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Impacto da expansão urbana no manancial superficial do sistema de abastecimento de água de Belém e Ananindeua, Brasil

Urban expansion impacts the surface water source of the water supply system in Belém and Ananindeua, Brazil

Impacto de la expansión urbana en la fuente de superficie del sistema de suministro de agua en Belém y Ananindeua, Brasil

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Resumo

O objetivo da pesquisa é analisar a evolução das ações antrópicas nas proximidades do Lago Bolonha, que é o principal manancial superficial do Sistema de Abastecimento de Água da área central dos municípios de Belém e Ananindeua. A pesquisa foi realizada em três etapas. Na Etapa 1, foi caracterizada a área do entorno e avaliada a importância do Lago Bolonha no contexto urbano. Em seguida, foram identificadas as ações antrópicas realizadas nos últimos 10 anos no entorno da área do manancial. Finalmente, na Etapa 3 foram analisados os impactos e os riscos de degradação ambiental, considerando a vegetação no entorno do Lago. Os resultados demonstraram que a expansão urbana reduziu a mata ciliar e ocasionou lançamento de esgoto sanitário nos lagos, o que pode comprometer a sua capacidade de autodepuração a médio e longo prazo, portanto, aumentando o risco de poluição/contaminação no Lago Bolonha. Foi concluído que o poder público precisa desenvolver e intensificar ações para evitar novas ocupações irregulares, implantar sistema de esgotamento sanitário e recompor a mata ciliar na área do entorno, já que a proteção do Lago Bolonha é essencial para o sistema de abastecimento de água potável de cerca de 1.000.000 habitantes dos municípios de Belém e Ananindeua que compõem a região metropolitana de Belém.

Palavras-chave: Mata ciliar; Qualidade da água; Código florestal.

Abstract

The aim of that research is to analyse the evolution of human activities close to Lake Bolonha, one of the main surface water sources for the Water Supply System in downtown Belém and Ananindeua, is investigated. Research consists of three stages. Stage 1 characterizes the environs and evaluates the importance of Lake Bolonha within the urban context. Stage 2 identifies human activities in the last ten years in the environs of the water source. Stage 3 analyzes impacts and environmental degradation risks, with special focus on vegetation around the lake. Results show that urban expansion reduced riparian vegetation and triggered sewerage flow into the lake, compromising self-cleaning capacity in the medium and long term, with an increase of pollution/contamination. The administration should develop and intensify activities to avoid irregular land occupation, establish a sewerage system and restitute the riparian vegetation lost. Lake Bolonha is highly relevant for the water supply system of approximate one million people of Belém and Ananindeua within the metropolitan region of Belém, Brazil.

Keywords: Riparian vegetation; Water quality; Forest Code.

Resumen

Analice la evolución de las actividades humanas en las cercanías del lago de Bolonia, la principal fuente de superficie del sistema de suministro de agua en el área central de los municipios de Belém y Ananindeua. En el Paso 1, se caracterizó el área circundante y se evaluó la importancia del lago de Bolonia en el contexto urbano. Luego, se identificaron las acciones antrópicas llevadas a cabo en los últimos 10 años alrededor del área de origen. Finalmente, en el Paso 3, se analizaron los impactos y riesgos de la degradación ambiental, considerando la vegetación que rodea el Lago. Los resultados mostraron que la expansión urbana redujo el bosque ribereño y provocó la liberación de aguas residuales sanitarias en los lagos, lo que puede comprometer su capacidad de autolimpieza a mediano y largo plazo, por lo tanto, aumenta el riesgo de contaminación / contaminación en el lago de Bolonia. Se concluyó que el gobierno necesita desarrollar e intensificar acciones para prevenir nuevas ocupaciones irregulares, implementar un sistema de alcantarillado y restaurar el bosque ribereño en los alrededores, ya que la protección del lago de Bolonia es esencial para el sistema de suministro de agua potable. cerca de 1,000,000 de habitantes de los municipios de Belém y Ananindeua que conforman la región metropolitana de Belém, Brazil.

Palabras clave: Bosque de ribera; Calidad del agua; Código florestal.

1. Introduction

Urban expansion is not always undertaken under the aegis of the preservation of the environment. Results comprise the degradation of natural resources and increase the required investments for city infrastructure. Moreira, (1999b) underscores that the rise of numerous building estates and the diversification of activities cause changes in the environment to fit human needs.

