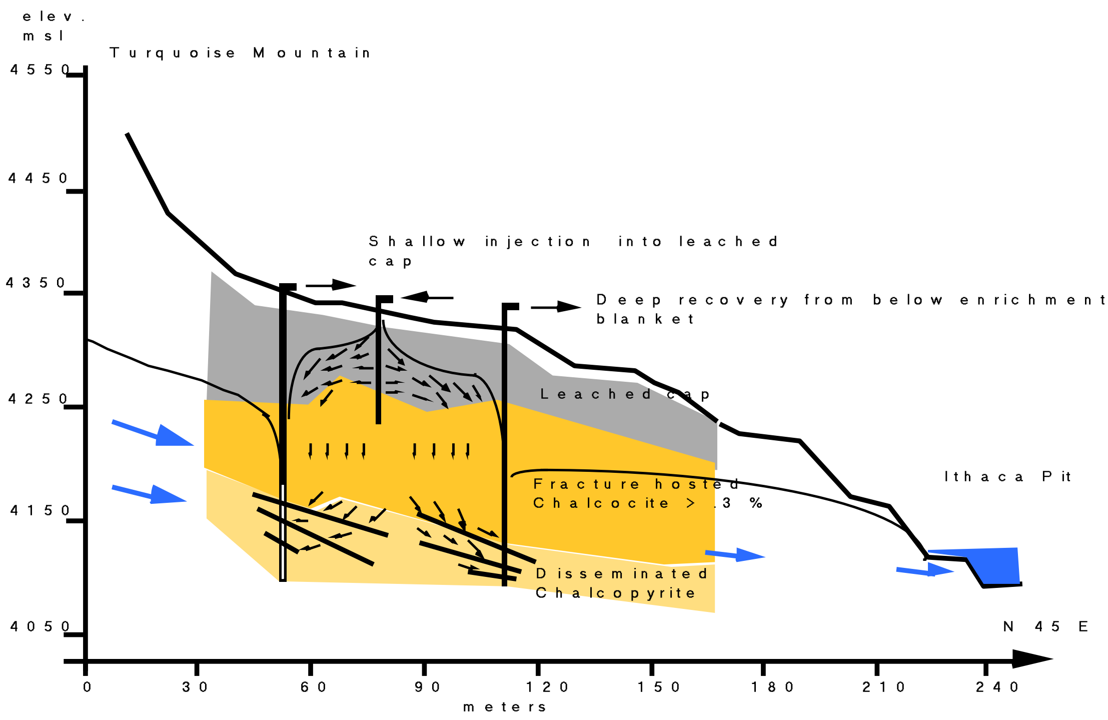

Figure 2. Mineral Park in situ leaching test site schematic cross section.

An EMS was set up at both the Santa Cruz and Mineral Park test sites both field demonstration projects that included timely communication with and feedback from state regulators. Extensive and constant monitoring systems ensured that no leach solutions would reach aquifers without detection and mitigation. Prior to conducting the field tests, laboratory experiments and computer modeling showed that the acidic solutions would be contained within the target ore zone and that the background groundwater quality outside these areas would be maintained. The EMS included the proactive plans for such comprehensive data gathering from monitoring and testing. At the Santa Cruz site an extensive database of the monitoring results was compiled. In addition, various publications including memos and brochures were produced for internal and external communication among the workers at the sites, state local and federal government representatives, regulators, and the public.

Desulfured Tailings, use for covers and reclamation.

Complete desulfurization of tailings, including pyrite, is an old technology with a new application in the era of environmental management of mine sites. Using floatation technology, pyrite and other sulfides can be readily removed using xanthates and other floatation agents. The target metal can then be removed from the sulfide-bearing concentrate using polishing floatation steps. For example, desulfured tails are produced at the Phelps Dodge Thompson Creek mine in Idaho (Idaho Mining Association, 2005). Desulfured tails is also a part of the EMS for the proposed Crandon mine in Wisconsin and has been an important step towards permit approval (Wisconsin Department of Natural Resources, 2005). Because the tails are desulfured and the pyrite concentrate is disposed in an offsite location, ARD from these facilities is not an issue. Hence environmental management can focus on remaining issues such as slope stability, water management, and dust suppression. Furthermore desulfured tailings can be used in the reclamation cover and to recontour existing ARD generating facilities such as older sulfide containing tailings and waste rock. Flexibility in reclamation design would be greatly enhanced if desulfurization is used in combination with paste technology (Landriault, 2005).

