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Original Article

Surveillance of the drinking water quality din the Legal Amazon: analysis of vulnerable areas

Vigilância da qualidade da água para consumo humano na Amazônia Legal: Análise de áreas vulneráveis

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Abstract

Low quality drinking water has been directly correlated to the occurrence of waterborne illnesses in northern Brazil. To minimize health risks related to the water supply, the Ministry of Health has proposed the implementation of the National Program for the Surveillance of Drinking Water Quality (VIGIAGUA) in Brazilian municipalities. Focusing on the Legal Amazon region, the present study demonstrates a historical account of the percentage of municipalities included in the VIGIAGUA program in place, which in 2013 reached 45.1% of the region municipalities. This study also identifies vulnerable areas in terms of the water quality in the states of Amapá, Amazonas and Maranhão. With this analysis of the current status of the drinking water supply, this study intends to support and direct the strategic efforts of environmental health monitoring in the region.

Keywords: legal Amazon; health surveillance; water quality and vulnerability.

Resumo

A baixa qualidade da água para consumo humano está diretamente relacionada à ocorrência de doenças de transmissão hídrica. Para minimizar riscos à saúde e vulnerabilidades relacionadas ao abastecimento de água, o Ministério da Saúde propõe a implantação do Programa Nacional de Vigilância da Qualidade da Água para Consumo Humano (Vigiagua) aos municípios brasileiros. Focando na região da Amazônia Legal, o presente estudo demonstra uma série histórica do percentual de municípios com o programa Vigiagua implantado, atingindo em 2013 a marca de 45,1% dos municípios dessa região. O estudo ainda identifica áreas muito vulneráveis nos estados do Amapá, Amazonas e Maranhão para a questão da qualidade da água. Com esta análise da situação do abastecimento de água para consumo humano pretende-se subsidiar e direcionar as ações estratégicas da vigilância em saúde ambiental na região.

Palavras-chave: Amazônia legal; vigilância em saúde; qualidade da água e vulnerabilidade.

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INTRODUCTION

Water is one of the greatest concerns on the planet regarding its preponderant uses, preservation, and as a resource for all of mankind in terms of adequate quantity and quality of supply for human consumption. Therefore, the General Assembly of the United Nations passed the Resolution 64/292 declaring safe and sanitary water essential for life and the realization of all human rights[1].

According to the Pan American Health Organization (PAHO), water and the human health are inseparable[2] since the poor quality of drinking water is directly related to diseases and/or waterborne illnesses caused by bacteria, viruses, protozoa and helminthes. Thus, it is necessary to create strategies to guarantee that the use of water does not cause health hazards in the near to long term future.

Brazil has adopted the Guidelines for Drinking-Water Quality, set forth by the World Health Organization[3], which provides quality parameters standards (radiological, physical, chemical and microbiological).

VIGIAGUA aims to develop efforts to ensure that Brazilian citizens have access to water in sufficient quantity and quality and compatible with drinking water standards established by the current legislation (Federal Law number 2.914/2011) as an integral part of the waterborne illnesses prevention and the promotion of health as established by SUS[4]. The term surveillance presupposes frequent and continuous evaluation of several factors in order to identifying potential human health risks and guide intervention and control actions, assuming thus a routine and preventive character[5].

Therefore, the drinking water quality surveillance process is presupposed by the performance of actions within three domains: 1) the identification and registration of the sources of water supply 2) the surveillance of the water supply authorities' performance and 3) the surveillance of the water quality performed by the health sector. It must be emphasized that a municipality is considered deployed by VIGIAGUA when it concomitantly performs actions under these three domains (Registration, Control and Surveillance).

- According to GM/MS Federal Law no. 2914/2011, the sources of water are classified as follows[4]:

  Water supply systems (SAA): An installation comprised of public works projects, materials and equipment, from the source of water collection to the water pipelines in buildings, and the production and distribution of drinking water through this distribution network

  Collective Workaround (SAC): a modality of a collective water supply aimed to publicly distribute drinking water via groundwater collection or surface water collection, with or without pipelines and without a distribution network.

