Vol. 14(3), pp. 112-118, April, 2020
DOI: 10.5897/AJMR2019.9064
Article Number: 66AC50263471
ISSN: 1996-0808

http://www.academicjournals.org/AJMR

African Journal of Microbiology Research

Full Length Research Paper

Physicochemical and microbiological evaluation of water from western part of the Rio Grande does Norte, Brazil

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Received 30 January, 2019; Accepted 6 March, 2020

The water quality evaluation with reference to parameters of drinkability is made through a series of analyses, which are physicochemical or microbiological. This study aims to evaluate the physicochemical and microbiological parameters of drinking water distribution network in the western part of the Rio Grande do Norte, Brazil. Water samples were collected in several neighborhoods, and divided into 5 zones. In each of those five points two samples were collected: Water receiver of water distribution network and household water collector. In relation to the physical parameters, color and turbidity recorded higher results in the collectors of homes, and identified the lack of maintenance. For the studied microbial tests, the presence of coliform group bacteria was verified, being the major contamination in the receivers. This was justified by the lack of maintenance and prohibition of sealing of these collectors, allowing the access of rodents, insects and other carriers of microorganisms. Therefore, the water consumed at the collection points in the western zone of the RN / Brazil presents adequate physicochemical and microbiological indices in disagreement with the legislation that regulates water portability.

Key words: Water quality, coliforms, microorganisms, portability, water supply.

INTRODUCTION

Water quality of public supplies, through chemical, physical and microbiological parameters, is an issue monitored by the government through regulatory agencies or consumers (Al-Mudhaf et al., 2009). There are so many reasons for that quality being compromised, such as some chemicals substances persistently remain stable to the conventional water treatment processes or simply by their cumulative effect (Inyang and Dickenson, 2015).

The composition of some chemical products used in the water treatment or its components which are naturally present in the water and their potential adverse health effects associated with long-term ingestion have been studied by Choi et al. (2013); this drives to the importance of policies that regulate issues surrounding water portability parameters for human consumption.

Ordinance N° 2914 of 12 December 2011 of the Ministry of Health (Brazil, 2011) currently holds in Brazil and provides procedures for controlling and monitoring water quality for human consumption and its portability

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standards. This legislation rules establish actions of supplier agencies involved in the water treatment processes and control to provide potable water to the population respecting the proper hygienic and sanitary quality standards, through physical, chemical and microbiological indicators (Morais et al., 2016).

In the assessment of water quality, a set of parameters must be considered as well as their maximum permissible values (MPV) in accordance with Brazilian legislation (Silva et al., 2014). Among these parameters, the physicochemical has fundamental importance because these characteristics can influence the water taste, color and odor, and produce harmful physiological effects (Blank and Vieira, 2014). According to the studies that portray the water quality for human consumption, the main physical and chemical parameters evaluated are pH, hardness, chloride, nitrate, alkalinity, color and turbidity, with standards established by Ordinance 2.914 / 2011 (Sousa et al., 2016; Lima et al., 2016; Fernandes and Scalize, 2015).

Beyond the physicochemical parameters, potable water must be free of pathogenic microorganisms and indicator bacteria which determine contamination, highlighting the coliforms group, total coliforms (TC), thermotolerant coliforms (TTC) and *Escherichia coli* (Fatemeh et al., 2014). These bacteria may be responsible mainly for gastroenteritis which remains a huge concern for public health in developing countries and regions with small financial resources and poor hygiene conditions (Cabral, 2010).

According to Tong et al. (2016), about 88% of gastroenteritis cases in the world are attributed to contaminated water containing these bacteria, which are common in cases of inadequate sanitation or insufficient hygiene. Thus, it is important to develop research into the environmental monitoring and diagnosis, in order to strengthen the scientific basis in the area, thereby allowing the adoption of control measures and management of pollution sources (Oliveira et al., 2009).

Therefore, there is a need for verification on the quality of potable water delivered by the supplier agency to customers of the west RN/Brazil under the following optics: (A) water receiver of water distribution network in the households and (B) household water collector.

