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# Correlation between water salinity and arterial hypertension

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**Abstract**

*Hypertension is the main risk factor for the development of cardiovascular diseases. The objective of this study was to evaluate the correlation between cases of hypertension and environmental aspects related to water salinity in the municipality of Arari-Maranhão. The following data were evaluated: 1) secondary data on cases of hypertension reported from 2002 to 2012 registered in the Hiperdia Program of the Department of Informatics of SUS (DATASUS), in the municipality of Arari-Maranhão; 2) a temporal series of climatic data and river water quality measured by the physicochemical parameters and the water flow of the Mearim River; and 3) the statistical correlation between the indicators of water quality and the cases of hypertension of the study sample. The results revealed a seasonality in cases of hypertension in the municipality of Arari. This variation was inversely related to the precipitation and the salinity of the river water. Thus, decreased precipitation resulted in increase driver salinity and, consequently, increased consumption of salt by the population, increasing the number of cases of hypertension. The correlation between cases of hypertension and precipitation or salinity was significant and negative. These results revealed a significant correlation between cases of hypertension, water quality, and climatic factors.*

***Keywords:*** *Hypertension; Water; Salinity*

## 1 Introdution

Chronic noncommunicable diseases (CNCD)are a major health challenge for global development in the coming decades. Threatening the quality of life of millions of people, CNCD represent the greatest cost to health systems worldwide and have a major economic impact on the people, their families, and society in general, especially in underdeveloped countries. Among CNCD, cardiovascular diseases (hypertension, infarction, stroke) account for about one-third of global deaths (BROOKS, 2016).

Hypertension is the main risk factor for the development of cardiovascular diseases. There are 1.6 million deaths per year dueto cardiovascular disease in the Americas, of which about 500,000 occur in people under 70 years of age, which is considered a premature and preventable death. Hypertension affects 20-40% of the adult population in the region, corresponding to about 250 million people with high blood pressure in the Americas (OPAS, 2016). In 2013, the prevalence of arterial hypertension (AH) was 24.1%among adults living in the Brazilian capitals and Federal District (IBGE, 2013).

In recent years, the field of environmental health has increasingly consolidated, encompassing public health, scientific knowledge, and the formulation of public policies and corresponding interventions (actions) related to the interaction between environmental factors and human health (FILHO; PONTES, 2012). One of the most frequent causes of hospital admissions in Brazil is problems related to water. Worldwide, a lack of treated water accounts for much of child mortality. Data on water scarcity are worrying. By 2025, an estimated two of three people on the planet will have access to only 50 liters of fresh water per day. In comparison, citizens of developed countries consume approximately 300 liters of fresh water per day (JUNIOR; SASSON, 2012).

Rising sea levels are a critical factor, making delta regions particularly vulnerable to climate change. Other environmental factors such as tropical cyclones are likely to interact with higher mean sea levels and contribute to increased numbers of storms and increased flooding (MINISTRY OF ENVIRONMENT AND FOREST B, 2006).

Health results from the dynamic balance between the organism and the environment; the imminent climate change and resulting ecological crisis will inevitably lead to a health crisis, as "The ecological concept of health presupposes harmony and compatibility between the organism and the environment. Environment” (HANARI et al., 1999).

Saltwater in the Bay of Bengal in Bangladesh has penetrated more than 100 km into the tributary channels during the dry season. This not only increases the potential for economic and infrastructural damage but also affects the livelihoods and increases health risks of the citizens through contamination of the drinking water(MINISTRY OF ENVIRONMENT AND FOREST B, 2006).Similar to the situation in Bangladesh, the population of the municipality of Arari-Maranhão (MA), comprising approximately 28,488 thousand inhabitants (IBGE,2010), depends heavily on Mearim River as a water source and wells for obtaining potable water. These sources have become severely saline due to the intrusion of seawater caused by environmental changes. The salinization of the groundwater supplying the wells increases with the advance of the salina wedge in the low course of the Mearim River.

However, available data are scarce and an investigation of the impact of water salinity on human health is needed to promote the adaptation of measures to avoid long-term consequences such as an epidemic of hypertension in the world's coastal areas, particularly in underdeveloped countries (TEIXEIRA; GUILHERMINO, 2006).

The present study analyzed the correlation between salinity in drinking water and cases of arterial hypertension in this population.

## 2 Methods

### 2.1 Data collection

This study used secondary data provided by Hiperdia Program of the Department of Informatics of the SUS(DATASUS) to constructa database containing data from cases of hypertensive patients registered in the municipality of Arari-MA between 2002 and 2012.

### 2.2 Monitoring of water for human consumption

The physicochemical parameters of the water samples in the Mearim River were obtained for 2016. These parameters were evaluated using a Multiparametric Sonda Horiba® instrument.

