

Environmental impact evaluation of metals in sediments from the Doce River Basin, Brazil

C. V. A. Santolin¹, V. S. T. Ciminelli², C. C. Nascentes¹, C. C. Windmüller¹

¹ Department of Chemistry, Universidade Federal de Minas Gerais (UFMG), 31270-901 - Belo Horizonte, MG, Brazil

² Department of Metallurgical and Materials Engineering, Universidade Federal de Minas Gerais (UFMG), 31270-901 - Belo Horizonte, MG, Brazil.

*claucw@netuno.lcc.ufmg.br

Keywords: sediments; metals; Rio Doce Basin

The Doce River Basin (DRB) is located in the southeastern region of Brazil, and is home to the largest steel complex in Latin America, including the largest open pit mining industry in the world. Several economic activities are performed along the DRB, including mining, agriculture and food industry activities. The mining activities involve the exploration of a range of minerals and gold on a smaller scale. The quality of water in the basin has been monitored since 1997 by the state agency for environmental control; however, there are no reports about metals in sediments of the basin. There is insufficient information for an assessment of metal distribution in the DRB, especially for the most toxic metals, such as mercury. We have quantified Al, Cr, Co, Cu, Fe, Hg, Mn, Pb and Zn levels and the physico-chemical parameters in sediment from the basin and statistically analyzed these variables. The results have also been discussed using the geoaccumulation index (I_{geo}) and enrichment factor (EF), which contributes to the knowledge of the metal geochemistry in this basin.

Sediment samples were collected from 19 sites selected in the basin in October 2011 by the State Institute of Water Management (IGAM), as shown in Figure 1. The points were chosen because of their classification as having poor water quality according to water monitoring report from IGAM.

The concentrations of total metals were performed employing a fast sequential flame atomic absorption spectrometer (FS-FAAS) Varian AA240FS, with the conditions specified for each element. Cobalt and lead were quantified by inductively coupled plasma optical emission spectrometry (ICP-OES), using a Perkin Elmer Optima 8000 instrument and the determination of total Hg was performed using a direct mercury analyzer (DMA-80, Milestone).

Geoaccumulation Index (I_{geo})

The I_{geo} index was established as a ratio between the local metal concentrations in sediments and a reference value taken as the standard or a background value:

$$I_{geo} = \log_2 C_m$$

$$1.5 \times C_{bg} \quad \text{where:}$$

C_m = measured concentration of metal M in the sediment;

C_{bg} = concentration taken as background (values from Costa et al., 2003) to the metal M;

1.5 = factor that minimizes the possible variations of the background values determined for the metal in the environment, as well as small anthropogenic influences.

Seven classes make up the I_{geo}, ranging from unpolluted to extremely polluted, which corresponds to a 100-fold enrichment relative to the value of the postulated background.

Enrichment Factor (EF)

The EF is the element concentration ratio in the sediment and its natural background concentration (Equation 2). In the case of EF, a reference element concentration, treated as the normalizer (element whose source must be natural and whose concentration should not vary greatly) is inserted in the calculation to balance the mineralogical variations in sediment (Qi et al., 2010).

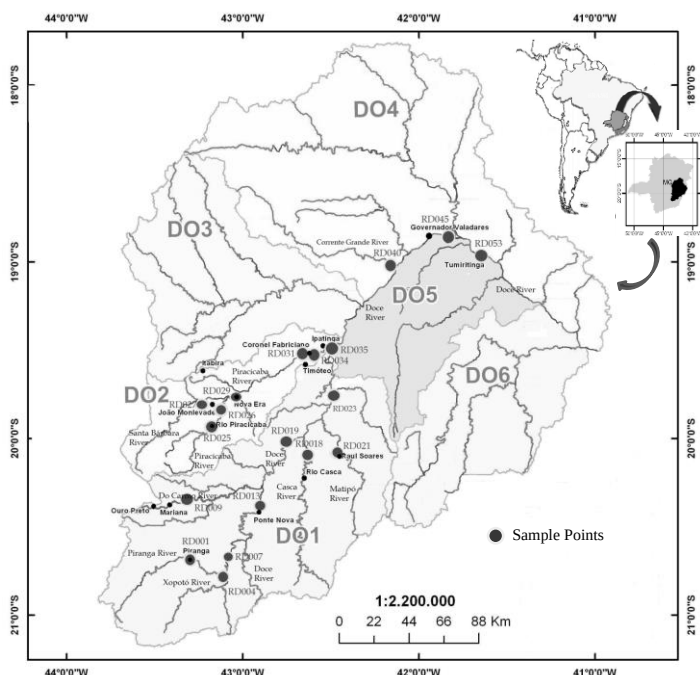


Figure 1. Doce River Basin map and collection sites.

