Irrigation and water quality of the Doce river after the Fundão Dam failure

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ABSTRACT

The Fundão dam collapse occurred in November 5th, 2015 resulted in iron ore tailings extravasation and promoted changes in water quality, temporarily restricting the uses of water at the Doce River in the states of Minas Gerais and Espírito Santo, Brazil.

This work aims to assess a possible causation between the disruption and temporal changes in water quality parameters with focus on irrigation use during the dry season (April to September), from Risoleta Neves HydroPower Plant to the mouth of the Doce River in the Atlantic Ocean.

Data from after the event, about water use licenses were analyzed. It was identified an increasing gradient in licenses obtained from upstream to downstream, with a greater number at Espírito Santo state. The water quality standards reveal 6.8% of non-conformities before the event, increasing to 7.1% of extrapolations in the samples taken post dam failure.

For water quality, the Brazilian standards (Conama Resolution 357/05, class 2) were analyzed, based on the sampling network monitored by institutions, applying statistical tests to compare the standards required for irrigation. Data obtained in the dry season were used for the pre failure (2010 to 2015) and post failure (2016 to 2019) periods.

The impact was more prominent in the region closest to the event, especially in the first year (2016), with subsequent general return to pre failure conditions. It is considered that the irrigation activity, in terms of water quality, is not compromised by the impacts caused by the rupture of the dam.

INTRODUCTION

On November 5, 2015, the tailings dam at Fundão mining, in the municipality of Mariana, state of Minas Gerais (MG), broke down, releasing about 39.2 Mi m3 of tailings in the river system.

This material reached the Santarém stream and the Gualaxo do Norte river, a tributary of the Carmo river, which flows into the upper Doce river. A large volume of tailings was retained in the reservoir of the Risoleta Neves Hydroelectric Power Plant (UHE Candonga), while part of it passed through this dam and followed the Doce River as a solid cargo to the Atlantic Ocean, in Linhares (ES). As a result, water quality has been altered, restricting the various uses of the Rio Doce for multiple purposes, including irrigation.

This work aims to evaluate the causal relationship between the rupture of the dam and the water quality parameters of the Doce River associated with irrigation.

METODOLOGY

A segmentation of the Doce River was adopted in four regions, separated by hydroelectric plants (Figure 1):

- Region 1: covers from the rivers that form the Doce River to the dam of UHE Candonga.
- Region 2: downstream of HPP Candonga to the dam of HPP Baguari.
- Region 3: downstream from HPP Baguari to HPP Aimorés.
- Region 4: goes from HPP Aimorés to the mouth of the Rio Doce.

To characterize the water quality, monitoring data from the Minas Gerais Water Management Institute - IGAM, Quantitative Qualitative Monitoring Program - PMQQS from the Renova Foundation, State Agency for Water Resources - AGERH and State Institute of the Environment of Espírito Santo - were used - IEMA.

