

REMEDIATION OF ACID MINE TAILINGS AND RECOVERY OF COPPER

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ABSTRACT

An interdisciplinary team of students from New Mexico State University has developed a solution to Task I of the 1998 WERC Environmental Design Contest. The proposed process addresses the treatment of mine tailings which generate acid and the recovery of metals contained in the tailings. The objective of the design is to recover and transport the mine tailings in a slurry; recover as much of the valuable metals as feasible; treat the tailings to a pH of 7.0-9.0; and design a system to recover the water from the slurry for reuse in the transport and treatment system.

In the proposed process, mine tailings are treated to oxidize the sulfides present and to solubilize and recover the copper present in the tailings. Potassium ferrate (K_2FeO_4) is used to oxidize the sulfides. The oxidation of the sulfides is important because it stops acid generation from occurring in the tailings and because 45% of the copper present is in the form of sulfides. The tailings are then treated with sulfuric acid (H_2SO_4) to solubilize all of the copper hydroxides produced. The copper is extracted using solvent extraction and the remaining tailings are treated to a pH of 7.0-9.0 and then deposited in an impoundment.

The total capital investment for the project was estimated to be approximately \$1,800,000 and the operating costs estimated to be \$6,000,000/yr. The total project cost is \$8,000,000. The following pages contain the technical details of the process, the economic details of the project, regulatory issues, and an extensive community relations plan for implementation of the project.

INTRODUCTION

Task I of the 1998 WERC Environmental Design Contest involves approximately 100,000 cubic yards of mine tailings. The objectives of Task I are: i) to recover and transport the mine tailings in a slurry to a new impoundment; ii) recover as much of the valuable metals as feasible; iii) treat the tailings to a pH of 7.0-9.0; iv) design a system to recover the water from the slurry for reuse in the transport and treatment system. The entire project must be completed within 24 months. The proposed design achieves the objectives of the task. One of the major accomplishments if this process will be the treatment of the tailings to prevent further acid generation, a common problem in the mining industry. This is accomplished using potassium ferrate to oxidize the sulfides present.

The slurry system has been designed to be a "closed-loop" system where the water that is used to transport the tailings is reused in the transport and treatment process. The process has been designed so that there is as little waste discharge as possible and so that water usage is kept to a minimum.

TECHNOLOGY ALTERNATIVES AND SELECTION

Technology Alternatives

Technologies available in the scientific literature to deal with copper ores (since the concentration of copper in these tailings is within ore classification) fall into three distinct categories:

- Flotation - Pyro-metallurgical: the copper is separated from the gang material using froth flotation, collected, then dewatered using filtration and subsequently sent to a smelting operation.
- Hydro-metallurgical: copper ores are leached using sulfuric acid (or other agents) and the pregnant leach solution is sent to a Solvent Extraction - Electro-Winning (SXEW) circuit or cementation.
- Biological treatment: bacterial action is used to transfer the copper from the solid matrix to a solution which subsequently is sent to SXEW or cementation.

Technology Selection

The use of the hydro-metallurgical approach combined with the use of ferrate was chosen over the other two approaches. In preliminary laboratory results, it was found that synergism in leaching copper can be attained by combining ferrate with acid leaching which lead to synergistic factors as high as 2. Further tests are to be carried out in the future to confirm this and to optimize the ferrate to acid ratio which will maximize the copper yield. An additional benefit of the Ferrate-Leaching (will be referred to as FL) approach is that the ferrate oxidizes the sulfides almost instantaneously. This in turn, reduces the volume of process equipment required for the planned throughput.

The pyro-metallurgical approach was not chosen due to potential problems, including the recovery of SO₂ and environmental controls. Furthermore, biological treatment requires a minimum of 48 hours to attain the leaching level which can be reached within minutes using the FL approach. Since the entire project must be completed within 24 months, the FL approach was adopted over the biological treatment approach. One more advantage of using the FL approach is that other metals present in the tailings may be recovered by subsequent SXEW, as discussed in more detail in the "Recovery of Metals" section.

