Mine Water and the Environment (2003) 22: 167–169 © IMWA Springer-Verlag 2003

Technical Communication

Pit Lake Systematics: A Special Issue

Rob Bowell

SRK Consulting, Windsor Court, 1 Windsor Place, Cardiff CF10 3BX, Wales, UK; e-mail: srk003@aol.com

Note from the editor-in-chief: The articles assembled for this issue overflowed the space available; we had an abundance of riches. As a result, one article, by Gammons et al., was printed in the last issue of this journal [22(3): 141-148] and another, by Dowling et al. will appear in the next issue [23(1)]. The Gammons et al. article was not integral to an understanding of pit lake dynamics, since it was focused on water quality in an underground mine near a pit lake, rather than the lake itself. However, Dowling et al. is a critically important case study and an example of how potential pit lake problems can be anticipated and constructively dealt with. It is a key component of this special issue, and was selected for displacement only because it was the right length. Please remember to keep an eye out for it in the next issue.

Introduction

When surface mining ceases, dewatering stops and groundwater flows into the pit. The local groundwater table rises and contributes to the formation of a pit lake, along with surface run-off from within the open pit area. Depending on the magnitude of net evaporation, the steady state pit lake elevation can be lower than the surrounding groundwater aquifer, resulting in passive hydraulic containment. Under this scenario, the lake acts as a solute sink and the only outflow is by evaporation. Alternatively, groundwater outflow occurs, passive containment is lost, and the pit lake water can interact with groundwater down gradient of the pit. The focus of this special issue is on understanding what occurs when pit lakes form, and what can be done to influence the outcome. When the lake dynamics and water chemistry are understood and can be predicted, then the water quality can be engineered and/or modified.

Monitoring Program

Site characterization and computer modelling can be used to assist mining operations to predict the evolving water chemistry of individual pit lakes but uncertainties arise due to paucity of actual data. Reducing the uncertainties associated with these predictions requires robust hydrologic data, including water levels, runoff records, precipitation-evaporation, and chemical data.

Parshley and Bowell (this issue) report on an example of a comprehensive five year monitoring program. Summer Camp Pit, at the Getchell Mine in Nevada, has been monitored regularly since cessation of mining in 1991. During a five-year period (1996-2001), the authors conducted a detailed monitoring program of the physical, chemical, and mineralogical characteristics of the Summer Camp Pit lake system. The information is being used to predict long-term geochemical behaviour of the lakes that will someday form in the other, still active, pits. The study identified seasonal and multi-year cycles within the column of water, along with the influence of contaminant loadings of inflow to the lake and attenuation processes.

The study is unique in terms of the level of detail that was acquired as the pit lake developed and attained hydrological and geochemical equilibrium. Few case studies like this exist in the literature, and it is only with such documentation that predictive models can be tested against comprehensive monitoring databases and improved. Another advantage of such monitoring programs is that they serve as an "early warning system". If monitoring programs indicate inaccuracies in predictions, the operator is then able to implement suitable contingency measures.

Pit Lake Hydrology

The second paper, by Fontaine et al., addresses groundwater-pit lake interactions from a hydrologic perspective. The authors use an analytical model, dubbed the Comprehensive Realistic Yearly Pit Transient Infilling Code (CRYPTIC). The approach is based on the Jacob-Lohman equation, modified to include the pit geometry and effects of precipitation and evaporation from the pit lake surface as well as the input/output of external flows. Case studies from two high-profile open pit environments that interact with groundwater, Berkeley Pit Lake, in Butte, Montana (see also Gammons et al. 2003) and the Pipeline Pit, in north-central Nevada are presented to show how the model can be used to predict inflow rates and the rate at which the pit will fill. The data from both sites agree well with the model.

It is worth noting that the two case studies are marked contrasts in terms of public notoriety. At the well-documented Berkeley Pit, the key concern is the protection of local groundwater from acidic metal-sulfate pit lake water. This old mine site is located in the middle of a populated area and has been used repeatedly by non-government organizations as an example of poor environmental stewardship by the hard rock mining industry. In contrast, Pipeline is an operating pit with an extensive and well-managed dewatering program that is being developed into one of the most significant gold mines in the world. Relatively little has been published on water management at this site despite, or perhaps because of its successful operation.

Pit Lake Water Quality

Pit lakes with good water quality have potentially sustainable multiple uses including recreation, water resources, and aquaculture. Examples of pits with reasonable quality include: Sleeper Pit, Nevada (Dowling et al., next issue); Yerrington, also in Nevada; Copper Flat in New Mexico; Goonshill in Cornwall, (UK); and Magcobar, in Ireland. At these sites, the development of a surface water body offers the potential for sustainable development of water resources (Bowell 2002). More well-known are the notorious sites, including the already mentioned pit lake in Butte, Montana, the Corto Atalaya pit, in Spain, the lignite mines of the former Eastern Germany, and Parys Mountain pit, in Wales. All exhibit low pH and high metal and sulphate concentrations (Klapper and Schultze 1995; Miller et al. 1996; Bowell 2002).

