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POLLUTION ISSUES OF LARGE RIVERS

Quality of the Solimões River water for domestic use by the riverine community situated in Manacapuru-Amazonas-Brazil

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Abstract The Amazon has the largest watershed in the world, with abundant fresh water reserves. Such abundance contrasts with the quality of the water consumed in the riverine communities. This work highlights the importance of assessing the quality of water of the Solimões River in the stretch situated opposite the Community Nossa Senhora das Graças-Costa do Pesqueiro, in front of the town of Manacapuru-Amazonas-Brazil. The research aimed to evaluate environmental indicators for the quality of the river water as well as in households in this community, according to the regional seasonality. The monitored parameters such as conductivity, dissolved oxygen, turbidity, color, pH, nitrate, nitrite, and sulfate were compared with the water quality standards in force in Brazil. Values well above the maximum level allowed (MLA) for color and turbidity parameters were found in some households, indicating that the water collected from the river is not getting appropriate treatment. The analysis of the correlation matrix of the parameters in the flood period of the river evidenced high correlation among dissolved oxygen (D.O), NO_3^-, Cl^-, SO_4^{2-}, and color. In this study, by principal component analysis (PCA), it was observed that the characteristics of the water, obtained from the river to be consumed in the households, in the flood period showed similarities with the river water samples, indicating absence of efficient treatment for human consumption.

Keywords Riverine communities · Water quality · Correlation

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Introduction

Most of the rural population in the Amazon region live in floodplain areas because of the expansive process of European colonization in the Amazon. The course of life of these populations moves as the cycle of water in the region, in which factors such as ichthyofauna, erosion, and sedimentary processes and forms of vegetation are directly influenced by the dynamics of this habitat. Among the subsistence practices of this population are family farms, poultry, and livestock, so it be desirable to adopt preventive strategies to minimize the problems caused by the seasonality of the waters of this region (Freire and Pinheiro 1994; Fraxe et al. 2007; Jochim 1983).

These subsistence practices, in addition to disordered occupation of river margin, untreated domestic waste-water discharge, and improper disposal of waste, may result in inadequate water quality of the water bodies in the Amazon area human settlements, to consume, to fishing practices, bathing, and landscaping in an extend that will depend on the level of change in the aquatic environment.

Although of recognized importance, sanitation conditions in rural areas have unfortunately been neglected and few reports about the quality of life in these communities, especially regarding the wetlands, are issued.

As these areas are subjected to seasonal flooding, plains situated on the margin of white or muddy waters, as the Solimões River, form a complex system of channels, lakes, islands, and levees that form a mosaic of key environments for the diverse uses of water resources by riverine, owing to the high productivity of fish and soil fertility (Sioli 1951; Moreira 1977). Lougon et al. (2009) highlighted the importance of evaluating the magnitude of the environmental impacts arising from human intervention and stressed the need to establish monitoring practices in order to provide subsidies to diagnose its origins. The rivers play a crucial role in the supply of water for consumption, where the production of drinking water is dependent on the chemical characteristics of the funding supply (Parmar and Bhardwaj 2014).

The Amazon River together with its tributaries forms the largest water complex in the world, covering 6 million km^2, of which 6.6×10^{12} m^3.year^{-1} is the volume of water being discharged into the ocean (Filizola et al. 2002). The Solimões River is one of the largest river basin districts of the Amazon Basin (Ramalho and Macedo 2009). However, it appears that, aside this abundance of water, there is an apparent lack of concern about maintaining the quality and preservation of the river margin, where there is human occupation. In some well-developed cities in the Amazon, there are rules for the use of water resources; municipal governments are responsible for the supply for the population, for the management of groundwater exploration or the treatment of river water, and due destination for human consumption. However, the isolated riverine communities do not have necessary guidance on the use of river water to domestic uses (Oliveira et al. 2008; Fraxe et al. 2007).

Considering the importance of scientific records on the evaluation of water quality of an amazonic river consumed by riverines who live according to the hydrological dynamics in this region, in this study, we selected a floodplain community on the Solimões River near the town of Manacapuru. This work intends to characterize the quality of water used for different uses by means of descriptive statistics and multivariate analysis of the data. The main objective of this work is to contribute to the studies about the influence of anthropic activity in lowland environments.

Materials and methods

Study area

The sampling sites (Fig. 1) are located near a community situated on the right margin of the Solimões River named Nossa Senhora das Graças-Costa do Pesqueiro in front of the town of Manacapuru-AM, in the Lower Solimões River region. Manacapuru has 85,141 inhabitants and an area of 7330.074 km^2, located 84 km from Manaus capital city, Amazonas state (Brazil). This location is 1500 km away from the mouth of the Amazon River. According to Filizola et al. 2009, the flow measurement section, between left and right margins at the weather station located 6 km downstream of the city of Manacapuru, is 3200 m. As this distance is significant, we may assume that sampling points located on the right margin of the river, in the riverine community Costa do Pesqueiro, are not affected by the anthropic activities of the city of Manacapuru, located on the left margin of the Solimões River. This riverine community have 88 households with an approximate length of 10.3 km. Fraxe et al. (2007) pointed out that this community has one of the highest percentages of crop species, either for subsistence or commercial purposes, among the lowland communities.

