A geochemical water quality index for the major Amazonian rivers

Un indice géochimique de la qualité des eaux pour les principals rivières amazoniennes

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RÉSUMÉ

Depuis le milieu du XXe siècle, les masses d'eau amazoniennes ont été classées en utilisant des typologies d'eau qui sont liées à des catégories chimiques. Bien que cette approche durable ait été utile pour les études limnologiques et d'écologie du paysage, il est difficile de décrire toute la variabilité hydrochimique naturelle en utilisant cette approche. Le modèle de l'indice de qualité des eaux (IQE) est un outil largement répandu et adapté à l'évaluation de la qualité des eaux de rivière. Cette étude vise à établir un IQE géochimique basé sur l'hydrochimie des eaux naturelles, afin de contribuer à la classification et à la gestion durable des ressources en eau de surface. Les principaux cations et anions, ainsi que les valeurs de pH, provenant d'un ensemble de données sur l'hydrochimie des principales rivières amazoniennes, ont été sélectionnés pour cette analyse. L'IQE a été calculé par deux approches (allant de 3,5 à 100) et ces résultats ont été reliés aux types d'eau classiques. Quelques suggestions pour le raffinement des calculs de l'IQE sont indiquées.

ABSTRACT

Since the mid-twentieth century, Amazonian water bodies have been classified by using water typologies which are related to chemical categories. While this long-lasting approach has been useful for limnological and landscape ecology studies, it is difficult to describe all the natural hydrochemical variability by using this approach. The water quality index (WQI) model is a widely held and suitable tool for assessing river water quality. This study aims to establish a geochemical WQI based on hydrochemistry of natural waters, aiming to contribute to the classification and sustainable management of surface water resources. The major cations and anions, and pH values, from a dataset on hydrochemistry of major Amazonian rivers, were selected for this analysis. The WQI was calculated by two approaches (ranging 3.5-100) and these results were related to the classical water types. Some suggestions for the refinement of WQI calculations are pointed out.

KEYWORDS

River and landscape ecology, river hydrogeochemistry, water quality index (WQI).

1 INTRODUCTION

Water typologies have been used since the mid-twentieth century to support limnology and ecology of Amazonian landscapes. However, due to the wide natural hydrochemical variability, both in space and time, observed in Amazonian water bodies, the classification of a given river within a particular chemical category becomes a complex task. Globally, the water quality index (WQI) model has become a popular and suitable tool for evaluating surface water quality (Uddin et al. 2021).

The aim of this study is to (1) establish a geochemical WQI based on hydrochemistry of major Amazonian rivers; (2) provide new insights into the limnological classification of Amazonian rivers, aiming to subsidy sustainable management actions on Amazonian water resources.

2 MATERIAL AND METHODS

A dataset available on hydrochemistry of Amazonian rivers were used (Richey et al. 2008; Ríos-Villamizar et al. 2020), which were collected in the course of 13 field surveys. The matrix analyzed was structured by 143 sites and 10 parameters such as major cations (Ca^{2+}, Mg^{2+}, Na^{+}, K^{+}), major anions (HCO_3^{-}, SO_4^{2-}, Cl^{-}) and pH values. The parameters were selected according to Ríos-Villamizar et al. (2020). The WQI was calculated by two adapted approaches from Uddin et al. (2021):

A simple additive aggregation function expressed as:

$$WQI\_1 = (\Sigma c_i w_i) / 5.767 \quad (1)$$

A multiplicative aggregation function expressed as:

$$WQI\_2 = (\Pi c_i^{wi}) / 2.315 \quad (2)$$

where c_i is the concentration (µeq/L) value for the different parameters and w_i (which ranges from 0 to 1) is the corresponding parameter weight value. It was adopted an equal parameter weighting value (0.1) system.

3 RESULTS AND DISCUSSION

The Solimões/Amazon, Negro and Tapajós rivers are considered prototypes for whitewater, blackwater and clearwater rivers, respectively. Nevertheless, geochemical variability in the catchments of the different tributaries, leads to variations in the parameters resulting in intermediate water types. A classification system of Amazonian lowland wetlands uses hydrochemical parameters for the differentiation between nutrient-rich whitewater and nutrient-poor blackwater rivers floodplains. These water types represent the upper and the lower end of the fertility gradient (Ríos-Villamizar et al. 2020).

