Iranian (Iranica) Journal of Energy & Environment
Journal Homepage: www.ijee.net
IJEE an official peer review journal of Babol Noshirvani University of Technology, ISSN:2079-2115

Ecological Risk Assessment in Sediments from the Urbanized Lagoon of the Olympic Park

I. Y. D. C. Rodrigues, J. D. C. Campos, R. M. Cavalcante, A. C. Coutinho, A. T. Netto*, A. L. D. S. Salomão

Department of Sanitary and Environmental Engineering, Rio de Janeiro State University, Rio de Janeiro, Brazil

PAPER INFO

Paper history:
Received 14 October 2020
Accepted in revised form 26 November 2020

Keywords:
Algal diversity
Coastal lagoon
Domestic effluents
Environmental risk
Industrial effluents
Lines of evidence

ABSTRACT

The Jacarepaguá Lagoon (JPAL) is part of a lagoon complex, located in the west zone of Rio de Janeiro city, and has largest drainage area of the complex. JPAL constantly receives the clandestine release of domestic and industrial effluents, in addition to diffuse contributions from drainage waters from different sources, with high pollution load. Ecological Risk Assessment (ERA) is an important tool with a more global view of the risks for the management of contaminated areas, including the identification of adverse effects of contaminants on the environment. This study aimed to develop an ERA for the JPAL, using two lines of evidence (LoE): Ecotoxicological and Ecological. The sediments samples were collected in four sampling points. The Ecotoxicological LoE was based on chronic ecotoxicity assays (Chlorella vulgaris and Ceriodaphnia dubia) to estimate the Ecotoxicological Risk. The Ecological LoE was based on the analysis of the richness and abundance of local algae species to estimate the Ecological Risk. The Environmental Risk was estimated by integrating the Risks of the two LoE. The Ecotoxicological Risk was 0.80±0.12, classified as very high risk. The Ecological Risk was 0.746±0.01, classified as high risk. The estimated Environmental Risk was 0.78±0.08, which was a very high risk. In summary, JPAL had an advanced stage of contamination, with a high content of organic matter in the sediment, caused by irregular effluents released. JPAL's current environmental risk exposes the urgent need for more inspection actions to prevent the release of sewage before the total degradation of the local ecosystem.

***doi**: 10.5829/ijee.2020.11.04.06*

INTRODUCTION

The clandestine release of domestic and industrial effluents into aquatic environments is an old and chronic problem in Brazil and in several countries around the world. Once in the environment, these effluents can cause acute or chronic adverse effects on human and environmental health, such as a toxic effect in general, an endocrine disruption effect and the spread of diseases in the water, among other effects [1].

The West Zone of the Rio de Janeiro city houses the Jacarepaguá Lagoon (JPAL), which is part of a tropical coastal lagoon complex, formed by four urban lagoons connected to the sea through the Barra da Tijuca channel [2]. In the last decades, the area has undergone intense occupation with the construction of several residential and commercial buildings, most of which are not connected to the sewage network, having instead its own decentralized treatment systems [3]. JPAL receives constant releases of clandestine domestic and industrial effluents and diffuse contributions of drainage waters from different sources, with a high polluting load of organic matter and other contaminants of emerging concern, representing an ecological and health risk for this region and the population.

The Ecological Risk Assessment (ERA) presents itself as an important tool for the management of contaminated areas, due to its more global view of risks, based on chemical, physical-chemical and biological analyzes, and the identification of adverse ecological effects of contaminants present in an environment [4]. ERA also aims to assess the ecological changes generated by different human activities in a given environment. Current ERA studies on contaminated sediments [5] have developed and improved based on the Sediment Quality Triad [6–8], which consists of three Lines of Evidence (LoE): Chemical, Ecotoxicological and Ecological. The objective of this study was to develop an ecological risk assessment for the sediment of the Jacarepaguá Lagoon, considering different levels of biological organization, through the ecotoxicological and ecological lines of evidence (LoE).

*Corresponding Author E-mail: alenanetto@eng.uerj.br (A. T. Netto)

Please cite this article as: I. Y. D. C. Rodrigues, J. D. C. Campos, R. M. Cavalcante, A. C. Coutinho, A. T. Netto, A. L. D. S. Salomão, 2020, Ecological Risk Assessment in Sediments from the Urbanized Lagoon of the Olympic Park, Iranian (Iranica) Journal of Energy and Environment 11(4): 287-291.

MATERIALS AND METHODS

Study area

The hydrographic basin of the Jacarepaguá Lagoon Complex has approximately 280 km^2 and is in the West Zone of the Rio de Janeiro city. The JPAL is part of a coastal lagoon complex formed by four urban lagoons, which together have a water surface of approximately 9.3 km² with 3.7 km² of them corresponding to the JPAL [2, 9]. JPAL is the most inland lagoon and has the largest drainage area in the lagoon complex with 102.8 km^2 and several water courses as tributaries (Marinho, Camorim, Guerenguê, Arroio Pavuna, Pavuninha) [9]. Therefore, the JPAL receives the biggest amount of water (equivalent to 34.3% of the entire hydrographic basin).