This study selected sampling points (Table 1) located as follows: three points in the middle of the river and three on the margin, where pumping of water for use in homes is carried out from approximately 1 m deep on the river margin. Sampling points are located upstream and downstream of Costa do Pesqueiro community. Five households were selected on the riverine community to evaluate the quality of the water used for drinking. The number of households included in the study is small because of the large travel time required between sampling sites and the laboratory in Manaus. However, even with a small sample size, the results are valuable for the discussion on water resources that are available in abundance in this region. To ensure the quality of life treatment processes are required especially for the removal of suspended solids. According to Filizola et al. (2002), the suspended solids are present in quantities as large as 447×106 ton.year^{-1} in a flow rate of 96,230 m^3.s^{-1}, for the Solimões River.

Sampling and analytical procedures

Sampling extended through the seasonal regimens of flood (June) and draught (September) of 2014. The methodology of collection and preservation of samples followed APHA-American Public Health Association and American Water Work Association-AWWA (2012). Measurements of in situ parameters (pH, turbidity, conductivity, and dissolved oxygen) were made in triplicate. The conductivity was measured with the aid of a portable conductivimeter Orion model 3 Thermo Scientific STAR brand. For the measurement of pH and dissolved oxygen, a portable pH meter Orion 3star-Thermo Scientific and an oximeter model Oxi 315i-WTW were used, respectively. Turbidity was measured using a multiparametric probe MS5-Hydrolab.

Samples for anion analysis and total suspended solids were collected with the aid of Van Dorn bottles, stored in inert polymer bottles, refrigerated and sent for laboratory analysis. For the quantification of total suspended solids (TSS), the gravimetric method D 2540, APHA-American Public Health Association and American Water Work Association-AWWA (2012).For the determination of the anions (HCO_3^-, Cl^-, NO_2^-, NO_3^-, SO_4^{2-}, PO_4^{3-}), water samples were filtered and analyzed by ion chromatography in a Modular DIONEX ICS 5000. The standard aqueous solutions were prepared from multi-element standard solutions traceable to the National Institute of

