USE OF QUANTITATIVE ECOLOGICAL AND HUMAN HEALTH RISK ASSESSMENT TO INFORM THE RECLAMATION PROCESS IN THE TIMMINS GOLD CAMP

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Porcupine Gold Mines (PGM) has extensive mining-related land holdings in and around the City of Timmins, Ontario. Many of these holdings consist of closed open pit and underground mines and mine waste management facilities that are at various stages of the closure and rehabilitation process. PGM is currently considering reclamation options for several of its sites, and is going beyond the traditional options selection process by utilizing quantitative Ecological and Human Health Risk Assessment (EHHRA) to inform its reclamation choices as well as technical, financial and other considerations. EcoMetrix Incorporated (EcoMetrix) is undertaking these analyses on PGM's behalf for its Aunor-Delnite, Pamour, and McIntyre and Coniaurum sites.

Generally, EHHRA work in Canada can be undertaken using federal risk assessment guidance (*e.g.,* Health Canada, Environment Canada, Federal Contaminated Sites Action Plan, or Canadian Council of Ministers of the Environment) as well as provincial guidance (*e.g.,* Ontario Regulation 153/04 for redevelopment of brownfield properties). EcoMetrix has adapted the relevant federal and Ontario risk assessment guidance within a mine closure context in order to assist PGM with its closure planning for these sites.

In general, risks from mine-related constituents in the environment are determined by two components: exposure and toxicity. Both components must be present for an environmental risk to exist. In this context, EHHRAs assess exposure and toxicity separately and then combine the results of each assessment to characterize risks. In this context, the risk characterization results are then used to prioritize source control options at closure. Uncertainties and assumptions made are also analyzed and evaluated in the EHHRA. The specific content of each section of the EHHRA is summarized in the following sections.

Problem Formulation

The first, and most important stage in an EHHRA is the Problem Formulation. In this section, the objectives of the EHHRA are defined, as a basis for design of the study. For our sites, the main objectives are to estimate human health and ecological risks for aquatic receiving environments and their associated riparian zones under current environmental conditions, and to develop Risk-Based Design Objectives (RBDOs) to

underlie the design of closure options at each site. These RBDOs are being used by EcoMetrix' closure planning team to identify appropriate closure options for each site.

The Problem Formulation also presents an analysis of who or what may be exposed to which environmental Constituents of Potential Concern (COPCs), as well as where and how these exposures may take place. EcoMetrix has relied on previous reports such as Environmental Effects Monitoring (EEM) studies, annual monitoring reports, and existing closure plans prepared for all three sites to determine the answers to these questions.

EcoMetrix has consulted with Ministry of the Environment and Climate Change (MOECC) and Ministry of Natural Resources and Forestry (MNRF) to ensure that this section is complete. The end result of this analysis is the Conceptual Site Model (CSM), which summarizes visually how constituents move from potential source areas on a mine site, such as a tailings impoundment, through the environment to the human and ecological receptors that may be exposed. An example of a CSM diagram is presented in Figure 1.

Figure 1: Illustration of a Conceptual Site Model (CSM)

Exposure Assessment

In the Exposure Assessment, EcoMetrix has investigated how much each human and ecological receptor is exposed to each COPC. Based on the CSM, an environmental fate and transport (pathways) model has been constructed that estimates the exposure value (EV) for each person or ecological receptor identified in the Problem Formulation. EV estimates are calculated using conservative exposure factors so that potential exposures are not underestimated. Site-specific data have been used wherever available; for these sites, measured concentrations of constituents in surface water, sediment, soil, terrestrial and aquatic plant tissues, and benthic invertebrate tissues have been used to quantify exposure.

Toxicity Assessment

In the Toxicity Assessment, also called an Effects Assessment in an ecological context, an effect level or benchmark value (BV) is identified for each COPC. The derivations of BVs are conservative by design, and may use the lowest available effect levels or include uncertainty factors to make sure the assessment does not underestimate risks. For humans, potential cancer, non-cancer, and developmental (fetal) effects have been evaluated. For ecological receptors, survival, growth, and reproductive effects were evaluated. In order to accomplish this task, EcoMetrix searched the literature for the health effects that each COPC might cause, summarized the results of the studies underlying the investigation of these health effects, and tabulated the numerical results.

Risk Characterization

In this section of the report, EcoMetrix has combined the results of the Exposure and Toxicity (Effects) Assessments into single measures of risk. Given the conservatisms in the Exposure and Toxicity (Effects) Assessments, these measures of risk are expected to be overestimates of true health risks. For non-cancer and developmental effects in humans, and for ecological receptors, the risk measure is the Hazard Quotient (HQ), which is calculated as the EV divided by the BV. For cancer effects in humans, the risk measure is the Incremental Lifetime Cancer Risk (ILCR). EcoMetrix has compared these measures to the targets set out in the various federal and provincial guidance documents to determine whether risks to human or ecological receptors could be ruled out. The relative magnitudes of the HQs and ILCRs have therefore been discussed in the context of uncertainties and overall conservatism to allow prioritization of environmental risks to be undertaken.

Risk-Based Design Objectives

For the higher priority human and ecological health risks, mitigation options were considered to be necessary at closure to protect the potentially affected receptors. Closure and reclamation options have therefore been developed that target the sources of, and pathways for, the high priority COPCs to mitigate potential health risks. These options have been developed using RBDOs. The derivation of a RBDO starts from the target measure of risk according to federal or provincial guidance, and works backwards through the risk assessment process to arrive at an exposure concentration that is not expected to result in a human or ecological risk.

Once all of the required RBDOs have been estimated using this reverse process, the Risk Characterization step is re-evaluated to demonstrate that with closure options in place, high priority health risks in the riparian receiving environment will have been reduced to an acceptable level. The closure options meeting the RBDOs can then proceed to further technical and financial analyses, as well as any other analyses deemed appropriate, so that a scientifically defensible closure plan that is protective of humans and the environment can be developed.

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