Distribution of Hydrochemical Parameters in the Surface Water Layer of the Zone of Mixing River and Sea Waters of the Amazon River Basin During the 52nd Voyage of the R/V "Academik Boris Petrov"

A. M. Seliverstova(✉), O. A. Zuev, and A. L. Chultsova

Shirshov Institute of Oceanology, Russian Academy of Sciences, 117997 Moscow, Russia
201219941315ann@gmail.com

Abstract. The article is written based on the results of 52 voyage on the R/V "Akademik Boris Petrov" from 22.11.2022 to 28.11.2022. During this period the work was carried out in the zone of mixing of river and sea waters in the estuary of the Amazon River. Hydrophysical and hydrochemical studies were carried out. According to the results of the work, it can be stated that these measurements were carried out during the "low" water season. River waters are well distinguished in terms of dissolved silicate distribution, total alkalinity and pH. Amazon River waters carry a lot of dissolved silicate, and very little phosphorus and nitrogen. The high oxygen saturation of the waters suggests an active photosynthesis process. The influence of the river plume was minimal.

Keywords: Amazon River · hydrochemistry · nutrients · dissolved silicate · dissolved oxygen · oxygen saturation

1 Introduction

The Amazon is the largest river in the world in terms of length, flow and basin area. The Amazon River System is located in the equatorial part of South America, starting from the confluence of the mountainous Marañon and Ucayali Rivers, flowing - mainly through the Amazonian lowlands - and flows into the Atlantic Ocean. Its average annual flow exceeds 209,000 m^3/s and its influence can be traced as far as the Cape Verde Islands and the Atlantic coast of Africa. The Amazon is full-flowing all year round, as seasonal fluctuations in runoff are smoothed out by different times of the rainy season on its right and left side; however, according to modeling and satellite observations, we can say that its runoff is more voluminous in July-August compared to other months and minimal in November-December [1]. Due to the high anthropogenic load on the banks of the river, as well as the increasing amount of microplastics brought to the World Ocean by the Amazon plume, it is necessary to conduct environmental monitoring of waters, including hydrochemical studies of nutrient parameters [2, 3]. These parameters reflect the intensity of production and destruction processes and allow us to judge the impact of anthropogenic pollution on the water area.

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The last large-scale studies of the river were conducted by the Institute of Oceanology only in 1983 (the 9th cruise of the R/V "Professor Shtokman") and the most important tasks of the 52nd cruise of the R/V "Akademik Boris Petrov" were not only to study the features of the structure of thermohaline, biogeochemical and hydrophysical fields in the zone of interaction between the coastal ocean circulation and mainland freshwater runoff and to update the available data, but also to develop international cooperation with Brazil - a partner country of BRICS. The main purpose of this work is to characterize the abiotic component in the zone of mixing of river and sea waters of the Amazon River basin.

2 Material and Methods

Hydrochemical works in the voyage "ABP 52" in the zone of mixing of river and sea waters on the shelf of the Amazon River were carried out from 22.11.2022 to 28.11.2022. Twenty-seven stations perpendicular to the shoreline were performed in transects from 2 to 5 stations (Fig. 1). All samples were pre-filtered through nuclear filters with a pore diameter of 0.45 μm. Such parameters as dissolved oxygen (O_2), pH, total alkalinity (Alk), dissolved silicate (SiO_2), phosphate (or mineral) phosphorus ($P\text{-}PO_4$), mineral forms of nitrogen nitrate ($N\text{-}NO_3$) and nitrite ($N\text{-}NO_2$) were determined according to the methods adopted in the modern hydrochemistry [4].

