IMC™ MANAGEMENT SYSTEM FOR CLOSING MINES

OVERVIEW

The IMC™ mine management technology method resolves two sources of hazardous substance migration to the environment from: 1) mine wastes; and 2) abandoned mines that are physically separate and distinct from each other by creating a permanent single remedial feature. The method utilizes mine waste as a raw material to manufacture a "beneficiated" in-mine stowing backfill product by coupling with the MBT™ reagent system treatment technology. The MBT end-product chemically retains its hosted hazardous heavy metal substances and treats its latent-acid generating properties and where the end-product product is an acceptable and beneficial in-mine stowing backfill material for abandoned mines or a part of a mine's workings. When placed in a mine to fill voids the MBT end-product will minimize water intrusion while continuing to retain its hosted hazardous substances, and treat hazardous substances and acidity generated by the mine (separate from the mine waste) and mitigate future drainage from the filled void(s) and egressing the mine to the environment. The mine and/or its or workings provide a secure and permanent containment for the mine waste so that the hazardous substances sourced from mine wastes and mine are retained, and a final closure for the mine can be achieved. Use of mine waste as a raw material results in its removal and the cleanup at where the waste was located, thus also eliminating that underlying geography of that site as a source of hazardous substance release.

The IMC™ method pertains to the collective and permanent management of mine wastes and abandoned mines through coupled beneficiation of both: 1) legacy/abandoned mines and/or mine works; and 2) harmful mine materials and/or mining-related residuals to purposefully retain separately and distinctly sourced migratory hazardous substances within a singular permanent remedial feature.

BACKGROUND

Mine waste and mining-related residuals (collectively, "mine wastes" or "wastes") are significant sources of heavy metals and acidity that impact the environment and human health when left in uncontrolled or inadequately protected states. As a result of weathering, erosion, acidification, dissolution of contained metals, mineralization and other forces and conditions, they can release hazardous metal substances and acidity from their masses. These pollutants can be further carried by snow-melt, precipitation run-off, percolation, and flowing waters to impact watersheds and downgradient waterways used for potable consumption, irrigation, livestock watering, recreation, and other uses causing or potentially causing harm to human health and the environment. While hazardous substance release from mine waste can be typically intermittent due to seasonal weather patterns and precipitation events, the substantial volumes of these materials and their susceptibility to produce contaminants is significant, unless of course they have been deposited directly in water courses and channels that continuously affect the release of the contaminants.

Abandoned, legacy, and active mines can also contribute to the release of hazardous metal substances and acidity that impact human health and the environment, particularly when drainage egresses the mine and carries acidity and heavy metals to downgradient waterways. Unlike mine waste, mines that are abandoned, dormant, or operating are legacies that can generate acid mine drainage that flows continually from mine tunnels, adits, and tunnels and contribute to downgradient loading of hazardous substances.

Mine waste and draining mines have been handled as separate and distinct sources of pollution, partly because of the regulations, but also because of their different natures, respective difficulties, and cost to remediate or restore, and the fluctuating values of commodity metals that drive or curtail continuous mineral extraction from their source mines. As such, mines have been left open for future use, but also because of mining and metal commodity economics, ownership, mine exhaustion, and regulatory and legal liability issues. Mine waste, because of its low to worthless value, the magnitude of its volumes, and regulatory issues, has been historically left in piles, tailing ponds, embankments, and the like over large surface areas typically in the same general vicinity as the mine from which they were sourced or the facility in which mined material was processed.

The extraction of metal-bearing ores from the earth and their processing has been a national strategic interest for hundreds of years. Minerals, including coal and those that contain metals such as gold, silver, copper, zinc, lead, and many others of economic importance and national strategic interest have been removed from ore bodies, lodes, veins, seams, reefs, or other deposits accessed by strip mining, pits, quarries, and underground workings for energy, and/or refinement and manufacture into products important to our daily lives since the global dawning of the age of metallurgy. In particular subsurface and underground mineral accessing mining approaches often encounter groundwater or receive water intruding through the mineral formation and into opened areas such as voids and mined caverns where access was created, and the mineral deposit formerly resided.

Mining has and continues to provide resources that facilitate the growth of our country and betterment of society. Unfortunately, extensive mining efforts and massive mine operations, often in remote or sparely populated areas, have also caused adverse impacts to human health and the environment as result of inadequacies related to restoration of mining lands, the management of resultant wastes and/or residuals, and ongoing chemical reactions related to these mining-related materials and their mining-disturbed sources via their subsequent exposure to naturally occurring water, air, and bacteria.