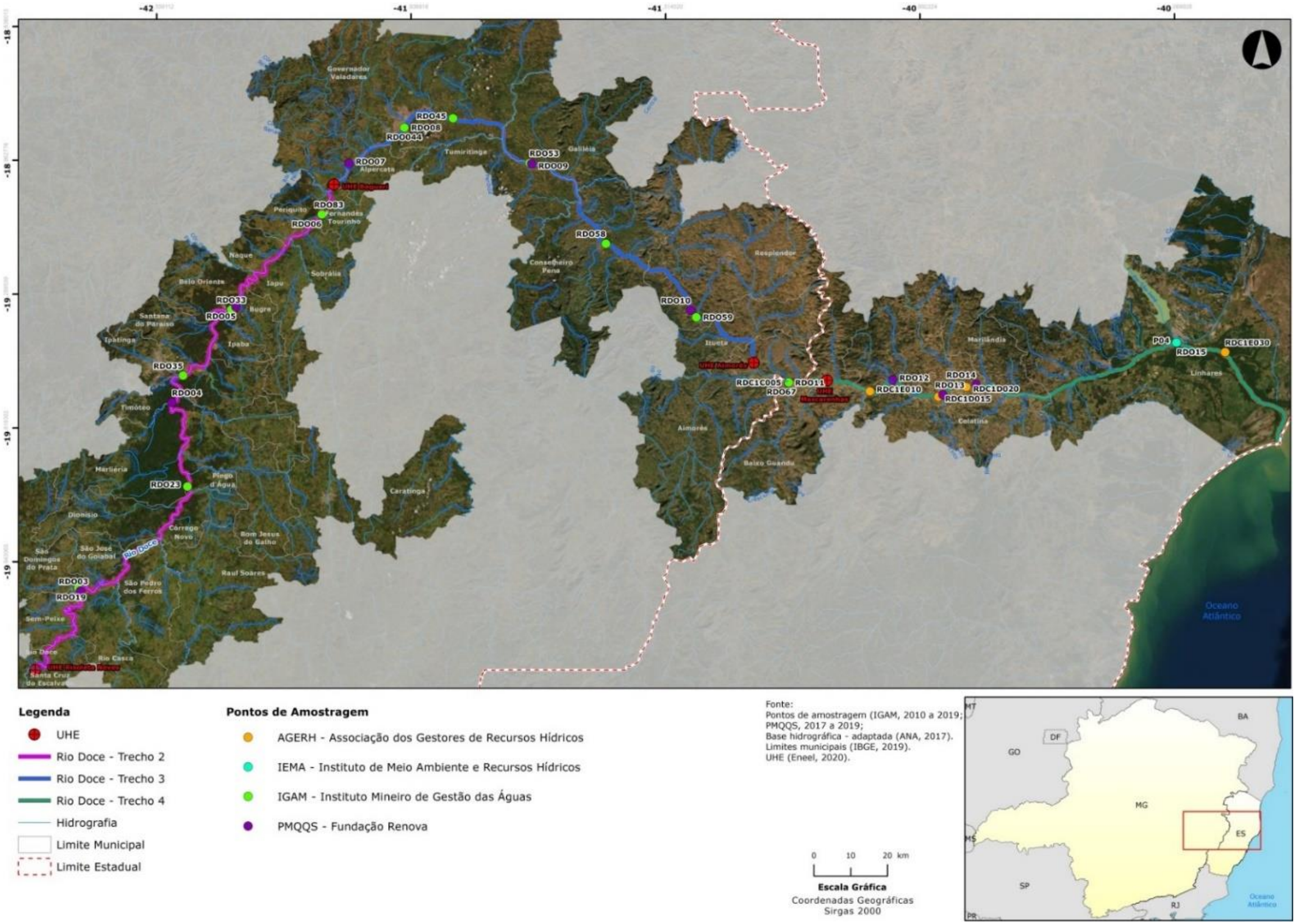


Figure 1 – Sampling network for water quality by region of the Doce River.

Source: Authors based on data from PMQQS, IGAM, AGERH and IEMA, 2020

The irrigation grants issued by the National Water and Basic Sanitation Agency - ANA, with validity equal to or after 11/05/2015, were analyzed in two periods: pre-breaking (2010 to 2015) and post-breaking (2016 to 2019). As irrigation is intrinsic to the drought period, water quality data between April and September, which characterize the drought in the region, were evaluated.

The data were compared to the limits of the current legislation and the percentages of non-conformities were determined. For non-conforming parameters and electrical conductivity, the Mann-Whitney test was performed to compare the pre and post-rupture periods. The Toxic Contamination Index (TC), adapted from IGAM (2020), was applied to 12 parameters.

RESULTS

In the period evaluated, Rio Doce had 343 grants, the majority (202) in Minas Gerais. Irrigation was the purpose of most concessions (36%) and the third in terms of volume granted, after industry, the main user of the waters of the Doce River, and sanitary sewage.