The mean WQI_1 values were 44.5±25.6 ranging 3.5-100; the mean WQI_2 values were 48.6±24.9 ranging 6.3-100. The values of WQI_1 and WQI_2 were plotted in regards with the pH value, the concentrations of major cations (alkali and alkaline-earth metals) and major anions, and their respective proportions (eq%). There exists a wide-ranging of overlapping between the WQI values of different rivers, as a result of hydrochemical parameters overlaps, which indicates the existence of many transitional hydrochemical stages and the variation in water quality between seasonal periods. Nonetheless, this classification can be useful for biodiversity assessment, in order to investigate the relations between the WQI and the biodiversity observed, and for management actions related to agriculture, ranching, fishery, and forestry along the fertility and hydrochemical gradient (Figure 1). The baseline hydrochemical conditions are relevant for assessing potential impacts, and this classification is extremely important from the standpoint of the legislation on water quality standards and the water resources management.

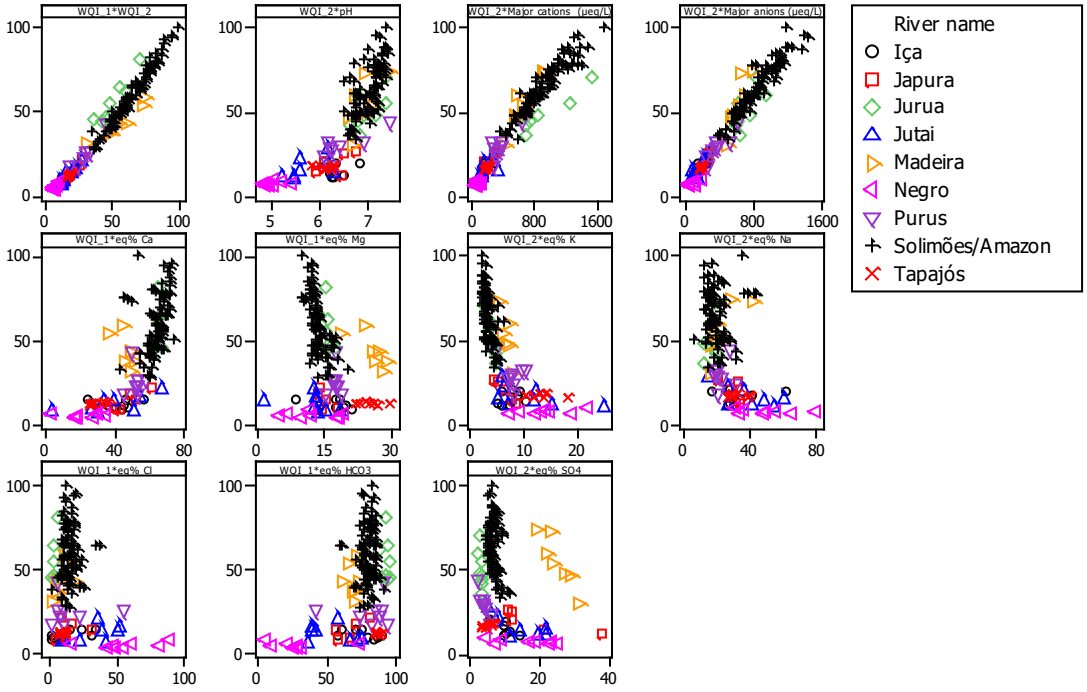

Figure 1 Relationship between the values of WQI_1 and WQI_2, pH value, the concentrations (µeq/L) and compositions (eq%) of major cations and anions of major Amazonian rivers. Major cations correspond to the sum of total concentrations of Ca^{2+}, Mg^{2+}, Na^{+}, and K^{+}; major anions correspond to the sum of total concentrations of HCO_3^{-}, SO_4^{2-}, and Cl^{-}.

4 CONCLUSIONS

As there are limitations of the traditional categorization methods, this preliminary approach on WQI-based classification is needed for the discussion of ecological ecosystem peculiarities related to biodiversity, primary production and decomposition, and management alternatives in the Amazonian rivers and connected wetlands systems. Some adjustments are going to be made for the improvement of this approach by including the silica concentration, the compositions (eq%) of the different parameters, DOC and nitrates concentrations, which are very important for water quality and aquatic ecosystems, and parameter weighting refinement in WQI calculations.

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