  Individual Workaround (SAI): a modality of individual water supply for private human consumption (a water well) which provides for residential homes of a single family, including their extended family members.

One of the main tools for the VIGIAGUA program functionality is the Surveillance of the Drinking Water Quality Information System (Sisagua), which aims to systematizing the data and control of the water quality surveillance, allowing the identification of risk factors that affect human health as a means of producing the information necessary for the execution of the water quality surveillance, aside from being an important managerial tool.

Another management and monitoring tool is the National Sampling Plan Guide, which determines the minimum number of samples that the environmental health regulators of each Brazilian municipality should collect from the water supply system network distribution. The goal is to evaluate three basic indicators of efficient water treatment and the distribution network integrity: turbidity of treated water, total coliform count and the presence of free residual chlorine (FRC) that must remain in treated water until consumption.

Upon these considerations, an evaluation and analysis of VIGIAGUA was performed in the municipalities comprised in the Legal Amazon region.

The Legal Amazon, as stated in Article 2 of Federal Law no. 5.173, of October 1966, encompasses the states of Acre, Amapá, Amazonas, Mato Grosso, Pará, Rondônia, Roraima, Tocantins, part of Maranhão and five municipalities of Goiás. It represents 59% of the Brazilian territory, or about 5 million square kilometers, distributed among 775 municipalities[6]. It is a vast territory that shows similar occupation processes and challenges to environmental sustainability and health[7], with all or part of their areas under the influence of the planet's largest biome of tropical, including part of the Earth's largest basin, the Amazon basin, and other river basins with high flow rates[8].

Although the Amazon states contain more than 80% of the available water in the country[9], this region presents challenges to the access of clean water for local populations. In the Legal Amazon, the percentage of permanent residences connected to the water supply was 60% in 2010, which was much lower than the national average for that same year (82.7%)[6].

It demonstrates how much these municipalities are different regarding their water resources availability and potentiality, once the first concept is sensitive to human pressures on the natural system, which imposes joint consideration of quantity and water quality required[10].

In addition, there was a low rate of perception of the importance of the reported problems about water resources and the possible implications to health as well as the conditions of life on the part of the population and the municipal environmental managers[11].

In this context the notion of water supply system vulnerability is essential to protect and promote the population's health,

since several studies indicate that water supply and sewage management interventions lead to positive impacts in various health indicators[12].

This study aimed to evaluate the degree of implementation of VIGIAGUA in the municipalities that compose the Legal Amazon region, as well as analyze the data on drinking water, and to evaluate vulnerable areas in order to subsidize and offer direct strategic action for the monitoring of environmental health in this region.

METHODS

This is a descriptive study conducted using data obtained from the Sisagua database, taking into consideration its five-year history (2009-2013). Therefore, the percentage of municipalities in the Legal Amazon that conduct registrations for the sources water supply was verified. The implementation of VIGIAGUA was also verified, which maintenance is performed based on the routinely generated data by professionals from the health sector (Surveillance) and those responsible for the supply of water (Control).

For the evaluation of the quality of water distributed in the Legal Amazon, a survey of data was performed for the year 2013 on the main sources of water supply: water supply systems (SAA) with and without treatment, Collective Workaround (SAC) with and without treatment and Individual Workaround (SAI). Other parameters considered were the percentage of sample turbidity out of the normal standards, the percentage FRC out of the normal standards and the percentage of samples with total coliform count out of the normal standards.

To create a map of vulnerable areas for the year 2013, the percentage of water supply systems without treatment, the percentage of Collective Workaround without treatment, the quantity of Individual Workaround, the percentage of turbidity samples out of the normal standards, the percentage of samples with free residual chlorine out of the normal standards and the percentage of samples with coliforms out of the normal standards were analyzed. The percentages of the samples with FRC, turbidity and coliform count out of the normal standards were considered for both SAA and SAC that receive treatment.

All data were tabulated with the help of Microsoft Excel spreadsheets and Tabwin. The tables with cited data were imported into a PostgreSQL database and the tabulations and classifications of the vulnerable areas were also performed in the PostgreSQL database.

