Radioecological impact of effluents from a nuclear facility being decommissioned in the Antas River hydrographic basin in the States of Minas Gerais, Brazil

Radioecological impact of effluents in the Antas Reservoir

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Abstract. The Antas Reservoir receives the treated effluents which come from acid drainage of uranium ore from the UTM-INB (Ore Treatment Unit – Brazilian Nuclear Industries), located in Caldas, MG. This study was conducted in order to determine the possible environmental impact caused by discharge of the treated liquid effluent from the UTM into the Antas Reservoir. Biological (ciliated protozoa and *Peridinium* sp. phytoflagellate) and physicochemical variables (manganese, zinc, sulfate, uranium, dissolved oxygen and temperature), trophic state and saprobity indexes were evaluated. Sampling in Reservoir (Cab, P41, P14S, and P14F points) took place during the dry winter season (July 2006). Each day, samples were collected four times (6:00 am, 12:00 pm, 6:00 pm, and 12:00 am). Biological variables analyzed at the Antas Reservoir classified it as an oligotrophic and beta-mesosaprobic environment. Chemical parameters indicate failures in the nuclear facility effluent treatment plant, showing that effluents outside of standard limits established by Brazilian current legislation for Class II water are being discharged at point P41. These results agree with biological analyses, since point P41 has the lowest diversity and biomass values for ciliated protozoa organisms, indicating possible environmental impacts on the ecosystem due to effluent discharge by this mining company.

KEYWORDS: ***uranium mine; ciliated protozoa; nuclear facility; Antas Reservoir*.**

1. Introduction

The Antas River Hydrographic Basin begins in the Antas Reservoir region which was constructed in 1982 for the purpose of providing water for the uranium milling plant of the Ore Treatment Unit – Brazilian Nuclear Industries (UTM-INB). In addition to providing water for the industrial process, the Antas Reservoir also receives UTM-INB's treated effluents resulting from acid drainage in waste rock piles of low uranium content ore (< 0.02%). UTM-INB is the first uranium extraction and production mine in Brazil and is currently undergoing a decommissioning phase.

This study proposes a limnological characterization of the Antas Reservoir in order to diagnose the current situation based on a multi-disciplinary (physics, chemistry, and microbiology) survey of data from the field and laboratory obtained with water and biota aquatic system matrices.

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In addition, the present study intends to contribute to the understanding of this ecosystem since there is lack of information about the qualitative and quantitative characterization of the main components of the microbial trophic network (dinoflagellate *Peridinium* sp. and ciliates protozoa) in environments that have experienced impact from uranium ore mining and milling in subtropical regions.

2. Material and Methods

Sampling in the Antas Reservoir (Cab $_{depth}$ = 0.5 m, P41 $_{depth}$ = 0.5 m, P14S $_{depth}$ = 0.5 m, and P14F $_{depth}$ = 6.5 m) took place during the dry winter season (July 2006). P41 is discharging point of liquid effluents treated by the UTM-INB and P14S and P14F are downstream of that. The Cab point (control point) is located upstream of discharging point of liquid effluents. Sampling was conducted four times (6:00 am, 12:00 pm, 6:00 pm, and 12:00 am) and samples were submitted to physical, chemical and microbiological analyses.

2.1 Physical and Chemical Measurements

The following chemical and physical measurements were performed: temperature and dissolved oxygen [1]. The manganese and zinc contents (atomic absorption spectrometry were done as in Eaton, Clesceri, Greenberg [1]. The sulfate concentration (spectrophotometry with barium chloride) was measured as described in ASTM [2]. Uranium analyze (spectrophotometry with arsenazo III) was performed as in Fukuma et al. [3]. The results of the chemical variables of the water samples from sampling stations were compared with the limits established by CONAMA Resolution 357 [4] for Class II waters. This resolution classifies water bodies in Brazil, gives environmental directives for a frame of reference, as well as establishes the conditions and standards for effluent disposal in Brazilian waters.