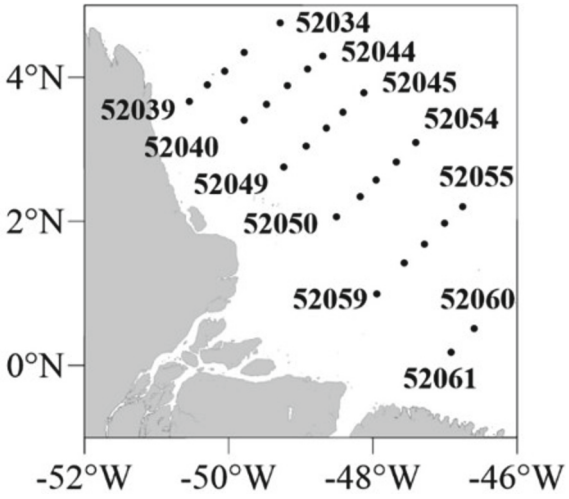

Fig. 1. Layout of stations at the estuary of the Amazon River

Dissolved oxygen in seawater was analyzed using a modified Winkler method. Oxygen saturation was calculated using the Weiss formula.

pH measurements were performed at a temperature of 25+−0.5 °C with the help of a pH electrode SI Analytics according to RD 52.24.495-2005 «Hydrogen Index and electrical conductivity of water. Methodology for Electrometric Measurements». Next,

pH was recalculated to in situ values on the NBS scale. Total alkalinity was analyzed by direct open-cell titration with hydrochloric acid (0.02 M). During titration, water samples were blown with an air stream freed of carbon dioxide and ammonia. The temperature correction for pH was introduced and the elements of the carbonate system were calculated using the CO2SYS program [5].

Determination of the content of dissolved inorganic phosphorus was carried out according to the method of Morphy and Riley. Determination of dissolved inorganic silicate - according to the method of Koroleff [6].

The determination of nitrite was carried out according to the method of Bendschneider and Robinson. The determination of nitrates was based on the method of reducing them to nitrites with cadmium and measuring colorimetrically.

3 Results and Discussion

According to the thermohaline characteristics of the surface water layer, two zones can be distinguished: a southwestern, coastal zone with increased temperature and decreased salinity (up to 29.7 °C and 30.18 PSU) and a northeastern, marine zone with decreased temperature and increased salinity (up to 27.7 °C and 36.61 PSU). The observed distribution is probably related to the shallow depth of coastal stations, coastal runoff of the Amazon and its inflows, and the influence of the warm Guiana Current moving northwestward [7] (Fig. 2).

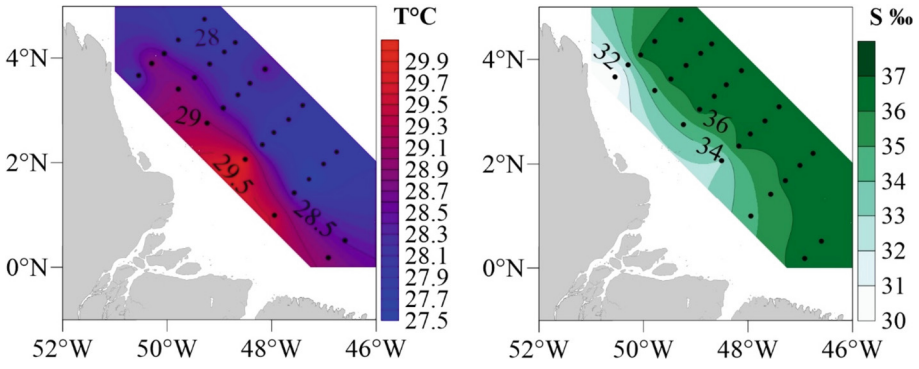

Fig. 2. Temperature (T) and salinity (S) distribution on a polygon at the estuary of the Amazon River

The distribution of total alkalinity and dissolved silicate correlate well with the distribution of temperature and salinity (Fig. 3). These parameters are markers of river discharge, as reflected in this polygon. The lowest values of total alkalinity (2038–2200 μM) and highest dissolved silicate (8.95–12.32 μM) are observed at the shore stations. As distance from the shore and from the river water discharge tongue, the values of total alkalinity increased and silicates decreased to 2433 μM and 0.45–0.55 μM, respectively. The pH values ranged from 8.18 (at shore stations) to 8.23 (in the marine part). Since Amazon River waters are characterized by low pH values of 4–5 scale units

[8], the distribution of this parameter in this case, as well as the distribution of total alkalinity and dissolved silicate, reflects the influence of river discharge.