Stockpile Regrading and Covers

Current regulations concerning stockpile reclamation vary from state to state and from country to country. States that have significant coal industries tend to apply prescriptive SMACRA related regulations to metals mines (Earley, 1999). The two considerations in stockpile regarding are slope stability and ARD generating potential. In some cases these goals may be mutually exclusive. For example slope grading of stockpiles originally built at angle of repose (Fig. 3) may result in larger footprints that have larger precipitation catchments (Fig. 4). Another consideration is the possible dislocation of existing runoff catchment ponds and seepage interceptor systems that prevents groundwater impacts

An EMS provides the tools necessary to evaluate the overall environmental footprint of the stockpiles and considers whether the gain in slope stability from stockpile regrading effects outweigh increased pollution risks to groundwater. In most cases the answer will depend upon site specific conditions and current mining practices. An EMS also will ensure that precipitation and potential for infiltration into stockpiles is monitored and quantified such that the site specific climate conditions can be accounted for in the BADCT. This type of information and analysis will allow mine planners to optimize the stockpile configuration for closure.

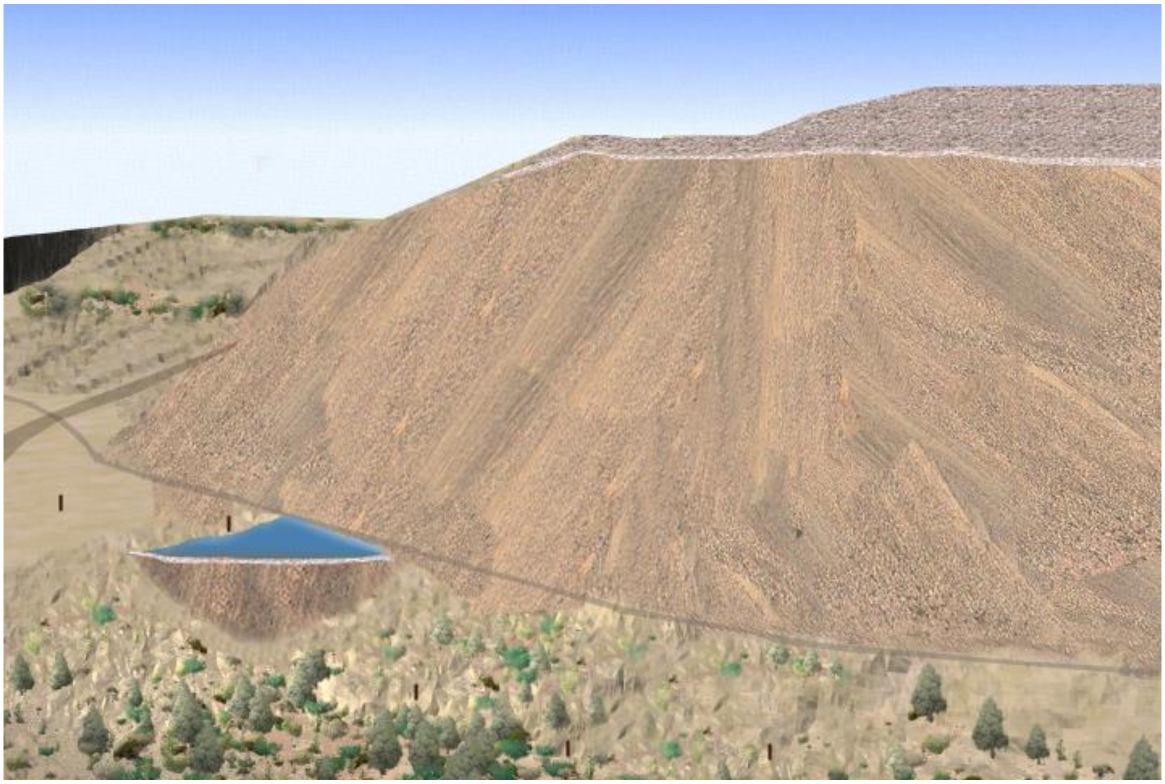

Figure 3. Unreclaimed stockpile at angle of repose.