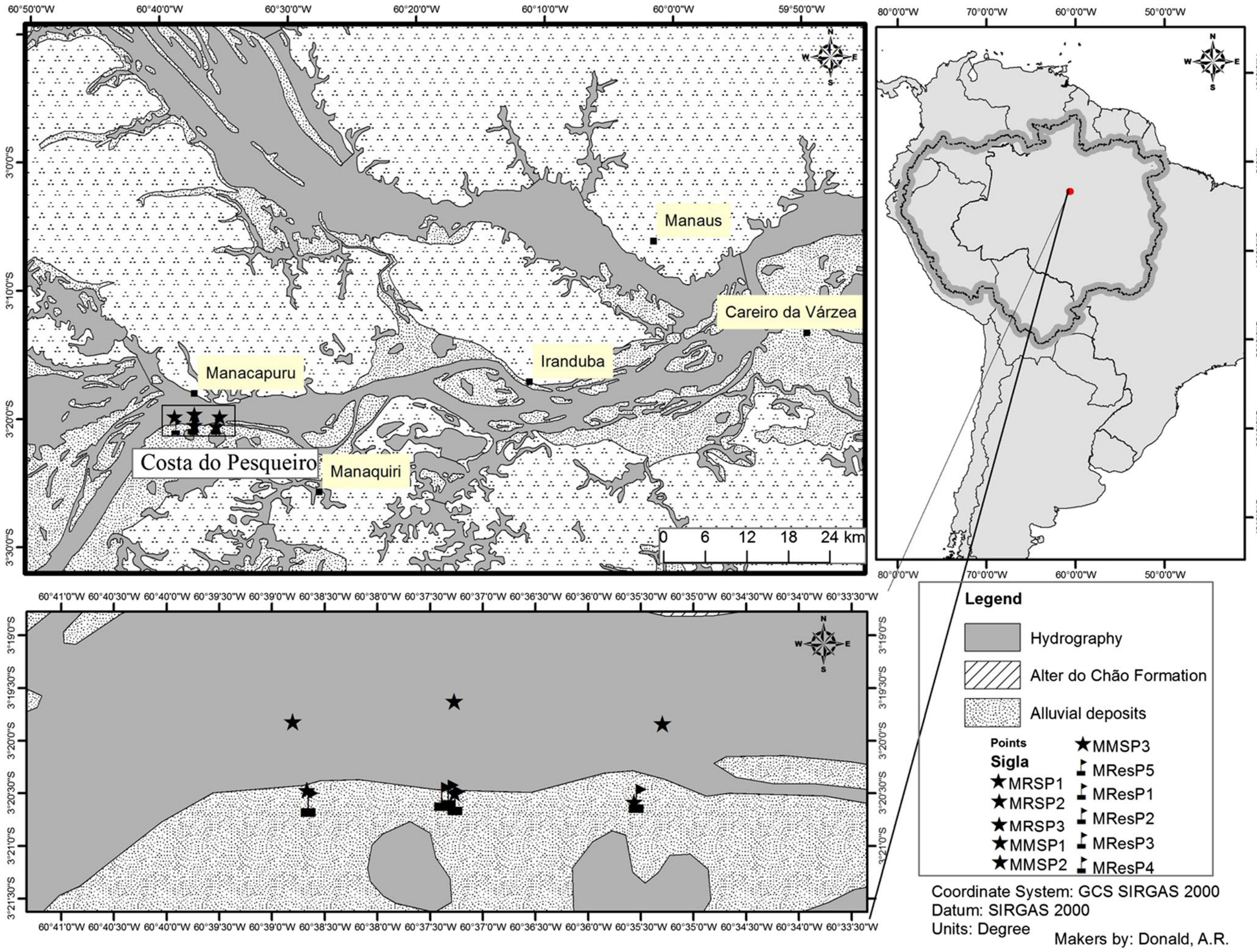

Fig. 1 Location map of the study area

Standards and Technology (NIST) and used for the construction of calibration curves. The analytical procedure followed the US Environmental Protection Agency (EPA)-Method 300.1: Determination of Inorganic Anions in Drinking Water by Ion Chromatography. Quantification limits for Cl^-, NO_2^-, SO_4^{2-}, and NO_3^- were 0.01 $mg.L^{-1}$ and for PO_4^{3-} was 0.05 $mg.L^{-1}$.

Table 1 Identification of sampling points and its geographical coordinates located in the riverside community Costa do Pesqueiro in the Manacapuru city-Amazonas (Brazil)

Sampling point	Point description	Geographical coordinates
MRSP1	Middle Solimões River point 1 (Upstream)	3°19′49.1″ S 60°38′48.3″ W
MRSP2	Middle Solimões River point 2 (in front of the community)	3°19′37.5″ S 60°37′16.2″ W
MRSP3	Middle Solimões River point 3 (downstream)	3°19′50.1″ S 60°35′17.7″ W
MMSP1	Margin Solimões River point 1 (upstream)	3°20′31.7″ S 60°38′40.1″ W
MMSP2	Margin Solimões River point 2 (in front of the community)	3°20′29.9″ S 60°37′16.0″ W
MMSP3	Margin Solimões River point 3 (downstream)	3°20′30.3″ S 60°35′33.7″ W
MResP1	Household point 1	3°20′35.0″ S 60°38′38.5″ W
MResP2	Household point 2	3°20′31.7″ S 60°37′22.4″ W
MResP3	Household point 3	3°20′31.7″ S 60°37′20.5″ W
MResP4	Household point 4	3°20′32.1″ S 60°37′15.0″ W
MResP5	Household point 5	3°20′34.0″ S 60°35′33.5″ W

Data analysis

The average results of the samples collected from the river were compared with the water quality standards in force in Brazil, by maximum levels allowed (MLA) by the National Council on the Environment-CONAMA Resolution 2005 and the samples collected from households with the maximum contaminant levels allowed by the Ordinance of the Ministry of Health 2914/2011.

To perform statistical analysis to verify the Pearson correlation between the indicators assessed, we used the Action 2.8 software free to use in R and Excel program platform in an integrated manner. Due to the large number of variables considered in this study, the principal components analysis (PCA) was applied to investigate the similarity or disparity between sampling points by *scores* graphic and analyzed parameter by *loadings* graphic and its possible causes. In order to work with different magnitudes data groups, it was necessary standardize the data for later application of PCA. This analysis was performed using the software The Unscrambler® × 10.3, specific to multivariate analysis.

Results and discussion

Hydrologic characterization of the main channel and influence of seasonality

The area studied in this work lies on Quaternary sediments dating from the Holocene which consist of quartz, K-feldspar, kaolinite, plagioclase, mica, sedimentary rock fragments, fragments of hematite, and carbonate rocks. The Solimões River percolates sedimentary rocks of the Solimões formation. The formation of these quaternary sediments occurred along the course of the river because of the constant deposition of suspended material as these waters percolated the ins and outs, resulting in the formation of wetlands. However, in upland, the Solimões formation supersedes the Quaternary sediments, as well as the remarkable contribution of sediments from the Andes influences the chemical composition of these waters (Queiroz et al. 2009; Horbe et al. 2007). Thus, it turns out that the geochemical phenomena such as physical and chemical weathering and laterization undergone along the course of the Solimões River significantly influences the chemical composition of its waters.