According to Costa & Peixoto, (2007), groups involved in social and space transformations contribute towards an increase in problems within the urban context since they represent different interests within a specific context and collaborate for social inequalities. The establishment of grand constructions, lack of control in irregular housing estates and the absence of basic sanitary infrastructure, resulting in the fast deterioration of the environment, are issues that Brazilian cities have to cope with. Salles et al., (2013), highlight the seriousness of issues derived from the evolution process and population expansion in cities.

The constant increase in water demands requires availability of this resource for multiple usages. Pimenta, et al., (2012), relate certain impacts caused by urban growth, such as decrease in water flow, increase in sedimentation rates, increase in water residence time, thermal stratification and decrease in concentrations of dissolved oxygen.

According to Do Carmo, et al., (2005) and Pinto, et al., (2012), water quality of hydrographic basins is endangered by the launching of domestic effluents and by fertilizers, agrotoxics, pesticides and similar materials. According to UNO, (2015), the collection, transport and adequate treatment of sewerage are a must for the improvement of the life style of the population and essential for the protection of the environment.

Concern with water quality is constantly underscored in cities with high expansion rates, deficient infrastructure and reduced population control. WHO (2014) insists that insufficient sanitation activities in certain regions greatly impact the populations concerned. One may observe great public works (avenues, flyovers, public buildings) without the implantation of sanitation infrastructure. Frequently these public works instigate the expansion of informal land occupation lacking sanitary sewerage, drainage and others.

Great concern exists with the destruction of vegetation on the banks and environs of water sources and rivers. Tundisi (2008) states that riparian vegetation is a buffer and filter between high lands and the water ecosystem and participates in the control of nutrients in the hydrographic basin through surface discharge and absorption of nutrients of sub-surface

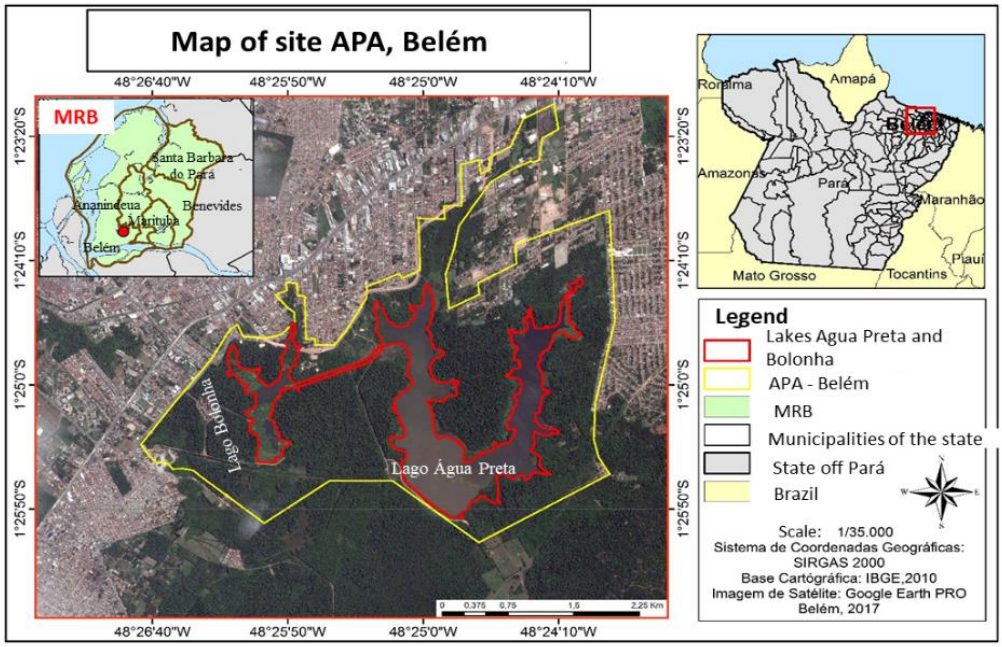
discharge. Machado & Torres (2012), corroborate the above and add that riparian vegetation impairs or makes difficult the carrying off of sediments towards the water system and contributes towards the maintenance of water quality in hydrographic basins.

Current paper analyzes the evolution of human activities close to the Lake Bolonha, a surface water source used by the Water Supply System that attends to the needs of about one million people in the central regions of the municipalities of Belém and Ananindeua, in the state of Pará, Brazil.