The samples were analyzed for the following physical and chemical parameters: pH; salinity (SAL – $g.L^{-1}$); total dissolved solids (STD – $g.L^{-1}$), and turbidity (TUR – NTU).

The evaluations of the quality indicators were made according to the parameters recommended by Administrative Rule no. 2.914, dated December 12, 2011, which "provides for the procedures for the control and monitoring of the quality of drinking water and its drinking water standard of the National Council for the Environment (CONAMA)”.

### 2.3 Assessment of climatic data

The water consumed by the population of Arari - MA is captured directly from the Mearim River, treated, and distributed by the Water Supply Center of the municipality. Thus, the physicochemical properties of the drinking water vary during the year according to their variation in the river water.

The climate directly influences the physicochemical properties of the river; in the rainy season, the increase in river water volume dilutes the salts and consequently decreases the salinity of the water. Similarly, in the dry period, the decrease in water volume causes an increased salt concentration and, consequently, increased salinity.

A temporal series of precipitation and temperature data was constructed in the study area to evaluate the variations of salinity in the Mearim River. Data were obtained from the National Institute of Meteorology from January 2002 to December 2012.

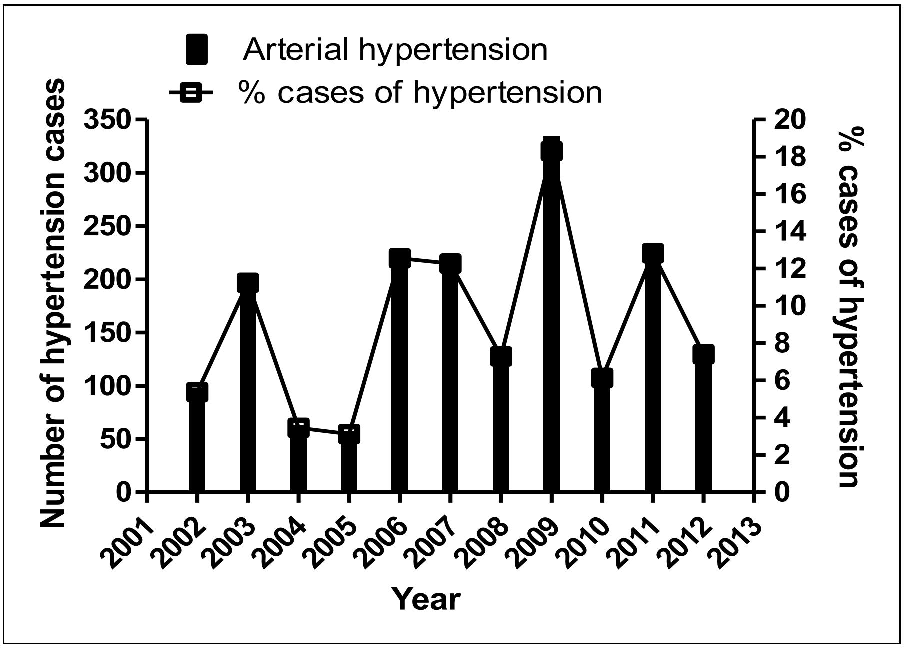
### 2.4 Statistical analysis

From the environmental and health database, a Spearman correlation analysis was performed between arterial hypertension and precipitation and maximum and minimum temperature, with $p < 0.05$ considered statistically significant.

This study was approved by the Research Ethics Committee of the CEUMA nº 2477.570.

Between 2002 and 2012, a total of 1,824 cases of arterial hypertension in the municipality of Arari-MA were enrolled in the Hiperdia program of the Department of Informatics of SUS (Datasus). Figure 1 shows the percentage of cases per year during the study period.

Figure 1– Annual numbers of hypertension cases in the municipality of Arari-MA (2002-2012)




Spearman correlation analysis (Table 1) revealed significant correlations ($p<0.05$) between hypertension and precipitation (positive correlation) and between arterial hypertension and minimum temperature (negative correlation).

Table1– Spearman correlation analysis: hypertension x precipitation or maximum or minimum temperature

| Parameters | ppt | Tmax | Tmin |
|---|---|---|---|
| Spearman R | 0.3000 | -0.1072 | -0.2419 |
| P Value | 0.0006 | 0.2265 | 0.0066 |

Ppt = Precipitation; Tmax = Maximum temperature; Tmin= Minimum temperature.

Figure 2 shows the temporal series from 2002 to 2012, relating the cases of arterial hypertension in the municipality of Arari to the precipitation in this period. The results reveal a seasonality in the cases of hypertension, in which the highest values occurred at the beginning of the rainy season. In 2002, 2004, 2005, 2007, 2010, 2011, and 2012, high numbers of cases of hypertension were also observed during the dry period.