Construction of the vulnerable areas map

The values of the variables were placed in ascending order to create quartiles, considering that municipalities with the same value of a specific variable could be in different quartiles.

The variables were weighted in order to improve this classification and define the degree of vulnerability for the municipalities. A weight of 1 was assigned to the lowest degree of vulnerability (very low) and a weight of 4 was designated to the highest degree of vulnerability (high). The intermediate weights 2 and 3 were classified as low and medium vulnerability, respectively.

The first weight corresponds to municipalities that possess values lower or equal to the maximum value of the first quartile (≤Q1); the second weight corresponds to municipalities that possess values higher than the maximum of the first quartile and lower or equal to the maximum value of the second quartile (>Q1 and ≤Q2); the third weight corresponds to municipalities that possess values higher than the maximum value of the second quartile and lower or equal to the maximum value of the third quartile (> Q2 and ≤Q3); the fourth weight corresponds to municipalities that possess values higher than the maximum value of the third quartile (> Q3).

This classification system was applied for each variable. In cases which the maximum value of the third quartile coincided with the minimum value of the fourth quartile, a weight of 3 was assigned corresponding to the municipalities with values greater than Q2 and less than Q3, and a weight of 4 to the municipalities with values greater or equal to Q3.

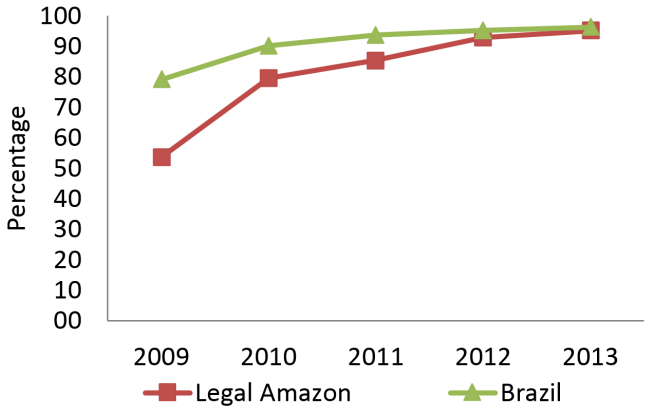
In order to obtain a final map of vulnerability, the sum of the respective variable weights was calculated and in turn was newly reclassified using the previously described weights. Maps were drawn using TerraView 4.0 software.

RESULTS AND DISCUSSION

From 2009 to 2013, a progressive increase in the percentage of municipalities with registered sources of water was observed in the Legal Amazon region (Figure 1). In 2009, 53.6% of the municipalities possessed water source registrations, which increased to 95.1% in 2013, corresponding to an increase of 43.6% during the analyzed period. These data indicate progress of the water quality surveillance in the region, considering that registration of water sources is an initial step to implementing the VIGIAGUA program.

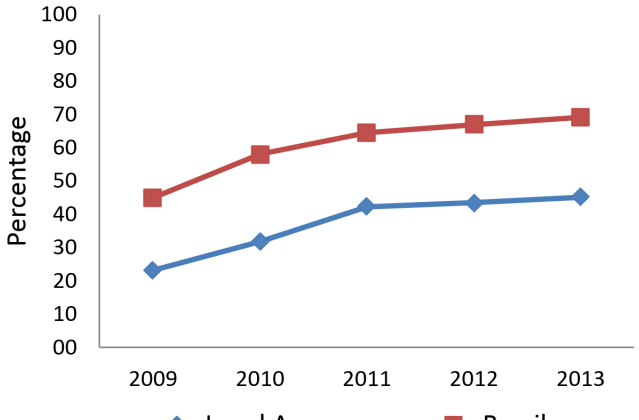
However, upon analyzing the percentage of municipalities with the water quality surveillance in deployment (Figure 2), the Legal Amazon region had less than 50% of the municipalities with VIGIAGUA in place in 2013, despite having increased registrations of the sources of water. Nevertheless, when considering the period from 2009 to 2013, there was a 45.5% increase in the implementation of the program.