PROCESS DESIGN

Tailings Recovery and Preparation for Transport

Before the approximately 100,000 cubic yards (76,450 cubic meters) of tailings can be transported to the new site, they must be recovered following all given guidelines. One important requirement is that the dust stirred up during tailings excavation be minimized. The dust can be easily minimized by keeping the tailings damp during excavation. A water tanker will be used for this purpose. Included in the preparation of the site for tailings removal is an adequate drainage system and a holding pond. The drainage system will allow any excess water to flow into the holding pond. The water in the holding pond can be emptied periodically for use in the slurry system. The holding pond will also prevent any acid runoff into the local water supply during tailings recovery.

The tailings will be slurried by pushing them into a concrete slurry mixing tank. This will be done using a scraper/bulldozer. The slurry tank will be located in close proximity to the existing tailings pile to minimize distance traveled. Using a time constraint of one 330 day year with 24 hour days, approximately 9.6 cubic meters of tailings must be excavated each hour. An average dry tailings density of 1.4 g/cm³ was assumed. This corresponds to approximately 13,470 kg of tailings being mixed with water per hour of operation. Another requirement was that the tailings be mixed into a slurry for transport to the new site. A slurry consisting of 10% tailings and 90% water was chosen for use. This mixture allows for viscous flow of the slurry. The slurry is to be mixed in a large continuously stirred tank. For this task, two concrete vessels, each with a one hour residence time, and a corresponding volume of 566 m³, are used, with the second serving as an emergency back-up. The one hour residence time of the mixing tank gives adequate mixing time (refer to process flow diagram, Figure 1).

Slurry Transport and Water Recovery Systems

Once the tailings have been mixed in a slurry, they must be transported to the new impoundment. The slurry transport system consists of two pumps, two pipelines and a water recovery unit. The slurry is first pumped into the pipeline leading to the lined impoundment. Two inline pumps with a total head of 9260 kg/m² are needed. The pipeline is approximately 804 meters (0.5 mi) long with an inside diameter of 0.25 m. The liquid holdup is approximately 38.8 m³. This corresponds to a residence time of approximately 17 minutes, and a flow rate of 0.762 m/s. This flow rate will prevent solids from settling in the pipeline. A hydrocyclone system is used to separate the water from the tailings.

To determine the size of the hydrocyclone needed, it was assumed an average of 30% sand, 50% silt and 20% clay was an approximate analysis of the tailings. The United States Department of Agriculture (USDA) particle size standards are also assumed. With sand 2 to .05 mm, Silt .05 to .002 mm, and Clay less than .002 mm. The optimum particle diameter to remove with the hydrocyclone was found to be 0.0152 mm which corresponds to a flow rate of 9,262 kg/hr of tailings and 34,655 kg/hr. of water. The hydrocyclone would have a pressure drop of 35 psi and a diameter of 0.5334 ft. This stream is then pumped into the lined impoundment. Removing any additional water is not economically feasible.

The slurry from the hydrocyclone underflow is pumped into a lined impoundment, where it is allowed to settle. Water is pumped off the top. It is assumed that 20% of the water entering is lost due to evaporation. More details on the impoundment design can be found in the section entitled "Discharge of Treated Tailings/Impoundment Design". A flow of 97,070 kg/hr of water can be recovered using this system. This water is then pumped into the second pipeline. Two inline pumps are used with a total head of 62,900 kg/m². After exiting the second pipeline the water enters a water holding tank. The water is combined with new tailings and the entire process is repeated.

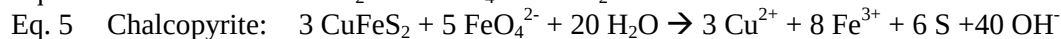
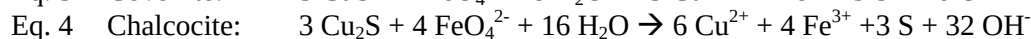
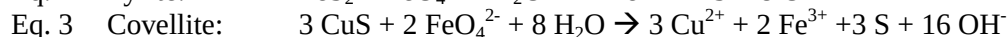
Treatment of Tailings

Once the tailings have been mixed into a slurry, the first step is to adjust pH of the resulting slurry. This step is necessary because optimum use of the ferrate requires that it be allowed to react with the tailings at a pH of 8.0 or above. While the tailings are pumped from the slurry chamber, caustic is added at the suction of the pump. A pH meter samples the pipe contents for pH and a process control loop is used to adjust caustic rate addition.