2. Methodology

Current quality-quantity field research, coupled to bibliographical and documental survey, analyzes the effects of human activities in Lake Bolonha, within the Metropolitan Region of Belem, Brazil, close to the border between Belém and Ananindeua. The lake has an area of approximately 1,348 ha and is an integral part of the Environmental Protection Area (APA Belém) established by State Law 1,552, published on May 3, 1993 (Pará, 2015), which also includes lake Água Preta and Environmental Park Utinga (PEUt) (Figure 1).

Figure 1 - Area under analysis.



Source: the authors, 2018.

Research has been divided into three parts: Part 1 evaluates the importance of Lake Bolonha for the water supply of Belém and Ananindeua. Part 2 identifies human activities

around Lake Bolonha during the last ten years; Part 3 investigates the pollution/contamination risk of Lake Bolonha according to current legislation.

The first stage comprised field survey and data collection from official documents and in technical and scientific papers for the assessment of Lake Bolonha within the water supply system of the municipalities of Belém and Ananindeua. The second stage identifies the main human activities undertaken close to Lake Bolonha during the last ten years, pinpointing possible impacts and risks in the preservation of water quality of the surface water source. The third stage discusses the impacts of urban expansion involving a decrease in riparian vegetation and an increase in pollution and contamination of the lakes within the APA area in Belém. Satellite images and photographs taken between 1998 and 2018 were employed to detect modifications of the city space caused a) by housing occupation and engineering works around the APA, Belém; b) by changes in the type of vegetal covering; c) by modifications in the area of the water body of Lake Bolonha. Compliance with current environmental legislation is verified.

3. Results and Discussions

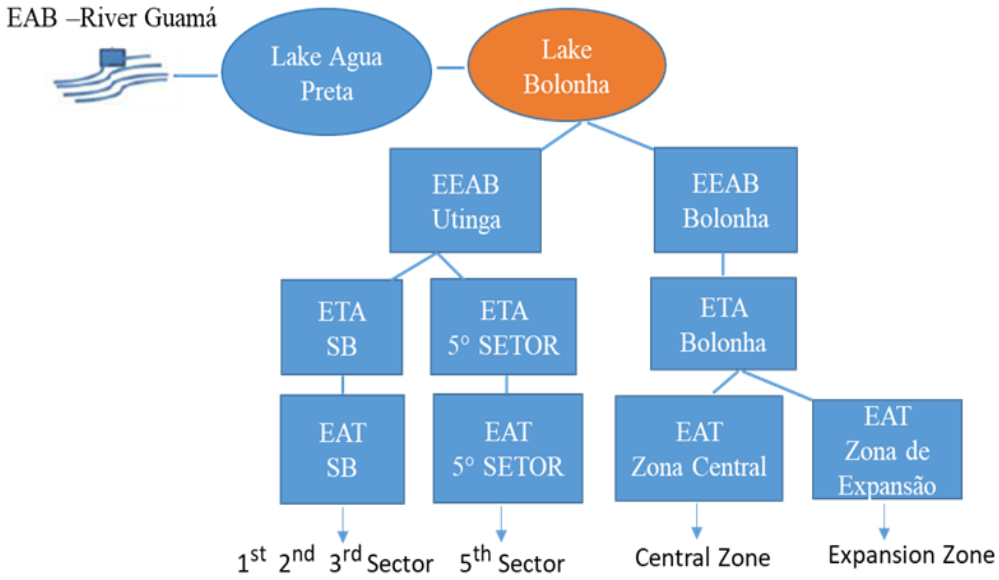
The Pará Public Works Company (COSANPA) is responsible for the water supply of 70% of the population of Belém and 30% of the population of Ananindeua (SNIS, 2016), with 490,118.5 m^3/month of water collected from the surface source and with approximately 210,050.8 m^3/s from underground sources (RIG, 2017). Water from the surface water source is totally collected and treated at the APA of Utinga where collection, adduction, treatment, reservoir and water-raising units of four immense systems are installed to attend approximately one million people of the central areas of the municipalities of Belém and Ananindeua. Crude water from the river Guamá is pumped and adducted to lake Água Preta (9,905,000.m^3), followed by water discharge to lake Bolonha (1,954,000 m^3) by gravity (Oliveira et al., 2018).

Further, lake Bolonha also receives rain water, underground water and drained water into its hydrographic basin (river Aurá, a section of the igarapés Tucunduba and Uriboquinha, sub-basins of the igarapés Murucutum and Água Preta).