The percentages of water sources according to treatment in the Legal Amazon for the year 2013 are shown in Figure 3. Upon comparing Figure 3 with the previous graphs, it was observed that despite the advances that were reached in increasing number of registrations and implementation of VIGIAGUA in



	2009	2010	2011	2012	2013
Legal Amazon	53.6	79.6	85.5	92.9	95.1
Brazil	79.0	90.2	93.7	95.3	96.3

Figure 1. Percentage of municipalities with forms of water supply registered in the SISAGUA database from 2009 to 2013. The red and green lines show percentages in the Legal Amazon and Brazil, respectively.



	2009	2010	2011	2012	2013
Legal Amazon	23.2	31.9	42.3	43.5	45.1
Brazil	44.9	58.1	64.5	66.9	69.2

Figure 2. Municipalities with Vigiagua program implanted in 2009 to 2013 period. The blue and red lines show percentages in the Legal Amazon and Brazil, respectively.

the Legal Amazon region, 54.2% of SAA and 81.76% of SAC did not have treatment values above the national average.

A worrisome characteristic concerning water sources is that many are superficial, which makes them susceptible to contamination by sewage, residential septic tanks, leaching, etc. Therefore, in 2011 a decree (GM/MS No. 2,914) established that all drinking water that is collectively captured from a superficial source must be submitted to a filtration process and go through a disinfection process or chlorination.

Another factor that creates vulnerability in the Legal Amazon region is the extensive consumption of water from residential water wells (SAI). This workaround solution has a low rate of

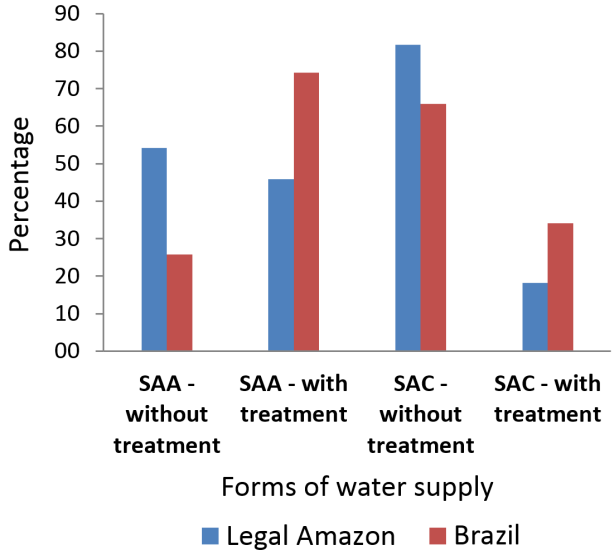


Figure 3. Forms of water supply per treatment. The red and green columns show data in the Legal Amazon and Brazil, respectively.

registration with Sisagua, making surveillance difficult regarding to water quality standards. However, this solution has its own value, especially in regions with poor or non-existent water supply[13].

In Manaus, Amazonas state capital, it is observed that a high population proportion consumes water of individual workaround, as a matter of preference, even where public water supply is available[14].

The percentage of samples out of the normal standards for the three previously mentioned parameters (free residual chlorine, total coliform count and turbidity) of water collected from SAA and SAC with treatment are shown in Figure 4. It is worth noting that many municipalities that have registered sources of water in the system do not have information for these basic parameters. Of the municipalities that have registered sources of water, 60.7%, 33.3% and 39.3% did not have information for the FRC, coliform and turbidity parameters, respectively.

Of the municipalities that perform analyses for these parameters, many present high percentages of samples out of the normal standards. It must be emphasized that the minimum number of samples analyzed via surveillance varies according to the municipality/state population size as determined by the National Sampling Plan Guide of the Surveillance of the Drinking Water Quality[15].