The flooding regions suffers subsequent floods, during flood season affecting a large quota of the river (Recursos Minerais 2014); this produces highly fertile soils that could reduce the need for application of fertilizer during activities of family farming. In the Lower Solimões region, the flood season occurs during the months of May, June, and July, when the waters flood much of the farmland. The receding has its beginning in August, extending until October (Bittencourt and Amadio 2007). In the drought season, the practice of irrigation increases resulting in infiltration and subsequent runoff of substances resulting from the fertilizers. Among these compounds are ammonium sulfate ($(NH_4)_2SO_4$), urea, superphosphate (P_2O_5), mono-ammonium phosphate (MAP), diammonium phosphate (DAP), potassium chloride (KCl), and potassium sulfate (K_2SO_4).

Filizola et al. (2009) examining data obtained from the hydrometric station of Manacapuru found that the discharge of the main course of the Solimões River is 103.000 $m^3.s^{-1}$ in an area of 2×10^{-6} km^2 and is equally distributed throughout the year. According to the authors, in the flood season, there is a significant increase in the main exhaust stream with subsequent reduction of the concentration of suspended material, particularly in the middle of the channel. Therein, it was reported that the discharge of the Solimões presented an average value of 59.901 $m^3.s^{-1}$ in the dry season and 122,001 $m^3.s^{-1}$ the flooding period. Many lakes situated in flood plains adjacent to the Solimões River are affected by its waters with consequent increase in quota levels. This increase in flow results in a reduction of the concentration of some elements caused by the effect of dilution. This phenomenon could be associated to the reduction of dissolved oxygen concentrations, observed in the flood period. Brito et al. (2014) found similar results for floodplain lakes of Central Amazon, where the reduction of dissolved oxygen in flood season has been attributed to dilution of phytoplankton biomass and higher oxygen demand from smaller tributaries.

In preserved environments, hydrochemistry is influenced of the environments where the water percolates. Figure 2 shows the results obtained for chemical and physicochemical analysis in the periods of flood (June) and draught (September).

When the results obtained for dissolved oxygen (DO), pH, color, turbidity, PO_4^{3-}, SO_4^{2-}, Cl^-, NO_2^-, and NO_3^- are compared with the maximum levels allowed (MLA) by the CONAMA Resolution 357/2005, for rivers classified as classes 1 (special water) and 2 (surface water with no apparent degradation), these waters could be destined for public supply only after treatment. Very high values for color and nitrate (NO_3^-) are observed in Fig. 2. These deviation values are known as "outliers." According to Di Blasi et al. (2013), an outlier is a record that is numerically distant from the rest of the data set so research to investigate the origin of these extreme values is advisable. In June, the MRSP3 point located downstream of the other points had a mean value for color of 82 uH, above the maximum allowed by the CONAMA resolution that is 75 uH. The high NO_3^- value was 21.0 $mg.L^{-1}$ (MLA is 10.0 $mg.L^{-1}$) is not expected to a point located in the middle of the Solimões River, due to its characteristic flow, should the result be a punctual occurrence. For these parameters highlighted in values, one must consider the future realization of monitoring and better evaluation of the data variation between seasonality.

