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ELABORATION OF THE WATER SAFETY PLAN IN A WATER SUPPLY SYSTEM IN THE BRAZILIAN NORTHEAST

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ABSTRACT

The Water Safety Plan is a tool used to identify, assess and manage health risks related to any water supply system. In order to do so, a study was carried out in a supply system, located in the northeast of Brazil, composed by Fountain Caldas (P1) and Well Cipó (P2), as sources of raw water abstraction, and by the Distribution Reservoir (P3) treated. Water collection, land use and land use assessment and analysis of possible risks were carried out in the vicinity of these three points and in another site (P4) to obtain the treated water. The quality of the raw water was evaluated by the parameters of the Resolution of the Conselho Nacional do Meio Ambiente n° 396/2008 and the water treated according to the parameters of Ordinance nº 2914/2011 of the Ministry of Health. Observing the probability of occurrence of risk and the severity of consequence of the events. Therefore, 17 control points with low rating were detected, and two with moderate rating. Control measures were suggested for each identified critical point, mainly related to water quality monitoring and system maintenance.

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INTRODUCTION

Water quality is fundamental to human health. Brazil, with its continental dimensions, has in its territory 12% of all the fresh water of the planet, but despite its abundance, it is not distributed to the population in the same quality standard (Mota, 2008). The world population with water shortages is expected to increase and theoretically reach two-thirds of the total population in the coming decades (Fekete, 2013). Water that can be consumed without risk to health or rejection to consumption, is classified as drinking water. Normally, in order to reach the recommended levels of drinking water, water treatment plants must be treated at the water treatment plants, since such procedures considerably reduce the rate of waterborne diseases (Deso, 2014). It is necessary, then, to study and adapt the water supply systems so that they have the best technological performance guaranteeing environmental security of the environment (Philippi Jr, 2004). Therefore, the Water Safety Plan (WSP) is a document that points out and prioritizes risks that can be identified in a water supply system, from the capture of raw water to the tap of the consumer, and thus adopts control measures so that the risks contamination can be reduced, thus guaranteeing the quality of water for human consumption (Brazil, 2012; Vieira and Morais, 2005).

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MATERIALS AND METHODS

Determination of the Study Area

The water supply system chosen for this study was the Rosário do Catete system, located in the central region of the state of Sergipe, 37 km from the capital Aracaju.

Field visit and description of collection points

Four visits were carried out from February 2016 to July 2017, so that it was possible to recognize the area, the use and occupation of the soil, and to collect water at points P1, P2, P3 and P4 (Table 1).

Table 1. Geographic coordinates of the points of analysis of the supply system studied

Point	Description	Geographical Coordinates
P1	Caldas Fountain (Water abstraction)	10°42' 20.21" S 36°59' 38.03" O
P2	Well Cipó (Water abstraction)	10°42' 41.30" S 37°01' 31.84" O
P3	Reservoir (Water treated)	10°42' 04.23" S 37°01' 45.63" O
P4	Distribution (Water treated)	10°42' 06.89" S 37°02' 14.67" O

The analyzes were carried out in the laboratories of the Instituto de Tecnologia de Pesquisa - ITP, except for the analyzes of the ions that were made at the Instituto Tecnológico e de Pesquisas do Estado de Sergipe - ITPS. The parameters were analyzed following the methods established by the Standard Methods for Examination of Water and Wasterwater (Apha, 2012). In the evaluation of the parameters of water quality in relation to the Maximum Permitted Values (MPV), Caldas Fountain (P1) and Well Cipó (P2) were characterized as raw water and were therefore governed by the resolution of theConselho Nacional do Meio Ambiente – CONAMA, nº. 396 of 2008, which deals with the standards of groundwater quality.

The reservoir (P3) and the Final Distribution (P4) were defined as water for human supply, so their maximum values for water quality parameters were analyzed according to Ministry of Health Ordinance No. 2914 of 2011. Fountain Caldas (P1) is an upwelling of groundwater located on the intermunicipal highway connecting Rosário do Catete to the municipality of General Maynard. The water collected at this source is filtered, chlorinated and transferred to the reservoir by means of pumps. Well Cipó (P2), is an artesian well with a depth of 42 meters. The water provided therefrom is filtered, chlorinated and transferred to the distribution tank by pumping.

The water storage tank (P3) which is about 40 m high and has a reserve capacity of approximately 250 m³. And, the health post of the municipality is part of the water distribution network, so it was chosen as one of the analysis points (P4). It was provided by the responsible company the projects of the water supply system of Rosário do Catete and the document that determines the form of water treatment of the system, where it could be observed that the water of the system is treated by the addition of Trichloroisocyanuric Acid in a concentration of 5mg of active Cl per liter of water (5mg / L). The treated water from the two abstractions (P1 and P2) is stored in a reservoir, considered as P3 (Figure 1), so that the water already treated is distributed for human consumption.

