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Socio-environmental and microbiological assessment of the river Piancó, Pombal, Brazil

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ABSTRACT. The River Piancó in the municipality of Pombal on the western stretch of the state of Paraíba, Brazil, receives contaminated effluents. Current assay evaluates the microbiological quality of the river water and analyzes the social and environmental aspects of the riverine community with regard to the water and its use of the river. The water´s microbiological quality was verified at four sites on the river in five two-monthly collections throughout the year (totaling 20 samples) for the following analyses: Most Probably Number (MPN), Total (TC) and Fecal Coliform (FC) and identification of *Escherichia coli*. The social and environmental aspects were assessed by a 15-question questionnaire given to thirty homes. Results report Fecal Coliforms (> 240 to > 1,100 MPN 100 mL^{-1}), Total (> 93 to > 1,100 MPN 100 mL^{-1}) and high concentrations of *E. coli* (> 898 to > 1,100 UFC 100 mL^{-1}) in all the sampling sites. The river is frequented by the riverine people for home consumption, recreation and fishing. Conditions of the River Piancó, especially in the stretch that margins the town of Pombal, are highly critical and exceed the limits of current Brazilian legislation with regard to drinking and swimming conditions.

Keywords: *water resources, coliforms, contamination, effluents, perception environmental.*

Avaliação socioambiental e microbiológica do rio Piancó, Pombal-Paraíba

RESUMO. O Rio Piancó, na sua porção oeste do Estado da Paraíba, no município de Pombal, recebe efluentes que têm causado a sua contaminação. Este trabalho objetivou avaliar a qualidade microbiológica deste rio e analisar aspectos socioambientais da comunidade ribeirinha sobre a água e o uso do rio. A qualidade microbiológica foi verificada em quatro pontos do rio, em cinco coletas bimestrais ao longo do ano (20 amostras no total), para análises do Número Mais Provável (NMP), Coliformes Totais (CT) e Fecais (CF) e identificação da *Escherichia coli*. A avaliação socioambiental foi por meio da aplicação de um questionário socioambiental constituído por 15 perguntas, aplicados a uma população de 30 residências. Os resultados reportaram a presença de Coliformes Fecal (> 240 a > 1.100 NMP 100 mL^{-1}), Total (> 93 a > 1.100 NMP 100 mL^{-1}) e altas concentrações de *E. coli* (> 898 a > 1.100 UFC 100 mL^{-1}) em todos os pontos amostrais. O rio é utilizado pelos moradores ribeirinhos, principalmente, para o consumo doméstico, a recreação primária e a pesca. A atual situação do Rio Piancó, na porção em que margeia a cidade de Pombal é crítica, ultrapassando todos os limites da legislação brasileira vigente quanto à potabilidade e balneabilidade da água do rio.

Palavras-chave: recursos hídricos, coliformes, contaminação, efluentes, percepção ambiental.

Introduction

Scarcity of water is one of the greatest issues that 21st century populations have to cope with. Population growth and its imbalance have caused an increase in the disposal of home and industrial wastes, with great impact on the environment, dissemination of diseases, increase in temperature and pollution, with serious changes in ecosystems (Costa, Marques, Delezuk, & Folkuenig, 2006).

The continuous urbanization processes have caused serious deteriorations in natural resources, especially water resources which are highly susceptible to contamination. Although water resources are very important for various human activities such as drinking, irrigation and aquaculture (Antony & Renuga, 2012), some have become useless for human consumption (Bregunce, Jordan, Dziedzic, Maranho, & Cubas, 2011).

Water degradation has several causes, mainly an increase in the use of drinkable water, the removal of riparian vegetation, disposal of wastes in rivers and the inefficiency of effluent treatment systems (Ide et al., 2013). Consequently, monitoring water quality is mandatory to verify its quality for human consumption and other activities since the disposal of untreated domestic wastes contaminated water by fecal matter makes it a vector of pathogenic diseases (Pinheiro et al., 2014).

The inefficiency of proper water treatment and regular monitoring may cause several problems to the populations concerned, such as dysentery, cholera, ancilostomiasis and ascariasis (Santos & Mohr, 2013). Moreover, the attention required to all urban and rural populations is more complex in arid and semiarid regions where conditions are compounded by inadequate, frequently non-existent, supply systems, and lack of care in the treatment of water resources (Guedes, Ribeiro, & Vieira, 2014).

Although the stretch of the River Piancó that margins the town of Pombal, Paraíba, Brazil is the source of water for human consumption in the region, it receives non-treated domestic wastes and other pollutants from different pollution sources. In fact, it is used by livestock for drinking, in the irrigation of crops of several communities living on the river's margins, in recreations and fishing. Current assay evaluates the microbiological quality of the River Piancó in the state of Paraíba, Brazil, and assesses the social and environmental aspects of the riverine communities with regard to the river and the use that populations make of it.