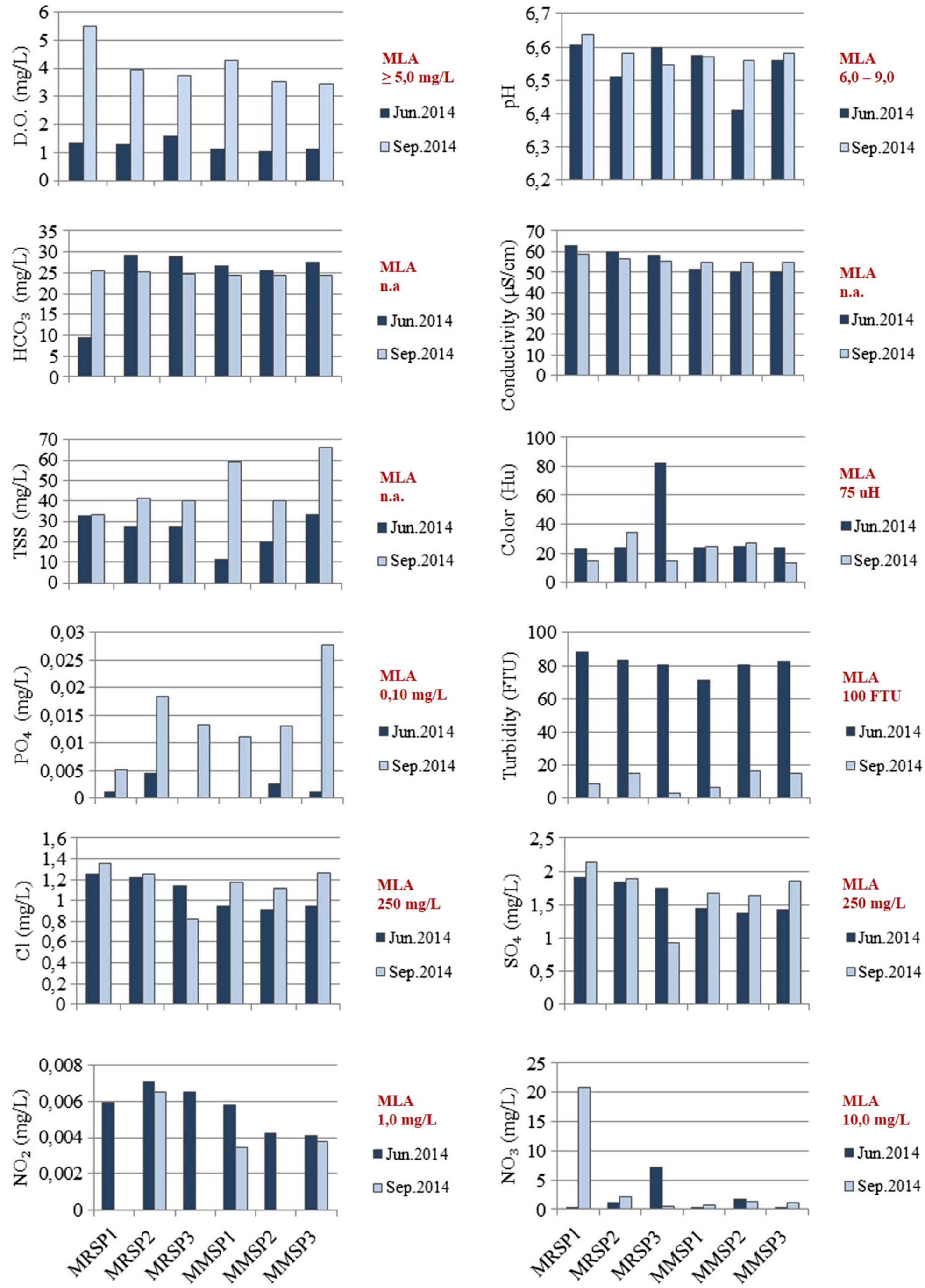

Fig. 2 Chemical and physicochemical parameter distribution in the margin and middle samples from river, in the periods of flood (June) and draught (September). *MLA* maximum levels allowed, *n.a.* parameter absent in CONAMA Resolution 357/2005

The dissolved oxygen (DO) values are above the limit stated in CONAMA, that is, 5 mg.L^{-1}. This result was for all points collected, except for MRSP1. This environmental resolution was established to regulate the quality of surface water for all river basins in Brazil, but some parameters do not apply to the characteristics of the Amazon region. The behavior of OD may be related to the high turbidity, indicating high presence of dissolved solids which influence the water temperature and also lower concentrations in the river flood period when the whole community land area was inundated. Turbidity and DO were the parameters that clearly showed differences in results between the flood and drought periods.

Examining the correlation in Table 2 among parameters registered in the river samples collected in June (flood), we found that the color was highly correlated with dissolved oxygen content (0.82) and nitrate (0.98). In the presence of OD, even this at low concentrations in the flood period, the ammonium ion (NH_4^+) is oxidized to nitrate (NO_3^-), process known as nitrification. The major sources of ion NH_4^+ in soils are human and animal waste, synthetic fertilizers, biological N_2

Table 2 Correlation between all parameters analyzed in June in the flood period in Solimões River samples

Parameters	C.E.	D.O.	HCO_3^-	Color	Turbidity	Cl^-	NO_2^-	NO_3^-	SO_4^{2-}	PO_4^{3-}	TSS
pH	0.45	0.59	−0.32	0.34	0.06	0.45	0.42	0.16	0.48	−0.64	0.30
C.E.	1	0.72	−0.51	0.22	0.65	0.99	0.77	0.20	0.99	0.19	0.49
DO		1	−0.08	0.82	0.29	0.71	0.68	0.78	0.73	−0.25	0.38
HCO_3^-			1	0.31	−0.57	−0.45	0.02	0.35	−0.45	0.16	−0.32
Cor				1	−0.09	0.19	0.34	0.98	0.23	−0.44	0.11
Turbidity					1	0.65	0.07	−0.07	0.64	0.41	0.87
Cl^-						1	0.79	0.17	1.00	0.25	0.52
NO_2^-							1	0.32	0.79	0.17	0.01
NO_3^-								1	0.20	−0.30	0.06
SO_4^{2-}									1	0.21	0.52
PO_4^{3-}										1	0.18
STS											1

fixation, and high rainfall events (Stumm and Morgan 1966). In September, the values of dissolved oxygen are higher than those in the month of June. The presence of DO cooperates with higher production NO_3^- caused by nitrification process. Also, in the flood period can be seen with significant correlation the turbidity and total suspended solids and the electric conductivity with Cl^- and SO_4^-.