The use of ferrate for oxidation has been chosen in part because ferrate with substrates present in the tailings material reacts quickly. The reaction of ferrate with sulfide has been studied (1) and proceeds as follows:

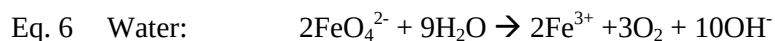


The reactions involving the tailings material are anticipated to proceed as:



Where the ferrate reacts with the sulfides to produce iron(III), elemental sulfur and copper hydroxides.

One major advantage of using ferrate, as reported by Johnson, is that it provides a mechanism for "self removal"(1). If a suitable reductant is not available, ferrate will react with water to form iron (III) and molecular oxygen (1):



This is important because in the event that ferrate is added to the system in a quantity greater than is necessary, no damage is done to the process stream.

Once the tailings reach a pH of 8.0, potassium ferrate (K_2FeO_4) is combined with the tailings in a reactor. The tailings and ferrate react and flow into a second reactor. The purpose of the second tank is to allow any gases generated in the reaction to escape and to insure that the reactants are well mixed.

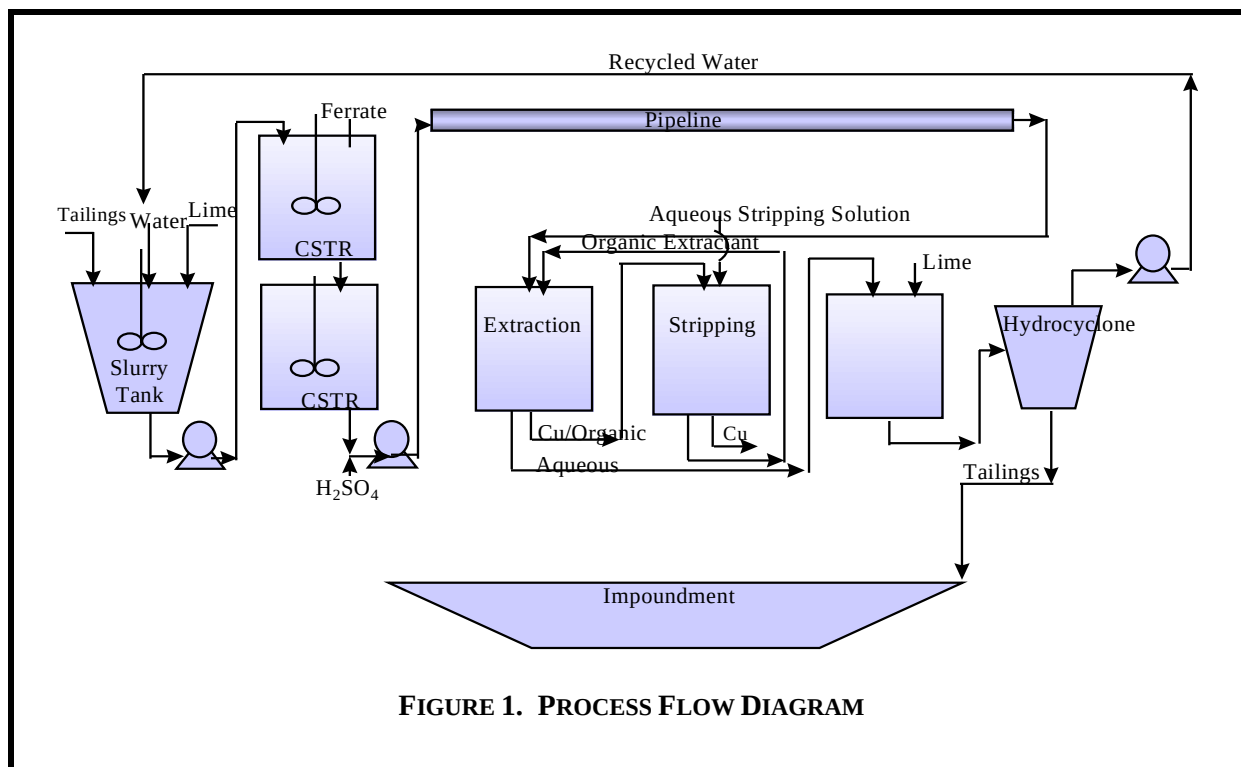
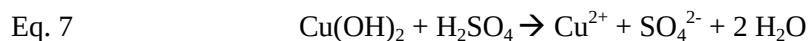