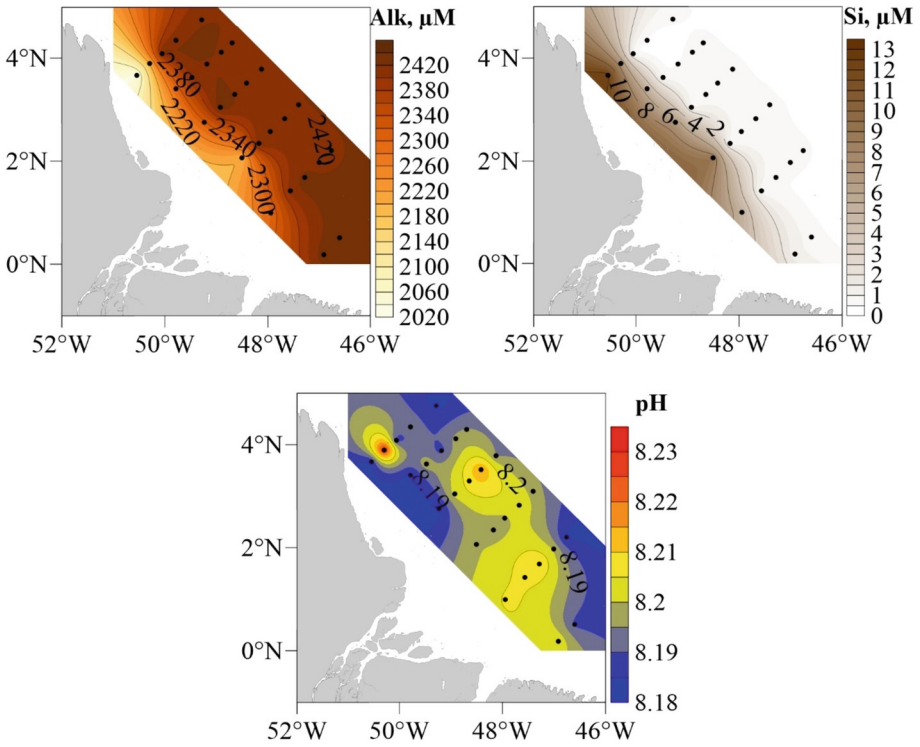

Fig. 3. Distribution of total alkalinity (Alk), dissolved silicate (Si), and potential of hydrogen (pH) on a polygon at the estuary of the Amazon River

Dissolved oxygen content at the polygon ranged from 4.35 to 4.95 ml/l (94–111% saturation) (Fig. 4). Maximums were observed at stations in the northwestern part of the polygon, where the influence of the Amazon River is most pronounced (4.94–4.95 ml/l, at 110–111% saturation), while minimums were observed at stations in the southeastern part, where the influence of rivers belonging to its basin is also observed (4.35 ml/l, at 94–98% saturation). Such low dissolved oxygen concentrations are typical for this region [9], but the high percentage of water oxygen saturation indicates active photosynthesis processes.

The contents of phosphate phosphorus, nitrate and nitrite nitrogen ions at the polygon were extremely low, averaging 0.10, 0.14 and 0 µM, respectively (Fig. 5). Local maxima of their content tended to the coastal stations, with the advancement to the seaside part the values dropped to zero values, which is associated with the decreasing influence of the Amazon River runoff.

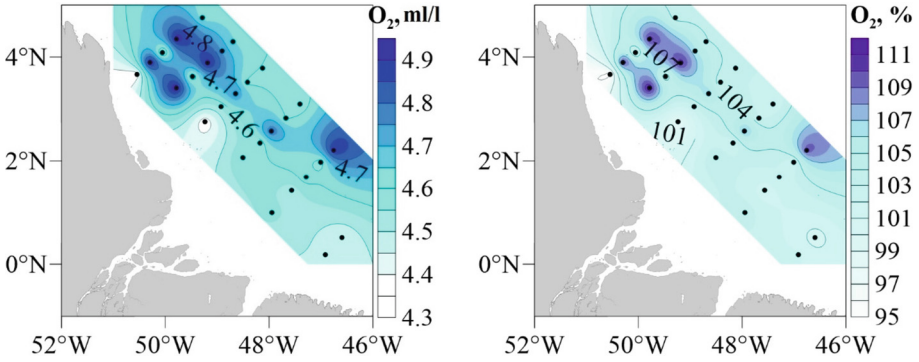

Fig. 4. Dissolved oxygen content (O2, ml/l) and oxygen saturation (O2, %) on a polygon at the estuary of the Amazon River

