QUALITY OF WATER FOR HUMAN CONSUMPTION AND ASSOCIATION WITH THE MUNICIPAL HUMAN DEVELOPMENT INDEX AT BAIXADA MARANHENSE, BRAZIL

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ABSTRACT - Water quality and quantity, for human consumption, can be considered as indicators for urban environmental quality, along with other human indicators. Thus, the present research evaluated the microbiological quality of water consumed by the urban population, as an indicator associated with the Municipal Human Development Index (MHDI) of Baixada Maranhense, a region of the state of Maranhão, Brazil. Ten municipalities were selected, divided into two groups, with higher and lower HDIs. Those with the highest HDI were: Pinheiro, Arari, Viana, Matinha and São Bento, and those with the lowest: Bela Vista do Maranhão, Monção, Cajari, Pedro do Rosário and Conceição do Lago Açú. Samples were collected in the public supply network at the urban area for 6 months, during the low-rainfall (October, November and December of 2015) and high-rainfall (January, February and March of 2016) periods. Microbiological analyses were carried out to search for the MNP (Most Probable Number) of total Coliforms, *Escherichia coli*, *Pseudomonas aeruginosa* and *Enterococcus faecalise*. The group of municipalities with the lowest HDIs showed a larger quantity of microorganisms when compared to the group with high HDIs. The inadequate supply and treatment system affect the quality of the water used by the population at Baixada Maranhense, possibly representing health risks.
KEY WORDS: Water quality, Indicators, Baixada Maranhense.

QUALIDADE DA ÁGUA PARA CONSUMO HUMANO E ASSOCIAÇÃO COM O ÍNDIDE DE DESENVOLVIMENTO HUMANO MUNICIPAL NA BAIXADA MARANHENSE

RESUMO: A qualidade e quantidade de água, para consumo humano, podem ser consideradas um indicador da qualidade ambiental urbana, justaposta a outros indicadores urbanos. Assim, a presente pesquisa avaliou a qualidade microbiológica da água consumida pela população urbana, como indicador associado ao Índice de Desenvolvimento Humano Municipal da Baixada Maranhense, região do Estado do Maranhão. Foram selecionados dez municípios, divididos em dois grupos, com maior e menor Índice de Desenvolvimento Humano Municipal: (maior) Pinheiro, Arari, Viana, Matinha e São Bento e (menor) Bela Vista do Maranhão, Monção, Cajari, Pedro do Rosário e Conceição do Lago Açú. As amostras foram coletadas da rede pública de abastecimento na zona urbana durante seis meses, no período de baixa pluviosidade (outubro, novembro e dezembro de 2015) e alta pluviosidade (janeiro, fevereiro e março de 2016). Foram realizadas análises microbiológicas para pesquisa do NMP de Coliformes totais, *Escherichia coli,Pseudomonas aeruginosa*, e *Enterococcusfaecalis*e. O grupo dos municípios com o menor Índice de Desenvolvimento Humano Municipal apresentaram maior quantidade de micro-organismos em comparação ou outro grupo. O inadequado

sistema de abastecimento e tratamento afeta a qualidade da água utilizada pela população da Baixada Maranhense podendo representar risco para a saúde.

PALAVRAS-CHAVE: Qualidade da água, Indicadores, Baixada Maranhense

1. INTRODUCTION

In a broader context, the Municipal Human Development Index (MHDI) evaluates life quality in cities. However, other indicators or indices are also used, among which are those that measure water quality for human consumption, for instance the Water Quality Index (WQI), created in 1970 in the United States. In 1975, the Environmental Company of the State of São Paulo (CETESB, in Portuguese) adopted this index and, today, it is the most widely used in Brazil (ANA, 2016).

Along with the adopted indices, the Health Ministry in Brazil has recommended attention with water quality through the ordinance 2914/11, which deals with the procedures of control and surveillance of water quality for human consumption and its potable patterns.

In Maranhão, the concern with water quality for human consumption is highlighted mainly regarding the precariousness of the sewage network treatment and the presence of open dumps with no sanitary treatment. These can possibly result in the contamination of groundwater and in the dispersal, via water, of pathogenic agents (MASULLO et al., 2010).

According to the National Water Agency (ANA, from the Portuguese *Agência Nacional de Águas*), the Occidental Northeast Atlantic Hydrographic Region comprehends, basically, the state of Maranhão, and a small oriental portion of the state of Pará. “The main need for water in the basin is for human consumption, corresponding to 45% of the total. Afterwards, comes animal demand, with 18% of the total use, and irrigation demand, with 15%”. In the state of Maranhão, the basin covers the entire area of the Baixada Maranhense micro-region (ANA, 2016).