Regarding the FRC parameter (Figure 4a), 10% of the municipalities presented between 85 and 100% of the analyzed samples outside of normal standards, the majority of which located in the states of Pará e Maranhão. The municipalities of Mato Grosso presented the best results with only about 3% of the municipalities within the range of 70 to 100% of the samples outside the standard. Chlorine is a chemical agent widely utilized

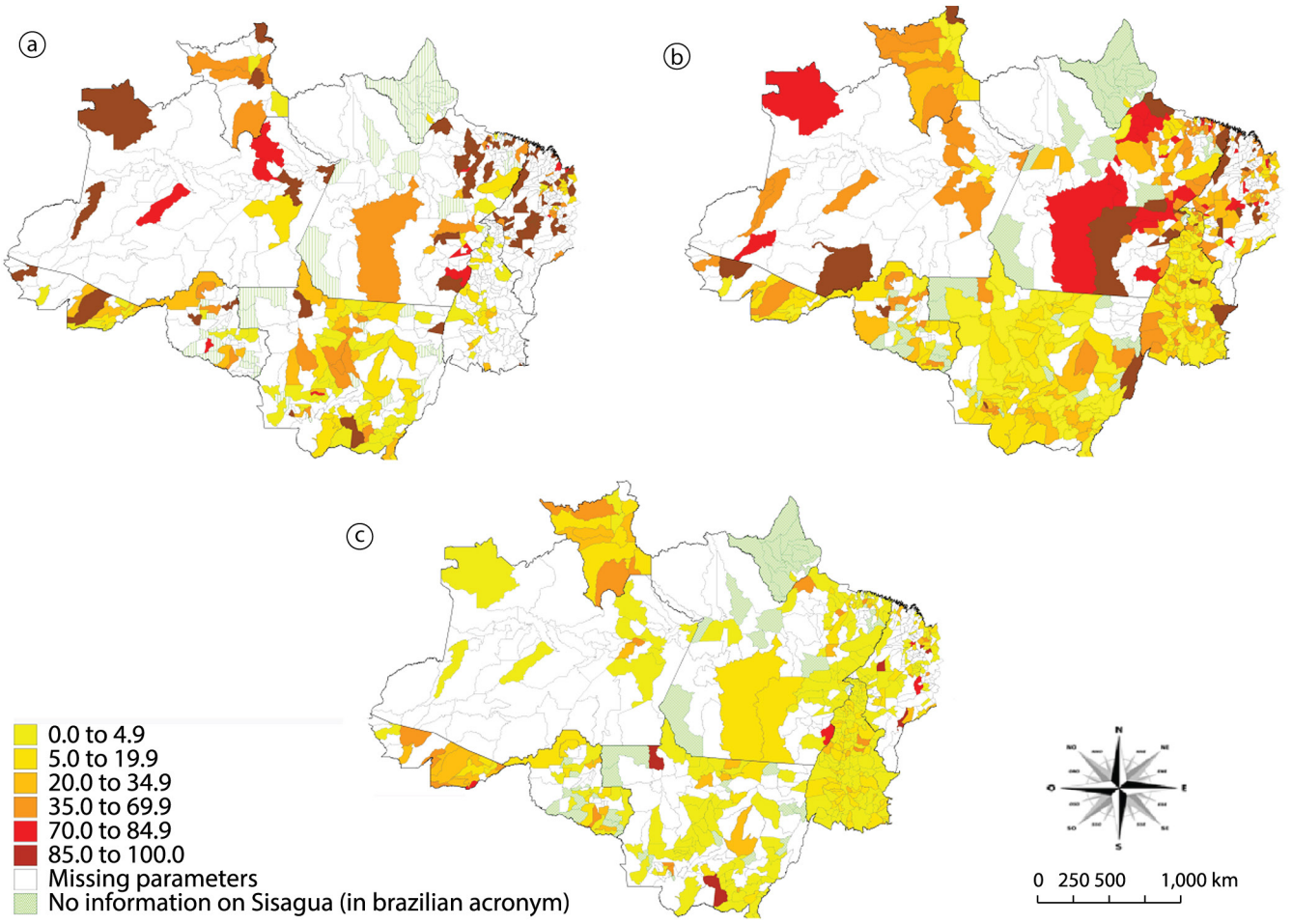


Figure 4. Percentage of samples out of standard: (a) FRC, (b) Total coliforms and (c) Turbidity. The map was constructed for Legal Amazon in 2013. Municipalities showed in brown are considered more critical while municipalities represented in white and green are either registered but have not entered one or more parameters data in Sisagua, or have no information in the system.

in the process of disinfection due to its capacity to maintain residuals minimally stable in the distribution network, which ensures the microbiological quality of the water even after any subsequent contamination. For this reason, free residual chlorine is considered an important indicator of the microbiological potability of water[16].