In Table 3, with data of September (drought), Cl^- and SO_4^2 $^-$ showed significant correlation, thus indicating that these ions predominate in the ionic composition of samples analyzed. The electrical conductivity of the Solimões River presented a significant correlation, with higher correlation coefficients than 7.0, to pH (0.84), dissolved oxygen (0.86), bicarbonates (0.96), and nitrate (0.90). These results also show little spatial variability for either the samples collected at the margin, and in the middle of the river. At pH>6, indicating low acidity in the study area may be attributed to the presence of bicarbonate.

The river water used for human consumption

The results presented in Table 4 are the parameters analyzed in the waters of five households at the riverine community Costa do Pesqueiro, located in front of city of Manacapuru. The analyzed waters are used specifically for drinking. Considering that in this riverine community, there is a record of the presence of 88 households, this study enrolled 5.7 % of households. Therefore, this study is a preliminary assessment to indicate the regional problems concerning the use of river water for drinking, without appropriate conditions for consumption.

During the study, the riverine community pumped water from the river margin directly to storage boxes 500–100 L in households for different uses, such as bathing, general clean-up, cooking, and drinking. According to reports of the families, the water used for cooking and drinking is stored in smaller containers where suspended solids were allowed to settle and subsequently filtered with a cloth. Some households perform the treatment of the water by adding aluminum sulfate to better flocculation and settling of suspended solids. Some homes perform the treatment of the water by adding aluminum sulfate ($Al_2(SO_4)_3$) to better flocculation and settling of suspended solids.

The Ordinance of the Ministry of Health 2914/2011 establishes maximum permitted values, potability standards for human consumption, as some parameters in Table 4, along with the results found in this work. Values well above the maximum allowed for turbidity where found in all households in the flood period, just as the color, except MResP2, suggesting that these waters used to drink was recently collected and stored by the consumers without efficient treatment to remove suspended particles and other impurities.

The extraction of groundwater as water supply has been an alternative that has been recommended in order to obtain drinking water in flooding communities (Azevedo 2006). However, this alternative has been little explored in the Costa do Pesqueiro Community. According to data provided by the Groundwater Information System (SIAGAS-CPRM), this community has registered only four private wells that have maximum depth of only 12 m, of these, only one is operative. As for surface water collected for human consumption, Wilbers et al. (2014) recommend the utilization of the main river rather than obtaining water from secondary channels as they accumulate more organic matter than the former. However, the high concentration of particulate matter of the Solimões River (Filizola et al. 2009) requires the application of some treatments to allow its use for drinking purposes. One of the forms of treatment widely applied is filtration and coagulation. Fernandes et al. (2010) observed the higher efficiency of the filtering process over coagulation due to its capability for the removal of slurry, and its ability to promote the removal of protozoa that are responsible for gastrointestinal diseases and are resistant to alternative treatments.

Table 3 Correlation between all parameters analyzed in September in the drought period in Solimões River samples

Parameters	C.E.	D.O.	HCO_3^-	Color	Turbidity	Cl^-	NO_2^-	NO_3^-	SO_4^{2-}	PO_4^{3-}	TSS
pH	0.84	0.85	0.68	−0.21	0.10	0.79	−0.05	0.93	0.82	−0.36	−0.27
C.E.	1	0.86	0.96	−0.07	−0.12	0.45	−0.13	0.90	0.51	−0.54	−0.68
DO		1	0.72	−0.18	−0.36	0.47	−0.23	0.91	0.51	−0.73	−0.44
HCO_3^-			1	0.07	−0.11	0.31	−0.06	0.76	0.37	−0.50	−0.78
Cor				1	0.43	0.17	0.55	−0.32	0.19	−0.03	−0.17
Turbidity					1	0.56	0.36	−0.11	0.56	0.51	0.12
Cl^-						1	0.40	0.53	0.99	0.07	0.13
NO_2^-							1	−0.37	0.34	0.57	0.46
NO_3^-								1	0.59	−0.59	−0.52
SO_4^{2-}									1	−0.01	0.03
PO_4^{3-}										1	0.68
STS											1

Whereas data are studied for different dimensions and difficult layout, it was applied to principal component analysis (PCA), which provides the composition of the principal components relative to the samples with grouping on score graphics, and in respect of variables, with the grouping on loading graphics. The filing jointly score and loadings graphics may indicate the influence of variables in the samples. Figures 3 and 4 show, respectively, the PCA in June (full period) and in September (dry season) for the samples collected and for registered parameters

The score graphic shows a deviation for MResP2 point in June (Fig. 3a) and MResP1 point in September (Fig. 4a), respectively, compared to the other points. As shown in loadings of June plot (Fig. 3b), it appears that this disparity is caused by the change in the concentration of ions SO_4^{2-} in these samples. However, concentration of the sulfate ions in these samples, are well below the maximum levels required by the Ministry of Health that is 250 mg.L^{-1}, recalling that SO_4^{2-} was a predominant ion in the river samples.