FIGURE 1. PROCESS FLOW DIAGRAM

Once the sulfides have been oxidized, sulfuric acid is added to solubilize the copper present in the tailings as oxide precipitates. The result of the reactions is copper sulfate as shown in the reaction. The reaction proceeds as:

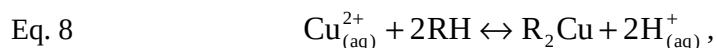


Once the copper is in solution it can be recovered from the process. The details of the copper recovery are discussed in the section that follows. The steps in the treatment of the tailings can be found in Figure 1.

Recovery of Metals

The solvent extraction phase is composed of two stages, the extraction stage and the stripping stage. In the extraction stage, the pregnant leach liquor (acidic) is contacted with an organic extractant (LEX) which is selective for copper. The extraction mechanism of copper is believed to proceed as a

complexation mechanism whereby copper is chelated. This reaction can be represented by the simplified general reaction (2,3):



where RH is an organic compound and **RH** and **R₂Cu** are not soluble in the aqueous solution. In the stripping stage, reaction (Eq. 8) is forced to go in the reverse direction by contacting the extract phase with a strong acid solution. This step will transfer the copper into this acid solution in a concentration that can be used directly for electro-winning.

At this time, the only metal to be recovered will be copper. Other precious metals are found in the stream, however, the recovery of these metals must be further investigated. The cost of recovery, additional process equipment, and generation of additional waste streams must be weighed against the advantages of recovery. At this time, the design does not include the recovery of other metals because the advantages have not been found to outweigh the disadvantages.

Discharge of Treated Tailings/Impoundment Design

Once the copper has been extracted from the solution, a pH adjustment is performed. Lime is added in the quantity required to raise the pH of the tailings to 8.0. This results in precipitation of many of the metals in the process stream. Due to the use of ferrate, the iron precipitates as iron (III) and the sulfur as elemental sulfur. The resultant precipitants do not include pyrite. Therefore, the tailings will not generate acid over the long term.

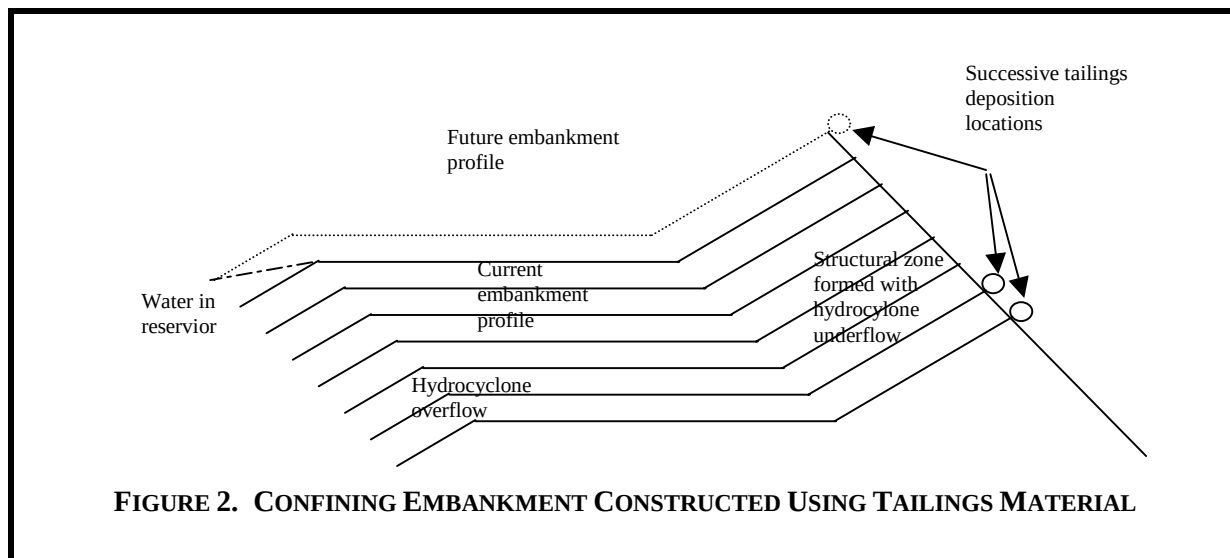
Separation is done using a hydrocyclone. The hydrocyclone separates the tailings into two streams: the coarse tailings containing mostly solids, and the fine tailings containing mostly water. The tailings are then deposited in a lined impoundment.