Analysis of the correlation between the cases of hypertension and the minimum temperature revealed a significant interaction as the cases of arterial hypertension decreased (p= 0.0066 and Spearman r = - 0.2419) (Table 1). This relationship is particularly evident between June and December in 2006, 2008, and 2009, (Figures 2 and 3).

Figure 2 - Temporal series of cases of hypertension in the municipality of Arari X precipitation (2002-2012)

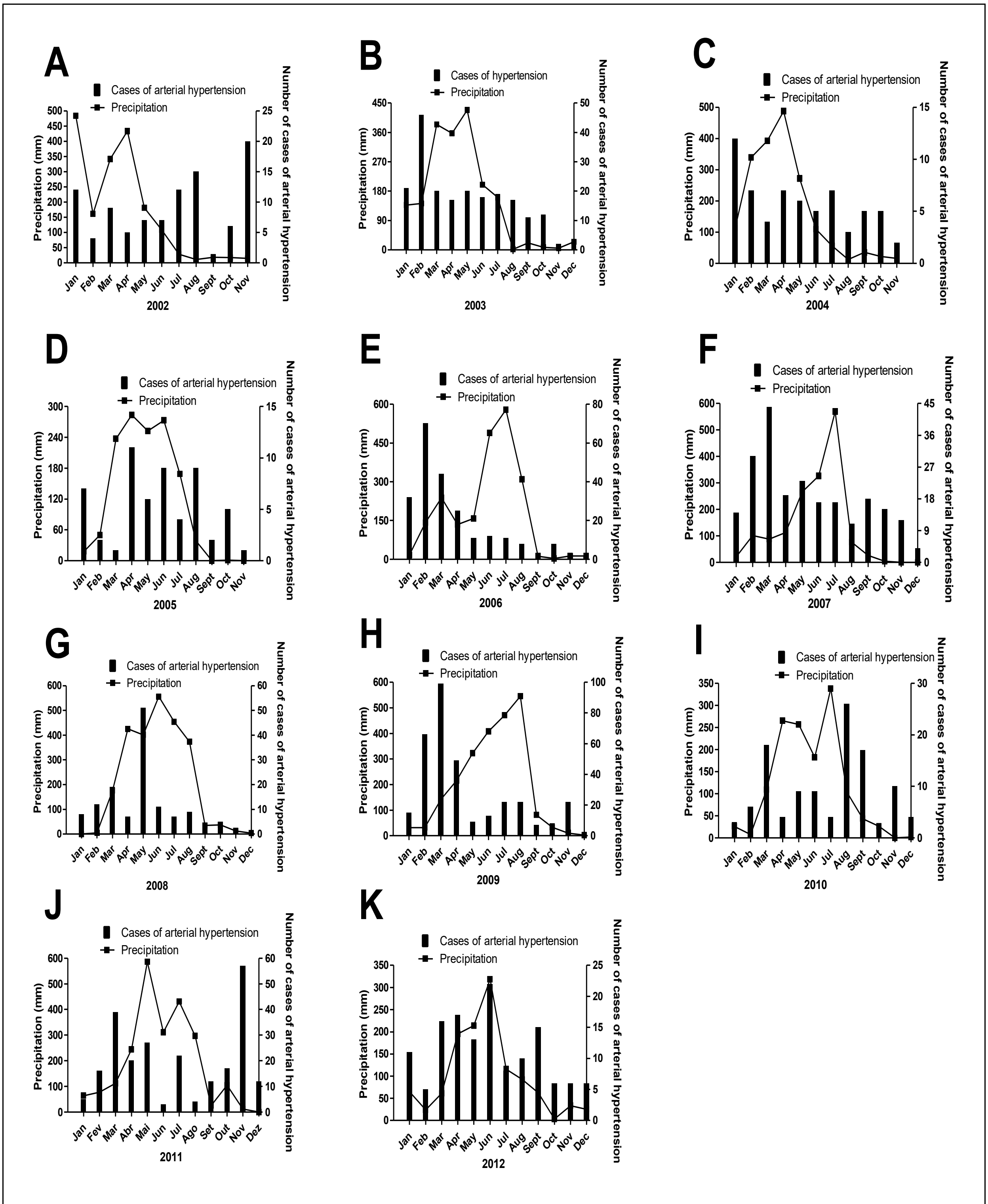



**Figure 2 - Temporal series of cases of hypertension in the municipality of Arari X precipitation (2002-2012).**

Figure 3 – Temporal series of cases of hypertension in the municipality of Arari X minimum temperature (2002-2012)

