Water Quality: Pit Lakes, Streams, Risk Management (Newsletter)[*]

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Regulatory implementation of the Clean Water Act sets quality standards as maximum concentration limits (MCL) of individual elements. Applied to all single-element constituents such values are mis-leading. Toxic metals (arsenic, lead, mercury) are of particular concern yet concentrations of the isolated element do not reflect the various compounds in which these metals are found in rocks, soils, surface waters, or ground waters. More importantly, such elemental concentrations do not reflect bioavailability or ecotoxicity of multi-element chemical compounds.

Pit lakes are created after de-watering stops at surface mines extending below the water table's surface. Such pits are dug to extract construction aggregates, coal, industrial minerals, or metals. Water quality concerns include the potential for impairment of designated beneficial uses that might occur.

Historically, management of environmental risk has been through financial surety instruments such as bonds. Because of inherent uncertainties about the future the bond amounts tend to be high, as are the premiums. For operators, these bonds keep capital from use in expanding operations or improving efficiencies.

Forecasting pit lake environmental risk is based on output of numeric models of geochemistry, ground water flow, leaching rates, and abiotic processes in standing waters. These models, such as PITLAKQ `<http://www.pitlakq.com/index.html>`, include everything that might affect water chemistry. The equivalent model for streams and rivers is HSPF (Hydrological Simulation Program, FORTRAN) `<http://water.usgs.gov/software/HSPF/>`. The inclusiveness and resulting complexity of these numeric models require assumptions of many unavailable constants and rates; change any of these values and the results can be greatly different.

Numeric models are either so general they do not adequately describe any specific system, or so specific that they are not applicable to any other water body. Developing and running these models is expensive and time consuming. The resulting uncertainties often result in regulatory retreat to the precautionary principal: if you do not know the future with certainty, and must do something, impose a large financial burden on the project proponent.

The greatest short-coming of numeric models is the necessity of fitting data to the model, even when not all requisite data are available. These data often have values below laboratory method detection limits, consist of elements or compounds that are only a portion of those in the water, or have different slopes for the response (dependent) variable across the range of explanatory (independent) variables.

A fundamental principle of environmental data analysis is to fit the model to the available data. This is done by selecting appropriate statistical models.

There are many analytic models to characterize available environmental data, to quantify cause-and-effect, and to forecast water quality. Such models are found in each of the three statistical frameworks: frequentist (hypothesis testing). maximum likelihood estimation (fitting a distribution to the data), and Bayesian (applying experience and prior knowledge to improve predictions). For each question needing to be answered there are models that work with the available data and produce quantitative, objective results.

Statistical models are objective, robust, and based on established mathematical principles; they are technically sound and legally defensible. The insights they provide allow operators and regulators to make, and justify, informed decisions.

Statistical modeling of environmental data is not limited to predicting pit lake water chemistry or current surface and ground water compliance with discharge permit conditions. These models should be applied to the entire mine life cycle (exploration, development, operation, closure, and reclamation); from baseline data for a NEPA document to evaluation of reclamation re-vegetation trajectory to support bond release. Statistical models should also be applied to environmental data of oil, gas, and electrical production, transmission, and storage. All regulated natural resource industries collect environmental data and statistical, not numeric, models should be used to address regulators' and society's concerns.

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