Figures 3a and 4a present that the score graphics are a clear evidence of the lack of similarity between the water samples from individual households for the samplings made in September as they are situated in different quadrants of the graphics. This reflects the absence of established procedures for the treatment of water collected from the river for the consumption in the riverine community. It is worth noting that the results for the samples collected in June (Fig. 3a) in the households (MResP1, MResP3, MResP4, and MResP5), appear with reasonable similarity to the components evaluated among samples from the river margin (MMSP1 and MMSP2) and from the middle of the river (MRSP2), indicating the lack of adequate and effective treatment for the water that is pumped from the margin of the Solimões River for use in the human consumption.

The loading graphic obtained for the month of June (Fig. 3b) showed that the electrical conductivity explains most of the variation in the data. In September, the parameter that is the principal responsible for the variation in data is dissolved oxygen (DO). The parameter responsible for the deviation MRSP3 point (Fig. 3a, b) was color with a value of 82 uH. This high value could be attributed to recent effluent emission, or to any event that caused re-suspension of sediments.

Table 4 Averaged results of the analyzed parameters of water used for drinking in the households from community Costa do Pesqueiro, in Manacapuru city

	MResP1		MResP2		MResP3		MResP4		MResP5		M.S. 2.914/11
Parâmetros	Jun/14	Set/14	Jun/14	Set/14	Jun/14	Set/14	Jun/14	Set/14	Jun/14	Set/14	
pH	6.816	6.686	5.272	5.814	6.58	6.610	6.502	6.704	7.222	6.91	6.0–9.5
Cor (uH)	26.50	3.300	5.400	2.600	24.20	14.60	25.4	66.10	22.80	21.4	15
Turbidez (UNT)	63.74	2.130	48.96	2.930	67.88	4.167	66.52	149.5	62.70	3.813	5
Cl^- (mg.L^{-1})	0.975	1.167	0.975	1.171	1.01	1.372	0.921	1.210	0.999	1.130	250
NO_2^- (mg.L^{-1})	0.009	n.d.	n.d.	n.d.	0.004	0.027	n.d.	0.004	n.d.	n.d.	1
NO_3^- (mg.L^{-1})	0.833	0.584	0.488	0.505	0.374	15.947	2.864	0.596	n.d.	1.506	10
SO_4^{2-} (mg.L^{-1})	1.533	21.11	28.02	n.d.	1.504	1.776	1.435	1.715	0.466	1.693	250

M.S. Ordinance of the Ministry of Health for quality levels of water 2914/2011, *n.d.* not detected

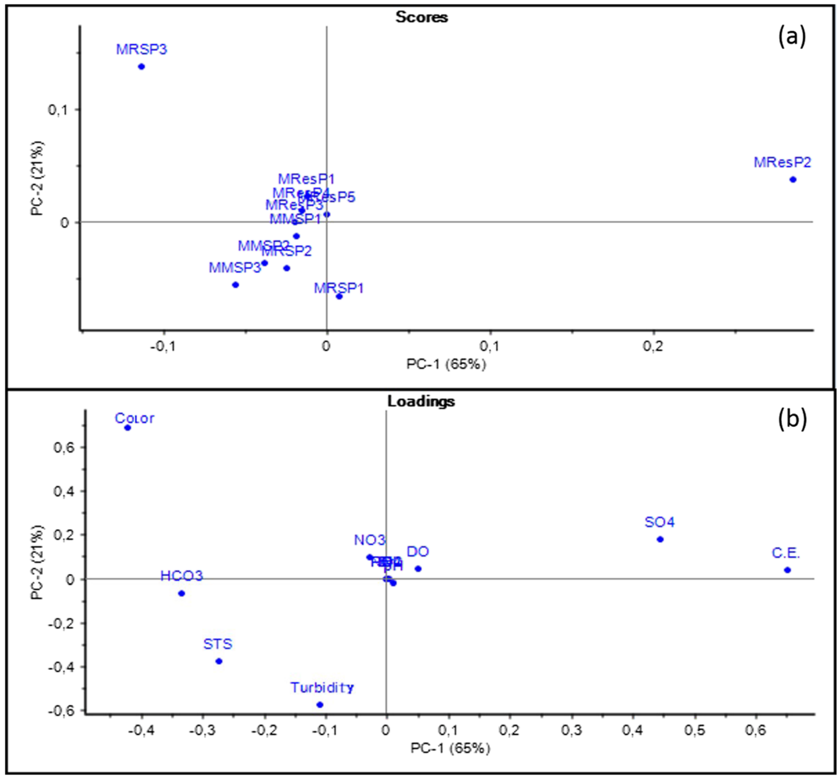

Fig. 3 Principal component analysis of the all sampled points (**a**) and registered parameters (**b**) in June (flood)