Development of WSP

According to the methodology of Vieira and Morais (2005), for the elaboration of a WSP it is necessary to form a multidisciplinary team whose tasks include the planning, development, verification and application of the WSP. After identification of the constituent team of the WSP, the description of the system was made as similar as possible to the reality of the municipality. To do so, it was necessary to obtain the following data, provided by the company responsible for supplying the region: General plan of the system, from the source to the consumer; Capture scheme (surface or underground); Description of the water treatment scheme, including the chemicals added; and Plant of the distribution system (reservoirs, conduits, accessories, etc.).

For the identification of hazards and risks, factors such as seasonal events, accidental or deliberate contamination, control measures, and hygiene of the system were considered, among others. The risks were analyzed through the probability of occurrence of the hazard causing damage to the population, in a certain time interval and considering the magnitude of this damage, being possible to classify the risk factor according to the Scale of Probability of Risk Occurrence, and through the determination of the severity of the dangerous event, understood as a consequence of the event.

After analyzing the probability of occurrence in relation to its severity, the risk classification was performed according to the Risk Classification Matrix. The interpretation of the Risk Classification Matrix also qualitatively informed the degree of severity considered of the hazard or dangerous event, through the Matrix of Qualitative Prioritization of Risks. After the identification of each Control Point (CP), the control measures were determined for each dangerous event. And later, the Critical Control Points (CCPs) were determined through the decision tree which is an interactive mode of answers pertaining to a set of four questions that should be asked for each dangerous event encountered. It is worth mentioning that the CCP is the event that can be controlled quickly by the body responsible for managing the system (Vieira and Morais, 2005). These are points that along the water supply system have dangers that can be monitored and that it is possible to determine their critical limits (Vieira and Morais, 2005).

RESULTS AND DISCUSSION

Development of WSP

A team was formed to prepare the WSP, by people who knew the supply system studied, who understood the systematization and methods for handling the WSP "tool", which had operational knowledge, besides having authority (hierarchical degree) before the system of the WSP County.

Risk Assessment Sheets

Fountain Caldas (P1): Raw water

In the surroundings of the system there is a sugar cane plantation, and according to Pignati *et. al* 2014, farmers, by spraying these poisons, contaminate the environment, with the aim of achieving "crop pests" (insect, fungus or weeds), but they are contaminated so that only 30% of the pesticides used reach the target and the rest goes to soil, water, air and plants.