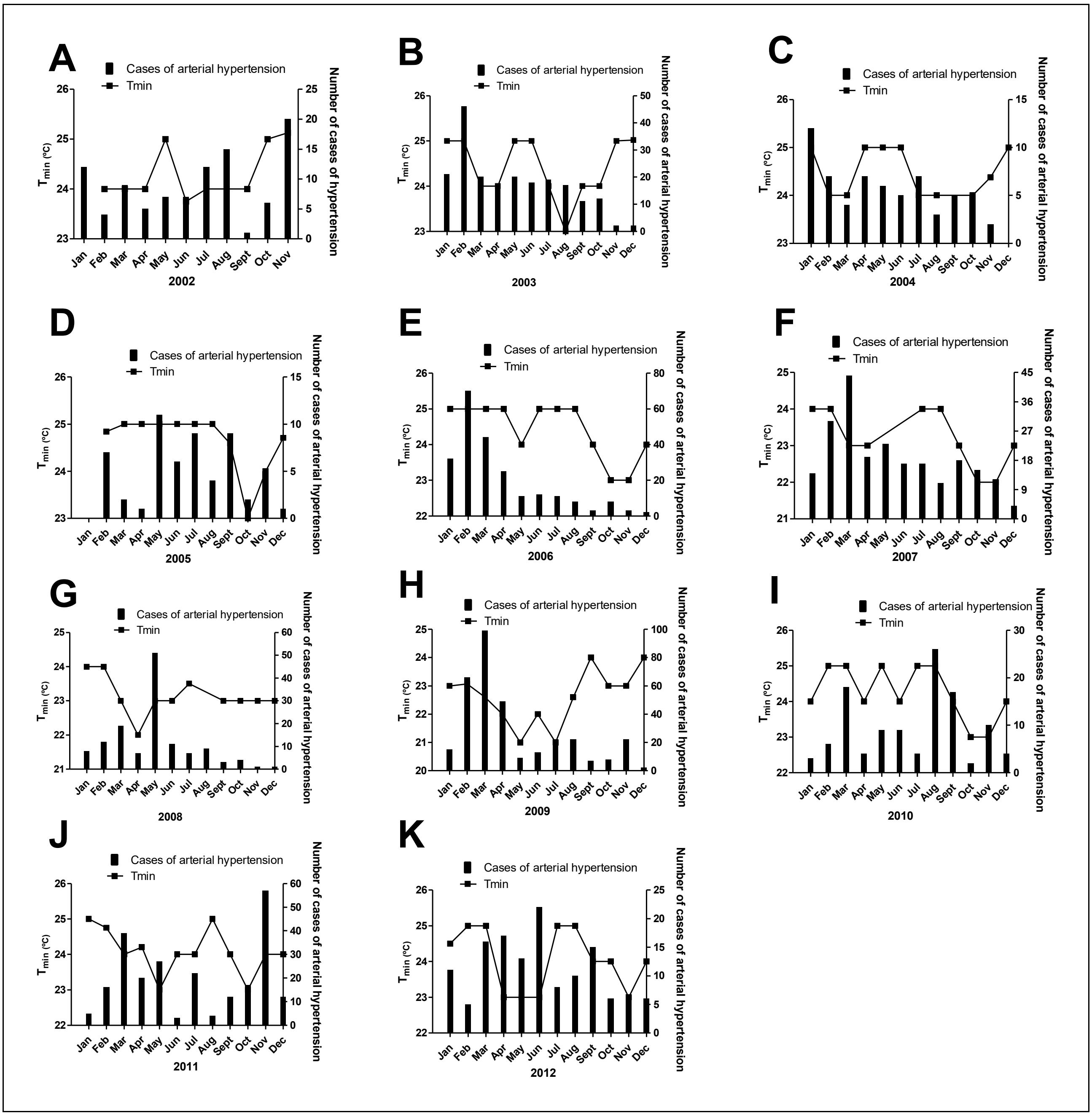
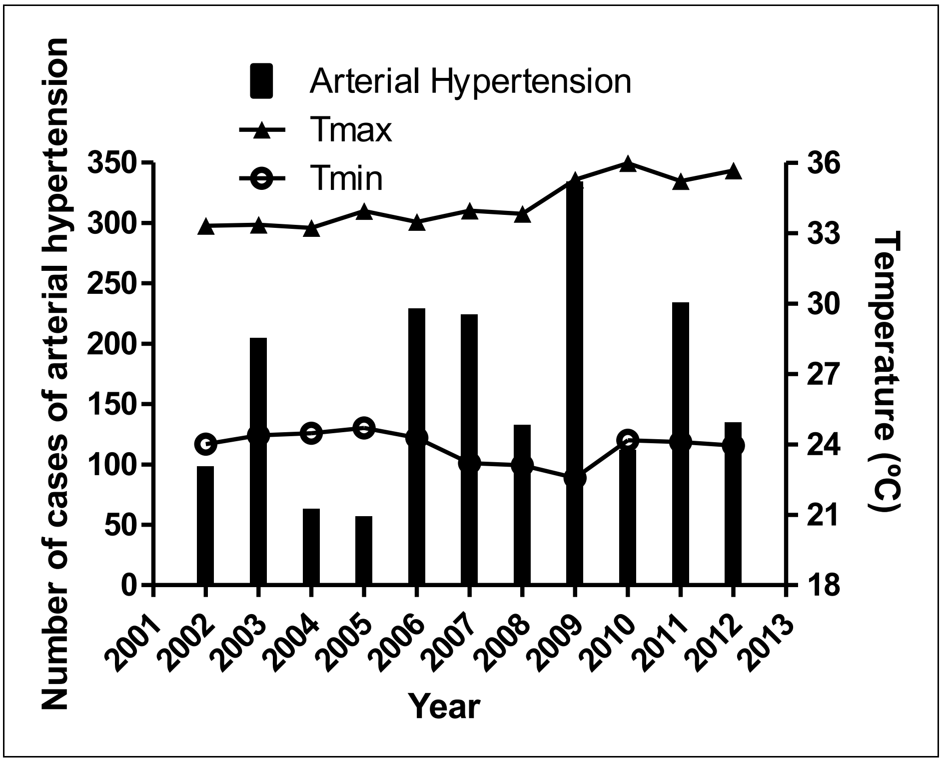