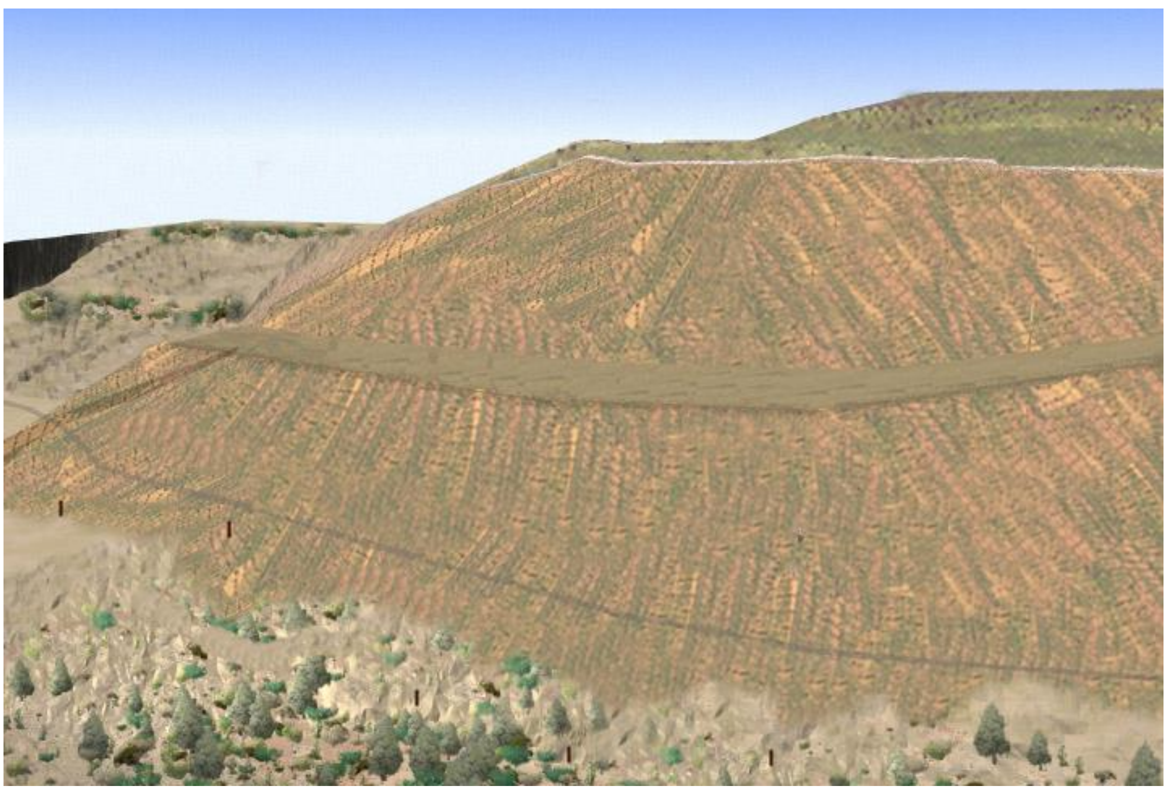

Figure 4. Reclaimed stockpile at 4:1 with expanded footprint.

Conclusions

For new metal mines reclamation bond costs can be reduced by implementing environmental management systems from the outset. State of the art pollution prevention measures such as in-situ mining and sulfur removal processing systems should be included and promoted by this system to the extent possible. Existing mine EMS may also include carefully planned ore and waste handling procedures that include geologic sampling and stockpile configuration visualization for environmental planning as well as production planning purposes. This will ensure the safe disposal of any unavoidable contaminant producing wastes generated at a particular site. The environmental management system should be tailored for site specific conditions.

At older mine sites there should be regulatory and economic incentives to keep existing mine sites active or to reactivate these sites. This is because there exist considerable mineral resources in old mining districts that have not been developed owing to economic and regulatory factors. Many of these areas are already disturbed and production from these sites lessens the need to find and develop new resources in pristine areas. Furthermore, the use of advanced technologies such as in situ mining or desulfurization of mine tailings can be used at older sites as well as at new mines to minimize additional impacts.