The map showed in Figure 4b presents the percentage of analyzed samples for total coliforms (a group of bacteria used as an indicator of microbial water contamination and treatment efficiency). Of the municipalities in the Legal Amazon region that assessed this parameter, 3.8% had between 85 and 100% of samples out of the normal standards. The municipalities of Mato Grosso and Tocantins presented the best results with the greatest number of samples within normal standards of potability, while the municipalities from the state of Para presented the worst results.

Finally, the turbidity parameter is a sanitation indicator, since high turbidity in drinking water, besides being visually unpleasing, interferes with the efficiency in the disinfection process[17]. Its removal through the process of filtration indicates the removal of suspended particles, including protozoan (oo) cysts[18]. This parameter presented the best results, with only 0.8% of municipalities with results out of the normal standards. Of the total number of municipalities, 34.4% obtained less than 5% of samples out of the normal standards (Figure 4c).

The states of Amazonas and Para did not present information for most of their municipalities for the three analyzed parameters. Almost all municipalities in the state of Amapá did not register their water sources nor had any information on the quality of drinking water. Of the total number of municipalities in the Legal Amazon region, 52 (6.7%) did not have any information about sources of drinking water in the Sisagua database in 2013.

Taking this information into account, Figure 5 presents the map of vulnerability of the drinking water quality in the Legal Amazon region in 2013. To construct this map, aside from the parameters previously mentioned, the sources of water (SAA, SAC, SAI) without treatment were also considered.

It was observed that in the states of Amazonas and Maranhão, 80.64% and 57%, of their municipalities, respectively, were classified as highly vulnerable. Despite the fact that these