In particular, metal-bearing sulfide class ores such as: argentite, chalcopyrite: galena; pyrite; pyrrhotites; sphalerite and many others that are more or less prevalent are either sought and extracted for their metal values of gold, silver, copper, lead, zinc, nickel, etc. or are undesirably encountered (as is the case for iron sulfides) in a particular formation being exploited along with the desired mineral or minerals. When such ore materials as sulfides are exposed through their extraction and processing to water, air (oxygen), and bacteria, acid mine/acid rock drainage (AMD/ARD) is created when sulfide is oxidized to its sulfate form as sulfuric acid with a low pH and high acidity content. As part of this natural degradation process, metals associated with the sulfide ore are released in dissolved and/or colloidal from and carried by the now acidic water. Other sulfide-mineral containing materials, unmined ore, or mine waste and mining-related residuals are similarly reactive as they are contacted by acidic water that seeps, flows or drains to perpetuate the release of metals and formation of acidity. Thus, release and migration of metals and acidity in the drainage is enhanced in near perfect precept and phenomenon of nature with these mineral types in both mine waste and mines.

As ore mineral formations are opened and accessed, and mineral ores of value are extracted, and processed; air, water, and bacteria contact with exposed sulfide minerals is greatly enhanced because of the increased surface areas that are created and provide significantly more chemically reactive sites. Mining processes including drill and shoot/blasting, mucking/hauling/handling, crushing/sizing/milling, and separation of gangue and other low-value materials to create high value ore concentrates all create more opportunity for sulfides to react that accelerates their conversion to acidic fluids that release, contain, and carry both acidity and solubilized heavy metals.

Often, low-grade/low value mineral deposits that are wasted or set aside, waste mine rock, overburden, or other mining-related processed or unprocessed materials may not exhibit acidity or low pH. However, these materials may still contain unreacted sulfide-residuals that have not been exposed to water and/or oxygen. As such, hosted acid-generating properties of these materials, that with exposure to moisture and oxygen, can also create AMD/ARD that will release and carry metals from their source. Examples of these materials include mine waste piles that are partially protected from exposures, or found in arid, dry climates, or those that remain submerged, or in anaerobic settings, and that when disturbed or exposed to anticipated severe global weather pattern climate changes, will create and release migratory hazardous substances.

In the United States, the Mining Act of 1872 provided the legal foundation to promote prospecting and mining for minerals and metals of economic (and strategic) importance on federal lands. In 1976, the Resource Conservation and Recovery Act (RCRA) was enacted. This act focuses on the management of all solid and hazardous wastes as defined in the act. Under its hazardous waste provisions, hazardous constituent presence and/or their characteristics within wastes defined various management options allowed under the law with respect to potential harm they caused. In 1977 Congress enacted the Surface Mining and Reclamation Control Act (SMCRA) to primarily regulate coal mining operations and to address environmental impacts of open pit coal mines and strip mining by requiring restoration of abandoned mines. In 1980, The federal government also enacted the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA or "Superfund") in 1980. This legislation established what is commonly called "Superfund" and provisions to direct and cleanup sources and impacted sites related to the presence hazardous substances and pollutants. Under the Act, the federal government can legally enforce responsible parties to clean up or cause the cleanup of contaminated sites containing hazardous substances that adversely impact human health and the environment. The Superfund legislation, subsequent amendments, and other regulations define and identify various hazardous substance pollutants including heavy metals and pH parameters common to mine wastes, residuals, and mining-related operations. Also, in 1980, RCRA was amended by the US Congress to accommodate the impracticality and cost burden the act put on mining operations related to expansive volumes of mining wastes and mine-related residuals generated by mining and ore-processing processes. Known as the Bevill Amendment, it created an exemption applicable to large volumes and masses of certain mine wastes from required management under hazardous waste regulations of RCRA. While large quantities of mine waste were exempted and remain exempt under the law from management of these materials as a waste, the law does not prevent the laws of nature from causing the release of hazardous substances that cause harm to human health and the environment where hazardous substances adversely impact water quality at both acute and chronic levels.

While these major pieces of federal legislation (and those of individual state governments) attempt to fully govern mining and its impacts, regulations and exemptions, legal interpretations, historic culturally engrained practices, and economic factors have contributed the presence of tens of thousands of abandoned, legacy, and/or dormant mines that continuously generate AMD containing hazardous metal substances that flow to creeks, streams, and rivers of a watershed, and further down gradient water supplies. While AMD from such mines continue to cause harm to the environment, so too does ARD sourced from millions upon millions of tons of mine wastes such as tailings (wet and dry), pastes, waste rock piles, partially processed ore, chat, gangue, and other slurried and solid materials that are common to mine sites and their local mining-related ore processing facilities. These also contribute to the downgradient loading of acidity and heavy metals.