In this context, this region needs studies that characterize the water quality indicators, looking to subsidize the implementation of guidelines and health monitoring actions that aim at assuring that people are able to safely consume water.

The urban indicator, in this study represented by the MHDI, and along with parameters of water quality, are important tools to monitor urban environmental quality and the population’s health. Therefore, the research evaluated the microbiological quality of water consumed by the urban population, as a parameter associated to the MHDI, of the

municipalities at Baixada Maranhense, a region of the state of Maranhão.

2. MATERIAL AND METHODS

2.1. Characterization of study area

The Baixada Maranhense region is divided into 21 municipalities, and covers an area of 17,579,366 km², with an estimated population of 563,877 (IBGE, 2010). Ten municipalities were selected and divided into two groups, with higher and lower MHDI, following the classification from the Atlas of Human Development. Those with the highest MHDI were Pinheiro, Arari, Viana, Matinha and São Bento, and those with the lowest were Bela Vista do Maranhão, Monção, Cajari, Pedro do Rosário and Conceição do Lago Açú (Figure 01).

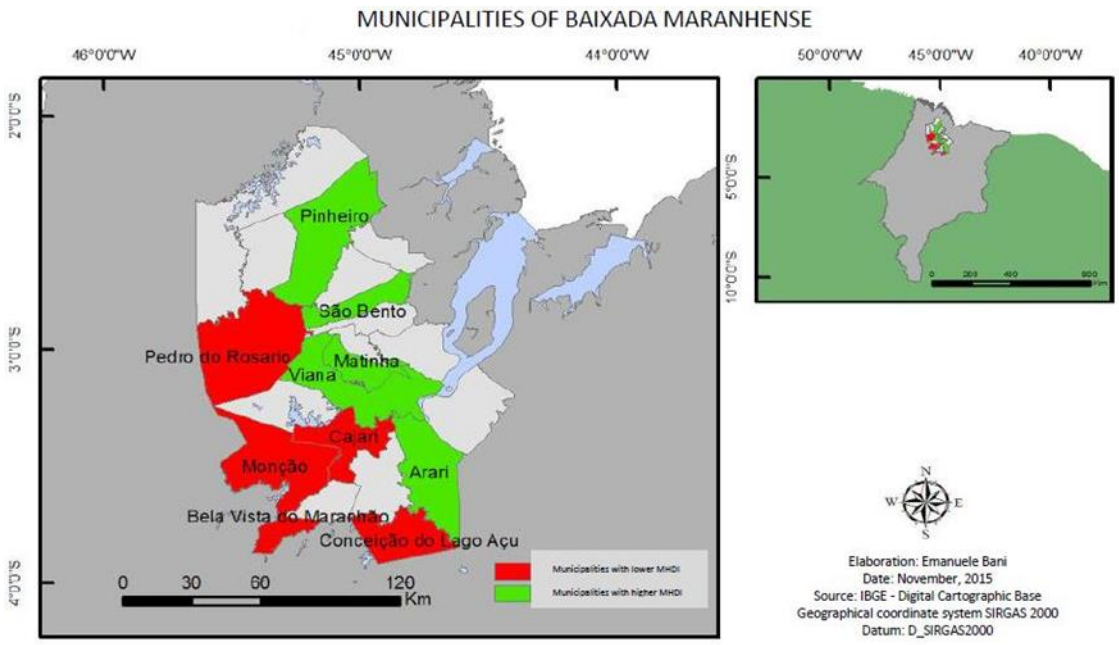

Figure 01- Location of the studied Baixada Maranhense municipalities. **Source:** IBGE, 2010.

The official water supply at the municipalities of Pinheiro, Matinha, São Bento, Monção, Cajari, and Conceição do Lago Açú is performed by the concessionaire Environmental Sanitation Company of Maranhão (CAEMA). For Arari and Viana municipalities, water supply is carried out by the Autonomous Service of Water and Sewage (SAAE), while in Bela Vista do

Maranhão and Pedro do Rosário it is done by Alternative Collective Solution (SAC).

2.2 Sample collection

Samples were collected at the public supply network on the urban zone of municipalities during 6 months: three months during the period of low rainfall (October, November and December of 2015), and three during the high rainfall period (January, February and March of 2016). Per month, five samples were collected in each municipality, to a total of 300 samples, that were stored in sterilized bottles, packed in isothermal boxes and sent to the Laboratory of Food Microbiology and the Laboratory of Food and Water Physicochemistry of the *Universidade Federal do Maranhão* (UEMA), where laboratorial analyses were carried out.