MATERIALS AND METHODS

Samples and location of sampling

Water samples were collected in several neighborhoods near the municipality of Mossoró / RN, divided into 5 zones (North, South, East, West and Central). In each of those five points were collected two samples – (A) water receiver of water distribution network and (B) household water collector. Samples were collected following the sample storage guidance and preservation, considering the parameter to be analyzed according to Funasa (2006). Ten samples were collected in each recipient at 15 day intervals, in the months of July to November 2016, totaling 100 samples.

Analyses

Samples were subjected to analysis according to the Standard Methods for the Examination of Water and Wastewater (Eaton et al., 2012). They were processed at the Veterinary Microbiology Laboratory and at Petroleum Engineering Laboratory; both belong to the Federal Rural University of the Semiarid. The following analyses were carried out:

pH

Using the potentiometer, the electrometric pH measurement principle is the determination of the ionic activity of hydrogen using the standard hydrogen electrode, which consists of a platinum rod on which the hydrogen gas flows at a pressure of 101 kPa.

Hardness

This is done through the titration process by complexation, using a standard solution of EDTA (ethylenediaminetetraacetic acid).

Nitrate

This is done by the use of phenol disulfonic acid method, with spectrophotometer reading.

Chlorides

This was done with titration with Silver Nitrate, where the standard solution of silver nitrate was placed in a 50 mL burette and the titration was carried out until the colour changed from white to red. This procedure was repeated twice and compared with the with test (distilled water).

Alkalinity

Using titration with sulfuric acid, which is determined by potentiometry is done by titration with standard solution of H_2SO_4;

Colour

The colour determination is made by visually comparing the sample with a coloured glass disk, suitably calibrated with standard solutions of different concentrations of (K_2PtCl_6).

Turbidity

This is determined by the nephelometric method, using a Turbidímetro.

Microorganisms (total coliforms, thermotolerant coliforms and *Escherichia coli*): the most probable number (MPN) technique also known as multi-tube method was used. 25 mL of sample was prepared aseptically and three successive dilutions (10^1, 10^2 and 10^3) were prepared and for each dilution three tubes containing 10 mL of Sodium Lauryl Sulfate Broth (LST) were used with inverted Durhan tubes, which were subsequently incubated at 35 to 37°C for 24 h. The positivity of the test was observed by the production of gas inside the tubes of Durhan.

Statistics

The data on physicochemical analyses were performed

Table 1. Chemical parameters, pH, hardness, chloride, nitrate, alkalinity of collected water in the areas north, south, east, west and center of the city of Mossoro followed by data extracted from the statistical tests.

Parameter	pH			Hardness			Chloride			Nitrate			Alkalinity		
Score/zone	**A**	**B**	**X**	**A**	**B**	**X**	**A**	**B**	**X**	**A**	**B**	**X**	**A**	**B**	**X**
North	7.9	7.9	40.2[bc]	112.0	118.6	63.4[b]	48.9	51.3	30.9[bc]	1.4	1.0	45.5[b]	91.0	91.2	53.1[a]
SD	0.3	0.1		14.6	23.0		6.1	6.7		0.3	0.5		27.0	25.7	
South	8.1	7.9	53.0[ab]	89.2	98.4	43.8[c]	60.3	61.6	74.1[a]	1.9	1.6	65.9[a]	96.2	87.0	53.5[a]
DP	0.2	0.2		19.3	10.2		3.5	3.7		0.7	0.5		27.9	22.8	
East	8.0	8.2	65.5[a]	29.3	34.6	10.5[d]	52.3	54.2	41.8[b]	2.1	1.5	65.5[a]	94.6	89.0	49.5[a]
DP	0.3	0.1		13.4	8.1		3.5	4.1		0.8	0.6		24.7	26.1	
West	7.8	7.7	31.6[c]	172.8	218.8	89.1[a]	49.6	49.5	26.6[c]	1.0	1.1	37.7[b]	87.1	88.4	40.0[a]
DP	0.3	0.2		46.0	24.1		9.2	4.3		0.4	0.2		37.5	34.1	
Central	8.0	8.0	62.0[a]	88.3	94.6	42.6[c]	62.6	62.9	78.9[a]	1.3	1.0	37.7[b]	96.1	90.5	56.2[a]
DP	0.1	0.2		17.9	15.9		6.2	3.4		0.4	0.4		26.4	25.1	
W		664.5			285.5			442.5			829.5			710.5	
P-value		0.798[ns]			0.0007**			0.136[ns]			0.013*			0.029*	
MAV*		**6.0-9.5**		**500 mg/L**				**250 mg/L**		**10.0 mg/L**				**NC**	