The controls on pit lake chemistry are complex and involve groundwater chemistry and inflow, precipitation and evaporation events, lake limnology and internal chemical processes, and pit wall-water interaction. As a result, a major flaw in many pit lake evaluations is poor control on predicting solute concentrations in future pit lakes.

In an attempt to reduce some of this uncertainty, Davis provides an example of a method applied in the prediction of pit lake chemogenesis following closure of an equatorial copper-gold mine. Critically, Davis considers the changing role of wallrock runoff as the pit lake develops, and the contribution of evaporation, something all too easily forgotten in many studies. Those with an interest in predicting pit lake water quality changes will find an interesting approach that could be applied elsewhere in simulating the contribution of wallrock runoff to pit lake water quality.

Where it is needed, more active management during site closure and reclamation may be required in order to prevent a violation of water quality standards. The closure of the Sleeper Mine open pit in 1996 is one such case. (Dowling et al., next issue). Operations were mostly below the water table and extensive dewatering was required to lower groundwater levels by 300 m to achieve the life of mine plan. Dewatering flows peaked at over 1072 L/s, with most flow contributed from an alluvial aquifer. An added complication was the heavily sulphidic wall rock in the pit. Both regulatory authorities and local organizations were concerned with development of poor water quality in the pit lake.

To overcome the issue, the authors instigated a positive recharge using the alluvial aquifer. The pit was rapidly filled with pumped alluvial groundwater to reduce the exposure time of sulphide wall rocks and waste rocks. The alluvial groundwater provided a large volume of alkaline water that was relatively low in total dissolved solids (TDS). This water controlled the early pit lake chemistry. Up to 60 tons per day of lime addition to the rising lake waters was then instituted to provide additional buffering to neutralize any acid that formed as the lake filled. This case study has not been published previously and is an important contribution to the topic. The water quality in the pit lake was engineered rather than remediated; a high water quality epilimnion was generated and is now being used for aquaculture. Applying knowledge of lake processes allowed the formation of a dense hypolimnion that acts as an "aquatic attenuation layer" for metals and acidity in the lake. Despite the success, little publicity has been gained for the project; once again, the public only learns about mining when environmental consequences are adverse. Hopefully publication of this paper will encourage others to testify, documenting other pits where successful mine water management has resulted in the sustainable development of a site once mining has ceased.

In our final paper, Loop et al. provide an alternative approach to water quality mitigation. They describe the reclamation of a former acidic (pH=3.6) surface mine pool located in the Eastern Middle Anthracite field of Pennsylvania, using alkaline fluidized bed combustion (FBC) ash. The remediation of acidic pit lakes is pertinent to many mining projects and the option of using alkaline ash from a power station is particularly relevant to many coal mines that have acidic lakes, as such mines are often situated close to power stations that generate this alkaline by-product. The use of alkaline fly ash may represent a cost-effective alternative to more conventional liming (e.g., Olem 1991), though of course the ash must be tested to insure that it won't in turn cause other environmental consequences.

Conclusions

In general, if passive containment cannot be demonstrated, then regulatory authorities will require demonstration of suitable water quality for sustainable development of the resource. The growing trend towards deeper open pits will no doubt generate an increased number of mine pit lakes. As more lakes appear, concerns regarding the eventual water quality in such pits will continue to increase as well. Uncertainties surrounding the prediction of groundwater recovery, pit lake formation, and geochemical interactions add to the complexity of the issue. The fact that in many climates, these lakes represent sustainable future water resources makes it critical that stakeholders be able to assess the reliability of model predictions. With a better understanding of pit lake geo-ecosystems comes the potential of providing a sustainable resource on a mining property after closure.

The papers presented here largely report on the successful application of scientific knowledge in developing engineering designs to manage mine waters in open pits. Only by publishing such case studies can the mining industry hope to raise its profile and demonstrate its high standard of environmental stewardship. Hopefully, this issue will inspire new research in this field and lead to additional papers in Mine Water and the Environment on pit lake water management.

Acknowledgements

This special issue has benefited greatly from numerous reviewers who gave considerable time and energy in the assessment of submitted manuscripts and the editor would like to acknowledge the contribution of Charles Cravotta, Richard Connelly, Steve Day, John Harman, Prof. F. Haefner, Bob Kleinmann, Jeff Parshley, Ben Rees, Martin Schultze, and Christian Wolkersdofer, as well as anonymous reviewers.

References

Bowell, RJ 2002 Hydrogeochemical dynamics of Pit Lakes. In: Younger PL, Robins N (eds) Mine Water Hydrogeology and Geochemistry, Geological Soc of London Special Publ 198: 159-186

Gammons CH, Poulson SR, Metesh JJ, Duaime TE, Henne AR (2003) Geochemistry and isotopic composition of H_2S-rich water in flooded underground mine workings, Butte, Montana, USA. Mine Water and the Environment 22 (3): 141-148

Klapper H, Schultze M (1995) Geogenially acidified mining pit lakes-living conditions and possibility of restoration. Int Revue ges Hydrobiol 80: 639-653

Miller G, Lyons WB, Davis A (1996) Understanding the water quality of pit lakes. Environ Science and Technol 30: 118-123A

Olem H (1991) Liming Acidic Surface Waters. Lewis Publishers, Boca Raton, FL, USA, 220 pp