In Region 2, the main irrigated crops are grass and corn. In Region 3, the main irrigated crops are grasses and pastures. In Region 4, the main irrigated crops are coffee and cocoa.

Thus, changes in water quality that result in the possibility of pipe clogging (related to the increase in the concentration of solids in the water), can cause damage to the irrigation activity. However, as the cultivation of vegetables and raw vegetables consumed does not prevail in irrigated agriculture in the region, health indicators of water quality, such as thermotolerant coliforms, are not limiting for irrigation.

In the period before the dam broke, there were 15 parameters with at least one non-compliance, which represents 6.8% of the total samples before the event. After rupture, 17 non-compliant parameters were identified, representing 7.1% of the samples (Figure 2). For both situations, E. coli, a parameter associated with sanitation, was responsible for the highest number of non-conformities in the three regions evaluated.

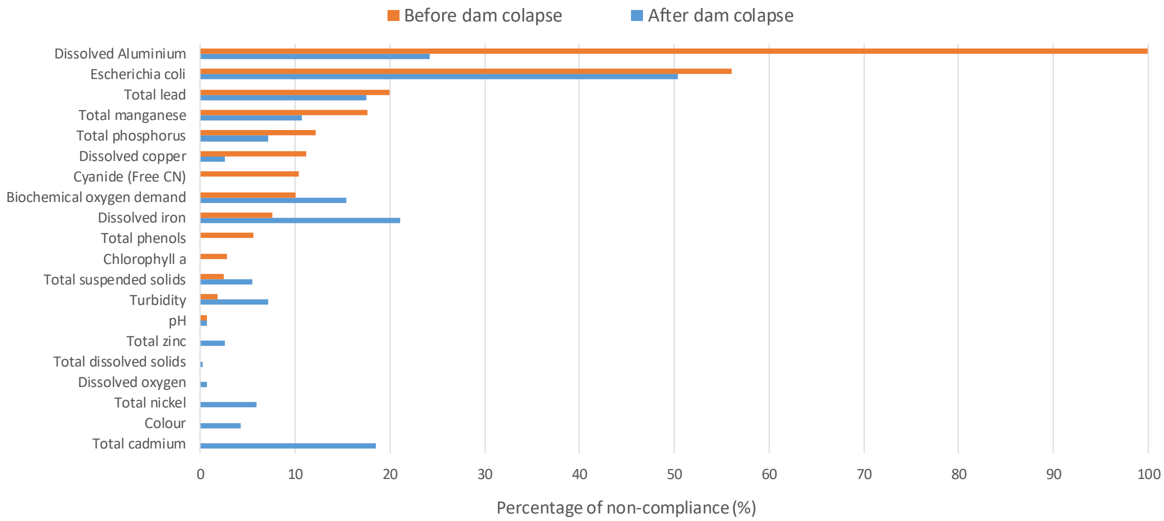
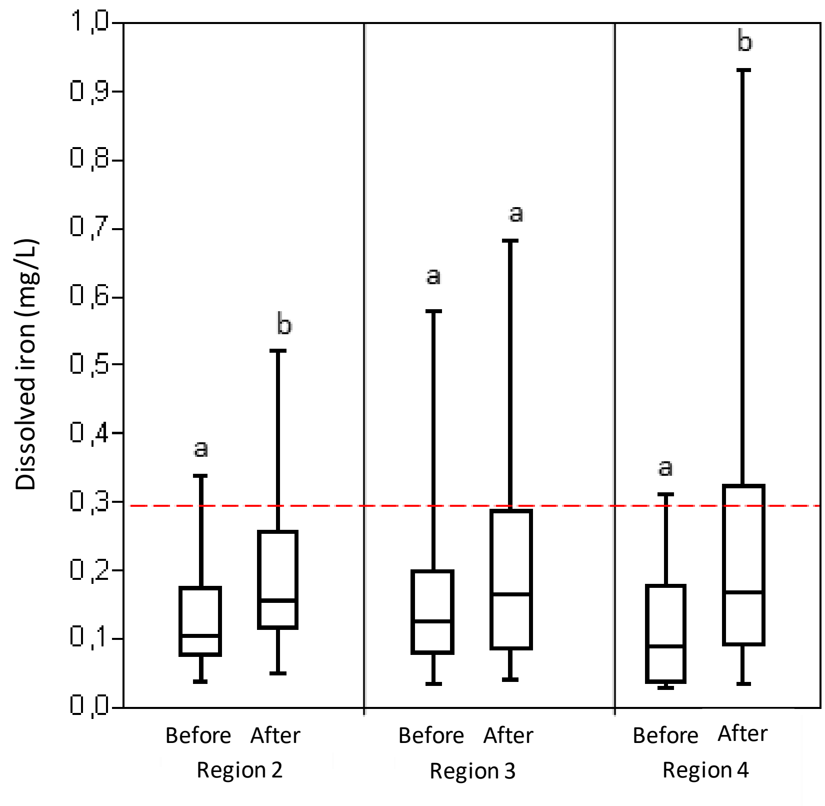