2.2 Microbiological Measurements

The sampling and quantifications were done for ciliates protozoans and *Peridinium* sp. phytoflagellate plankton [5]. The main source of literature utilized to the ciliates protozoan and dinoflagellate identification: Edmondson [6]; Foissner and Berger [7]; Lee, Hutner, Bovee [8]; Pennak [9] and Laybourn-Parry [10], respectively. Measurements of cellular biovolumes were performed through geometric shapes closest to the morphology of the organisms [11]. The biovolume values to ciliates protozoans and *Peridinium* sp. were multiplied by a specific conversion factor, 0.00000019 $\mu g.\mu m^{-3}$ [12] and 0.00000022 $\mu g.\mu m^{-3}$ [13] resulting in carbon biovolume values, respectively. The carbon biovolume values were used to calculate the biomass estimative values, according to Sorokin and Kadota equation [14]. For the diversity analysis, a Shannon-Weaver Index was used as described by Odum [15]. The Pantle and Buck Saprobity Index (SIPB) was used as described by Foissner and Berger [7]. The chlorophyll *a* [16] and chlorophyll c were also measured [17]. The Trophic State Index (TSI) of the Antas Reservoir was calculated according to Carlson [18], modified by Toledo et al. [19]. The parameter utilized for the calculation of this index was the concentrations of chlorophyll *a*.

3. Results and Discussion

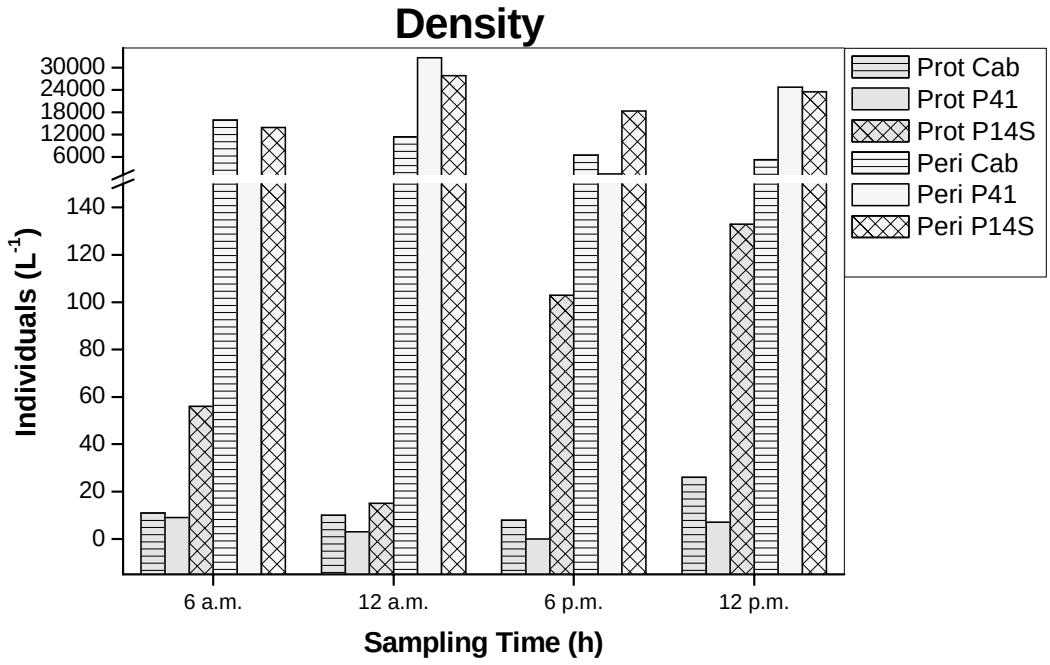
Average values of water temperature varied from 15.5 ºC (Cab) to 17.7 ºC (P41). For dissolved oxygen the average values (6.00 $mg.L^{-1}$) showed that the level was within the limit established by current legislation for Class II water, according to CONAMA Resolution 357 (> 5 $mg.L^{-1}$) [4]. All manganese values recorded in water samples of the Antas Reservoir (0.45 to 20.30 $mg.L^{-1}$) were above the predicted limit by the legal limits (0.1 $mg.L^{-1}$). Water samples from Cab point had average zinc value (0.25 $mg.L^{-1}$) above stipulated by legislation (0.18 $mg.L^{-1}$). The average values obtained for uranium were lower than 0.05 $mg.L^{-1}$.