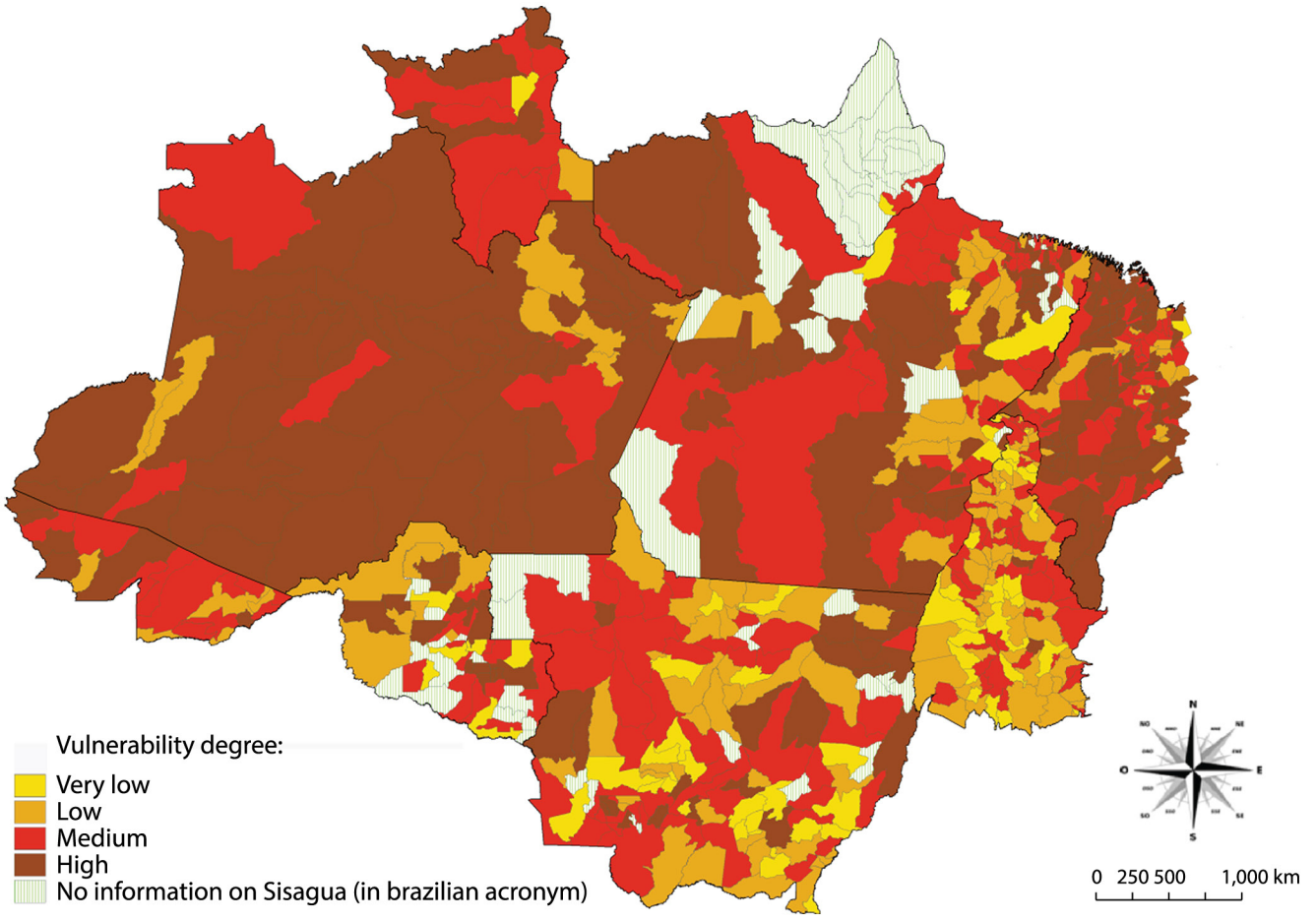


Figure 5. Vulnerability map constructed for Legal Amazon. Image shows degree of vulnerability according to the parameters inserted on Sisagua. Brown indicates high vulnerability, red shows municipalities with medium vulnerability and orange and yellow indicate low and very low vulnerability. Municipalities represented by lighter yellow have no information in the Sisagua system.

municipalities had registered their sources of water, the vast majority had not performed treatment and few assessed the basic parameters.

In a study conducted on the Manaus peripheral area it was found that 79.8% of the population consumes water of individual workaround, and among these, 49.8% without the minimum treatment (disinfection) required by ordinance potability, setting a high-risk situation[19].

Approximately 86% municipalities of the state of Amapá did not have information on sources of drinking water, in other words, are also considered at high risk due to the lack of information related to sources of water in these localities. The states of Tocantins and Mato Grosso presented the lowest percentages of municipalities with highly vulnerable areas, 1.44% and 21.27%, respectively.

Although the study is based on the method of quartiles, a descriptive statistics method, it was a largely qualitative study as the data was not submitted to prior quantitative analysis and standardization which could affect the results.

It is important to point out that the water supply studies focused on vulnerabilities based on drinking water quality indicators in the Amazon region and Brazil are incipient. Researches on the Legal Amazon comprising the sanitation subject are related to environmental vulnerability indicators[20], aquifer's water vulnerabilities[21], and sanitation indicators related to populations in situations of social vulnerability[22,23].

CONCLUSIONS

The performance of Environmental Surveillance related to the quality of drinking water in the Legal Amazon region has strengthened in the last five years, considering the great increase in municipalities with data related to the identification and registration of the sources of water.

However, despite the increase in percentages of these municipalities regarding the VIGIAGUA program in the Legal Amazon region between 2009 and 2013, less than 50% of the 771 municipalities of this region have concomitantly executed registration, control and water quality surveillance. In this sense, the necessity of intensifying action in the health sector in the

region must be emphasized with the objective of strengthening the VIGIAGUA program.

It is also noteworthy the need for the health sector to work together with their respective water authorities in in order to implement a treatment process for SAA and SAC that provides water naturally to the population, with the objective of minimizing the risks to health and ensure the improvement in sanitary conditions of the diverse sources of water supply, promoting the health and safety of drinking water.

Finally, it must be emphasized the need for a joint effort between VIGIAGUA and other related sectors, including the areas of sanitation, environmental and water resources, in order to integrate efforts and strengthens the health sector in the Legal Amazon region.

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