Material and methods

Study area

Current analysis was performed in the hydrographic basin of the River Piancó (Figure 1), or rather, in the stretch which margins the urban area of the municipality of Pombal (888.8 km²), with approximately 32,712 inhabitants, in the western region of the state of Paraíba, Brazil, within the geo-environmental unit of the Hinterland Depression in a typical semi-arid landscape (Instituto Brasileiro de Geografia e Estatística [IBGE], 2015).

The hydrographic basin of the River Piancó lies within the states of Rio Grande do Norte and Paraíba, with a total draining area of 43,681.50 km², with 26,183.00 km² in the state of Paraíba (Ferreira, Queiroz, Sousa, Garrido, & Costa, 2014).

Sampling and collection

Samples were collected at four sites (P1 to P4) on the River Piancó in its stretch that margins the urban area of the town of Pombal (Figure 1). There were 5 collections at two-month intervals as from March 2014, throughout the whole year (*Conselho Nacional de Meio Ambiente* [CONAMA], 2005). One microbiological sample and a bio-monthly sample, totaling 20 samples, were collected for each sampling site.

Samples were collected some 3 m from the margin at a 30cm-depth, in sterilized 500 mL-glass flasks. After collection, the flasks were conditioned in asbestos boxes and samples were conserved in ice and taken to the laboratory for microbiological analyses as soon as they arrived.

Microbiological analysis

Fecal and Total Coliform microbiological analyses were performed by the Most Probably Number (MPN) method, following Hitchins, Hartman and Todd (1992) to which was added 1.0 mL of the initial sample in 9.0 mL of Sodium Citrate for each sample in dilution 10^{-1}; the same procedure was undertaken from this dilution and dilutions 10^{-2}, 10^{-3}, 10^{-4}, 10^{-5}, 10^{-6}, 10^{-7}, 10^{-8}, 10^{-9}, were obtained; further, odd dilutions 10^{-1}, 10^{-3}, 10^{-5}, 10^{-7}, 10^{-9} were then selected.

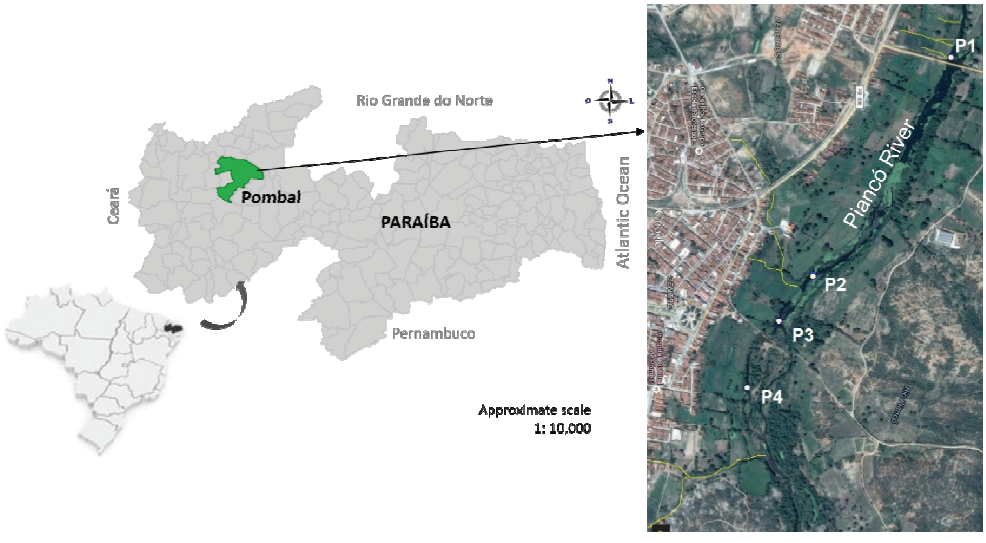

Figure 1. Study area and location of sampling points (P1 to P4) in River Piancó.
Source: The authors adapted from Google Maps.

Lauryil Sulfate Tryptose (LST) broth and the Brilliant Green Bile (BGB) broth were used in the presumption and confirmation tests respectively. Tubes with positive gas production had to be confirmed for BGB, positive for total coliforms. Each tube with Brilliant Green Blue (BGB) with gas production meant a positive result and confirmed the existence of total coliforms. Positive samples in EB (*E. coli* broth) were transposed to petri plates with Eosin Methylene Blue agar (EMB).