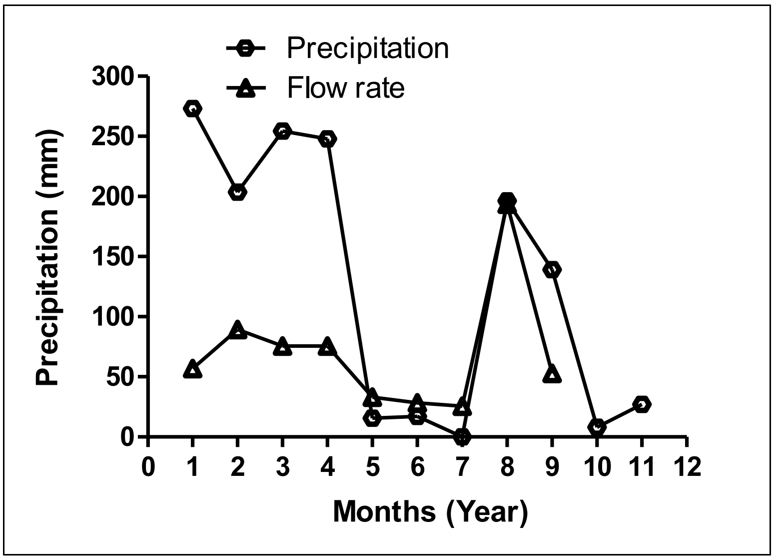

Figure 4 presents an overview of the annual hypertension parameters and maximum and minimum temperatures.

Figure 4 – Correlations between cases of hypertension X maximum temperature X minimum temperature per year (2002-2012)