Figure 2 - Percentage of non-conformities by parameter in the pre-breaking (2010-2015) and post-breaking (2016-2019) drought period.

Source: Authors based on data from PMQQS, IGAM, AGERH and IEMA, 2020

The temporal variations suggest a causal link due to the increase in the concentrations of dissolved iron in Region 2, since the increase was statistically significant after the rupture. However, this parameter did not affect the water quality for irrigation, as the maximum concentration median (0.169 mg / L) remained below the class 2 limit, although pulses that exceeded this pattern were identified in the evaluated regions (Figure 3).

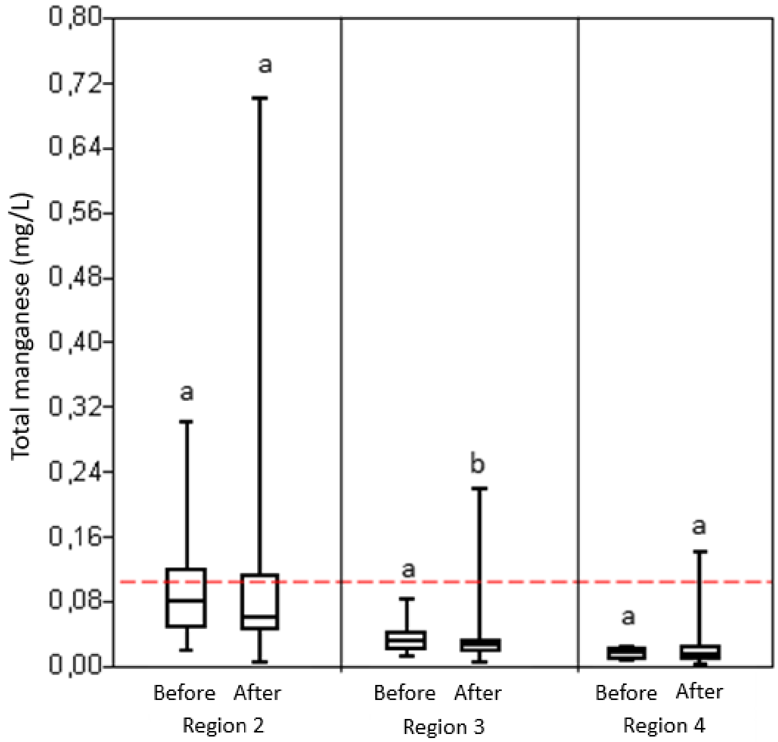


Legend: red line = maximum allowed value for freshwater class 2.