The sampling campaign, in 2019, collected sediment samples from the bottom of the lagoon and surface water at four sampling points (P1, P2, P3 and P4) close to the banks (Figure 1). A reference area (P0) was chosen for the assessment of background and natural conditions of the region, in an area upstream of the influence area where JPAL is located. Each sediment or water sample was divided into several subsamples for appropriate conditioning according to the ecotoxicity assays or ecological analysis, following the recommended national guidelines [10].

Ecological risk assessment

The Ecological Risk Assessment methodology was based on the risk integration of two Lines of Evidence (LoE) for the estimation of the Environmental Risk of JPAL: Ecotoxicological LoE and Ecological LoE. The results obtained in each LoE and in the Environmental Risk were quantitatively translated, in index scales from 0 to 1, where: 0-0.25 corresponded to low risk; 0.25-0.50 to moderate risk; 0.50-0.75 to high risk; and 0.75-1.0 to very high risk.

Ecotoxicological LoE

To assess the ecotoxicological risk index (EcotoxRI) two chronic ecotoxicity bioassays were conducted with the elutriate of the sediment samples collected at the sampling points. The elutriate of the sediment samples was previously prepared in the proportion of 1:4, with a part of sediment, for four of dilution water, being homogenized vigorously for 30 minutes. After resting for 60 minutes, the supernatant was removed and used for toxicity tests [11]. The chronic toxicity bioassay of growth inhibitory effect with the microalgae *Chlorella vulgaris* was evaluated with 96 h of exposure time, under static condition nonrenewal technique [12]. Five days before conducting the bioassays, an initial algae culture was prepared to ensure the exponential growth phase in the beginning of the bioassays. The assays were carried out in 125 mL Erlenmeyer containing 75 mL of sample (n=4) and known density algal suspension (final density of 10^5 cells mL^{-1}) under continuous cool white light 6,000 lux exposure, and temperature 25 ±2 °C. The cell counting was performed under an optical microscope with 400x magnification, using the Neubauer chamber. The growth inhibitory effect of algal biomass was statistically evaluated by comparing the results of the exposed algae with the negative controls (Ctrl). The chronic toxicity bioassay of effect on reproduction rate with the micro crustaceans *Ceriodaphnia dubia* was evaluated in 8 days of exposure (n=10) with no dilution [13]. In each vial 15 mL environmental sample or culture solution (negative control) were added and a *C. dubia* female 6 to 24 h old. The vials were cleaned, and the neonates were counted daily. The assays were conducted in an incubator with a photoperiod of 16:8 h (light:dark, with cold light) at 25 °C, the organisms were fed daily with algae cultures. EcotoxRI was estimated based on the results of chronic bioassays, according to the methodology proposed in literatures [8, 14]. The results obtained were quantitatively translated, on scales ranging from 0 to 1, where 0 corresponded to the minimum risk and 1 to the maximum risk.

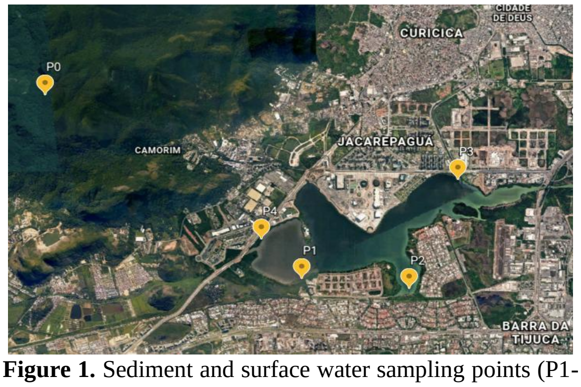

Figure 1. Sediment and surface water sampling points (P1-P4) in Jacarepaguá Lagoon and the Reference point (P0). Source: Google Earth

Ecological LoE

Ecological LoE consisted of biomonitoring of phytoplankton communities in real field conditions (*in-situ*). The pollution effects on ecological receptors were assessed by analyzing the function and structure of communities (wealth-abundance, diversity, and density of species). Surface water samples were fixed in lugol for phytoplankton identification and verification of phytoplankton densities (cells mL^{-1}) under an inverted microscope [15]. The individuals were counted in random fields until reaching at least 100 individuals (colonies, filaments, cells) of the dominant species [16]. Community diversity indicators were calculated according to the Shannon-Weaver biological diversity index [17]. Statistical analysis was performed using PAST v2.16 [18]. The result of the biomonitoring of each sample was compared to that obtained at the reference point (P0) for the calculation of the ecological risk index (EcoRI), according to the equations of the BKX Triad (scaling of the ecological parameters evaluated in a single value) [8]. The results obtained were quantitatively translated, on scales ranging from 0 to 1, where 0 corresponded to the minimum risk and 1 to the maximum risk.

