## Giant Mine – Viability of Constructed Wetlands as a Water Treatment Technology

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| **Objective:** | Evaluate the viability of treating mine/surface water from the Giant Mine with constructed wetlands. |
| **Technology Synopsis** | |
| Design Concepts | • *Subsurface-flow wetlands*: Effluent moves through granular media (e.g., gravel or sand) in which plants are rooted. Can be configured for horizontal or vertical flow. Generally require less land area but are less suitable as wildlife habitat when compared to surface-flow wetlands.<br>• *Surface-flow wetlands:* Effluent moves above the soil/media in a planted marsh or swamp.<br>• *Subsurface bioreactors:* Effluent moves vertically through porous media with organics (e.g. manure, straw, wood chips and sand) where anaerobic conditions result in metals precipitation. |
| Applications | • Constructed wetland systems have been applied primarily to the treatment of nutrients in domestic sewage, alkalinity addition to acidic streams and for metals precipitation from mine waters<br>• The main application of constructed wetlands in the removal of metals and metalloids has been in the treatment of acid mine drainage where arsenic was not the priority pollutant. |
| Removal Mechanisms | • Like all natural systems, removal mechanisms are extremely complex and there is limited information on the processes responsible for the transformation and retention of arsenic.<br>• Removal is believed to be dominated by the chemical processes of precipitation, co-precipitation and sorption.<br>• Chemical removal processes are enhanced by microbes living in the wetland media. Plants play only a minor role in arsenic uptake, however, they are assumed to improve chemical removal by: stimulating the growth of metal oxidizing bacteria and the transfer of oxygen into the wetland media and conversely but contributing organic detritus that produces reducing conditions and precipitation of arsenides.<br>• Arsenic is retained mostly in sediments or media, rather than accumulated in plants. Research suggests that uptake and accumulation of arsenic by plants is minor when compared to other processes. Instead, arsenic is mostly retained in media and sediments.<br>• Complex chemical and biological processes can result in cycles of arsenic removal and release. For example, the presence of organic matter can remove arsenic from water, but also releases it from solid phases and therefore can increase arsenic concentrations in the aqueous phase. |
| Removal Efficiencies | • Few experimental studies have investigated arsenic removal in wetland systems and field data on removal efficiencies is very limited. This is particularly true for wetlands in extreme northern settings.<br>• Removal efficiencies are highly dependent on the source water quality and site-specific factors.<br>• Based on the limited amount of available research, high removal efficiencies can be achieved for mine waters with elevated arsenic concentrations. For example, Robert and Scott (2009) report mine water arsenic removal efficiencies ranging from 33% to 99%. However, the influent arsenic concentrations cited in the studies are typically much lower than those at Giant Mine which is projected to have short-term (i.e., pre-freeze) arsenic concentrations above 33,000 µg/L. Furthermore, it is unlikely that the performance data of the available studies would be readily transferrable to a northern context.<br>• Wetland removal efficiencies typically decline significantly when influent concentrations are already at low levels. In fact, some studies involving low arsenic concentration influents identified negative removal efficiencies (i.e., higher arsenic concentrations in effluent), presumably due to re-solubilization of arsenic from wetland media. For example, recent studies of arsenic removal from natural wetlands at AANDC's Terra Mine site in the NWT suggest that the wetland is not effectively sequestering dissolved arsenic in effluent from a tailings pond. Instead, cycling of arsenic between sediment and water is resulting in seasonal arsenic discharges from the wetland to the surface water. |
| Design Considerations | • Currently, there is no official guidance on how a wetland should be designed for arsenic removal. Extensive lab, pilot and field scale testing is necessary to verify potential performance and develop site-specific design criteria.<br>• Both surface and sub-surface wetlands require surface saturation. This can result in percolation of wetland water into the underlying groundwater system.<br>• Biochemical processes are strongly influenced by temperature. For instance, sulphate-reducing bacterial activity is usually optimal at warmer temperatures (approximately 30$^{o}$C), as is vegetative growth. Physical factors including seasonal freezing of surface waters and granular media are also relevant considerations. In general, very little is known regarding wetland operation and removal performance at cold temperatures.<br>• Periodic harvesting of plant matter or arsenic contaminated sediments may be necessary to: a) promote plant growth; and/or b) isolate/manage contaminants accumulated in plant mass (although this is not typically a major concern for arsenic) and sediments.<br>• Fencing of constructed wetlands is desirable in some circumstances (e.g., to prevent wildlife from exposure to untreated effluent entering the wetland and/or consumption of vegetation)<br>• Many constructed wetlands require some degree of "operation", care and maintenance (i.e., they are not completely passive) |

| **Potential Applications to Giant Mine** | | | |
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| **Design Concepts** | **Design Requirements** | **Advantages** | **Challenges / disadvantages** |
| A) Treatment of Raw Mine Water | • Influent arsenic concentrations: >33,000 µg/L short-term (pre-freeze) and approximately 3,000 µg/L long-term (post remediation)<br>• Effluent quality objectives:<br>o 100 µg/L (Base Case)<br>o 10 µg/L<br>• Throughput of 400,000 $m^3$/year (+/-) over a seasonal discharge period of a few months<br>• Off-site construction of wetlands assumed to be unacceptable | • No requirement for a conventional treatment plant<br>• Ammonia removal would also be realized | • Unlikely that minimum effluent quality objective can be achieved<br>• Highly improbable that desired removal efficiency can be achieved<br>• Exclusive reliance on an unproven technology within this context<br>• Limited data available to guide design<br>• Sufficient land may not be available on the Giant site (unknown land requirements but assumed to be significant)<br>• Requirement for surface saturation will likely result in recycling of water into the mine |
| B) Polishing of Treated Mine Water | • Influent quality: 100 µg/L arsenic (assumed performance if iron-coprecipitation used as a pre-treatment)<br>• Effluent quality objective: superior to chemical processes (i.e., < 10 µg/L)<br>• Throughput of 400,000 $m^3$/year (+/-) over a seasonal discharge period of a few months<br>• Off-site construction of wetlands assumed to be unacceptable | • Effluent quality objective for arsenic *may* be achievable (performance unproven)<br>• Ammonia removal would also be realized | • Requirement for conventional plant for pre-treatment<br>• Unproven technology for this application/context<br>• Limited data available to guide design<br>• Sufficient land may not be available on the Giant site (unknown land requirements but assumed to be significant)<br>• Requirement for surface saturation will likely result in recycling of water into the mine |
| **Overall Conclusion** | For the Giant Mine, there is no evidence to suggest that constructed wetlands alone would be capable of achieving the effluent quality objectives that could otherwise be achieved by conventional treatment technologies. Constructed wetlands could be used to polish the effluent from a conventional treatment system. However, there are a number of disadvantages with the use of such an approach, the most notable of which is the performance uncertainty (i.e., there is currently insufficient information concerning the arsenic removal efficiency of constructed wetlands, particularly in situations similar to the Giant Mine). The overall conclusion is that proven treatment technologies are currently the most appropriate approach to achieve desired effluent quality characteristics. | | |

Sources:


Kadlec, R.A. and S.D. Wallace 2009. *Treatment Wetlands – Second Edition*.

Lizanna, A. et al. 2011. *Removal Processes for Arsenic in Constructed Wetlands*. Chemosphere 84 (2011) 1032-1043.