Therefore, lake Bolonha (577,127 m^2) is a natural reservoir and, at the same time, the site of crude water collection at two places attending four systems of surface water supply. The following units are installed on its banks: a) Crude Water Pumping Station (EEAB) of Bolonha which serves the Bolonha water treatment and distribution systems – Central Zone

and Bolonha System – Expansion Zone; b) Crude Water Pumping Station (EEAB) of Utinga, which supplies water for treatment and distribution at the Utinga systems - São Brás and in the Utinga System – 5th Sector, as may be seen in Picture 1.

Picture 1. Supply system of the Metropolitan Region of Belém.



Source: the authors, 2019.

Since Lake Bolonha lies within the urban perimeter, decrease in operational costs is important (particularly, electricity) with regard to water supply systems in the central areas of the municipalities of Belém and Ananindeua.

Another relevant item is the huge capacity (6.7 m³/s) of the surface source which allows operational flexibility and, in tandem, a guarantee for the continuous water supply for many years to come, as forecasted in the Planning Directory of the Water Supply Systems of the Municipalities of Belém and Ananindeua.

Since it is a lake within the city area, a remark by Ulian, Ivan & Lima (2017), is highly relevant: water availability in Brazilian municipalities increases without taking into account strategies that improve water management and reduce its demand.

The preservation of lake Bolonha is a great concern for municipal authorities, mainly due to possible human activities that may impact the environs of the water source, with risks in significant quantitative and qualitative changes of the stored water.

In spite of institutional efforts to minimize impacts, several modifications in the natural environment close to the lake Bolonha have been identified during the last ten years,

namely, disordered urban expansion, lack of infrastructure in sanitation, extension of Avenue João Paulo II and engineering works in the Utinga Parque Ambiental.

3.1. Disordered urban expansion

According to Trindade Junior (1998) and Rodrigues (2018), the urban dispersion of low income populations around the APA Belém occurred without any prior planning of basic needs was implemented by the state or town authorities of Belém.

The authorities published Decree 1552 on May 3, 1993 establishing the Parque Estadual do Utinga (PEUt) as a Conservation Unit (CU) of Integrated Protection of 1.393 hectares, inserted within the Metropolitan Environmental Protection Area of Belém (APA Belém) only when the land close to the lake Bolonha was illegally occupied and consolidated.

Irregular land occupation prior to the publication of Decree 1552/1993 made highly difficult the organization, regularization and installation of infrastructure and sanitation works even when one of the aims of the Parque Estadual do Utinga was the recovery and maintenance of the environmental quality in lakes Água Preta and Bolonha, river Aurá and their respective hydrographic basins. In fact, the effective protection of water sources required the management of the entire hydrographic basin.

Rodrigues (2018), criticizes the streets around the lakes Bolonha and Água Preta, and complains that permission of thoroughfare for cars and people occurred without previous EIA/RIMA. The Moça Bonita, Utinga and Ceasa Highways, close to the Utinga water sources, were mentioned in the document, since these road increased the circulation of people and vehicles. Further, the first dense alterations of deforestation were detected on the northeastern region of APA Belém, close to lake Água Preta, where the housing estates Palmeiras do Açaí (60 houses), Canindé (74 houses) and Verdejantes I, II, III, IV (1,200 houses) were built (Bordalo, 2006).

Later, the so-called ‘spontaneous occupations of land’ started to arise within the APA Belém. Bordalo (2006), identifies the spontaneous estates Bom Sossego I (90 houses), Jacaré (70 houses), Japonês (60 houses), Lixão I (ND), Lopolândia (200 houses), Mon Cherry (82 houses), Nova Águas Lindas (1,122 houses), Orlando Ventura (49 houses) and São Judas Tadeu (329 houses). Further, Menezes, et al. (2013) report that disordered occupation in the whereabouts of PEUt and other activities related to urban pressure triggered processes involving soil degradation and stream pollution. Such deforestation was actually a threat to the maintenance of water quality of lakes Água Preta and Bolonha.

The 2011 state decree 265 reestablishes the boundaries of the Utinga State Park to enhance tourism and environmental education and to stop further irregular land occupation within the APA Belém. However, several issues had already been consolidated, such as environmental pollution derived from deficiencies in the basic sanitation infrastructure which are still a threat to the lake Bolonha.

Ferreira, et al. (2017) state that the collection of solid wastes occur regularly three times a week even though there are certain waste accumulation sites throughout the disordered occupation areas of APA Belém. Concern is real because waste matter may be carried off to the lake Bolonha during rainfall.

