

Hydrochemical and isotopic evidences of discharge of acid effluents from a uranium mine in a river basin.

C. A. de Carvalho Filho^{1*}, R. M. Moreira¹, V. V. M. Ferreira¹, P. H. Dutra¹, A. F. G. Oliveira¹, O. E. A. Branco²

¹ Centre for Development of Nuclear Technology (CDTN/CNEN), 31270-901, Belo Horizonte, Brazil

² Universidade Federal de Juiz de Fora, 36036-330 Juiz de Fora-MG, Brazil

* cacf@cdtn.br

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The uranium mining and milling facilities of Caldas, located at Poços das Caldas Plateau in southeastern Brazil, are in the process of decommissioning. The main environmental problem of this site is the generation of acid mine drainage (AMD) (Fernandes and Franklin, 2001). This work presents a hydrochemical and isotopic study aiming at characterizing the AMD, originated at the tailings dam and at the waste rock pile 4, which ends reaching the drainage basin downstream the Caldas mining. This basin is formed by three small watercourses that belong to the Verde River watershed: Consulta Brook, Soberbo Creek and Taquari River (Figure 1).

Twelve sampling stations were established in order to carry out the investigation (Figure 1). Two of them were located at effluent ponds: A2-25 at the exit of the settling pond, which receives the effluent from the tailing dam, and A1-75, inside the Nestor Figueiredo pond (BNF), which collects the acidic mine water. Sampling was in the rainy and dry seasons of 2010 and 2011.

The Piper diagram in Figure 2 shows that the water at stations upstream the uranium mining and milling facilities (A1-2, A2-9, A3-5, and A3-1) are sodium-potassium bicarbonate type, which corresponds to the natural or geogenic ionic composition of the respective watercourses. Stations A1-75 and A2-25 show an ionic composition corresponding to calcium-sulfate waters type, which demonstrates the influence of the discharge of effluents.

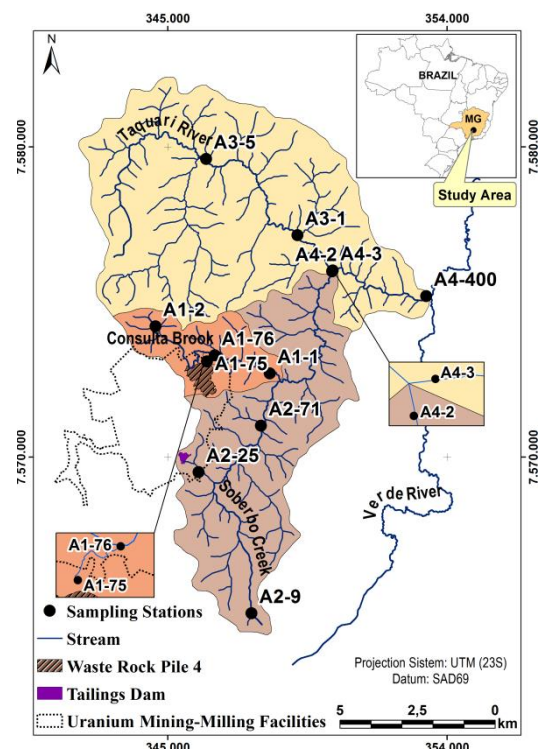


Figure 1. Location of the study area: drainage basins and sampling stations.

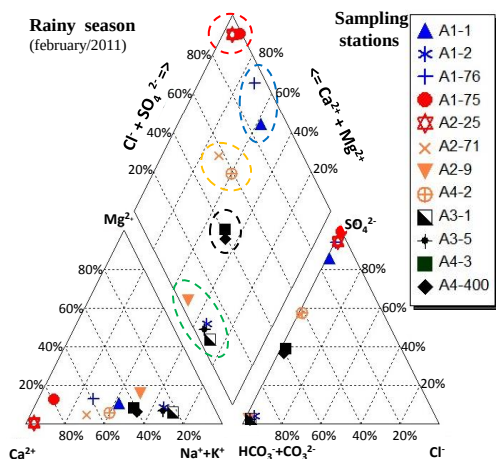


Figure 2. Piper diagram of water samples.