2.3 Analyses of water samples

Microbiological analyses were carried out in 100 mL samples in order to determine the Most Probable Number (MPN) of total Coliforms, *Escherichia coli, Pseudomonas aeruginosa* and *Enterococcus faecalis*. The adopted technique was the fast method with chromogenic enzymatic substrate (Colilert®, Pseudalert® and Enterolert®), through which it was possible to quantitatively determine the studied microorganisms (APHA, 2005), following instructions from the manufacturer.

Microbiological analyses' results were tabulated in spreadsheets using Microsoft Excel, and were afterwards represented in tables, following the interpretation of values as proposed by the Ordinance 2914/11, from the Health Ministry. According to this ordinance, the threshold allowed for total Coliforms and *Escherichia coli* is < 1.0 (BRASIL, 2011). According to the Resolution of Board of Directors 274/05 from ANVISA, the maximum limit for *Pseudomonas aeruginosa* and *Enterococcus faecalis,* is also < 1.0 (BRASIL, 2005), which regulate drinking water standards for human consumption.

2.4 Statistical analyses

Pearson's correlation test was used to measure the association level between periods of low and high rainfall, as well as between higher and lower MHDI at the studied municipalities. All statistical analyses were carried out using the computational package R (2014), considering a level of significance of up to 5% probability.

3. RESULTS AND DISCUSSION

Microbiological analyses are used to verify the occurrence of oral-faecal contamination,

the efficiency of water and sewage treatment processes, and the possible deterioration or water post-contamination in the supply system. Traditionally, the established parameters are used by practical, technical and economic limitations, since it becomes impossible to examine all potential pathogenic organisms present in the water (SOUZA and DANIEL, 2008).

During the period of low rainfall, analyses demonstrated higher rates than recommended by the Ordinance 2914/11 for total Coliforms, *Escherichia coli, Pseudomonas aeruginosa* and *Enterococcus faecalis* at Matinha and São Bento municipalities (higher MHDI), and in all municipalities with lower MHDI. The only municipalities where the presence of *Escherichia coli, Pseudomonas aeruginosa* and *Enterococcus faecalis* was not detected were Pinheiro, Arari and Viana (Table 01).

Table 01 – Determination of identified microbiological parameters, during low rainfall, 2016

	Municipality	N	Total coliforms	*Escherichia coli*	*Pseudomonas aeruginosa*	*Enterococcus faecalis*
HIGHER MHDI	Pinheiro	15	0,0	0,0	0,0	0,0
	Arari	15	0,0	0,0	0,0	0,0
	Matinha	15	15	10	15	13
	Viana	15	0,0	0,0	0,0	0,0
	São Bento	15	04	01	10	01
LOWER MHDI	Bela Vista do Maranhão	15	07	03	02	01
	Monção	15	13	07	12	09
	Cajari	15	15	15	11	15
	Pedro do Rosário	15	14	11	10	10
	Conceição do Lago Açu	15	10	03	10	01

During the period of high rainfall, analyses detected high concentrations of total Coliforms, *Escherichia coli, Pseudomonas aeruginosa* and *Enterococcus faecalis* at Matinha (higher MHDI), and again in all municipalities with lower MHDI. São Bento (higher MHDI) showed contamination by total Coliforms, *Escherichia coli* and *Pseudomonas aeruginosa,* while Pinheiro and Viana (higher MHDI) showed contamination by total Coliforms, and Arari (higher MHDI) by *Enterococcus faecalis* (Table 02).

Table 02 – Determination of identified microbiological parameters, during high rainfall, 2016.

	Municipalities	Microorganisms				
		N	Total Coliforms	*Escherichia coli*	*Pseudomonas aeruginosa*	*Enterococcus faecalis*
HIGHER MHDI	Pinheiro	15	01	0,0	0,0	0,0
	Arari	15	0,0	0,0	0,0	01
	Matinha	15	15	11	14	07
	Viana	15	01	0,0	0,0	0,0
	São Bento	15	04	01	11	0,0
LOWER MHDI	Bela Vista do Maranhão	15	07	02	02	02
	Monção	15	11	04	13	06
	Cajari	15	10	09	05	09
	Pedro do Rosário	15	15	08	08	11
	Conceição do Lago Açu	15	15	05	15	09

Source: research data, 2016.

At periods of high and low rainfall, the microorganisms count was estimated in MPN/100 mL in the municipalities ranged between 1.0 and >2419.6, noting that the biggest contaminations took place in Matinha (higher MHDI) and Conceição do Lago Açú (lower MHDI), where every parameter showed high counts. On the other hand, contamination rates were lower in Pinheiro and Arari, both with higher MHDI.