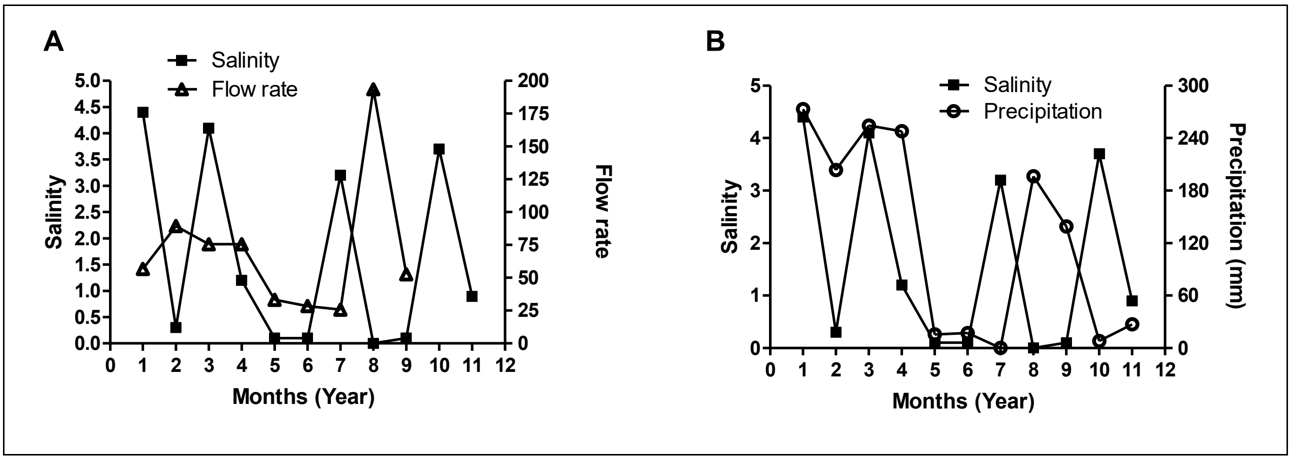

The municipality of Arari is located at the mouth of the Mearim River. The water quality of the river is influenced directly by tidal flow every six hours. The volume of water present in the river in this region, as indicated by the flow, is influenced by rainfall throughout the Mearim River basin (Figure 5). The Spearman correlation index resulted in an r-value of 0.6500 and p-value of 0.0666.

Figure 5 – Precipitation and flow of the Mearim River, Arari municipality



Salinity, a physicochemical property of water, is influenced by both precipitation and flow (Figure 6). However, the response of salinity to variations in precipitation and flow is not immediate due to the time it takes for the surface runoff of the water along the basin to mix with the tidal water in that estuarine region.

Figure 6 – Time series of (A) salinity and precipitation data and (B) salinity and flow




Spearman's correlation coefficient considering a one-month lag time (Table 2), resulted in r = 0.7306 and p = 0.0458, indicating a statistically significant positive relationship between salinity and flow, and a non-significant correlation between salinity and precipitation (r = 0.5215, p = 0.1231). This finding is explained by the fact that salinity and flow have a faster interaction when compared to that of salinity and precipitation.

Thus, salinity is a physicochemical property of water that is heavily influenced by flow and precipitation.

Table 2 – Spearman correlation: Salinity x flow x precipitation with one month of salinity lag

| Flow x salinity | Salinity x precipitation |
|---|---|
| 0,7306 | 0,5215 |
| 0,0458 | 0,1231 |

## 3 Discussion

The results of the present study show that 1,824 cases of hypertension were reported in the municipality of Arari-MA between 2002 and 2012. In 1967, the Brazilian Institute of Geography and Statistics (IBGE) implemented the National Household Sample Survey (PNAD)to provide basic information for the socioeconomic development of the country. A study using PNAD data found the prevalence of SAH to be 18.0% in 1998, 19.2% in 2003, and 20.9% in 2008, which represents a growth of 16.11% in this period, with greater representativeness the Northeast and Southeast.

The present study also showed that precipitation, maximum temperatures, and minimum temperatures in certain periods of the year are correlated to the emergence of cases of hypertension in the municipality of Arari. Several studies have suggested that environmental variations influence the incidence of preeclampsia (PE), mainly because low temperatures lead to an increase in the incidence of pregnancy-related hypertension (DHEG). Studies conducted in

Colombia, Israel, Mozambique, Kuwait, Texas, Japan, and Sudan have shown a higher incidence of eclampsia and PE at lower temperatures (MORIKAWA et al., 2014; ALI; ADAM; ABDALLAH, 2015; MAKSEED et al., 1999).

It is questioned whether these events are due to vasospasm and/or the increase of vasoconstrictor substances, released as a function of the changes in temperature, or the lower temperature. In addition, changes in sympathetic nervous system activity, vascular tone, and release of vasoconstricting substances are involved in the pathophysiology of PE. These changes could be influenced by climatic factors, thus explaining the increase in the occurrence of PE at low temperatures (WELLINGTON; MULLA, 2012; ALI; ADAM; ABDALLAH, 2015). In particular, a Brazilian study carried out in Recife observed a higher prevalence of DHEG in the colder months (MELO et al., 2014).

The reported positive correlation between salinity and flow variables is due to the fact that they have a faster interaction; a study that estimated the individual salt intake of the river water for a coastal community in Bangladesh, which included data of monthly salinity measurements on the Passur river in Khulna (a coastal area), concluded that the mean salinity level of the river was an estimated 8.21 g/L of water in the dry season. Assuming an average daily intake of 2 L of water per individual, the corresponding salt intake from the river water was up to 16 g/day. This level of ingestion may be an underestimate since dietary salt intake was not considered (KHAN et al., 2011).

The Bangladesh-Ganges region reports contaminated salt solutions in drinking water sources, with reported salt levels of 0.6-8.2 g/L resulting in salt consumption above the level recommended by the World Health Organization (WHO) and which are associated with high blood pressure in young adults and pregnant women. Substantial evidence suggests that the ingestion of high salt and elevated blood pressure (BP) are linked to cardiovascular and renal diseases (WHO, 2013; KOLIAKI; KATSILAMBROS, 2013).