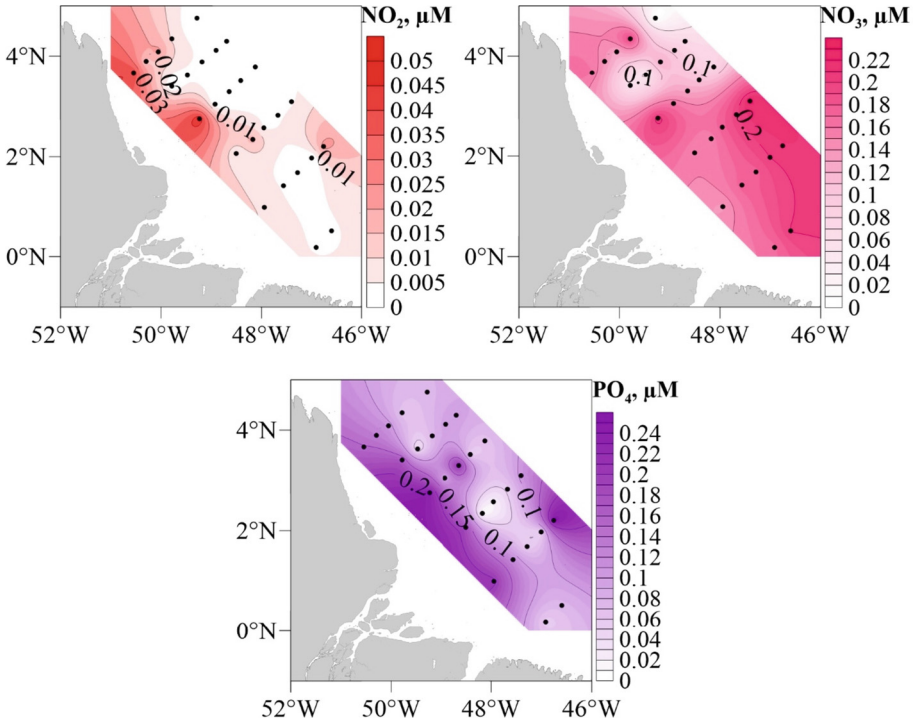

Fig. 5. Distribution of phosphate phosphorus (P-PO4, µM), nitrate nitrogen (N-NO3, µM) and nitrite (N-NO2, µM) on a polygon at the estuary of the Amazon River

It should be noted that at two neighboring stations in the northwestern part of the polygon, maxima dissolved oxygen and local minima of nitrate and nitrite (due to photosynthesis processes) were observed in one case and maxima phosphate, nitrate and

nitrite with minima dissolved oxygen (due to organic matter oxidation processes) in the second case.

4 Conclusion

Despite the fullness of the Amazon River throughout the year, the periods from July to August, when higher water is observed and from November to December, with lower flows, stand out. The work in the ABP 52 cruise on November 2022 fell during the "low" water season, as evidenced by the distributions of thermohaline characteristics in the surface water layer, as well as total alkalinity and dissolved silicate.

Amazon waters are considered to be among the most chemically poor waters on Earth [7]. The low content of phosphorus and nitrogen in river runoff and elevated silicate content have been previously noted [1, 10], which is confirmed by our results.

Low concentrations of nitrogen forms in the surface water layer in both the river and marine parts of the polygon may indicate a low anthropogenic impact on the river basin. To more fully explore the impact of the Amazon plume, measurements are needed at different times of the year, as well as closer to shore, perhaps even moving further inland along the river.

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