It can be seen in Figure 2 that the natural sodium-bicarbonate waters, upstream the facilities, are converted to the calcium-sulfate type immediately downstream the effluent discharge stations (A1-75 and A2-25). However, these waters are progressively restored to their former condition as they move away from the discharge stations, indicating a natural attenuation process.

Particularly in the Consulta Brook, the water analysis show contamination by F, Cd, U, Zn, Al,

Mn and acidity (pH lower than 6), along with a pronounced increase in Ca, SO₄, Mg, Pb, As, ²³⁸U, ²²⁶Ra, ²³²Th and ²²⁸Ra. This was probably due to the discharges of the acid effluent from the BNF pond. For the Soberbo Creek the effluents from the settling pond (A2-25) caused enrichment in Ca, F, SO₄ and Mo, downstream its point of discharging (A2-71). An example of the impact pattern due to some selected chemical species, F, U, As, SO₄ and pH is shown in Figure 3.

Figure 4 presents results related to stable isotopes, $\delta^{18}\text{O}$ and $\delta^2\text{H}$, in surface waters and in effluents collected in September-2011 (Carvalho Filho, 2014), together with historical local water isotopic data (Nordstrom et al., 1990). This figure indicates that: (1) the effluent from the BNF pond (A2-25) presents a typical isotopic composition of evaporated waters (plots below the GMWL); (2) the surface water samples have isotopic signatures similar to shallow groundwater. These samples are more enriched in the heavy isotopes (²H and ¹⁸O) than the deep groundwater of the Caldas mine and of the Morro do Ferro anomaly; (3) the effluent at station A1-75 presents an isotopic signature value between those of deep groundwater and surface water.