Another great risk that threatens the water quality of the lakes Bolonha and Água Preta is the sheer lack of sanitary sewage collector network. Crude sewage is directly discharged in the soil and in the rainwater micro-drainage network. Although several inhabitants have dug sanitary cesspits, most people do not have any network for the elimination of closet or kitchen effluents. Sewage frequently reaches the water bodies of the APA Belem.

The lack of sanitary sewage collection may also contaminate underground water with great risks for the inhabitants that consume the water and for the lakes that may be contaminated through the underground aquifer. According to Ferreira, et al., (2017), a great number of uncontrolled wells exist, dug by the inhabitants without any technical criteria.

APA Belém may also be environmentally impacted due to the closeness of the former Aurá landfill which polluted for many years the region´s underground water and may have contaminated water quality of the water springs in the preservation area, including lakes Bolonha and Água Preta which supply most of the metropolitan region of Belém. Siqueira & Aprile, (2013), demonstrate that Al, Cr, Fe and Ni metal ions may be present in the slurry of the Aurá sanitary landfill at the basin´s source.

The most imminent risks identified in lake Bolonha are related to underground and surface water resources. According to studies by Bahia, et al. (2008), since lakes and igarapés in the area lie in relatively low topographic sites (between 0 and 5 m) from the environmental protection area, featuring vulnerable geological characteristics, the surface and underground hydric system are situated in a high vulnerable state which may be reached and degraded with great aggressiveness. In fact, crude sewage, solid residues and eventual leaching of the landfill are not biodegraded.

Moreover, surface and underground pollution may further the occurrence of grave eutrophication of water sources, already reported in lake Bolonha with cost increase in water

treatment by Bolonha, 5th Sector and São Bras pumping stations. Environmental practices should have been undertaken in the basin´s engineering works.

The main public task comprised the 4.7 km extension of the four-lane Avenida João Paulo II, (Pará, 2018) which has not been followed by the implantation of sanitary sewage collection network even in the stretch which passes through the APA Belém. In spite of the great importance of urban mobility for the inhabitants of Belém and Ananindeua, the impacts on APA Belém were reported throughout the execution of the public works between 2013 and 2018, caused by the elimination of riparian vegetation, removal of great amounts of soil and the construction of two bridges with 176 m and 224 m respectively over lake Bolonha and Agua Preta. On the other hand, on the conclusion of works, followed by more access to cars and people, the preservation of the lakes of APA Belém was endangered, as Figure 2 demonstrates.

Figure 2. Areas that allows easy access of cars and people to APA Belém.

Source: Atayde, 2013.

Intermittently during the last ten years, other public works were undertaken in secondary roads within areas close to the APA Belém, triggering the expansion of urban occupation. They comprised asphalting, drainage of rain water and public illumination, as may be seen on Arara street and Ceará street (within APA) and on Pantanal street, Buiussuquara street and Cruzeiro street (surrounding the APA).

3.2. Assessment of decrease in riparian vegetation

Geographic Information System and Remote Sensing verified that, in spite of attempts for control by the authorities, human activities including the building of housing estates and public works modified the environment, especially deforestation within and around the APA

Belém. Its total area had reached 14.83 km² in 1988 (Cardoso, et al., 2009), but legally decreased to 13.93 km² through state legislation n. 1552/1993.

The above decree *de facto* legalized human activities within the excluded section which had been classified as irregular. Further, legal actions were insufficient to remove spontaneous land occupations within the APA´s 1.393.088 hectares. Consequently, the administration failed to abide to its obligation to protect and preserve the area around the water sources, which involved the removal of the premises of a social club, housing estates and company premises installed within the ARA area.

According to Bordalo (2006), the forest area of APA Belém was also impacted by agriculture and pastureland undertaken within the agro-forest-pasture experimental installations of the Brazilian Company for Agriculture and Stockbreeding Research (Embrapa Amazônia Oriental) and of the Rural Federal University of the Amazon (UFRA). Later, state decree 1330/2008 insisted on the APA´s total area of 1,393.088 hectares and determined that the Belem Environmental Park would be renamed Utinga State Park (PEUt), as an Integrated Protection Unit.

The 2013 PEUt´s management plan revealed that the removal of irregular housing estates and reforestation between 1998 and 2008 reduced the area impacted by human activities and increased total forestation land in APA (Pará, 2013). However, an increase in human activities within the PEUt occurred between 2008 and 2018 due to control decrease and to publics works involving the extension of the Avenida João Paulo II.