There is a need to implement market based incentives for companies to maintain an EMS and to use BATs that go beyond the scope of regulation. Certification of mines that produce metals in the most sustainable manner allows the commodity to be sold at a premium price based on trading practices that recognize ISO 14000 and other international standards such as the Global Reporting Initiative and the International Cyanide Code of Practices (International Cyanide Management Institute, 2005).

There also is a need for informed government policies that promote a technology-transfer strategy that includes training of engineers and managers in sustainable development and environmental technology, and grants for collaborative research projects and information dissemination efforts (Warhurst, 1994). Indeed, the United States Department of the Interior has adopted a sustainable development policy that recognizes the need for this strategy (USDOI, 2003). Technology transfer and training should be built into new joint ventures and investments because there is a need for technical and managerial capabilities to deal with new and emerging technologies and to evoke environmental management strategies. There is also a need to broaden technology transfer concepts to embrace knowledge based technical change to compliment physical based change centered on equipment and engineering. For example knowledge concerning mined materials takes the form of geologic databases on mined material distribution and composition. Such knowledge is used in decision making concerning long term tailing and stockpile stability and reclamation. Lastly, there is a need to train regulators (state, federal and local) on the concept of sustainability and cross media compliance to get agencies thinking about overall environmental performance when they are prescribing control technology at operating facilities.

It is the capacity to effect technical change, not just the skill to operate an item of environmental control technology that will ultimately determine the success with which firms build up competence in environmental management and breakthrough technology. Public policy and regulation should encourage mining companies to be innovative and financially capable of evoking best pollution prevention practices that go beyond regulation. Such companies will also be healthy enough to have the capacity to develop new closure and reclamation practices.

References

Arizona Department of Environmental Quality (ADEQ), 1989.Aquifer Protection Permit Rules. October, 1989.

Brundtland, G.H. 1994. Oslo Symposium on Sustainable Consumption. January.

Dillard, G. 1995. Industry-government project has big potential. Southwestern Pay Dirt. February. p. 4A-9A.

Earley, D. III. 1999. Comparison of state metal mining laws and regulations in the western U.S. In Goldsack, D., N. Belzile, P. Yearwood, and G. Hall (eds.), 1999, Sudbury '99; Mining and the Environment II; Conference Proceedings, Volume 3, p. 971-980. Presented at the Sudbury "99 Conference held September 13-17, 1999, Sudbury, Ontario, CANADA.

Earley, D. III, R.D. Schmidt, and K. Kim. 1996. Mitigation of acid rock drainage through the application of in situ mining technology to fracture hosted, supergene copper sulfide ore deposits. In: Scheiner, B.J. and Richardson, P.E. (eds.), 1995. Technological Solutions for Pollution Prevention in the Mining and Mineral Processing Industries, Engineering Foundation, New York, NY, p. 57-74

Idaho Mining Association, 2005. Thompson Creek Mine. www.idahomining.org/story2.html.

International Cyanide Management Institute, 2005. http://www.cyanidecode.org.

Landriault, D., Johnson, J.M., and Palkovits, F., 2005. Thickened tailings and paste technology: The future of industrial waste disposal. SME Annual Meeting Preprint 05-111. 10 p.

Pugliese, J.M. 1989. Generic design manual: Cost model for in situ copper mining. US Bureau of Mines, IC9216, p. 7-13.

Schmidt, R.D., and Earley, D III, 1998. In situ leaching of fracture-hosted chalcocite copper ore at the Cyprus, Mineral Park Mine, Arizona. . U.S. Bureau of Reclamation Open File Report.

Staub, M.W. and Cooper, J., 2004. Recent Trends in the Use of EMS for Improving Environmental Performance: A practical Guide for the Mining Industry. SME Annual Meeting, February 23-25, Denver, Colorado.

USDOI, 2003. EMS Transmission 11/24/2003, Information Bulletin No. 2004-035. Subject: Sustainable Development and Mining-Statement of Support. November 21.

Warhurst, A., 1994. Environmental best-practice in metals production. In Hester, R.E. and Harrison, R.M. 1994. Mining and its Environmental Impact. The Royal Society of Chemistry. Issues in Environmental Science and Technology 1. p. 133-159. http://dx.doi.org/10.1039/9781847551467-00133

Wisconsin Department of Natural Resources, 2005. Project Description. Crandon Mine. www.dnr.state.wi.us/org/es/science/crandon/project.htm.