With respect to and in summary of the regulations that affect contamination from mines and mine waste, CERCLA defines hazardous substances that are toxic and cause adverse conditions impactful to human health and the environment. These substances include heavy metals. The regulation does not stipulate or otherwise specify how these substances are to be managed or controlled. RCRA, on the other hand, does stipulate and specify what a waste is and what type it is to be classified. If a material is a waste as defined, and the Bevill Amendment exempts large quantities of material from becoming a waste, then that waste must not exhibit characteristics of toxicity that is defined for eight (8) specific heavy metals including: arsenic, barium, cadmium, chromium, lead, mercury, selenium, and silver. Other metals common to the mining industry such as aluminum, copper, manganese, nickel, and zinc are not regulated under the federal RCRA laws, but they remain hazardous substances under CERCLA.

While CERCLA and RCRA have historically been the driving regulatory forces for clean-up of contaminated site across the US, they have not caused many cleanups of mining areas that remain abandoned as legacy features across large swaths of land, both that privately owned, as well as that managed by federal and state land management agencies, primarily due to the magnitude of the problem and cost.

Further, much of the material is exempt from solid waste regulation under Bevill, and the hopes of such material becoming of strategic importance or economic value has focused cleanup efforts and private and public funds to sites of extreme or severe impact. While primarily mine wastes have been primarily been left without mitigation, actively discharged mines also continue to contribute hazardous substances to the environment. Only the worst contributors to down gradient pollution of water and waterways have been addressed, and those using lime and lime-based treatment system. Many of these systems have plans to be operations for tens if not a hundred years as no effective solution to the active drainage has been developed.

As part of the regulatory system, specific tests have been devised and implemented under the regulations have not been fully expanded to address the issue of hazardous substances released from mine sites, and the management of these mine wastes and materials defined and disclosed by the IMC technology. The test methods apply synthetic fluids to evaluate the leachability of metals and other constituents from solid matter as described in greater detail herein.

USEPA's SW-846 Test Methods for Evaluating Solid Waste: Physical Chemical Methods specifies procedures and methods for sampling and analyzing waste and other solids materials, including those for evaluating leachable constituents from the host matrix for determination as to the classification of whether a solids waste is hazardous or non-hazardous under the toxicity rule for hazardous waste as defined in RCRA. Other methods are also included for determining the leachability of constituents from the solid material or waste. These extraction methods include: Method 1311 (TCLP – Toxicity Characteristic Leaching Procedure); Method 1312 (SPLP – Synthetic Precipitation Leaching Procedures); and Method 1320 (MEP – Multiple Extraction Procedure). While all methods can be modified to some degree, they cannot be if resultant data is to be used to classify a solid waste as hazardous or not, or if the solids waste is to be managed where it can be exposed to acid rain or acidic fluids of improperly constructed or managed landfills.

In brief summary of the convention EPA test methods for evaluating the leachability of various hazardous substances in solids and solid waste:

The TCLP Method 1311 is used to distinguish between hazardous and non-hazardous waste. Should any metal in TCLP extract exceed the corresponding concentration limit for toxicity as defined under RCRA, the waste is classified as hazardous. If the material is hazardous and treated to render it a non-hazardous waste, the parameter concentration must be less than the limit established by USEPA under its Landfill Disposal Restrictions regulations. The TCLP extraction method utilizes a fluid made from laboratory reagent grade acetic acid, sodium hydroxide, and deionized water to achieve a pH of approximately 4.93 S.U in one form of the fluid, and 2.88 S.U. in another form without the use of sodium hydroxide. Solid sample matrix is then sized to particles of less than approximately 3/8", and prescribed volume of the appropriate fluid, based on buffering capacity of the solid, is added to a prescribed mass of the solid. The solid and extraction fluid is then tumbled for specified time, decanted, and the supernate is filtered and analyzed for the metals it contains. This test method utilizes a fluid that is intended to replicate the fluids found in landfill leachate where organic matter degrades to organic acids that include acetic acid. While required for determining whether as solid waste is hazardous or not for its internment in a landfill, it neither adequately test material that would be placed in a mine, nor does it evaluate whether the solid material will remove heavy metals from the AMD found within a mine. Further, the TCLP method consists of only one extraction cycle that does not allow for determination of long-term stability through repeated exposure to abrasive conditions, or the acidity found in a mine.

The EPA's SW-846 Method's 1312 (SPLP) and Method 1320 (MEP) use ratios of sulfuric and nitric acid to replicate acid rain characteristic to either the eastern or western US. As with the TCLP method, these also utilize laboratory grade reagents that due not replicate the constituents, such has heavy metals and acidity, found in AMD.