Other studies have shown that sources of drinking water in Asian deltas, most notably the Ganges, Mekong, and Red River deltas, are highly vulnerable to saltwater contamination. In the Mekong Delta, significant saline contamination of the surface and groundwater affectingthe water supply has been reported (HOQUE et al., 2016).

Buschmann et al. (2008), reported a mean sodium concentration of 330 mg/L in groundwater in southern Vietnam, for example, in the Mekong Delta,well above the Vietnamese water quality standard (200 mg/L), with a maximum concentration of 4 g/L. This represents significant health concerns for the large populations living and working in these areas.

The problem of salinity in these areas is aggravated by the increased sea levels induced by climate change. For example, the projected 30-cm increase in sea level by 2050 is expected to increase of the extent and intensity of the salinity intrusion in the Mekong Delta Region (MDR) (FLEENOR et al., 2008).

Thus, salinity is a chemical and physical property of water that is heavily influenced by flow and precipitation. Studies have reported that geographic location and climatic seasonality can influence the magnitude of adverse effects ofsalinity and precipitation on human health (BAARS et al., 2012). For example, climate can modify the association of fine particulate matter (PM) with morbidity and mortality. Although temperature is most often studied, humidity, atmospheric pressure, and season can also act as modifiers of health events (FRANCHINI; MANNUCCI, 2012).

The increased salinity- especially in the dry season - in some river deltas does not imply that all coastal populations are exposed through their drinking water. In many places, desalination plants will be used to reduce salt concentrations. However, the effects of increased salinity on health will be seen in low-income countries in which water is insufficiently treated or untreated (IPCC, 2007).

The results of this study showed a correlation between the prevalence of cases of hypertension, water salinity, and climatic factors. These results corroborate previous reports, indicating that there are well-known associations between the incidence of diseases in man and animals and the abundance or deficiency of major, minor and trace elements in the environment, particularly in water. Examples of these associations include the relationship between goiter (thyroid hypertrophy) and iodine deficiency; severe anemia, dwarfism, and hyperpigmentation of the skin and zinc deficiency; skeletal and dental fluorosis and excess fluoride; higher incidence of dental caries and deficiency in fluoride; anencephaly and mercury; and inappetence and selenium (PUTTI, 2010).

## 4 Conclusions

Health interventions to reduce salt exposure need to be implemented. Short-term dietary and lifestyle interventions need to be investigated. In the long run, the promotion of potable water alternatives (e.g. rainwater harvesting) and identification of low-cost water technologies such as desalination will also be necessary. It is important to act now with potential interventions to reduce the increase in the burden of chronic diseases associated with elevated blood pressure and unmanaged hypertension while also better characterizing the salt intake pathways in high-salt environments such as that in the municipality of Arari - MA.

This research can generate evidence for the elaboration of public policies to adapt the population of the municipality to the new environmental reality of increased water salinization and help managers to ensure a good quality water supply for the population.

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## References

ALI AA; ADAM GK; ABDALLAH TM. Seasonal variation and hypertensive disorders of pregnancy in eastern Sudan. J Obstet Gynaecol. 2015; 35(2):153-4. DOI: http://dx.doi.org/10.3109/01443615.2014.948815. PMid: 25141293.

BAARS H, ANSMANN A, ALTHAUSEN D, ENGELMANN R, HEESE B, MÜLLER D. Aerosol profiling with lidar in the Amazon Basin during the wet and dry season. Geophys Res Atmospheres, 2012; 117(D21):1-16. DOI: https://doi.org/10.1029/2012JD018338.

BROOKS, YR. Melhoria da Atenção à Saúde dos Usuários com Hipertensão e/ou Diabetes na Unidade de Saúde do Caic, José de Freitas-PI / Yaima Ribeaux Brooks; Fabiana Vargas Ferreira, orientador (a). 70 f.: il. – Pelotas: UFPI, 2016.

BUSCHMANN J, BERG M, STENGEL C. Contamination of drinking water resources in the Mekong delta floodplains: arsenic and other trace metals pose serious health risks to population. Environ Int, 2008; 34(6): 756–64.

FILHO, E. B. B; PONTES, J. R. S. A inserção da vigilância em saúde ambiental no sistema único de saúde do Brasil. Revista Brasileira de Promoção da Saúde (Impr); v. 25, n. 1 (2012).

FLEENOR, W; HANAK, E; LUND, J; MOUNT, J. Delta Hydrodynamics and Water Salinity with Future Conditions – Technical Appendix C. Public Policy Institute of California; 2008.