Counts of Colony Forming Units (CFUs) were undertaken by counting MPN, when there was a typical and characteristic growth of *E. coli*. After counting, samples of colonies were inoculated for Plate Count Agar (PCA) to confirm *E. coli* whereas biochemical tests were undertaken by Citrate, Methyl Red and Voges-Proskauer, and Tryptone tests.

Environmental assessment

Research was also based on a social-environmental assessment by applying a structured questionnaire to inhabitants that live close to the margins of the River Piancó. Sampled population was estimated, following Rocha (1997) and thirty homes were interviewed where one member answered the questionnaire. All items were related to consumption and to the social and environmental attitudes of the inhabitants with regard to the use of water, especially the water of the River Piancó (Table 1).

The questionnaire contained 15 questions of which 10 were structured questions following the Likert scale, with five response levels (Completely disagree: level 1 to Totally Agree, level 5). Besides, there were several classifications (gender, age, schooling) and demographic (how many people in the home; how long have you lived in the district) variables.

Table 1. Statements on the Likert Scale and discursive questions applied to the interviewees.

Statement on Likert
I drink only bottled water.
I am concerned with the river water quality.
I am also responsible for the river´s pollution.
I try to make people concern on the preservation of the river.
The river is an important income resource for me.
I know the consequences of river pollution.
The polluted river may have negative effects on me.
I am aware of diseases vectored by water.
If the previous question was positive, which are the diseases?
I am aware of the wastes disposed of in the river.
I always eat fish from the river.
Discursive questions
How do you and your family use the river water?
Do you think the river water is good for drinking?
Do you drink tap water? If positive, say whether there is any water treatment or whether you use a water filter.
Does your home effluent (drainage) go directly to the river?

Source: Authors (2015).

Statistical analysis

Questions on the Likert scale were evaluated with regard to consistency and reliability by the Cronbach alpha test with SPSS 20.0. Cronbach alpha was equal to 0.76, or rather, the questions were satisfactory with regard to the two items above. The other collected data were analyzed by descriptive statistics with Microsoft Excel 2013.

Results and discussion

Table 2 described microbiological results for Fecal and Total Coliforms. Contamination by Total and Fecal Coliforms, identifying *E. coli*, were reported.

Table 2. Most Probable Number (MPN) of Fecal and Total Coliforms (MPN 100 mL^{-1}), of water from the River Piancó, Pombal, Paraíba, and its classification according to different legislations in Brazil.

Sample	Local	Coliforms		CONAMA nº 274★	CONAMA nº 54	CONAMA Nº 20		
		Fecal	Total			Class I	Class II	Class III
1	P1	240	240	E	No	No	Yes	Yes
	P2	240	93	E	No	No	Yes	Yes
	P3	240	240	E	No	No	Yes	Yes
	P4	240	460	E	No	No	Yes	Yes
2	P1	240	240	E	No	No	Yes	Yes
	P2	240	240	E	No	No	Yes	Yes
	P3	240	240	E	No	No	Yes	Yes
	P4	240	240	E	No	No	Yes	Yes
3	P1	23	240	E	No	Yes	Yes	Yes
	P2	240	> 1,100	E	No	No	Yes	Yes
	P3	240	> 1,100	E	No	No	Yes	Yes
	P4	240	240	E	No	No	Yes	Yes
4	P1	> 1,100	> 1,100	I	No	No	No	Yes
	P2	240	240	E	No	No	Yes	Yes
	P3	240	240	E	No	No	Yes	Yes
	P4	240	240	E	No	No	Yes	Yes
5	P1	240	240	E	No	No	Yes	Yes
	P2	240	240	E	No	No	Yes	Yes
	P3	240	240	E	No	No	Yes	Yes
	P4	240	240	E	No	No	Yes	Yes

E: Excellent; I: Improper. No: disagree or inadequate; Yes: agree or adequate. ★For fecal coliforms only.

Source: Authors.

Highest contamination rates occurred in the collection of the third two-month peRiod, with rates higher than 1,100 MPN. The water of the River Piancó at all collection sites (P1, P2, P3, P4) under analysis were inadequate for human consumption according to CONAMA Resolution 54 (CONAMA, 2000a) which established maximum limit of total coliforms at 2.2 MPN or absence in 100 mL.

According to CONAMA Resolution 20 (CONAMA, 1986), only two samples for total coliforms at Sites P2 and P3 and one sample P1 respectively for collections 3 and 4 could not fit in Class 1 water, for total and fecal coliforms, or rather, those for home supply, for the protection of water communities, for primary recreation and irrigation of vegetables.