With these methods, as published in EPA SW-846, the extract fluids are prepared from solutions of sulfuric and nitric acids. While these acids are constituents of acid rain, sulfuric acid is common to acid mine and acid rock drainage. SPLP-approved fluids are chosen from one of two fluids that attempt to replicate the ratio of sulfuric and nitric acids in acid rain common to the eastern and western United States. Test Method 1320 provides for ten (10) sequential extractions of the same sample aliquot using fresh SPLP fluid appropriate for the region of the country where a particular site and waste material is located. While both test methods can be modified in the nature of the extraction fluid used, the SPLP test consists of only one extraction which does not reflect long term exposure to abrasion or acidity. Unlike the SPLP method, the MEP does accommodate long term exposure to abrasive conditions and acidity. However, both methods relate to the exposure of material to acid rain but can be modified to accommodate the rigors and harshness of fluids found within mines. Only the MEP test, however, with modification will allow for exposure of a solid material sample aliquot to repeated and long-term exposure of abrasive conditions and acidity, even when fresh extraction fluid is required for the continued extraction of the same sample aliquot. It is noted however, that results of the MEP test are used to look at release of heavy metals over the sequence of ten (10) or more extractions, and that additional extractions may be required if constituents in extracted fluids show increasing concentrations in the later extracted sample. The method does not look at the levels of constituents present in the extract fluid prior to its use to extract the solid sample mass. As such, the method is limited in that results do not evaluate the effects of the solid mass being tested against the extraction fluid characteristics throughout the test method.

USEPA has recently developed another leaching test protocol system under SW-846. These series of test methods (Methods 1313-1316) are called the Leaching Environmental Assessment Framework (LEAF) and provide a means to evaluate sample material and provide additional information to make environmental-based decisions for the management of the tested material. Without delving into the specifics of each test method, they collectively apply laboratory grade reagents consisting of water, calcium chloride, nitric acid, and/or potassium hydroxide in various combinations and concentrations to yield solutions of various pH ranges. Solid samples, depending on their physical state and pH buffering capacities are then batch-extracted in parallel using a variety of the fluids across a range of pH in each extraction. Sample extracts are then analyzed for total metals. Unfortunately, and as with the aforementioned test methods, the extraction fluids of this method are made from pure laboratory quality reagents, and because a specific sample aliquot is not sequentially extracted with fresh fluid or actual AMD, the test method results cannot reflect long-term exposure to abrasive conditions, the pH and metal content of fluids in mines, or the acid generating properties and metal content of mine waste that can be released over prolonged exposure.

In summary of the methods accommodated by regulation and used by environmental professionals, these fluids attempt to replicate landfill leachate and/or acid rain in a simple short-term exposure test. While one test method does attempt to evaluate long-term exposure to robust abrasion and acidity, it also utilizes sequential exposure of a solid material to synthetic acidic fluid that is not acid mine drainage. In another set of test methods, solid matter is exposed in parallel to different synthetic fluids of a controlled pH to model release of hosted constituents. Other approved and long accepted methods used by engineering and geotechnical professionals to evaluate physical strength and stability characteristics, are appropriate for evaluation of certain conditions that may be applicable to the material, but they do not accommodate chemical considerations related to the degradation of material due to prolonged exposure to robust erosion and acidity and the release of hazardous substances from the solid material. Further, no test methods consider the removal of hazardous substances from the fluid that will contact the solids material in its final placement and storage location. Geotechnical and leaching test methods are both important factors for the management of any material where it may be placed, but first and foremost for the IMC innovation is the ability of any material to retains its hazardous substances and treat hosted sulfide-minerals so as to not generate acid, and to remove heavy metals from any fluid it contacts where such heavy metals are also present and will be in contact with the solid material.

Environmental regulatory agencies, environmental professionals, mining entities and mining professionals have typically addressed pollutants derived from mine wastes and mines separately.

Mine wastes are typically removed and put into a repositories engineered and constructed on site. These often include massive earthworks such as excavation, moving, hauling, importing or manufacture of clean earthen material and aggregate products and their placement to build an appropriate containment facility. Geosynthetic materials are also included in these facilities as may be plastic membrane materials common to those used in conventional landfill construction. These facilities often require large surface areas that are problematic and difficult to locate due to steep remote areas in mountainous settings that also further disturb and cause harm to often the environment during construction. Further, these repositories require long-term maintenance and corrective action to repair breaches and damages caused by a variety of events such as erosion, forest fires, severe precipitation events, mud and rockslides, avalanches, floods, wind, freeze-thaw and wet-dry cycling, seismic activity, as well as vegetative root mass and burrowing animal penetrations.