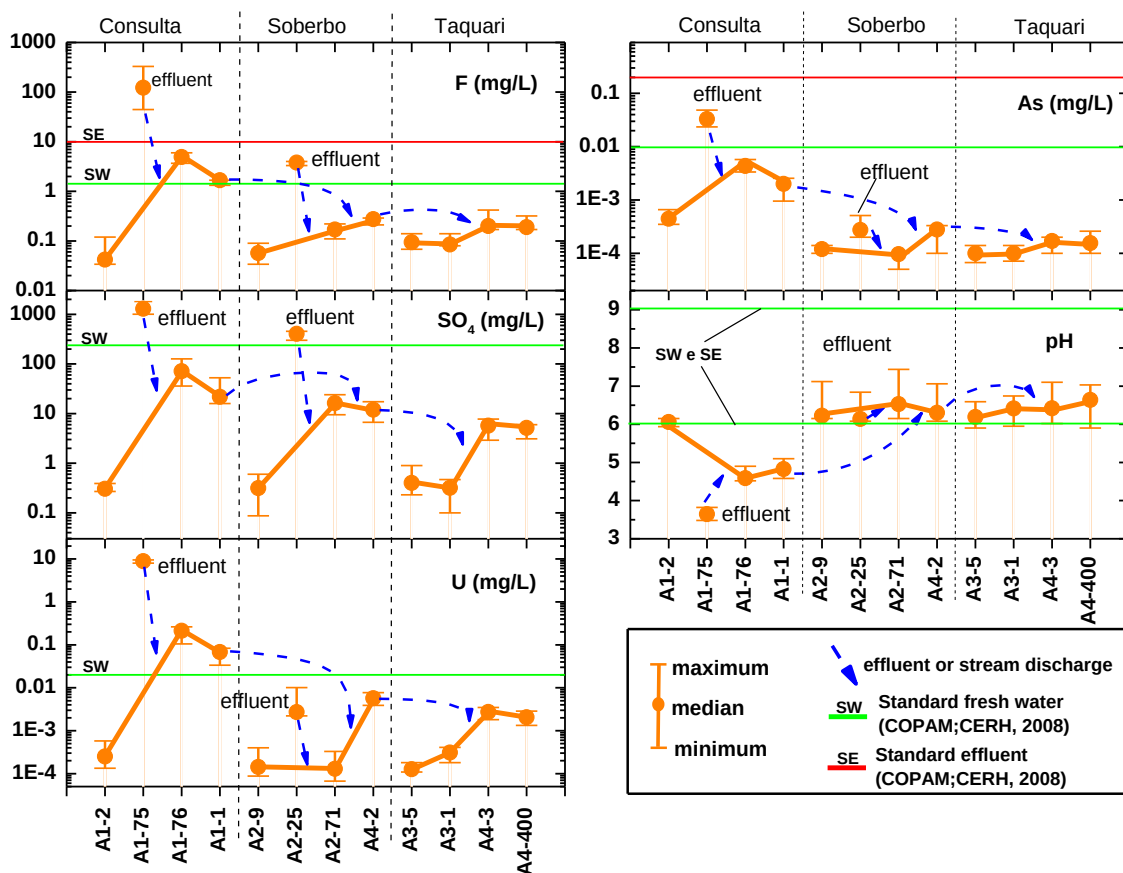


Figure 3. Spatial distribution of pH and selected chemical species (Carvalho Filho, 2014).

Briefly, the variation of $\delta^{18}\text{O}$ and $\delta^2\text{H}$ values along the watercourses (Figure 4) mainly suggests that: i) discharges from the BNF pond (A1-75) promoted a depletion of $\delta^2\text{H}$ and $\delta^{18}\text{O}$ in the water downstream the discharge point (from A1-2 to A1-76); ii) the effluent from the tailings pond (A2-25) has enriched the heavy isotope composition of the waters downstream its discharge, (as measured at station A2-71).

The results showed some evidence that the acid effluents arising from the mining facilities

caused interference in the composition of downstream waters, especially in the Consulta brook. Stable isotopes have proved to be effective as natural tracers of effluent discharges from the ponds to the watercourses downstream. Further studies of the groundwater at the study area should be carried out in order to assess the need to improve the mitigating actions such as inserting liners or barriers downstream the discharges. Presently, the mining company is already undertaking some remediation actions.

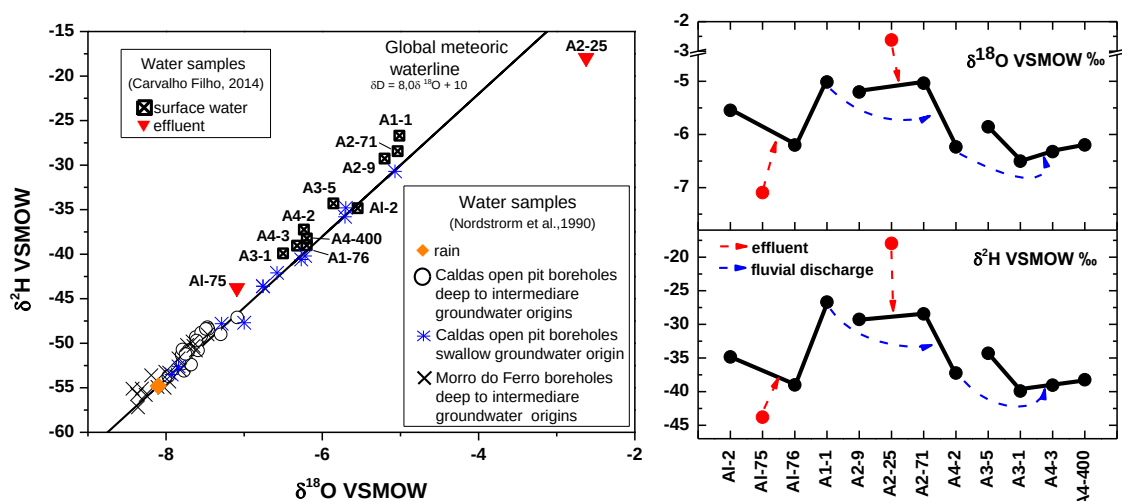


Figure 4. Stable isotopes ($\delta^2\text{H}$ and $\delta^{18}\text{O}$) composition of the water and effluent samples from the several sampling station (Left). $\delta^{18}\text{O}$ and $\delta^2\text{H}$ values along the watercourses (Right). VSMOW – Vienna Standard Mean Ocean Water.

References

- Carvalho Filho, C. A. (2014). PhD Thesis, – CDTN/CNEN, Belo Horizonte.
- COPAM/CERH. (2008) Deliberação normativa COPAM/CERH nº 1 de maio de 2008. Minas Gerais, Belo Horizonte.
- Fernandes, H. M.; Franklin, M. R. (2001). Journal of Environmental Radioactivity 54:5–25.
- Nordstrom, D. K.; Smellie, J. A. T.; Wolf, M. (1990). SKB Technical report, Stockholm

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