The layout of the tailings impoundment requires that it be designed with the utmost of safety in mind. There are two main elements that compose a tailings impoundment, the confining embankment (tailings dam) and the impoundment of deposited material (4). Since there is no existing pit or valley that can be used for the embankment, the confining embankment will be constructed. The embankment will be constructed using the tailings material.

A tailings impoundment contains seven main components, which include: 1) a system to deliver the tailings to the depository, 2) embankments to confine the deposited material, 3) an arrangement to divert natural runoff around the impoundment, 4) a system to deposit the tailings within the impoundment, 5) a method for decanting the supernatant water, 6) measures to protect the environment from contamination, and 7) a system to monitor the depository.(4)

High density polyethylene (HDPE) lines will be used to deliver the tailings to the impoundment since they resist wear from the solids in the tailings. The lines are also resistant to chemical corrosivity.

A main element for safety of the impoundment is the confining embankment. The embankment will be constructed using tailings material in the structural zone. Tailings material is separated by use of a hydrocyclone into coarse material and fine material. The coarse material, or hydrocyclone underflow is used to construct the embankment. The fine material, or hydrocyclone overflow, is deposited into the impoundment. The design of the impoundment is shown in Figure 2.



Diversion of natural surface water is accomplished by construction of channels around the perimeter of the impoundment. It is important not only to ensure that there is no contamination of the surrounding environment, but also to ensure the integrity of the structure.

A barge pump is used to provide a decant system. This was chosen over other decanting methods, such as a decant tower or chute, because it is safer and more flexible. The increased safety and flexibility results from the fact the pump is accessible and can be moved as the profile changes over the life of the impoundment.

Contamination of the surrounding area can be caused by seepage of the liquid from the impoundment into the groundwater or surface water, or by dispersion of the solids. This will be avoided by installing a protective liner at the base of the impoundment before deposition begins and capping the impoundment when deposition is complete. The lining will be made of an impermeable material. The capping will also be made of an impermeable layer. Once the impoundment has been capped, a layer of soil and grass will be placed upon the cap. A grass that is native to New Mexico will be planted. This will not only help prevent erosion of the surface, but it will also have a positive visual impact for the surrounding area.

The decant system in the impoundment allows further separation of the water from the solids. All of the water reclaimed using these two methods will be reused for transport/treatment at the beginning of the process.

Sampling of Soil and Groundwater

Analyses will be conducted to determine if contaminants from the previous unlined impoundment have migrated into the surrounding soil and/or groundwater. Monitoring wells will be installed at strategic locations downstream from the impoundment. In addition, various soil samples will be drawn at locations surrounding the impoundment. X-ray fluorescence will be used to determine if there are any metal contaminants. An advantage to this method is that large areas can be sampled quickly. If contaminants are detected in either the soil or the groundwater, a complete remediation process will be designed and implemented immediately to insure that further migration of contaminants does not occur.

Proposed Schedule

The project will be completed within 24 months. The actual processing of the tailings will take place over a period of 12 months. The construction and decommissioning of the project is estimated to take 12 months. The community relations will last the entire life of the project. The time required for each task in the project is shown in Table 1. It has been assumed that all relevant permitting and preliminary environmental studies have been completed before construction is begun.