(A) Water receiver of the city water distribution network; and (B) water household collector. In the X columns, averages followed by the same letter do not differ among each other, at 5% probability, the Kruskal-Wallis test; [ns], *, **not significant; significant at 5% and 1% significant, respectively, by Wilcoxon test. *** Ordinance No. 2914/2011(BRAZIL, 2011); NC = not quoted; DP = Standard Deviation; MAV= maximum allowed value.

using two tests for statistical treatment. The Kruskal-Wallis test was used to compare the parameters for the Zones (North, South, East, West and Central). In the samples collected on point A and B, were used the Wilcoxon test – Paired; the hypotheses are tested about equality of means or medians of dependent populations with unknown distributions (Spiegel et al., 2013). The ActionStat v.3.0 software developed by ESTATCAMP was used for the analysis.

In statistical microbiological analyses, data were tabulated in Microsoft Excel 2016 spreadsheet application. Logarithmic transformation was used (LOG) and comparing means was proceeded using the Tukey test, with the level of 5% probability. The software used in the analysis was the SAS (Cody and Smith, 2004).

RESULTS AND DISCUSSION

The averages of results referring to the chemical parameters pH, hardness, chlorides, nitrates and alkalinity to the North, South, East, West and Central zones are described in Table 1. The averages of the two samples through the test Kruskal Wallis are described in the column identified by the letter X, which tests the statistical difference between the zones. The p-value represents the Wilcoxon test that describes the significance between A and B.

In the Western region, lowest values for pH in both Samples A and in B in the studied households were observed. This may be associated with the nature of the mineral soil, that can be acidic naturally s by a deficiency in the origin soil basis or by processes of soil forming that leads to a removal of basic elements such as K, Ca, Mg and Na. This result differs statistically from the other zones ($p > = 0.05$); however is found to the extent required by law. There was no significant difference statistically in the pH measured between samples A and B ($p = 0.758$).

The default for pH tells that the pipes probably have no corrosion or fouling, suggesting that water used to supply at low pH values less than 4 may contribute to corrosiveness and values greater than 7 increase the possibility of fouling, highlighting the need for control (Sousa et al., 2016).

Hardness recorded in the water samples was between 29.3 and 218.8 mg/L, respectively on the East and West zones. These data are probably due to variation in the multivalent cations concentration in the water solution, either in the sample A or B, being most common calcium and magnesium (Ca^{+2}, Mg^{+2}). That can originate from nature (dissolution of limestone) or by man

Table 2. Physical parameters color and turbidity of the water collected in the areas north, south, east, west and center of the city of Mossoro followed by the data extracted from the statistical tests.

Parameter	Color			Turbidity		
Zone/point	**A**	**B**	**X**	**A**	**B**	**X**
North	3.00	6.48	41.70[a]	0.99	1.13	56.07[a]
DP	2.78	9.71		1.04	0.89	
South	5.23	4.73	50.22[a]	1.05	1.98	63.12[a]
DP	5.20	3.62		1.10	1.80	
East	3.70	3.87	46.50[a]	0.39	0.53	27.27[b]
DP	2.06	2.10		0.15	0.35	
West	6.59	9.32	59.62[a]	0.78	1.6	55.17[a]
DP	8.37	11.70		0.41	2.64	
Central	5.06	4.75	54.45[a]	0.99	0.82	50.85[a]
DP	3.85	2.35		1.20	0.51	
W		327.0			390.0	
P-value		0.382[ns]			0.027*	
MAV – Legislation ***		15uH			5uT	

A) water receiver of the municipal water distribution network and B) household water collector in the X columns, averages followed by the same letter do not differ at the 5% probability, the Kruskal-Wallis test. [ns], *, **not significant; significant at 5% and 1% significant, respectively, by Wilcoxon test. ***Ordinance No. 2914/2011(BRAZIL, 2011); DP = Standard Deviation; MAV= maximum allowed value.

actions (disposal of industrial effluents). In supersaturation conditions, these cations react with anions in the water, forming precipitates (Brazil, 2011; Sousa et al, 2016).

