27th WEDC Conference Lusaka, Zambia, 2001

PEOPLE AND SYSTEMS FOR WATER, SANITATION AND HEALTH

Water quality in mining lakes

E von Sperling and C.A.P. Grandchamp, Brazil

THE STATE OF Minas Gerais, Brazil, is characterized by a very intensive mining activity (mainly iron and gold). Near the capital city of Belo Horizonte (3 million inhabitants) is located one of the largest iron ore deposits in the world, the so called *Quadrilatero Ferrifero* (Iron Quadrangle). Among the several mines that are exploited in the region (Dorr, 1969) one of the most important (*Aguas Claras Mine*) has been recently exhausted after 28 years of operation. Águas Claras is a tabulated ore body of soft hematite (with small lenses of hard hematite), 1600 m long, 250m wide and 500 m deep. The mine belongs to Minerações Brasileiras Reunidas S/A – MBR, one of the leading mining enterprises in the country. The production started in 1973 and since that time, the mine has exploited about 300 million tons of iron ore. The average annual production was about 12 million tons. The dewatering of this mine began in 1981 by drains and in 1988 several wells started to operate. In 2000 the water level was located at about 275 m below its original position.

The remaining pit is now being filled with water and will form the deepest lake in the country (maximum depth: 234 m). Our staff at the Federal University of Minas Gerais is responsible for the expertise related with water quality and possible uses for the future lake.

Aquifers

The iron ore forms the main local aquifer, being a semi-confined, heterogeneous and anisotropic with interstitial porosity and fractures (Grandchamp et. al., 2001). The total porosity determined in laboratory is 50% for the soft hematite and field determinations leaded to an effective porosity of 15%. The semi-confinement is due to the anisotropy of the permeability controlled by the ore banding and by the textural variation. The permeability of coarse hematite is about 3 m/day and the permeability of fine hematite is about 0.3 m/day. The electrical conductivity is about 10 mS/cm, the pH is about 5 to 6, the major anions are bicarbonate and cloride and the major cations are calcium and sodium.

The mine dewatering

In 1981 the water level of the Águas Claras Mine in the Cauê aquifer reached the altitude of 1,165 meters. From that date up till 1990, the drainage was done by open channels, while the mine was in flank. The hydrogeological studies to project the dewatering started in 1986 and recommended the previous dewatering through tubular deep wells. Drilling of the wells started in 1988 and, since that time up till 1999, a group of wells have been operating with a total average outflow of 73 l/s. In the beginning of the dewatering process the outflow was about 100 l/s to 150 l/s. After February 2000, the wells started to be closed and, by the end of 2000, the last one was closed.

Formation of the lake

The water for the formation of the lake comes from three main sources: surface water, rain water and groundwater. The most significant morphometric features of the lake are as follows:

Area: 0,67 km^2

Volume: 58 million m^3

Shoreline: 3772 m

Maximum depth: 234 m

It can be seen from the morphometric data that the future lake is characterized by a very high surface area to depth ratio. This can be conveniently expressed by the morphometric parameter known as *relative depth*. It is calculated dividing the maximum depth by the mean diameter of the lake, i.e. the diameter of a circle that has the same area as the lake. In the case of the Aguas Claras Lake the relative depth will be 25 %, which is actually a very high value. This means that the lake will have difficulties with performing complete vertical circulation. Such water bodies with partial circulation are called *meromitic*. Moreover the lake will be steep sided and well sheltered from winds. With regard to the water quality this meromitic condition means that the lake will have a permanent anaerobic layer at its bottom. Nevertheless the general water quality of the lake will be pretty good, since, due to its depth, the eventual phosphorus remobilization will not reach the euphotic zone (Cole, 1983). Hence eutrophication problems will probably not appear in Aguas Claras Lake. A summary of the main physical, chemical and biological processes and their influences on Aguas Claras Lake is given in Table 1.

Monitoring program

The monitoring program for the flooding of Aguas Claras Lake encompasses the main physical, chemical and biological parameters. The sampling frequency will be monthly.

The here presented monitoring program is able to identify eventual pollution problems and allows a very detailed assessment of the water quality of the lake. This project has a pioneer character in Brazil, since there is in this country no limnological information available about lakes deeper

Table 1.

Exposure to solar radiation	**Small area – 0.67 km2**
Assimilation capacity	High volume relationship Hypoliminion / Epiliminion
Hydrology	Precipitation higher than evaporation
Circulation pattern	Meromitic
Biological productivity	Low
Trophic degree	Oligotrophic
Hydrodynamics	Limited horizontal and vertical circulation
Silting	Controlled by a peripheric drainage system and by a slow filling rate
Water residence time	High
Recreational conditions	Very good

Table 2. Parameters of the monitoring programme

Water temperature	Ammonium nitrogen	Lead
Air temperature	Nitrate	Copper
Secchi depth	Soluble and total iron	Chrome
PH	Soluble and total manganese	Mercury
Dissolved oxygen	BOD	Zinc
Color	Chloride	Faecal coliforms
Turbidity	Sulfates	Fecal streptococci
Suspended, dissolved and total solids	Oil	Phytoplankton
Conductivity	Phenol	Zooplankton
Total alkalinity	Aluminum	Zoobenton
Total hardness	Arsenic	Chlorophyll *a*
Soluble and total phosphate	Cadmium	

than 200 m. The formation of the lake, besides being an environmentally sound technique for the rehabilitation of the area, leads to the creation of an extremely scenic water body.

Future uses of the lake

One of the most conspicuous issues in the environmental study of the lake formation is the destination of the future water body. Due to the prognosis of a very good water quality the possible uses of the lake will be directed to recreation (swimming, diving, sailing, fishing) and water supply. This latter use will have a remarkable topographic advantage, since the lake location (a pit formed in the mountains) will enable a water distribution by gravity.

Some learning points

The most important suggestion related with the filling of mining pits refers to the necessity of a deep knowledge about the physico-chemical and biological characteristics of the filling water. It is absolutely worthwhile developing a well structured monitoring program at the very beginning of the lake formation in order to guarantee the ecological quality of the future water body. Another significant issue is the clear determination of the possible uses of the lake as well as the kind of occupation that will be allowed in the drainage basin.

References

COLE, G., 1983, *Textbook of Limnology*. C.V. Mosby Company, Toronto, 401 p.

DORR, J. N., 1969. Physiographic, stratigraphic and structural development of the Quadrilátero Ferrífero, Minas Gerais, Brazil. *United States Geological Survey*, Professional paper, 641- A: 1-110.

GRANDCHAMP, C.A.P., BERTACHINI, A. C., SPERLING, E.v. & ALMEIDA, D.C. (2001) Aguas Claras Mine: a successful dewatering story, *International Mine Water Association Symposium,* Belo Horizonte, Brazil, Electronical Proceedings, IMWA.

E VON SPERLING, Federal University of Minas Gerais, Brazil.

CAP GRANDCAMP, MBR (Mineracoes Brasileiras Reunidas), Basil.