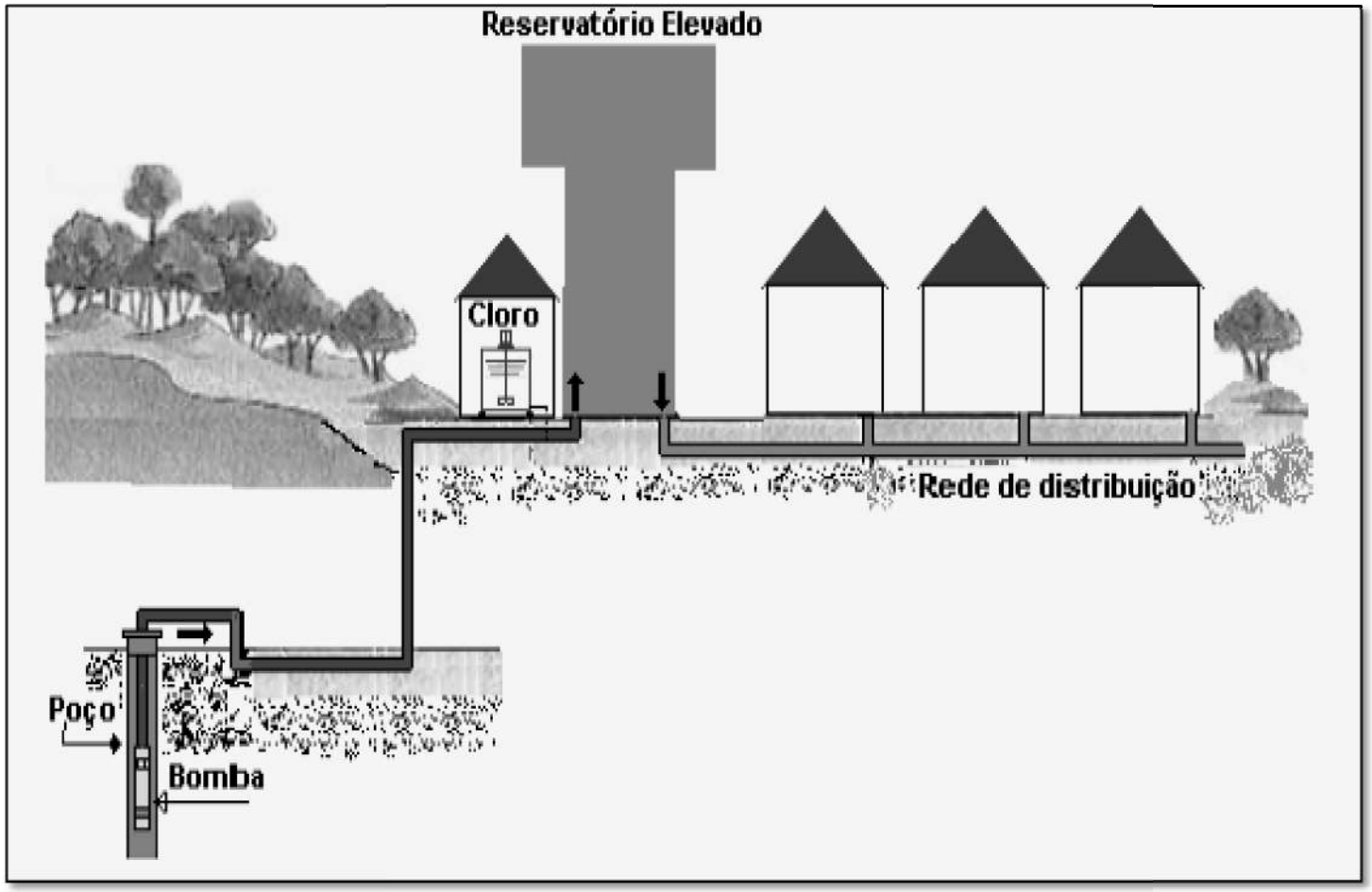

Figure 1. Illustration of the System of collection and water supply in Rosario do Catete (Deso, 2014)

Therefore, in the Fountain Caldas there is a danger of the presence of pesticides in the water that must be monitored through the identification of possible sources of contamination and management measures in the catchment basin or to assess the risk of contamination of surface and groundwater by pesticides in the vicinity of the water catchment system.

This risk was not assessed as a critical control point, and has a low risk characterization. The second dangerous event identified was the presence of livestock near the spring, thus offering a possible contamination of the water by total and thermo tolerant coli forms.

It was the event that presented a higher risk class among the others analyzed at this point, obtaining an evaluation of 6 points, considered a moderate risk and that, through the decision tree, it was classified as a CCP. In the search to cure it, the control measure that can reduce this risk of contamination of raw water must, verify and correct the fragility points regarding the access of the spring, thus avoiding direct contamination. Regarding the dangerous event related to the presence of antimony in the catchment water in the rainy season, it was not evaluated because it was presented only in a water collection, but it is an item that should be analyzed in the next collections.

Well Cipó (P2): Raw Water

In the assessment of Well Cipó, the presence of livestock near the treatment system was characterized as a dangerous event, resulting in a possible presence of total and thermo tolerant coli forms contaminating the water. In addition, the presence of animals may cause damage to the capture and treatment system. Thus, with these dangers offered and with their relative ease of correction, this event was also characterized as a critical control point, being possible a correction by the company responsible for the system. It was also observed the presence of petroleum extraction zones in the vicinity of the water capture and treatment system. This proximity can cause water contamination by the water table.

Therefore, it is necessary to monitor the system observing possible contaminations, but despite the risk offered, this event was not characterized as a critical control point. It is worth noting that, according to Finotti and Caicedo (2001), there are no water control standards in cases of subterranean contamination by petroleum products. Lastly, the last dangerous event cited refers to the vulnerability of the catchment and treatment system, being susceptible to human and animal invasions, which may pose a risk to water quality. This event was positively classified as a critical control point because it is the responsibility of companies responsible for capturing, treating and distributing water, monitoring and ensuring the integrity of the system, since, according to Amaral *et. al* (2003), preventive measures help protect water sources and treatment plants by reducing the risks of waterborne diseases. Even though it has been classified as low, there should be greater concern regarding sabotage or vandalism, although the likelihood of occurrence is rare, severity is moderate (Costa, 2013).

Distribution Reservoir (P3): Treated Water

In the distribution tank there is a tendency for irregularities in the water storage service, which may lead to a deviation in water quality due to improper handling. This is a low severity event, but because it has conditions to be corrected by the company responsible for water management, it has been classified as a critical control point.