Figure 3 - Iron dissolved in the pre-rupture (2010-2015) and post-rupture (2016-2019) drought period

Source: Authors based on data from PMQQS, IGAM, AGERH and IEMA, 2020

In relation to total manganese, for which non-conformities were already recorded in the period prior to the rupture, there is a higher peak in 2016 in Region 2, reaching 0.7 mg / L, and a reduction in concentration in later years. However, the median of post-rupture values (0.063 mg / L) was not significantly different from that obtained in pre-rupture in this region, remaining below the limit for freshwater class 2 (Figure 4).

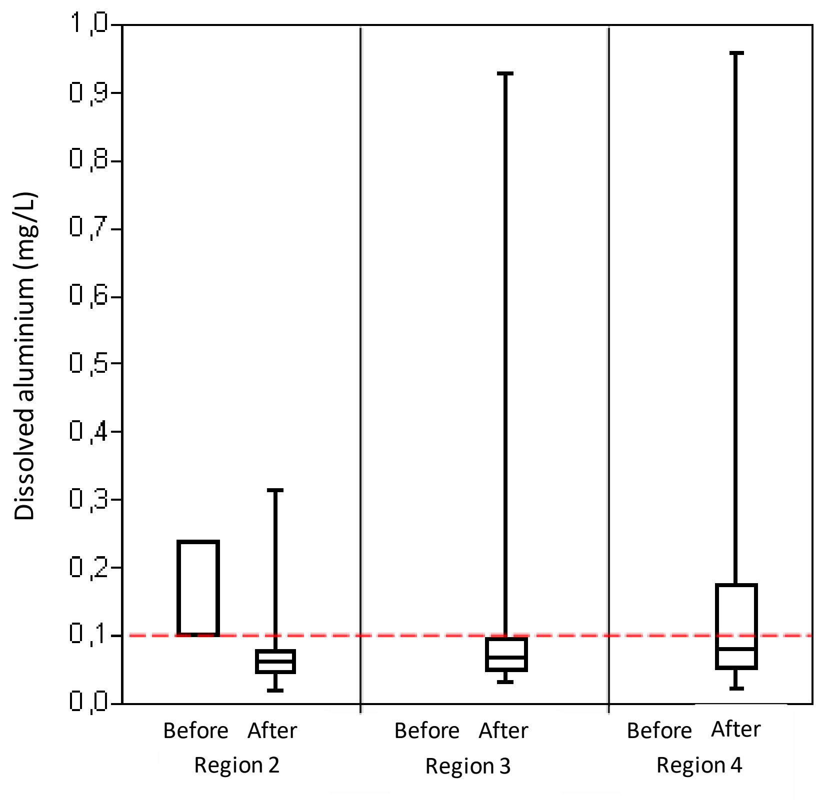


Legend: red line = maximum allowed value for freshwater class 2.

Figure 4 - Total manganese in the pre-breaking (2010-2015) and post-breaking (2016-2019) drought period.

Source: Authors based on data from PMQQS, IGAM, AGERH and IEMA, 2020

For dissolved aluminum, there are no data for the pre-rupture period for Regions 3 and 4 and, for Region 2, there was a decrease in the post-rupture period, therefore, no causal link with the rupture was identified (Figure 5). Possible peaks of concentration in Regions 3 and 4 are not an impediment to irrigation, in view of the high natural availability of aluminum in the region's soils.



Legend: red line = maximum allowed value for freshwater class 2.

Figure 5 - Aluminum dissolved in the pre-breaking (2010-2015) and post-breaking (2016-2019) drought period.

Source: Authors based on data from PMQQS, IGAM, AGERH and IEMA, 2020

The variations in electrical conductivity and dissolved solids, parameters associated with the potential for soil salinization, indicate a causal link due to the increase in the values of these parameters after the rupture, with a peak in the three regions in 2017 and subsequent decay, however, without restricting the use water for irrigation.

According to Almeida (2010), the usual variation in conductivity for irrigation sources is from 0 µS / cm to 3,000 µS / cm. In monitoring, greater electrical conductivity was recorded in Region 4, in the pre-breaking period (490 µS / cm), an adequate value for irrigation (Figure 6).