Our findings indicate that water samples from P41 at 12 pm had concentrations of sulfate (278.70 $mg.L^{-1}$) and zinc (0.21 $mg.L^{-1}$) above the limits established by CONAMA Resolution 357($sulfate_{limit}$ = 250 $mg.L^{-1}$) [4].

Based on the average Trophic State Index values the Antas Reservoir was classified as oligotrophic ($TSI_{average}$ = -6.6). The samples collected throughout the day at all of the collection points were classified as beta-mesosaprobic ($SIPB_{average}$ = 1.9), according to saprobidity index. Only the sample collected at 6:00 am from point P14F had a higher SIPB value ($SIPB_{average}$ = 2.0), being classified as an alpha-mesosaprobic environment.

For points Cab and P14S, the highest ciliated protozoa density values were observed at midnight, while P41 didn't have oscillation in the density values during the day. Density values obtained at point Cab for *Peridinium* sp. dropped throughout the day, while at P41 and P14S the density values had two peaks during the day that is, one at noon and the other at midnight (Fig. 1).

Figure 1: Average density values for ciliated protozoa (Prot) and *Peridinium* sp. (Peri) in Antas Reservoir points throughout the day in the dry period.



According to Laybourn-Parry [20], *Strombidium* sp. feeds on diatomaceous, algae, and bacteria. Diatomaceous are rich in chlorophyll c. However, according to Fig. 2 there was no relation between the biomass values obtained for *Strombidium* sp. and the concentration of chlorophyll c and *Peridinium* sp. values. The chlorophyll c concentrations detected in the present study are probably related to the occurrence of *Peridinium* sp. [21]. The phytoplankton communities with high specific surfaces (nano and picoplankton) are well adapted to low nutrient concentrations [22], [23], and [24], which could explain the high density (Fig. 1) and low biomass of *Peridinium* sp. phytoflagellates (Fig. 2) observed in this study.

The Fig. 3 shows that the main effect of UTB-INB treated effluent discharge into the Antas Reservoir was the reduction of diversity of ciliated protozoa observed at P41 when compared to the value obtained for point Cab, P14S and P14F. The lowest values for biomass as well as diversity were observed at P41, which received the treated effluents from UTM-INB.

Figure 2: Variation on chlorophyll c values, *Strombidium* sp. biomass, and *Peridinium* sp. biomass in Antas Reservoir points throughout the day in the dry period

