Best Available Techniques for Mine Impacted Lands (BATMIL)

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This issue paper has been developed by The Sierra Fund to frame the Best Available Techniques track of the Reclaiming the Sierra 2015 conference. This and the three other issue papers associated with the three other event tracks are ***working documents*** *intended to frame the conference track. As a result, they will be revised and updated leading up to the conference. The Sierra Fund will produce an outcomes paper on this topic based on the conference proceedings, which will be published after the conference.*

Definition of BATs

Best Available Techniques (BATs) is used here to refer to the most appropriate, cost-effective methods to abate environmental contamination. Similar terms include *Best Available Technology, Best Available Means, Best Management Practices* or *Best Available Environmental Option*. Determining BATs is a moving target because best and/or available techniques change over time, and must be re-evaluated periodically. BAT selection is by nature an adaptive management approach. Also, what is considered best depends on site-specific factors, there is no one-size-fits-all solution.

Application of BATs at Mine Impacted Lands

BATs are commonly applied to abate air and water emissions from industrial operations. BATs for Mine Impacted Lands (BATMILs) are techniques that abate pollution associated with previous mining activities. BATMILs may be required to address multiple contaminants in multiple environmental compartments (land, air, and water), and consider both the long-term benefits and the potential for re-mobilization of contaminants during reclamation activities.

BATMILs can be evaluated and applied in the remediation process as part of the I.) initial site assessment, II.) remediation activities, and III.) evaluation of effective cleanup.

BATMILs are integral at all steps of the abandoned mine remediation process:

I. BATMILs for abandoned mine site assessment
    1. BAT for assessing contaminants
    2. BAT for risk assessment
II. BATMILs for remediation activities
    a. Effective contaminant containment and removal
    b. Passive and semi-passive treatment
    c. Multiple benefits
    d. Feasibility of technology options
III. Post-remediation BATMIL effectiveness evaluation
    a. Performance measurements
    b. Predictions and reality
    c. Independent auditors

1) BATMILs in Abandoned Mine Site Assessment

Identification and inventory of the contaminant(s) of concern (COCs) with best available assessment methods is required to determine if a technique or technology is effective at removing the COCs. Good baseline data, including current contaminant status and historical information, should be compiled at the beginning of reclamation planning. Specifically, assessment should include:

1. **BATMILs for assessing contaminants.**
   a) **Historical Operations.** Identification of the contaminants of concern for an abandoned mine site should be informed by historical operations by employing a registered archeologist and geologist. Understanding the historical operations can help identify where mercury was stored and retorted, where discharge was released from chlorination works, and where ore was crushed and processed. Soil sampling should target these areas as potential hot spots to identify contaminated areas (concentrations of COCs) and to determine the extent (depth and width) so that remediation techniques can be designed to site specific conditions.

   b) **Multiple Contaminants.** BATs need to be employed to identify multiple forms of contaminants (i.e. dissolved and total metals; elemental and methylmercury; nitrate/nitrite/ammonia) and a broad range of contaminants of potential concern (i.e. fuels, pesticides) in multiple environmental media (air, water, soil). The analytical limits of detection should be sensitive enough to determine contaminant concentrations at very low levels.

   c) **Hydrologic Flows.** Best assessment methods need to include seasonal events and a range of hydrologic flows. Sampling during runoff conditions identifies particulate-bound contaminants that move when stream power increases during storm events. Water sampling also needs to be conducted during low flow periods to assess contaminants moving via groundwater.

2. **BATMILs for Risk Assessment**. Historical and contemporary baseline data, such as discussed above, are important to determine contaminant sources and delineate contaminant pathways. Once contaminants, their mobility, and pathways are known, potential "receptors" (fish, land mammals, birds, humans) potentially at risk can be determined. In this way, cleanup priorities are identified and the appropriate BATMILs brought forward for discussion.
   a) **Ecological Receptors.** Apex predators such as eagles or large fish may receive high loads of contaminants as a result of biomagnification and bioconcentration through the food chain. Once contaminants are identified, the potential for food chain effects through chemical mobilization and transformation need to be assessed. This should include measurement of contaminant concentrations at different levels of the food chain.
   b) **Human Receptors.** The extent to which humans are at risk from direct contact (ingesting contaminated soil or water) and indirect contact (ingesting contaminated fish) must be understood prior to remediation activities. This may include modeling, regional and ethnic consumption surveys, and other methods.
   c) **Thresholds.** Determining the receptors that are at risk from exposure to the contamination will dictate the applicable thresholds for the remediation action. Cleanup

standards for water quality and soil depend on current and future uses for the site, and will guide the site specific regulations and permits. For contaminants such as mercury and arsenic, which can bioaccumulate and biomagnify once incorporated into the food chain, water and soil regulatory thresholds are indicators of contamination potential rather than definitive benchmarks.