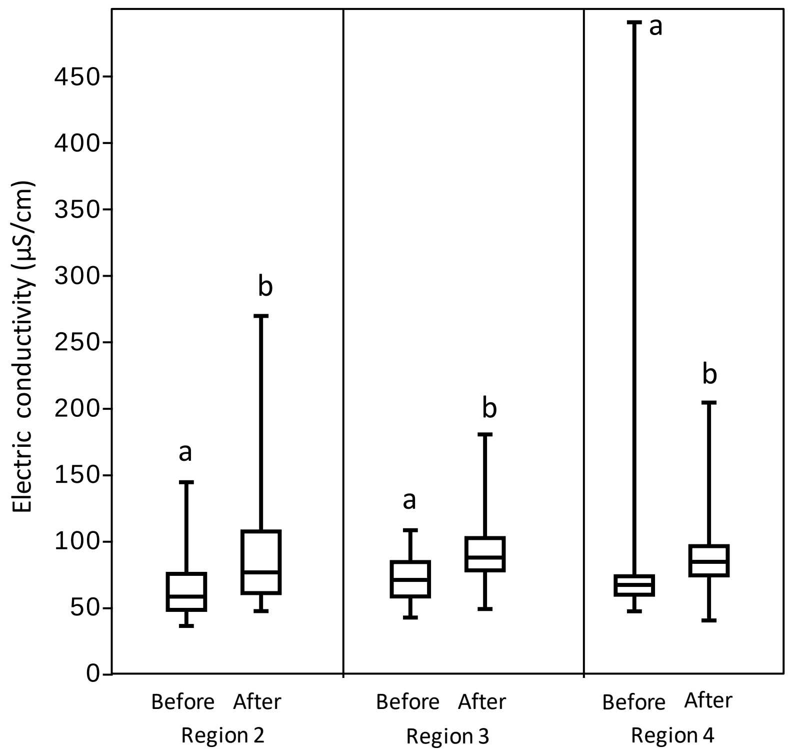
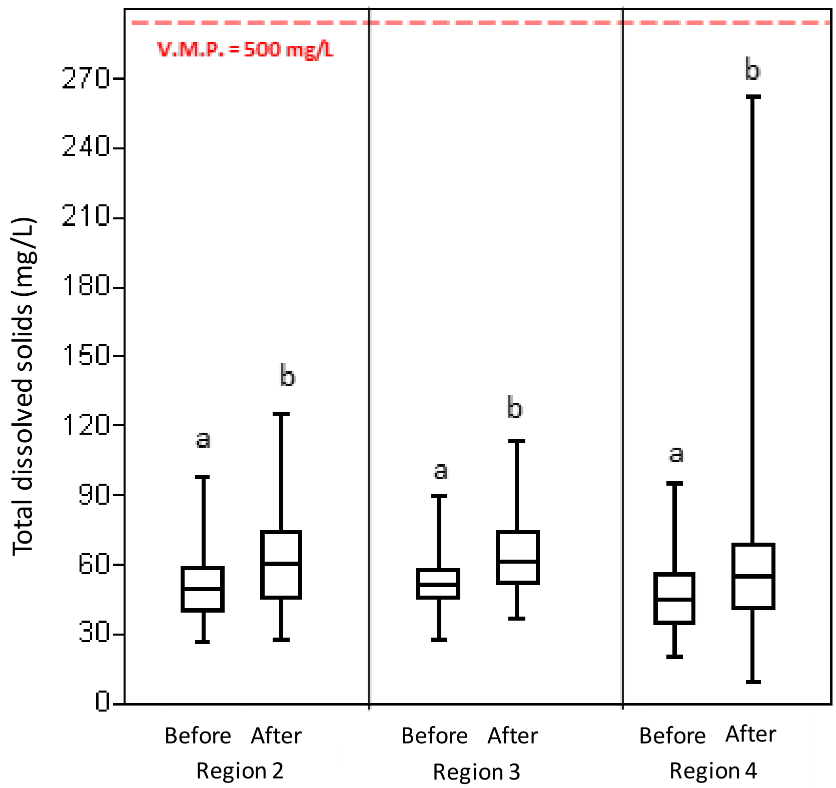


Figure 6 - Electrical conductivity in the pre-break (2010-2015) and post-break (2016-2019) drought period.