TABLE 1. PROPOSED TIMELINE

Project Task Months:	2	4	6	8	10	12	14	16	18	20	22	24
Community Relations												
Construction of Process												
Treatment of Tailings												
Construction of Impoundment												
Capping of Impoundment												
Decommissioning of Process												

BENCH-SCALE

Design

The bench-scale process has been designed to model the process that will take place on the full-scale level; therefore, the steps in the bench-scale process are the same as the steps for the full-scale. First, the tailings are mixed with water to form a slurry in a vessel. Second, the slurry is adjusted to a pH of 8.0 by addition of caustic. Potassium ferrate is then added. Once the potassium ferrate has been properly mixed and allowed to react, sulfuric acid will be added. The pH is adjusted to 2.0. At this time, all of the copper will be in solution. An extraction will be performed to separate the copper from the stream using commercially available LIX-984 from the Henkel Corporation. The remainder of the stream is once again adjusted to a pH of 8.0 by adding caustic. The resultant precipitant is separated from the water using vacuum filtration.

Results

Laboratory experiments on the bench-scale level have shown promising results. An experiment was conducted to compare the amount of copper recovered using sulfuric acid alone, ferrate alone, and a combination of ferrate and sulfuric acid. The solutions were analyzed using an atomic absorption spectrophotometer to detect copper in solution. As expected, when ferrate was used alone no copper was detected in solution. This is because at a pH of 8.0 the copper is insoluble as copper hydroxide. When the solution containing both ferrate and copper was analyzed, the concentration of copper was shown to be significantly higher than the concentration of copper when only acid was used. This indicates that the ferrate is oxidizing the copper sulfides (of which 45% are present in the tailings) and the subsequent addition of sulfuric acid solubilizes the copper present. It is believed that all of the copper present in the tailings is solubilized; however, the initial concentration of copper in the tailings was not known. If the initial copper concentration in the tailings is known, studies could be done to indicate what percentage of total copper can be solubilized using K_2FeO_4 and H_2SO_4 .

TABLE 2. ECONOMIC ASSESSMENT

ASSESSMENTS**Economic**

The total project cost has been assessed and can be found in Table 2 and is estimated to be \$8,000,000. The total capital investment of the project is approximately \$1,800,000 and was estimated using a Lang factor (5). The operating costs are approximately \$6,000,000 per year of operation (5,6,7). Annual earnings of approximately \$6,000,000 for the sale of copper were accounted for in the calculation of the operating costs. The price of copper was estimated at \$1.70/kg (5,6,7). The price of ferrate is currently approximately \$2.20/kg, however, it was assumed that the cost will decrease as ferrate becomes available in industrial quantities.

Equipment	Cost (uninstalled)
Concrete Slurry Tank (2)	\$28,600
Slurry Pump	\$7,200
Water Pump	\$3,400
CSTR (3)	\$87,600
Water Tank	\$27,000
Pipeline	\$75,000
Hydrocyclone	\$10,000
Extraction Unit (2)	\$50,000
Stripping Unit	\$20,000
Impoundment	\$50,000
Total	362,000
Total Capital Investment	\$1,814,000
Product Cost	\$12,020,000
Copper Earnings	\$5,800,000
Operating Costs/yr	\$6,220,000
Total Project Cost	\$8,034,000

Impact to Community

The process has been designed to minimize the impact to the community from process start to completion. During the process, the amount of water used will be kept to the minimum allowable level. Water conservation is a main objective, thus water that is used is recycled for reuse in the process. While tailings are being recovered into the slurry, the dust levels will be kept to a minimum. This is done by keeping the tailings damp and by pushing the tailings into the slurry pit. Since the tailings will not be lifted, a smaller amount of dust is generated. The process has been designed to require a minimum amount of heavy machinery. This will help reduce the impact of noise levels in the community. The only step in the process requiring use of heavy machinery is the tailings recovery system, and that use is minimal. Since the process has been designed to be a "closed-loop" system, the community should not be impacted by any process waste streams. At all times during the project, all federal, state and local regulations will be met or exceeded. All applicable regulations can be found in the regulatory compliance section. Included is the Emergency Planning and Community Right-To-Know Act, which enables the community to be aware of the hazards present. The public relations plan is discussed later in the paper, which details community involvement from project conception to completion. This will enable the community to identify further impacts that may have been unforeseen up until this point.

