ACID ROCK DRAINAGE IN THE URANIUM MINING AND MILLING SITE OF POÇOS DE CALDAS, BRAZIL — DURATION ASSESSMENT, POLLUTANT GENERATION MODELLING AND REMEDIATION STRATEGIES

H.M. FERNANDES, M.R. FRANKLIN
Instituto de Radioproteção e Dosimetria, Rio de Janeiro, Brazil

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1. SCOPE OF THE WORK

Acid rock generation is a serious problem in many mining sites all around the world and is the major environmental issue at the uranium mining and milling facilities of Poços de Caldas - Brazil (see Table I). The chemical treatment of the generated acid drainage imposes high annual expenditures to the mine operator. As a result of this problem, the objective of this work was to examine the problem of acid rock drainage generation in detail in order to assess the duration of the problem; to predict the typical concentrations of pollutants to be expected in the drainage in the long term; to propose remediations to be implemented based on cost x effectiveness analysis; and indicate possible future studies to be carried out.

TABLE I: CHEMICAL COMPOSITION OF WRP - 4 DRAINAGE

Parameter	Average	Minimum Value	Maximum Value
^{226}Ra ($Bq.L^{-1}$)	0.29	0.14	0.58
^{238}U ($Bq.L^{-1}$)	175	71	315
Al ($mg.L^{-1}$)	96	61	161
F ($mg.L^{-1}$)	99	5.1	167
Mn ($mg.L^{-1}$)	75	6.6	105
pH	3.3	2.9	3.7

2. STUDY AREA

The uranium mine and mill site is located at the Poços de Caldas plateau, southeast region of Brazil. The uranium enrichment in Poços de Caldas mine is related to hydrothermal events (primary mineralisation) and to latter weathering processes (secondary mineralisation). The mining and milling facilities began commercial operation in 1982. However, the original intended production of 500 $ton_{(U308)}$ /a was never reached. As of 1995, 1,172 tons of U_30_8 were produced. This amount corresponds to a uranium concentration in the range of 675 - 1,700 $mg.kg^{-1}$. In the development of the mine 44.8 x 10^6 m^3 of rock were removed. From this amount, 10 million ton were used as building material. The rest was disposed off into two major rock piles, waste rock pile 8 (WRP-8) and 4 (WRP-4). Presently acid waters are being collected and neutralised, the solid material being disposed off in the tailings dam.

3. METHODS AND RESULTS

Three different approaches to deal with the understanding and predictions of the process duration as well as the concentrations to be expected in the drainage were used. The first one - mass balance calculations - depended on a large extent in the availability of monitoring data and information about the waste rock composition. The second strategy (column leaching experiments) was addressed to check some possible heterogeneity of the material and to compare the obtained results - specially the intrinsic oxidation rate - with the results coming from calculations where monitoring data were used. The third one - geochemical modelling - allowed for the prediction of equilibrium pollutant concentrations in the drainage.

It has been demonstrated that acid drainage generation at the study site is a long-term problem. A very good agreement of the results coming up from the three approaches was obtained. The intrinsic oxidation rate related to the material deposited in the dump can be represented by a value in the range of $1.0 - 6.0 \times 10^{-9}$ $kg(O_2)m^{-3}s^{-1}$. The time for the consumption of all pyritic material will be long enough - hundreds of years - to justify the implementation of permanent solutions. These should be directed to the reduction of the oxygen diffusion into the dump. This may be attained by covering the dump with some sort of material - e.g. clay or compacted clay that shows lower coefficient of diffusion than that of the rocks forming the dump. The costs related to this strategy amounted US$ 5.0 million for each waste rock pile. In respect to drainage geochemistry it has been demonstrated that ^{226}Ra co-precipitation with $BaSO_4$ accounts for the disequilibrium in relation to uranium isotopes (238 and 234) and this is a favourable process to reduce the emissions of this harmful radionuclide to the environment. The geochemical modelling has shown that pyrite oxidation is mostly supported by oxygen diffusion being the oxidation process promoted by Fe^{3+} of minor importance. The obtained results agreed fairly well with data from the monitoring programme (see Table II). Future works should be directed towards a better understanding of the real infiltration rates applicable to the study case and the knowledge of oxygen distribution in the dump. These may be achieved by means of the installation of lysimeters (work already being undertaken) and installation of oxygen probes in the dump to measure oxygen concentration at different depths in the dump. As a result efforts shall be directed to the development of computational codes that can account for these aspects.

TABLE II: ESTIMATED CONCENTRATIONS x OBSERVED CONCENTRATIONS OF CHEMICAL SPECIES IN THE WRP-4 DRAINAGE

Chemical Species	Estimated Concentration ($mg.L^{-1}$)	Observed Concentration ($mg.L^{-1}$)
SO_4	943	1010
Al	53	96
Fe	340	--
SiO_2	25	--
K^+	63	--
pH	4.34	3.30

An alternative strategy to deal with the problem would be the economical recovery of uranium present in the acid drainage. If the uranium average concentration in the drainage (of about 10 mg/L) is taken into consideration, its economical recovery may be thought about. This strategy will imply in the recovery of 30 tons U_3O_8 per year - representing 30% of the mean annual production of the installation. The recovery would include the use of ion-exchange resins. The technical and economical viability of the strategy as well as technical and economical issues concerning the application of a dry cover to the waste rock piles will be presented and discussed in detail.

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