Environmental risk index

The integrated environmental risk of the JPAL was estimated from the risk indexes (EcotoxRI and EcoRI) obtained in each of the lines of evidence evaluated. The integration procedure was performed according to methodology [14], including the assignment of different weighting factors (wf) for each risk index of each LoE: Ecotoxicological LoE (wf = 1.5); and ecological LoE (wf = 2.0). Therefore, EnvRI was calculated as the weighted arithmetic means of the two risk index.

RESULTS AND DISCUSSION

Ecotoxicological risk index

The chronic bioassays with the microalgae *C. vulgaris* showed inhibition effect for all sampling points (Figure 2). After the microalgae growth inhibition data and statistical evaluation, it was possible to calculate the ecotoxicological risk and verify that P4 was the point of highest risk with 0.97, followed by P3 with 0.86, P1 with 0.77 and finally, but still with a very high estimated risk, P2 with 0.73.

The chronic bioassay with the microcrustacean *C. dubia* showed a toxic effect for almost all sampling points (Figure 3). Except for the P4 (0.03), who presented extremely low risk, the risk index was high to very high for the others sampling points, a very high risk estimated for P3 (0.98), and a high risk estimated for P2 (0.65), and P1 (0.64). This very high risk index was attributed to the acute effect (mortality) on most organisms exposed to the environmental samples from P1, P2 and P3 sampling points.

Ecological risk index

The lagoon sampling points P2 and P3, it presented a

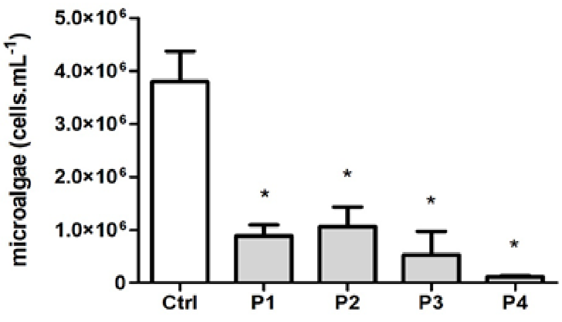

Figure 2. Chronic bioassay with the microalgae *C. vulgaris* and elutriate of the sediment samples from four sampling points (P1-P4)

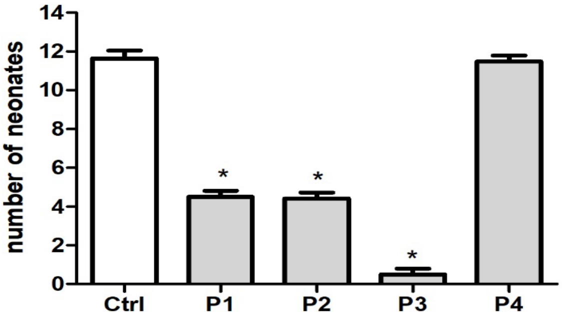

Figure 3. Chronic bioassay with the microalgae C. vulgaris and elutriate of the sediment samples from four sampling points (P1-P4)

phytoplankton composition typical of eutrophic environments with a dominance of cyanobacteria (Figure 4). The diversity evaluated according to the Shannon-Wiener Index (H') revealed higher values in P0, P1 and P4 than in the P2 and P3 (Figure 4), therefore, a greater diversity of species [19]. The high density of cyanobacteria assessed at the JPAL sampling points is an alarming situation from an environmental point of view. The EcoRI for the sediment of JPAL was estimated as a high risk (0.75), considering the average value of all sampling points. Regarding the sampling points, there was no great variation in EcoRI (0.73-0.76). However, the P3 (0.76) and P2 (0.75) presented the highest EcoRI, being classified as very high risk, followed by P2 (0.74) and P1 (0.73), classified as high risk.

Environmental risk index

The estimated risk index of the Ecotoxicological and Ecological LoE assessed, did not vary significantly (> 0.4), therefore, the two LoE contributed at similar levels to the integrated risk. Therefore, the JPAL's estimated environmental risk was 0.78, which is very high risk Figure 5. Regarding the sampling points, P3 presented the highest risk index (0.88), followed by P4 (0.79), being classified as very high risk. The sampling points P1 (0.72) and P2 (0.72) presented a high risk.