FRANCHINI M, MANNUCCI PM. Air pollution and cardiovascular diseases. Thromb Res. 2012; 129(3): 230-4. DOI: https://doi.org/10.1016/j.thromres.2011.10.030.

HANARI, M., et al. (1999), Ecologia da Saúde: Saúde, Cultura e Interação Homem/Ambiente, Londres, Routledge.

HOQUE MA, SCHEELBEEK PFD, VINEIS P.. Drinking water vulnerability to climate change and alternatives for adaptation in coastal South and South East Asia. Clim Change, 2016; 136(2):247–63.

IBGE. Instituto Brasileiro de Geografia e Estatística (IBGE). Censo Demográfico 2010. Disponível em: https://censo2010. Ibge. gov. br/sinopse/index.php?Uf=21 Acesso em 05 de junho de 2018.

IBGE. Instituto Brasileiro de Geografia e Estatística. Pesquisa nacional de Saúde: percepção do estado de saúde, estilos de vida e doenças crônicas-Brasil, grandes regiões e unidades da federação Brasília (DF), 2013; Disponível em: http:// ftp.Ibge.gov.br/PNS/2013/pns2013.pdf Acesso em 05 de junho de 2018.

IPCC, 2007: Climate Change 2007: Synthesis Report. Contribution of Working Groups I, II and III to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change [Core Writing Team, Pachauri, R.K and Reisinger, A. (eds.)]. IPCC, Geneva, Switzerland, 104 pp.

JUNIOR, C. S; SASSON, S. Biologia-Genética, evolução e ecologia. Volume 3.3 serie. 7 edição. São Paulo. Saraiva. 2010.

KHAN, A. E; IRESON, A; KOVATS, S; MOJUMBER, S. K; KHUSRU, A; RAHMAN, A; VINEIS, P. Drinking Water Salinity and Maternal Health in Coastal Bangladesh: Implications of Climate Change. Environ Health Perspect. 2011 Apr 12.

KOLIAKI C; KATSILAMBROS N. Dietary sodium, potassium, and alcohol: key players in the pathophysiology, prevention, and treatment of human hypertension. Nutr Rev, 2013; 71(6):402–11.

MAKHSEED M; MUSINI VM; AHMED MA; MONEM RA. Influence of seasonal variation on pregnancy-induced hypertension and/or preeclampsia. J Obstet Gynaecol. 1999;39(2):196-9. DOI: http://dx.doi. Org/10.1111/j.1479-828X.1999. tb03372.x. PMid:10755779.

MELO B; AMORIM M; KATZ L; COUTINHO I; FIGUEIRA JN. Hypertension, pregnancy and weather: is seasonality involved? Rev Assoc Med Bras. 2014; 60(2): 105-10. DOI: http://dx.doi.Org/10.1590/1806-9282.60.02.006. PMid:24918996.

MINISTRY OF ENVIRONMENT AND FOREST B. Coastal Land Zoning in the Southwest: Report on ‘‘Impact of Sea Level Rise on Land use Suitability and Adaptation Options’’. April, 2006.

MORIKAWA M; YAMADA T; CHO K; SATO S; MINAKAMI H. Seasonal variation in the prevalence of pregnancy-induced hypertension in Japanese women. Obstet Gynaecol Res. 2014; 40 (4):926-31. DOI: http://dx.doi.org/10.1111/ jog.12304. PMid:24612433.

OPAS. Dia Mundial da Hipertensão. Organização Panamericana de Saúde, 2016. Disponível em: <http://www.paho.org/ bireme/index.php?option=com_content&view=article&id=330:dia-mundial-da-hipertensao-2016&Itemid=183&lang=pt> Acesso em 10 de junho de 2018.

PUTTI, L. D. Estudo e percepção das etapas de tratamento de água no município de Jaú. 138 folhas. Monografia (Especialização em Ensino de Ciências). Universidade Tecnológica Federal do Paraná, Medianeira, 2011ª.

TEIXEIRA, J.C; GUILHERMINO, R. L. Análise da associação entre o saneamento e saúde nos estados brasileiros, empregando dados secundários do banco de dados indicadores e dados básicos para a saúde 2003-IDB 2003. Rev. Eng. Sanit. Ambient. Vol. 11. No. 3. Rio de janeiro, jul-set, 2006.

WORLD HEALTH ORGANIZATION (WHO). A Global Brief on Hypertension: Silent Killer, Global Public Health Crisis [Online]. 2013. Disponível em: http://www. thehealthwell.info/node/466541 (August 2016, date last accessed). Acesso em 30 de junho de 2018.