The presence of total Coliforms and *Escherichia coli* in human consumption waters is an indicator of precarious hygienic and sanitary conditions. This microbe group occurrence in waters creates subsidies to the discussion about flaws in the water treatment or distribution systems, since these microorganisms are found in several natural environments, but not in drinking water (MICHELINA et al., 2006).

For Drewes and Fox (2000), water quality depends on the treatment, distribution and storage phases of the product. Thus, in order to successfully meet its functions, a quality program needs to not only to possess an adequate technology available for treatment and distribution, but the storage system must also be efficient, since flaws during treatment and distribution stages expose the population to water-borne diseases.

During the general result computing, the correlation analysis showed a statistically significant difference between periods of low and high rainfall, with the former showing the highest correlation (Table 03).

Significant correlations were classified, according to Dancey and Reidy (2006), in: low (between ± 0.10 and ± 0.29); moderate (between ± 0.30 and ± 0.49); and strong (between ± 0.50 and ± 1.0).

Table 03 – Correlation of microbiological parameters in relation to rainfall at Baixada Maranhense municipalities.

	CORRELATION	Low Rainfall			
		Total Coliforms	*Escherichia coli*	*Pseudomonas aeruginosa*	*Enterococcus faecalis*
High Rainfall	Total Coliforms	0.48	0.29	0.29	0.36
	Escherichia coli	0.38	0.20	0.25	0.21
	Pseudomonas aeruginosa	0.26	-0.04	0.63	0.16
	Enterococcusfaecalis	0.36	0.29	0.08	0.30

*Values highlighted in red do not have significant effect for correlation (P<0.05).

Seasonal variation in microorganism levels during the studied period was different, as it was noticed that a higher contamination occurred during the low rainfall period. Contamination of hydric bodies can be related to incorrect human actions, such as domestic sewage and industrial effluents runoff, deforestation and inadequate soil management, causing erosion and, consequently, river silting.

Throughout the studied period, it was also observed that the quantity of microorganisms was always higher in non-treated water when compared to treated water, and that municipalities with the lowest MHDI showed a higher quantity of microorganisms when compared to municipalities with higher MHDI. This may be related to the inefficiency in the water treatment analyzed, and to the lack of sanitation.

It should be noted that the study addressed 10 municipalities from a region officially composed of 21 municipalities, and a population estimated at 563,877 inhabitants (IBGE, 2016). Therefore, the research presented a significant sample of the lack of water quality for human consumption.

The ANA, through its water quality monitoring policy, establishes the Program to Encourage Water Quality Data Dissemination (QUALIÁGUA), which has as one of its objectives the strengthening in water quality monitoring. The agency classifies Brazilian states in three big groups: those that "operate water quality networks and can expand them immediately"; those that "operate networks, but need to increase operating capacity", and the third group, consisting of 12 states, in which "monitoring is non-existent or is not consolidated", those

being the states of Acre, Alagoas, Amapá, Amazonas, Maranhão, Pará, Piauí, Rondônia, Roraima, Santa Catarina, Sergipe and Tocantins.

According to FUNASA (2001), potable water supply to the population is of total responsibility of government's public agencies, and the water intended for human consumption should be in accordance with potable patterns, while its microbiological, physical, chemical, and radioactive parameters should not pose health risks.

4. CONCLUSION

All of the studied municipalities showed contamination by at least one of the microorganisms analysed, and municipalities with the lowest MHDI were the ones with the highest contamination rates. Contamination by total Coliforms, *Escherichia coli, Pseudomonas aeruginosa* and *Enterococcus faecalis* can be associated with point sources of pollution and the lack of treatment at the distribution system.

The hydric bodies which supply municipalities at Baixada Maranhense work, in most cases, as sinks for solid and liquid wastes. Sewage is released with no kind of treatment.

By the seasonal variation in levels of microorganisms, it was noted that the highest contamination happened during the period of low rainfall. Values of total Coliforms, *Escherichia coli, Pseudomonas aeruginosa* and *Enterococcus faecalis* were found to be out of the maximum limit established by current legislations, the Health Ministry's Ordinance n° 2914/11, and the Resolution of Board of Directors 274/05, on the technical regulation for bottled water and ice (BRASIL, 2005; BRASIL, 2011).

It is noted that, even though data revealed higher contamination and/or non-conformity to legislation in municipalities with lower MHDI, those classified or ranked as higher MHDI were also found to have irregularities. Thus, the quality of the water analyzed and used by municipalities' populations has issues, possibly representing health risks.

Monitoring water quality indicators as parameters juxtaposed to the MHDI was a way to aggregate another dimension to the index in order to evaluate urban environmental quality, as well as to evaluate public policies on health and environment. Public managers should prioritize population health, and one of the means to reach that is through high quality water.

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