Menezes (2013) analyzed PEUt and underscored that the neighboring urban areas are mainly clustered within the boundaries of the important avenues Almirante Barroso, João Paulo II and BR-316. The author insists that, prior to the establishment of the Park, housing estates were within the northern section, due to land invasion for urban housing nuclei, deforestation and direct sewage discharge into the Água Preta and Bolonha water sources. Table 1 has been prepared to observe the oscillating situation at the environs of the water sources, featuring the percentage variations of the tree area with regard to total area between 1988 and 2018.

Table 1. Evolution of human activities by QGIS.

Classes	1988	1998	2008	2018
	km²	km²	km²	km²
Total area	14.83	14.83	13.93	13.93
Area with human activities	2.29	1.57	1.41	1.91
Total tree area	9.48	10.29	10.45	9.95
% tree area / total area	63.92	69.39	75.02	71.43

Source: Authors.

One may perceive a 1.8% increase in forestation area for the protection of water sources between 1998 and 2008, as a constrast to the following period (2008 -2018) with a 2.03% decrease, with the tree area reduced to 9.95 km². Studies by Bahia et al. (2011) and Menezes et al. (2013) demonstrate that the suppression of vegetation between 2008 and 2018 was due to the disordered growth of spontaneous housing estates close to PEUt during the last decades.

Secondary vegetation area decreased by approximately 2.56% during the 1988-2018 period, with activities modifying these conditions. Rocha et al. (2012) state that secondary vegetation in the PEUt area and its neighborhood is within the recovery process with an attempt to fill the vegetal space by trees and continuous canopy.

However, the area featuring high human activity is on the increase and impacts the area with vegetation, with serious risks to the PEUt water sources. According to Salles, et al. (2013), the eradication of primary vegetation, deficiency in environmental sanitation and human activities in the neighborhood may trigger erosion processes even faster still. The above authors have insisted that environmental degradation areas coincide with those in which social degradation is rife, with greater risks or more serious damages.

The engineering works and the circulation of people may account for the removal of vegetation from the PERt´s total tree sector, as Table 2 demonstrates

Table 2. Vegetation area by QGIS.

Classes	1988	1998	2008	2018
	km²	km²	km²	km²
Total tree area	9.48	10.29	10.45	9.95
Primary vegetation	8.91	10.02	9.80	9.50
Secondary vegetation	0.57	0.27	0.65	0.45

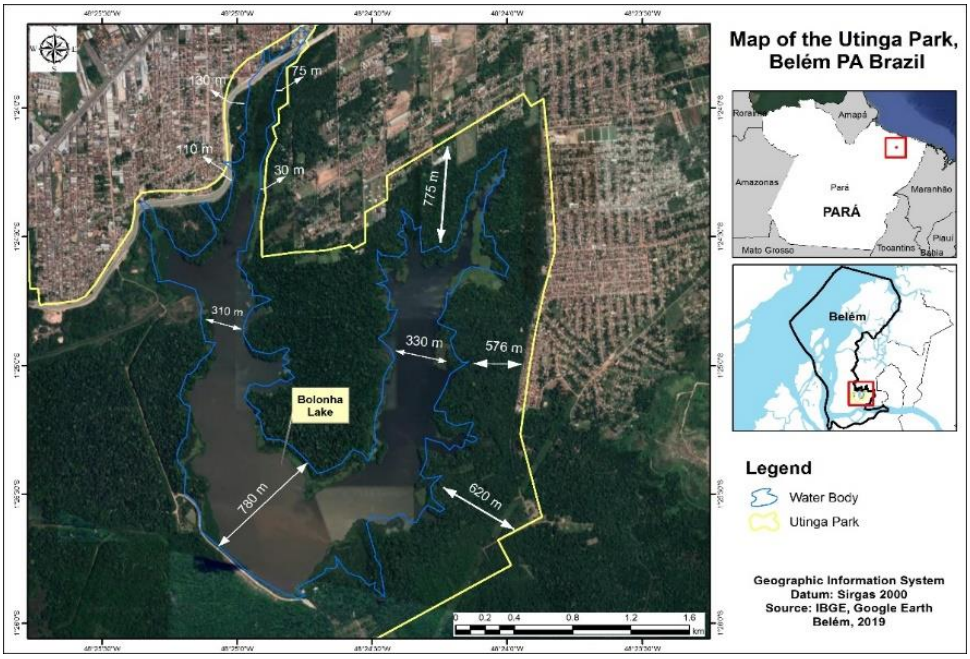
Sources: the authors.