Source: Authors based on data from PMQQS, IGAM, AGERH and IEMA, 2020

The total dissolved solids met the legal criteria before and after the dam burst. However, in the post-rupture period, the results were significantly higher in all regions, with a maximum of 262 mg / L in Region 4 (Figure 7).

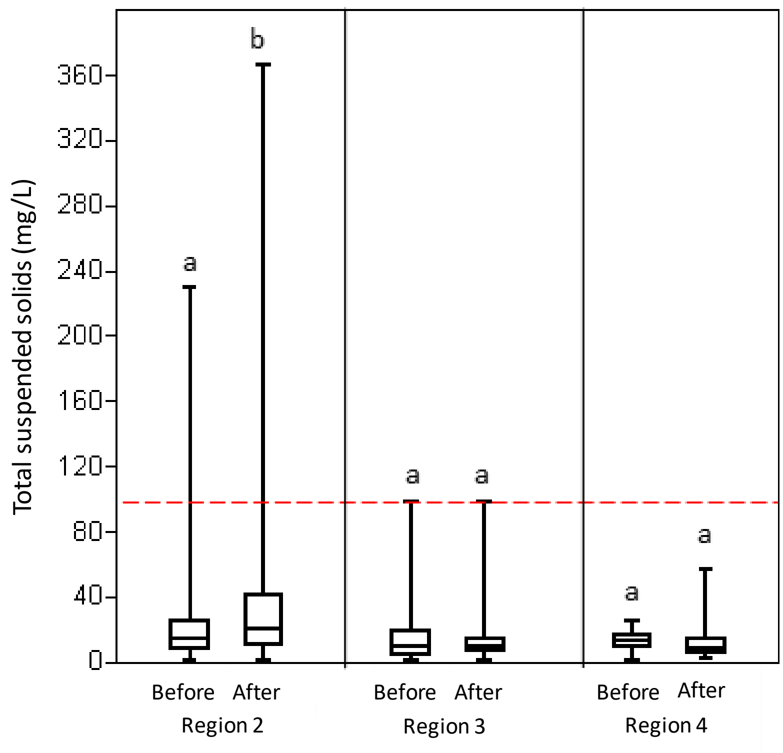


Legend: red line = maximum allowed value for freshwater class 2.

Figure 7 - Total dissolved solids in the pre-breaking (2010-2015) and post-breaking (2016-2019) drought period.