REGULATORY COMPLIANCE**Regulatory and Permitting Requirements**

All applicable federal, state and local regulations for the project are identified and described in Table 3 (8,9,10,11,12,13). At all times during the life of the project, all regulation and codes will be either met or exceeded. Most of the environmental regulations that pertain to a privately owned site in New Mexico are covered by the state of New Mexico with the exception of the federal stormwater regulations.

TABLE 3. REGULATORY REQUIREMENTS

CATEGORY	REGULATION	DESCRIPTION
Acid Mine Treatment	30 CFR Part 876	Acid Mine Drainage Treatment & Abatement Program.
Mine Land	30 CFR 56.3401	Examination of ground conditions
Air Pollution	30 CFR 56.5001	Exposure limits for airborne contaminants
Analysis of Pollutants	40 CFR Part 136	Guidelines for analysis of pollutants
Gila River Basin Standards	20 NMAC 2501.A	pH, temperature & bacteria standards
Surface Water Quality	NMSA 1978, Section 74-6-4.C	Standards to ensure safe supply of water to animals, plants and humans
Groundwater Quality	NMSA, Chapter 74 Article 6	Water quality standards based on human health or aesthetic reasons
Mine Reclamation	NMSA, Sections 69-25-B	Guidelines for abandoned mine reclamation
Surface Mining	NMSA, Section 69-25A	Regulations, Public Liability, Impoundment Dam Construction, Citizen Law Suits
Mine Close-out	19 NMAC 506.A	Close-out plan based on site-specific characteristics
Mine Close-out Schedule	19 NMAC 506.B	Time & work schedule for close-out
Air Pollution	NMSA, 74-2-1 to 74-2-17	Air pollution standards
Aerosol Products	NMSA, 74-5-1	Regulations pertaining to aerosol products
Mine De-watering	NMSA, 72-12A	Mine de-watering governed by the Mine De-watering Act
Environmental Quality	40 CFR 1502.25	Coordination of environmental assessments and impact statements
Performance & Reclamation	19 NMAC 507	Reclamation of permit area to allow re-establishment of a self-sustaining ecosystem
New Mexico Mine Reclamation Plan	30 CFR 931.25	Approval of New Mexico Mine Land Reclamation Plan Amendments
Abandoned Mine Reclamation	30 CFR Part 870	Abandoned Mine Land Reclamation
Mine Subsidence	30 CFR Part 881	Subsidence & strip mine rehabilitation
Re-vegetation	30 CFR 715.20	Standards for re-vegetation
Surface Mining Permits	30 CFR Part 780	Surface mining permit applications
Water Quality Standards	40 CFR Part 131	Water quality standards
Toxic Chemicals	40 CFR Part 372	Standards for toxic chemicals release
Emergency	40 CFR Part 355	Emergency planning, reporting and notification
Land Disposal	40 CFR Part 268	Land Disposal Restrictions
CERCLA	40 CFR Part 307	CERCLA Claims Procedure
Spillage/ Leakage	30 CFR 56.4102	Standards governing spillage and leakage
Chemical Usage	30 CFR 56.5050	Restricted use of chemicals
Moisture Levels	30 CFR 870.18	Excess moisture control allowance
Tribal Grants	30 CFR Part 886	Tribal reclamation grants
Personnel	29 CFR 1910	OSHA, concerns the health & safety of workers
Decision Making	40 CFR 124	Issuance, modification, revoke, or termination of all permits
Reporting	10 CFR 31	Reporting of defects and non-compliance
Fire Controls	29 CFR 1910 Part L	Fire controls on mine site
Illumination	29 CFR 1910.120	Lighting will meet minimum requirements
Warning Signs	30 CFR 56.4101	Standards governing warning signs for mine workers
Test procedures	40 CFR 136	Guidelines for establishing test procedures
EPCRA	40 CFR 310, 350, 355, 370	Emergency Planning, Community Right-To-Know
Occupational Illness	29 CFR 1904	Reporting & recording of illnesses and injuries

COMMUNITY RELATIONS PLAN

Hazardous materials are commonplace and a remediation process is a necessity. Many different technologies exist, or are being created to accomplish various cleanup tasks. However, no technology, regardless of effectiveness, can do the job if it cannot be implemented. Implementation of a technology is dependent upon two factors: financial resources and cooperation from stake holders.