Legacy and abandoned mines, and those that discharge mine fluids containing heavy metals and acidity are typically addressed by treatment of the drainage using lime-based treatment systems. Some mines have been modified to include plugs or seals, or bulkheads to minimize the release of water and the contaminants it can carry.

Another approach to mines and AMD is the installation of bulkhead and plugs within the mine. These will prevent or at least minimize AMD release from actively draining mines, but water levels within mines will rise and create water pressures from standing water within mine works, stopes and shafts, and connective passages between mines that can also cause seeps and releases from geologic rock fractures, veins, and other conveyance pathways not necessarily related to the specific mine. While elevated water levels within former mine workings may isolate unreacted sulfide materials from oxygen, most if not all pooled and retained mine water will remain acidic and contain dissolved metals and find it release by overtopping bulkheads or other pathways. As such, these features may minimize flow and thus heavy metal loading, but they do not remove heavy metals or acidity.

Also, efforts have addressed air supply, thus oxygen, into the mines that facilitates the production of AMD. In these cases, ventilation shafts and mine portals of entry have been sealed. Rarely are mines filled with backfill materials as they are continued sources of heavy metals, and because the mines are often desired to be remain accessible for future extraction. For those that are exhausted or otherwise worthless, and where mine waste is backfilled, say for closing of only a portion of the mines working, these materials will continue to leach and contribute heavy metals to the mine. Further and when mine waste is processed, it is often modified with cement, pozzolans, and/or other metallic hydroxide generating materials to lower metal leachability. Unfortunately, the acidity of the mines and their fluids will neutralize these altered materials and metals will be released. Similarly, acidity will degrade the physical strength of the mine waste over time, again causing release of heavy metals once the buffering capacity of the fill material is overcome by the mine's acids.

In other approaches where mines are used to manage mine wastes, such as for radioactive materials, and to protect it from mine fluids and water, wastes are packed in tightly sealed containers approved for underground waste disposal to handle mechanical strains, meet regulatory standards, and most importantly provide long-term protection against acidic corrosivity and subsequent degradation of the waste container.

Mine wastes and AMD release from mines have been separately and distinctly addressed using technologies applicable to either one or the other problem source, the specific metals released from either. Further and specifically, no technology existed until now that will stop the formation of AMD within mines, fill the mine voids where water collects to curtail its release, and prevent the migration of hazardous metal substances from mines, but that will also address the problem with mine waste not associated with the mine. An approach and tool is needed by both mine and environmental professionals to mitigate the cause, formation, and release of hazardous substances from mines and mine waste using a collective and combined approach that is technically viable and converts legal and financial liabilities of the problem sources to assets of value by providing a long-term permanent solution to both mine wastes and mines where acidic fluids form and can drain to the environment with detrimental impacts to human health and the environment.

IMC™ SUMMARY and DESCRIPTION

The IMC method provides a tool for: the cleanup of mine waste; mine waste's permanent storage in a secure facility; the mitigation of migratory mine drainage containing hazardous substances from a mine; and the mine's ultimate permanent closure. IMC management abates release of hazardous substances such as heavy metals and acidity to the environment sourced from the mine wastes as well as from the filled mine or portions thereof. The method is well suited for using multiple sources of mine waste as a raw material from a mining area for beneficiation and for storage and closure of an abandoned legacy mine or mines where acidity and migratory heavy metals are also sources of hazardous substance release.

At minimum, implementation of the IMC approach includes two (2) sources of contamination that impact human health and the environment due to their contributing releases of acidity and hazardous substances as defined under USEPA CERCLA and other federal and state regulations where one source is mine waste and other is a mine with void space. The program converts valueless, if not harmful and previously resolved, adverse and toxic mining legacies to a final and permanent singly functional remedial feature.

The IMC technology provides a primary function of sealing mines by filling previously extricated mine voids with a beneficial re-use material where: the release of heavy metals by leaching from the backfill material is minimized; mine fluids are neutralized and heavy metals are removed from the mine water as a result of contacting the beneficial re-use material during or after its placement within the mine; water within the formation around the mine workings' voids find natural alternative pathways around the filled void as a result of gravity and reduced hydraulic pressure and resistance.

In an integrated application of the IMC system, the Advanced Neutralization™ (AN™) treatment technology for the processing of AMD acidity and heavy metals, may be utilized to treat mine fluids that are displaced during stowing of the MBT end-product. Combined, IMC, MBT, and AN technologies provide a foundational solution for legacy and abandoned mines that release acidic fluids and hazardous heavy metals to downgradient waters and the environment.