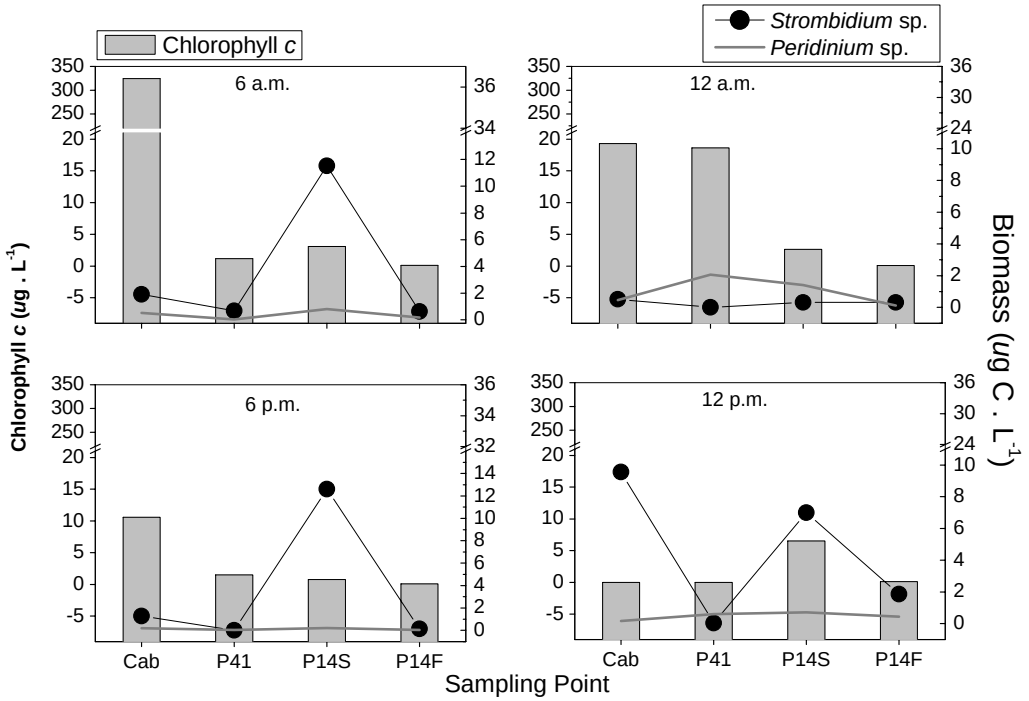
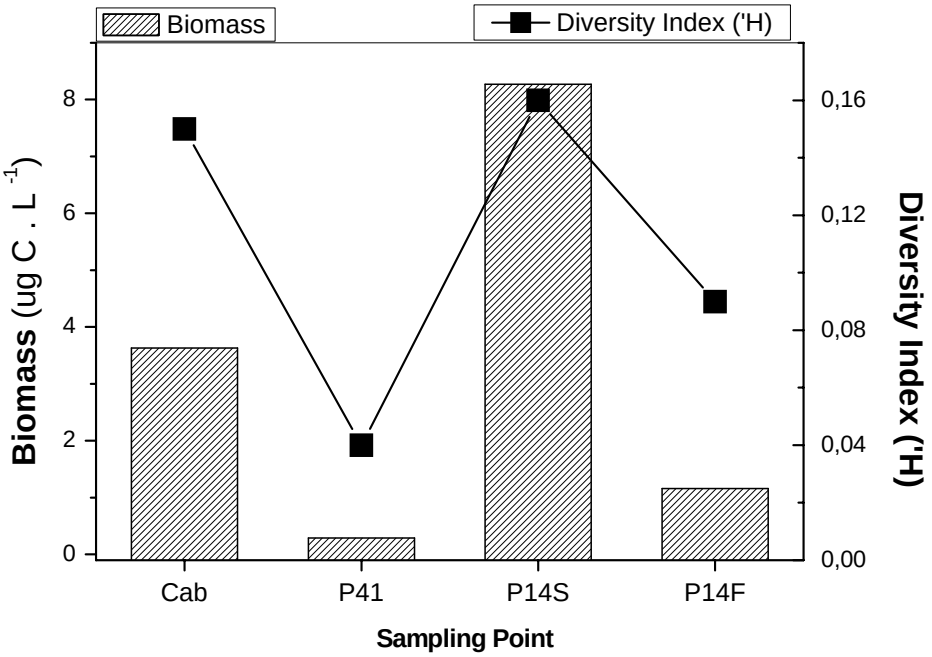


Figure 3: Variation of average biomass values and Shannon-Weaver Diversity Index in the Antas Reservoir points at the dry period.



4. Conclusion

Chemical parameters indicate failures in the nuclear facility effluent treatment plant, showing that effluents outside of standard limits established by current legislation for Class II water are being discharged at point P41. These results agree with biological analyses, since point P41 has the lowest diversity and biomass values for ciliated protozoa organisms, indicating possible environmental impacts on the ecosystem due to effluent discharge by this mining company.

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