II) BATMILs for Remediation Activities at Abandoned Mines

Choosing the most appropriate BATs to apply in remediation should consider not only the cost, availability, and ability to implement the BAT, but also take into account indirect benefits or harm associated with the remediation technique. An emphasis is placed on water quality and quantity, as remediation of water resources is generally the most problematic issue on a site.

The following criteria are proposed for evaluating techniques for BATMIL status. While all criteria cannot always be applied for every mine remediation site, they should all be considered and whenever possible implemented to be considered a BATMIL Remediation.

Technology selection criteria:

1. **Remove and contain contamination.** BATMILs should remove or contain contaminants of concern and whenever possible go beyond temporarily retaining them on site or making them temporarily inert with the modification of environmental conditions such pH or solubility. The fate and transport of contaminants such as mercury and arsenic means that the BATMIL approach must consider best available science regarding transport mechanisms that may lead to offsite contamination. Evaluation of BATMILs needs to consider and minimize re-mobilization, including atmospheric transport and risks from remediation activities themselves, such as dredging or moving soil, that can risk re-releasing contaminants.

2. **Passive and Semi-Passive Treatment.** Passive and semi-passive treatment are technologies employed to contain contamination temporarily (e.g. require dredging) or permanently on site with a low carbon footprint, and may be the only feasible option in remote areas that are not serviced by year-round road access or the power grid. However, evaluation of these technologies with other options must consider the potential for contaminants to enter the environment (e.g. mercury methylation or gaseous emissions) under both routine operations and if there is an upset in the treatment system.

3. **Assess potential for harm.** BATMILs should not create additional impacts to surface water bodies by increasing, diverting or discharging flow to drainages. Similarly BATMILs should not negatively alter the stage, flow paths or water quality of groundwater resources including private wells. Technologies need to be assessed for the potential to adversely impact water quality and water resources, including the potential for mine-related contamination to travel off site during and after mining and/or reclamation.

4. **Multiple Benefits.** BATs should take into account multiple benefits associated with the remediation technique. For example, if a contaminant is removed, will a fishery be restored, is water storage space returned, is a sellable product created such as aggregate or gold that can be used to offset the costs of remediation? Multiple benefits can also be evaluated using models,

such as pollution offset models, where a predicted reduction in a pollutant at a downstream location is made based off of upstream remediation/removal of contaminants.

5. **Feasibility of Technology Options.** BATMILs should consider "tried and true" technology, such as lime treatment for acid drainage, and new, innovative technologies or proven technologies taken to a different scale or different environment. When evaluating BATMILs for a site, it is important to consider the foundational reasons for potential success, but to be prepared in the event of partial or complete failure.
    a) **Precedent of Proof of Concept.** Under what conditions has the technology been applied? What were the standards or contaminant concentrations that needed to be met? New technologies should not be taken directly from the lab to a remediation site. To determine the effectiveness of removal techniques or technologies, replicate tests with control groups may be necessary. This testing phase can be very expensive and can be done at a pilot scale to inform full operation conditions and environmental permitting. Successful pilot scale testing should then be applied to small-scale remediation plots before being applied to large scale sites.

    b) **Contingencies and backups.** Contingency and backup actions need to be considered in case the chosen BATMIL is ineffective or only partially effective. The point at which these need to be employed may be obvious, or may be decided after regular evaluation of the effectiveness of the applied technologies.

III) Post-Remediation BATMIL Effectiveness Evaluation

The desired outcome is for the after-project condition to have less contaminant(s) than the before-project condition. The effectiveness of the BATMILs employed needs to be assessed over time as part of an adaptive management strategy. Once BATMILs are chosen, the criteria by which they will be assessed for effectiveness needs to be decided on, as well as secondary measures to employ if the original approach is ineffective.

1. **Performance Measures.** Before remediation activities begin, site-specific performance measures should be created that will be used to evaluate the effectiveness of the remediation techniques. The performance measures should be explicitly stated for each BATMIL project to ensure that treatment techniques are successful and benefits are long lasting.

    a) **Regulatory Criteria.** One type of performance measure could be meeting regulatory criteria for water and air quality standards, and explicitly stating the water quality uses that will be attained under successful remediation.

    b) **Biological Criteria.** Performance measures could include specific and measurable improvements in habitat, macroinvertebrate abundance and diversity, or ecosystem function. It could include a measurable decrease in contaminants in the food chain over a stated period of time.

2. **Predictions and Reality.** Specific performance goals and measurable results need to be written into the reclamation permit. The reclamation permit needs to require regular evaluation periods during which the effective results are measured. Additional or different reclamation techniques may

need to be employed to achieve the stated goals and results if predicted results are not observed in the expected time.

3. **Independent Auditors.** Both the development of performance measures and the actual evaluations should involve independent auditors in addition to regulators and responsible parties.