Source: Authors based on data from PMQQS, IGAM, AGERH and IEMA, 2020

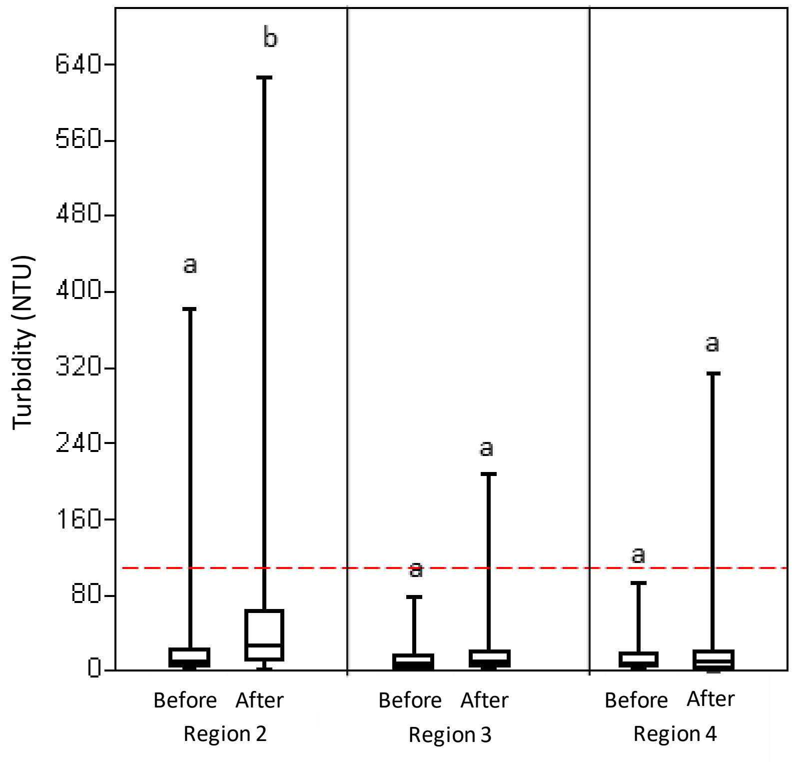
A similar condition was detected in relation to total suspended solids and turbidity, which showed a significantly higher result after the rupture, with pulses verified in 2016, in Region 2, indicating a causal nexus with this event. However, the concentrations were reduced in the following years and the medians remained below the limit of the legislation in the different periods and regions evaluated, indicating the possibility of use for irrigation (Figures 8 and 9).



Legend: red line = maximum allowed value for freshwater class 2.

Figure 8 - Total suspended solids in the pre-breaking (2010-2015) and post-breaking (2016-2019) drought period.

Source: Authors based on data from PMQQS, IGAM, AGERH and IEMA, 2020



Legend: red line = maximum allowed value for freshwater class 2.

Figure 9 - Turbidity in the pre-breaking (2010-2015) and post-breaking (2016-2019) drought period.

Source: Authors based on data from PMQQS, IGAM, AGERH and IEMA, 2020

The Escherichia coli index, the parameter with the highest number of non-conformities, is associated with fecal loads, attributed mainly to the release of untreated domestic effluents and animal waste in pasture areas. There was an increase in faecal contamination right after the rupture, in 2016, in the three regions, but a decrease was detected in later years.

Phosphorus showed non-conformities in the three regions, both in the pre- and post-rupture period. In 2016, the high phosphorus content obtained in Regions 2 and 3 may be associated with the rupture of the dam, since part of the marginal vegetation and soils were dragged to the Doce River channel with the passage of the tailings. However, considering that the values did not exceed, on average, the levels determined for class 2 fresh water and that this element is not a restriction factor for irrigation, this change does not compromise the use of water for agriculture.

Libânio (2020) found similar patterns for the parameters E. coli and total phosphorus, in the study of the quality of the waters of the Doce River in the dry period (2018-2019).

The parameters that make up the Toxic Contamination Index (TC) show that Rio Doce had predominantly the Very Low classification in the pre-break period, a condition also maintained in the post-break period. In the period prior to the rupture, there was a unique situation of Low contamination in Region 2 and an Average situation in Region 3, due to non-conformities of free cyanide and copper, respectively, at a sampling point in each region. After contact with the tailings, the CT was averaged exclusively in a sample from Region 3, due to the cadmium content.

CONCLUSION

In spatial terms, Region 2, which is closer to the rupture of the dam, presented a greater number of non-conformities in relation to the legislation, with a reduction of extrapolations in the Doce River downstream. Thus, Region 4, with the largest volume of water granted for irrigation, suffered the least impact from the disruption. As for the temporal variation, there was an increase in the frequency of non-conformities in 2016, with a significant drop in subsequent years.

There were substantial changes in the quality of the water resulting from the rupture of the Fundão dam, especially in Region 2 and mainly in the first year, but the parameters showed a significant improvement in water quality in the following years. Thus, it is considered that the irrigation activity with waters of the Doce River is not compromised by the impacts caused by the disruption.

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