Another observed event was the presence of possible contaminants in the distribution pipes of the system, which is due to the irregularity in the cleaning and the monitoring of the distribution system which, being the responsibility of the company in charge of the water distribution, is a critical point of control, even if with a low rating. It was verified that there is a point with higher risk classification, related to leakage of water in the distribution network.

It is understood that because the human need to obtain water in their faucets is directly connected, this event risks the possible lack of water in certain regions of the municipality. In addition, all items related to the hazardous events of this treated water were considered CCP, since these events can be solved or minimized before WSP implantation. It is worth mentioning that, according to Morais *et. al* (2010), there is a certain acceptable degree of water loss in the system. The last topic observed in this table was the pressure variation which, like distribution leakage, may be responsible for the lack of water in certain regions. In addition, the pressure variation increases the turbidity index of the water and causes in the presence of microorganisms. This pressure variation must be monitored and controlled by the body responsible for water distribution, which makes pressure variation a critical control point.

Driving (P4): Treated Water

There were 5 types of possible dangerous events to occur, in which the first one evaluated was the water leakage from the distribution pipelines. For Fontana (2015), this event is one of the main challenges for water supply managers, since it is capable of causing the reduction of the flow due to the decrease of the volume of water drained from the exhaust. Even though it was classified as low risk in this study, for Ramos *et al.* (2001) apud Fontana (2015) to search for solutions that try to minimize this type of problem is necessary, because due to the occurrence of leaks in the network, besides generating the decrease of the available water, it can happen to the interruption during the maintenance of the ducing users' dissatisfaction. For this type of event, according to the authors, the adoption of a loss management strategy would be a viable option for the control of this type of occurrence.

For the second event, the accumulation of sediment inside the pipeline was assessed as a possible risk factor. For Silva *et al.,* (2009) apud Brito (2013), the user has a fundamental role to guarantee the continuity of the water quality inside the home, where, to give this continuity, pay attention to the pipes, reservoirs , and water treatment equipment, are attitudes that may contribute to this happening. An analysis of the piping and its state, the risk of contamination of the water due to the accumulation of sediments inside it is a matter of concern, because according to Jerba (2000), such microorganisms, when in contact with water, are capable of causing infections and depending on the degree, lead to death due to contamination of food after washing. For this event, the risk index was considered high when compared to the other evaluated, but the maintenance and cleaning of the ducts in a preventive way is an action that may decrease this index, avoiding future disorders. According to Correia *et. al* (2008), water turbidity occurs through the suspension of solids in the fluid, in which, when this suspension index is above the limits indicated by the World Health Organization (WHO), they are able to interfere with the standards of water potability. For event 3 (rupture of pipes), water turbidity was also classified as a possible risk, which may lead to water contamination. In addition to this, the lack of water due to the reduction of flow and the exposure to hazardous substances due to this rupture were two factors that were also considered as risky situations.
For the cases observed in the table, it is necessary to identify the possible sources of contamination together with the management measures. In addition, it is necessary to monitor

the distribution system, cleaning and performing preventive maintenance. All of these control measures must be performed by the company responsible for the distribution, that is, it is positively classified as a critical control point.

Through the data obtained, it is possible to observe the importance of the implementation of safety policies regarding the treatment and distribution of water mainly for human consumption. With this investment, it is possible not only to improve the quality of life of the population with better quality water, but also to reduce the number of people with diseases resulting from the consumption of contaminated water, which reduces the demand of hospitals. With regard to the study of a WSP, the established and effective drinking water portfolios become fundamental tools to ensure that the quality of the delivered water is within the permissible parameters in force.

Conclusion

The study highlighted the importance of the Water Safety Plan for the treatment and distribution of water mainly for human consumption. With this investment, it is possible not only to improve the quality of life of the population with better quality water, but also to reduce the number of people with diseases resulting from the consumption of contaminated water, which reduces the demand of hospitals. With regard to the study of a WSP, the established and effective drinking water portfolios become fundamental tools to ensure that the quality of the delivered water is within the permissible parameters in force.
With the activities carried out, it was possible to observe the critical points to prevent the contamination of the water in the supply system, thus, a scenario was constructed to evaluate the system of abstraction and water supply according to the methodology recommended by the World Health Organization, 2005).

As results, we identify the risks of contamination of water, with proposals for solutions to minimize these risks, in addition to evaluating the events identified as CCP. However, it is important to manage the water supply system by the responsible company, in addition to the commitment of its employees, so that the preparation of the WSP, based on current norms and subsequent implementation of the same, the local population is the biggest beneficiary, since the risks occurring at any stage of the system, from capture to final distribution, will be eliminated or reduced.

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