The values recorded in the study can be said to be classified as not hard (29.37 to 34.69 mg/L) in the East, moderately hard (89.28 to 118.60 mg/L) in the central, South and North regions, and hard (172.82 to 218.82 mg/L) in the Western region. Despite presenting statistical difference between the areas, the observed results are in accordance with the standards of the law.

The statistical difference observed (p <0.007) can be attributed to anthropic action on the receptors of residences with the accumulation of calcium and magnesium in the water pipes. However, Lima (2015) stated that high levels of hardness do not cause health disorders to population.

The result from analysis presented values between 48.9 and 62.9mg/L independently of samples origin A and B, below the limit established by law (250 mg/L) presenting statistically significant differences between zones. Chloride (chlorine in the ion form of Cl^{-1}) is one of the most common ions in natural waters and pollution indicator for domestic sewage. This justifies the water portability studied at the reception points and capture in this parameter, and the absence of salt taste with laxative properties (Filho et al., 2015). The amount of chlorides in the samples A and B presented no statistical significant difference (p = 0.136). This confirms the research by Vanuchi et al. (2014) and Moreira e Condé (2015) where they studied the presence of chlorides in the cities of Ubá / MG and Ariquemes/RO, which presented similar results to those of this research, with low levels of chloride between 18 and 20 and 19.3 and 35.4, respectively.

Nitrate ion ($NO3^-$) is a byproduct of nitrogen cycle (Stüeken et al., 2016).It is the inorganic contaminant of concern in groundwater which may be from sewage and fertilizer application (Baird and Cann, 2011). The results found in the quantification of nitrate presented a statistical difference, being equal in East and South zones with the averages observed around 1.8mg/L.

The alkalinity results were between 87.1 and 96.2mg / L in zones studied showing that the analyzed water had no major changes by organic matter decomposition processes, effluent discharges or by metabolism of microorganisms through their respiratory activity and release of carbon dioxide.

Although the Brazilian legislation does not mention a maximum permissible value for the parameter, Libânio (2010) describes that the alkalinity of natural waters in the country is less than 100 mg/L of calcium carbonate ($CaCO_3$). This study presented no statistical difference among the regions; however the samples A and B expressed statistically different results, probably due to the presence of $CaCO_3$ originating from rock formations.

The physical parameters shown in Table 2 of the colour of the water supply of the analyzed areas were observed standard values, where the maximum value found was verified in the West region. The result was not statistically different (p ≤ 0.05) between the zones and between samples A and B studied.

Turbidity is related to the presence of suspended solids

Table 3. Values average for microbiological water parameters CT, TTC and *Escherichia coli* collected in the areas North, South, East, West and Center of the city of Mossoro followed by the extracted data in the statistical tests.

Zone	CT	Parameter X (Averages)	
		TTC	***E. coli***
North	35.55[a]	13.87[a]	2.0[a]
South	75.19[a]	15.16[a]	0.9[a]
East	274.19[a]	15.20[a]	2.9[a]
West	60.04[a]	24.64[a]	2.75[a]
Central	224.89[a]	6.96[a]	1.8[a]
POINT			
A	130.41[b]	15.24[a]	2.35[a]
B	137.54[a]	15.09[a]	2.370[a]
VMP – Legislation*	Absence in 100 mL		

The measure unit is the Most Probable Number in 100ml of sample (MPN / 100 ml). Averages followed by same letter do not differ in the column, 5% probability by Tukey test. *Ordinance No. 2914/2011(Brazil, 2011).

in the water, which act to reduce the transparency (Paludo, 2010). High turbidity values highlight the undesirable appearance of water and suspended solids can provide shelter for pathogenic microorganisms (Perpétuo, 2014).