One of the main risk drivers for all cleanup projects is implementation hold-ups due to public outcry. In order to yield the expected cash flows, contract jobs must adhere to the time table used to calculate costs. When jobs are interrupted, or are stopped before they begin, fixed costs continue to pile up, while no work is accomplished. Prevention of public outcry and interference becomes the next key point.

Public involvement and ownership of the project is the best way to not only guard against interference, but assure assistance in accomplishing the cleanup task. "Ownership" in that statement refers to a general feeling by the stake holders that the technology being used is not only in their best interests, but that it is in part their accomplishment. How then can the public be involved to such a degree?

Governments including, federal, state, local, municipal, and tribal as well as local interest groups and site neighbors are potential stakeholders that might oppose the planned process. These entities need to be approached in a variety of ways. All areas affected by the cleanup process must be included in the identification stage. This applies not only to the cleanup site, but to transportation routes, and disposal areas. To give a more cohesive overview of stakeholder identification and interaction, those groups previously mentioned will be addressed individually.

Governmental Relations

Awareness of applicable legislation, permit requirements, and standards for cleanup is vital. The process of identifying all relevant regulations and laws should be done by a professional who is both knowledgeable, and adept at dealing with the Federal Government, specifically the EPA. In many instances State requirements exceed Federal, and must be addressed. An experienced environmental engineer or environmental specialist should be employed to ensure compliance. Local Government is one of the best sources of initial public involvement for any operation. Local politicians tend to know their constituents, and are able to lead them, to a certain extent, in the direction of understanding and cooperation with a cleanup proposal. Obtaining the names of groups and individuals who will hold the most potential for assistance, as well as hindrance, is often the easiest through local politicians.

Tribal Relations

Cultural differences between Native American tribes and entities implementing remediation action which takes place on or requires transport through tribal land, can lead to confidence breaking mistakes done out of ignorance. An individual who has an intimate knowledge of the tribe in question must educate all those coming in contact with the tribal members and representatives as to the proper ways to interact. A respected tribal member should be employed as a liaison for that purpose. Ideally, one or more tribal members who have qualifications in either the business or technology realms should be considered for employment in the design and implementation process.

Interest Group Involvement and Public Interaction

Project planners cannot expect to simply let public interest groups know what they are doing, and expect to receive no resistance. Interest groups must be involved in the design process to ensure all goes smoothly. Since roughly 70% of project costs are incurred in the design stage, a technology not understood or immediately liked by such groups will probably never see the light of day. Indeed, simply being told that even the best possible technology is already slated for implementation will cause some groups to balk and set out to prevent the startup of the process.

Going to interest groups to talk about the problem that needs to be addressed, and inviting them to make suggestions, and identify specifications for the cleanup is the first step. Contacting these groups can be done by asking to speak at functions, and attending public meetings such as those for the city council and school board to talk briefly about the task at hand. Interested individuals should then be given the opportunity to form an advisory committee to work closely with design engineers. Going to the public and eliciting opinion and exchanging information is the only sound method of public involvement.

Addressing these concerns, outlining a plan for accomplishing the large tasks of governmental and tribal relations, and public involvement is the best way to insure the success of the project. This will inevitably provide credibility in the eyes of agencies or businesses reviewing bids for research and eventual implementation of remediation processes, making implementation possible.

CONCLUSIONS

The proposed design achieves the goals set forth by Task I of the 1998 WERC Environmental Design Contest. The process provides for the recovery and transport of the mine tailings, the design of the slurry system, the recovery of metals present in the tailings, the recovery of water for reuse and the treatment of the tailings for final disposition in a lined, capped impoundment. The total project cost is estimated to be approximately \$8,000,000. An extensive community relations plan has been prepared which includes community involvement from project conception to completion. The impact of the project to the community has been minimized. The regulatory and permitting requirements of the project have been addressed. The proposed process, while achieving the goals of the task, contains features that represent good environmental practice.

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10. Code of Federal Regulations, Chapter 10.

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