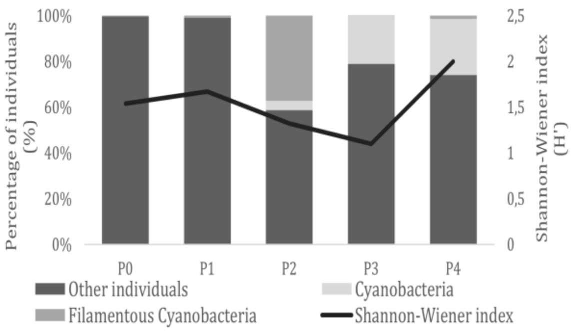

Figure 4. Percentage of Cyanobacteria, filamentous cyanobacteria, and the total algae species (other individuals), at the sampling points P1-P4 in the Jacarepaguá lagoon and reference area (P0)

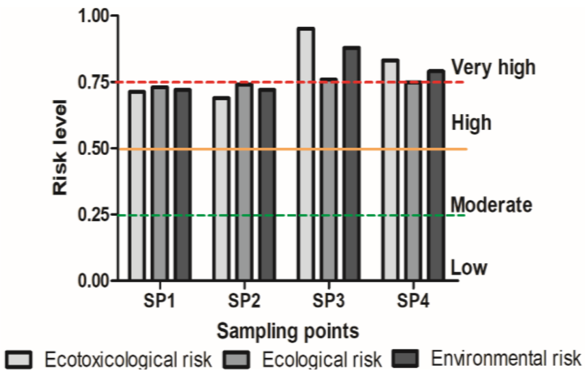

Figure 5. Ecotoxicological, Ecological and Environmental Risk Index, for the four sampling points (P1- P4), in the Jacarepaguá Lagoon

CONCLUSION

The very high Environmental Risk Index estimated for the sediments of the Jacarepaguá Lagoon highlighted the advanced contamination process in this area with great social, economic, and ecological interest for the region. Therefore, it is concluded that environmental inspections are fundamental and urgent to prevent the release and arrival of sewage (domestic and industrial) in the lagoon, as well as remediation actions on the site, in an attempt to protect the integrity of this ecosystem. Based on the risk indices estimated at the different JPAL points, it is expected to contribute with tools and information for a broader discussion on management actions and mitigation of ecological risks in the lagoon and in the region as a whole.

ACKNOWLEDGEMENTS

The authors acknowledge the financial support by the National Council for Scientific and Technological Development (CNPq) and the Coordination for the Improvement of Higher Education Personnel (CAPES) Code 001.

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Persian Abstract

DOI: 10.5829/ijee.2020.11.04.06

چکیده

تالاب Jacarepaguá (JPAL) بخشی از یک مجموعه تالاب است که در منطقه غربی شهر ریودوژانیرو واقع شده است و دارای بزرگترین منطقه زهکشی مجموعه است. JPAL علاوه بر کمک‌های انتشار یافته از آب‌های زهکشی از منابع مختلف، با بار آلودگی زیاد، به طور مداوم انتشار مخفیانه پساب‌های خانگی و صنعتی را دریافت می‌کند. ارزیابی خطر زیست محیطی (ERA) ابزاری مهم با دید جهانی‌تر نسبت به خطرات مدیریت مناطق آلوده، از جمله شناسایی اثرات سو آلاینده‌ها بر محیط زیست است. این مطالعه با هدف ایجاد ERA برای JPAL، با استفاده از دو خط شواهد (LoE): سموم شناسی و زیست محیطی انجام شده است. نمونه رسوبات در چهار نقطه نمونه‌گیری جمع‌آوری شد. LoE اکوتاکسیلوژیک برای برآورد خطر اکوتاکسیلوژیک بر اساس آزمایش‌های مسمومیت با مسمومیت *کلرلا ولگاریس* و *Ceriodaphnia dubia* بود. زیست محیطی LoE بر اساس تجزیه و تحلیل غنای و فراوانی گونه‌های جلبک محلی برای تخمین خطر زیست محیطی ساخته شده است. ریسک زیست محیطی با ادغام خطرات دو LoE تخمین زده شد. خطر سمیت سلولی ۰/۱۲ ± ۰/۸۰ بود، که به عنوان ریسک بسیار بالا طبقه‌بندی می‌شود. ریسک اکولوژیکی ۰/۰۱ ± ۰۶/۷۴۶ بود، که به عنوان ریسک بالا طبقه‌بندی می‌گردد. برآورد شده از نظر خطر محیطی ۰/۰۸ ± ۰/۷۸ بود که خطر بسیار بالایی بود. به طور خلاصه، JPAL یک مرحله پیشرفته از آلودگی، با محتوای بالای مواد آلی در رسوب، ناشی از پساب‌های نامنظم آزاد شده را دارا بود. خطر زیست محیطی فعلی JPAL نیاز فوری به اقدامات بازرسی بیشتر را برای جلوگیری از انتشار فاضلاب قبل از تخریب کامل اکوسیستم محلی نشان می‌دهد.