The results for the analyzed samples presented a maximum value of 5uT. The East zone presented results statistically difference for the other zones. Statistical difference was found (p = 0.027) in the samples A and B. This can be attributed to the possible presence of solids waste in household receivers of South Zone, which presented the highest rates. The highest value was found in the average of the samples B South Zone, and the lowest averages in sample A of the East Zone. Values below the maximum permissible values were common in the analysis and the highest value observed can be explained by the lack of maintenance of the water with the presence of solid waste. Some researchers analyzed water intended for human consumption and the result observed for turbidity was similar to this research. Vitó et al. (2016) analyzed possible contamination in artesian well water in the state of Rio de Janeiro and obtained average results of 0,77uT as compared to the 5uT obtained in the research.

In relation to the microbiological analysis of total coliforms, thermotolerant coliforms and *Escherichia coli*, there were presence of total coliforms and thermotolerant coliforms in the study areas except *Escherichia coli* in the south. The highest average value of total coliforms was recorded in the East Zone (274.19 NMP) and Central Zone (224.89 NMP), followed by South Zone (75.19 NMP), West Zone (NMP 60.04) and North zone (35.55 NMP) (Table 3).

The water coliform contamination is important to specify the possibility of pathogenic microorganisms that can transmit waterborne diseases (Moura et al., 2009). The highest value of thermotolerant coliforms was positive in the West region (24.64 NMP), followed by East region (15.20 NMP). The lowest average value was found in the central region (6.96 NMP). The presence of thermotolerant coliforms indicates the possibility of fecal contamination and enteric pathogenic microorganisms (Silva et al., 2016).

The abundance of *Escherichia coli* was found in the East region (2.9 NMP), West region (2.75 NMP), North region (2.0 NMP) and the central region (1.8 NMP). The presence of *E. coli* is indicative of contamination that directly compromises the portability of water. The result of TC, TTC, and *E. coli* parameters does not differ statistically between the studied regions. Geldreich (1998) states that the runoff water is the main factor that causes changes in the microbiological quality of groundwater. This is because the water on contact with the ground carries organic matter, animal waste and particulate matter in large quantities to the well; this region still presents exposed cesspools in public via.

The lower results of total coliforms in the North and West region at these places have recently been changed by the water distributor, added to the constant maintenance on the network, reduce occurrences of contamination during distribution, disagreeing with the information presented in the report published by Water and Sewerage Company of Rio Grande do Norte-Brazil. It was observed that the water is distributed to households with compromised sanitary quality. This factor can be explained by the location of the well, probably by water contact with cesspools due to lack of sanitation in urban and rural areas, which is one of the main causes of a large amount of contaminated water in Brazil (Scapin et al., 2012).

When comparing the means of all samples collected at the receptors (A) and collectors (B) of the households, higher values were observed for B receptors, obtaining 137.54 MPN and 2.37 MPN, for CT and *E. coli*, respectively. The value of the TTC from point B was similar to point A presenting 15.09 NMP. The results of the collection points A and B were statistically different just for CT. Thus, higher values were found at the collectors of the households for this parameter, which indicates lack of maintenance. Regarding the TTC and *E. coli* parameters, the results of samples A and B are worrisome, since *E. coli* has as primary habitat the gastrointestinal tract of humans and other animals and is commonly responsible for urinary infections and diarrhea.

Conclusion

It can be concluded that, in relation to the physical parameters, color and turbidity recorded higher results in the collectors of homes surveyed, identified the lack of maintenance of these. As chemical analyses of pH, chlorides and alkalinity not described large changes between the studied areas, since the hardness and nitrate analyses were higher in places where there is difficulty in sanitation or where there was a greater chance of contamination water, like sewage in the sky and garbage. For the studied microbial tests, it was verified presence of coliform group bacteria at all points in less than one of the collection, being the major contamination in the receivers. This is justified by the lack of maintenance and lack of prohibition of sealing of these collectors, allowing the access of rodents, insects and other carriers of microorganisms; and leaks in the piping that distributes water throughout the city may also be responsible for contamination.

Thus, the water consumed at collection points in the areas of the city of Mossoró presents physicochemical indices used and microbiological indices in disagreement with a legislation governing portability. So there is need to develop a supply company check critical points of the pipe mesh to minimize bacterial contamination pollution indicators.

CONFLICT OF INTERESTS

The authors have not declared any conflict of interests.

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