$$EF = (M_{sed}/R_{sed}) / (M_{bg}/R_{bg})$$

Equation 2

where

M_{sed} = measured concentration of metal M in the sediment;

R_{sed} = concentration of R normalizing element, which is one whose source must be natural and whose concentration should not vary greatly in the sediment;

M_{bg} = concentration taken as background to the metal M;

R_{bg} = background concentration assumed as the R normalizing element.

The normalization technique is used to distinguish the natural variability of metals from the variability associated with the accumulation in the sediments due to anthropogenic activities. Normalization of sediment for trace metals can use the concentration of elements such as Al, Fe, Li, and Y, among others, in addition to parameters such as organic matter and particle size.

The sediment analyses revealed that 15% of DRB samples were above the Canadian Sediment Quality Guidelines (CCME, 1999) TEL for Hg, 100% for Cr, 53% for Cu, 21% for Zn and 21% for Pb. Together, these results are equivalent to a total violation of 41%, related to the SQG, for the DRB sediments. The classification using geochemical standards of quality of the collection points of the DRB as to the origin of the

metals analyzed revealed that sites RD001, RD009, RD025, RD029, RD031, RD034 and RD035 were considered contaminated because of their Igeo and EF values.

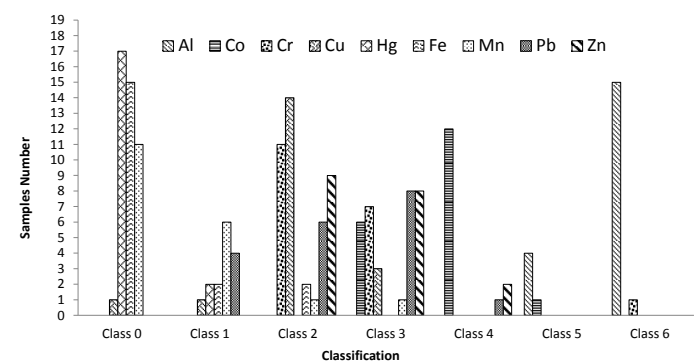


Figure 2. Histogram Geoaccumulation Index.

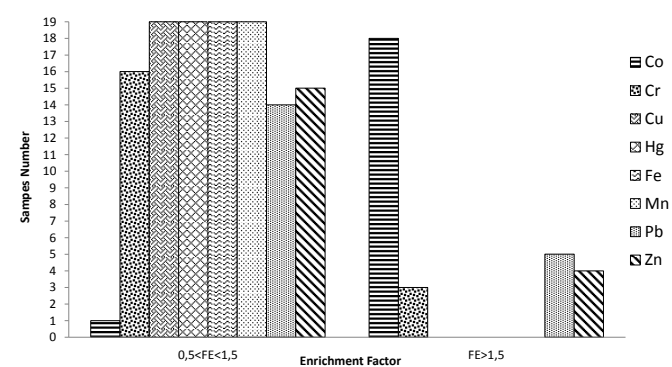


Figure 3. Enrichment factor histogram.

When compared to the results obtained by analyzing the SQG, it can be concluded that these sites are the most impacted in the DRB, probably because of anthropogenic activity. The results indicated that it is important a quality monitoring program of sediments, and also studies of speciation and mobility of these metals in this basin in order to better understand the geochemistry of possible contaminants and also propose mitigation ways when necessary.

Acknowledgements

This study was supported by CNPq, FAPEMIG (project APQ 03861-09).

References

Santolin C.V.A., Ciminelli V.S.T., Nascentes C.C. and Windmöller, C.C. 2015. Environmental Earth Sciences, v. 74, p. 1235-1248.

Qi S., Leipe T., Rueckert P., Di Z., Harff J. 2010. Journal of Marine Systems, v. 82, p. S28-S42.

CCME. 1999. Canadian Sediment Quality Guidelines for the Protection of Aquatic Life. Canadian Environmental Quality Guideline. Winnipeg: Canadian Council of Ministers of the Environment.