We can observe that the measured turbidity values are much higher in the flood period than in the receding period (Fig. 2). PCA of loading graphic (Fig. 3b) shows that the turbidity parameters, bicarbonate, and total suspended solids are in the same quadrant, indicating that the chemical composition of the water in the flood period is significantly

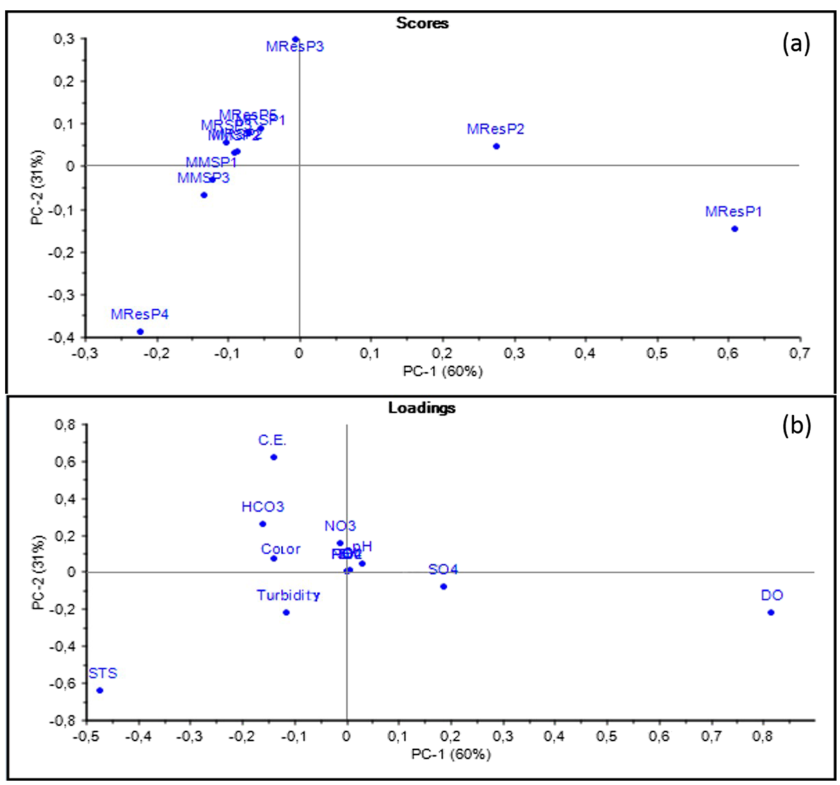

Fig. 4 Principal component analysis of the all sampled points (**a**) and registered parameters (**b**) in September (drought)

influenced by the regional geochemistry. The high regional rainfall as well as the use and occupation of lands which causes deforestation contributes significantly with the natural erosion process in the region (locally call "fallen lands") are factors that increase the particles inlet to the water bodies resulting in increased turbidity of these waters.

Final considerations

This study contributed to the assessment of the use of water from the Solimões River for consumption in riverine communities, enabling the observation of indicators of standard of quality for the water body, as for the water collected and conducted for the consumption in the studied households. In Fig. 2 on the preliminary analysis, it can be seen that there are no differences in the behavior of the logged parameters between sampling points in margin and in the middle of the river. Among these results, the high levels of turbidity for collection on the flood period (June) stand out, than for the collection during the drought period (September). This difference can be observed by OD concentrations that were very low in the flood period, when the whole land area in the riverine community is flooded. The OD was a parameter that had values higher the MLA by CONAMA.

The analysis of the correlation matrix of parameters in flood period allows to check the concordance between turbidity and total suspended solids, also high correlation between DO, NO_3^-, Cl, SO_4^{2-}, and color, all featuring a correlation coefficient >8.0. Among the parameters analyzed, the correlation of Cl with SO4 indicates the predominance of these ions in the ionic composition. A significant correlation of DO with NO3 indicates the effect of nitrification processes in the environment and the concentration of dissolved oxygen.

In the study of the samples of the households, for evaluating the use of river water for human consumption, the turbidity and the color showed values that are elevated and are higher than those established in the Brazilian norm of the Ministry of Health (Ordinance 2.914/2011). This indicates that the water collected from the Solimões River for the consumption is not getting appropriate treatment for this purpose.

The principal component analysis (PCA) evidenced the similarity in the behavior of samples and parameters studied. In the flood period, the water samples to drink in the households presented similarity among themselves and were grouped with some samples of the river, thus indicating the absence of an effective treatment for the pumped water consumption from the river. In the drought period, just the MResP5 sample was grouped with the river samples, and other samples of households were in different quadrants, indicating lack of standardization in the treatment of drinking water in the riverside community. The main parameters responsible for differences in PCA were SO_4^-, DO, and color. The parameters responsible for the similarity of behavior were turbidity, bicarbonate, and total suspended solids indicating that the chemical and physicochemical water samples are mainly influenced by the intense transport of suspended sediments in the Solimões River.

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