The maintenance of primary and secondary vegetation preserves the flora and fauna still extant in PEUt and provides climate comfort, activities in environmental education and leisure spaces, such as forest tracks, cross country walks, that affect directly the population´s life quality (Melo, 2009).

Since environmental parks in urban areas stimulate activities in environmental education in the people (Neto, et al., 2014), knowledge on their true conditions is crucial for decisions by public administrators and for awareness of society on the importance of preserving the APA under analysis, with its 13.93 km².

The boundaries of the APA´s riparian vegetation were evaluated. ArcGis identified a variation between 30 m and 1500 m from urban expansion sites till the lake´s banks. Denser vegetation area (riparian vegetation up to 1.5 km) in the southern, southeastern and southwestern regions still provides protection close to the water sources. However, shorter distances (up to 30m) verified in the north, east and west of the lakes already reveal the enormous difficulty to preserve these water environments. According to the Brazilian Forest Code, the minimum distance between the preservation areas in the environs of the water bodies should be 200 m from each margin. Such distance does not occur in most of lake Bolonha. with shorter distances at several sites, as Figure 3 demonstrates.

Figure 3. Distance between lake and its respective margins.



Source: the authors, 2019.

It should be underscored that the removal of vegetal covering and urban occupation contribute towards an increase in surface discharge in the direction of lake Bolonha and other water bodies within the Murutucum hydrographic basin.

Progressive deforestation of the Bolonha water resource area reduces the preservation of biodiversity since decrease in riparian vegetation hinders any protection against surface erosion and increases silting from the margins and water sources of lake Bolonha. Further, human activities impair the self-cleaning of the water body in the medium and long term, with an increase in pollution and contamination risk due to poor sewerage collection and treatment in area occupied by housing estates and by spontaneous buildings near the lake´s water sources.

The situation has been commented by Bahia, *et al.* (2011), or rather, the conservation of rich biodiversity in the Utinga forest is crucial for the capacity and maintenance of lakes Bolonha and Água Preta, since great liquid and solid material discharge is launched *in natura* from homes and industries into the water body, causing great eutrophication problems.

Moreover, the sanitary sewage system near the APA goes contrary to state legislation 7731, published in 2013, disposing on State Policy in Basic Sanitation and Belem´s Municipal Organic Law, Chapter VI on the Environment, articles 157 – 167. In fact, it fails to attend to Art. 38, Item VI, by which the municipality commits itself to "Protect the environment and combat pollution of all types". It is the duty of the administration to avoid disordered urbanization, establish a sewerage system in the area, recover riparian vegetation and promote a monitoring program for lake Bolonha´s APA, which, together with lake Água Preta, is used as a surface water source of the water supply system for nearly one million people in the municipalities of Belém and Ananindeua.

4. Conclusion

Several studies have demonstrated the relevance of lake Bolonha for the water supply system of the municipalities of Belém and Ananindeua, since it accumulates crude water from the river Guamá, stored in lake Água Preta. The latter is the water source where water is collected and pumped up to the Bolonha Pumping Station of the water supply system of the central region of Belém and Ananindeua. Consequently, pollution and contamination of this water environment should be avoided.

Progressive expansion of the region has increased disordered occupation and decreased the vegetal cover around the lake. Quantity and quality aspects of stored water have been jeopardized and requirements and costs in water treatment have increased.

Significant urban growth is concomitant with reduced riparian vegetation on the northern section of the lake which does not merely go beyond the established limits of current legislation, but facilitates the rapid surface discharge of pollutants and contaminating material produced nearby.

It should be emphasized that even with the implantation of big public works, such as the further extension of the Avenida João Paulo II, the authorities have not implanted a collecting and treatment system for the adequate management of sanitary sewerage in the areas close to lake Bolonha. Consequently, besides the environmental recuperation of the APA area, it is highly relevant to introduce methods to lessen or eliminate pollution risks and water contamination of crude water from the Lake Bolonha. The authorities should develop activities to avoid further and irregular housing occupations, implant a sewerage system and recover riparian vegetation in the vicinity. These activities are crucial for the protection of lake Bolonha and its supply water system to approximately one million people of Belém and Ananindeua.

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