However, they fit Class II waters, proper for home supply after conventional treatment, primary recreation, irrigation of vegetables and for livestock (Table 2). With regard to swimming conditions, all samples were improper for swimming according to CONAMA Resolution 274 (CONAMA, 2000b) since they fit in rates for fecal coliforms, however, they showed exceeding rates for *E. coli* (800 UFC 100 mL^{-1}) and did not fit within limits required by legislation for adequate water. This type of water does not fit within the limits required by CONAMA Resolution 54 (CONAMA, 2000a) which established rates for the quality of natural water, with absence of *E. coli* and fecal and total coliforms in 100 mL. All samples were improper.

According to the Health Ministry ordinance MS n. 518/2004 (Secretaria de Vigilância em Saúde, 2004) on the drinkability of water for human consumption, all samples with 100 mL of *E. coli* and total coliforms were inappropriate.

In the case of *E. coli* counts, great variability was reported between the sites or collection peRiods, namely, between >898 (P3) and > 2,095 UFC 100 mL^{-1} (P1), with no site having higher rates among the others (Table 3). According to CONAMA Resolutions 274 and 54 (CONAMA, 2000b and a), all samples were improper for swimming and exceeded the limit 800 UFC/100 mL (Table 3).

Table 3. Counts of the MPN for *E. coli* of water from the River Piancó, Pombal, Paraíba.

Local	Sample				
	1	2	3	4	5
P1	> 922	> 1,615	> 1,090	> 2,095	> 1,193
P2	> 1,181	> 1,432	> 1,665	> 1,303	> 1,210
P3	> 1,090	> 898	> 1,351	> 1,056	> 1,448
P4	> 1,014	> 1,394	> 1,340	> 1,220	> 1,950

Source: Authors.

Social and environmental assessment

Interviewed people comprised 73.3% (n = 22) females and 26.7% (n = 8) males, most of whom (83.3%; n = 25) had up to incomplete basic schooling. Most of the interviewed (76.7%; n = 23) stated that river water was improper for drinking but only 10.0% (n = 3) drank bottled mineral water. However, 76.7% (n = 23) admitted they drank tap water treated by the local waterworks firm (Table 4).

The water consumed in 36.7% (n = 11) of homes under analysis was treated by an earthenware filter. Although 80.0% (n = 24) reported that water used in the homes is treated by the local waterworks firm (CAGEPA), only 36.7% (n = 11) stated that the water was good for consumption. Further, 86.7% (n = 26) was concerned with the quality of water supplied.

Although 80.0% (n = 24) declared that they are responsible for the pollution of the river, only 40.0% (n = 12) talk to neighbors on the preservation of the water from the river. Currently, 46.7% (n = 14) state that the river is a relevant source of income.

Even though the consequences of contaminated water are evident, 36.7% (n = 11) do not know the consequences that river pollution may cause. However, 60.0% (n = 18) are sure that home wastes are disposed of in the river, worsening still an already bad situation.

Table 4. Social and environmental data of the interviewed inhabitants.

Statements	I disagree completely or partially	Neither agree nor disagree	I agree completely or partly
I drink only bottled water.	66.7	6.7	26.7
I drink tap water without treatment	80.0	3.3	16.7
I drink tap water treated by CAGEPA*	0.0	3.3	96.7
The water I use is good	16.7	6.7	76.7
I trust the quality of water we drink	53.3	10.0	36.7
I am concerned with the river water quality	10.0	0.0	90.0
I am also responsible for the river's pollution	6.7	0.0	93.3
I try to make people concern on the preservation of the river	43.3	6.7	50.0
The river is an important income resource for me	33.3	0.0	66.7
I know the consequences of river pollution	36.7	0.0	63.4
The polluted river may have negative effects on me	3.3	3.3	93.3
I am aware of diseases vectored by water	36.7	3.3	60.0
I am aware of the wastes disposed of in the river	50.0	3.3	46.6
I always eat fish from the river	43.4	10.0	46.7

*Local waterworks firm.

Source: Authors.

Further, 93.3% (n = 28) are aware that a polluted river has negative effects on health since there is a high dissemination of diseases. Only a small section, 33.3% (n = 10), acknowledges that diseases may be transmitted by using inadequate water. Moreover, 69.2% (n = 9) of the people who were aware of diseases transmitted by improper drinking water mention diarrhea as the most common (Figure 2a).

On the other hand, 50.0% (n = 15) of the interviewed failed to mention the wastes deposited in the river. However, 36.7% (n = 11) eat fish from the river without any knowledge or information that consumption may be risky for health.

Most interviewed people (67.4%, n = 60) use tap water for domestic activities and for consumption (Figure 2b). However, 60.0% (n = 18) do not have a water filter or any other type of water treatment. Further, 20.0% (n = 18) use the river for recreation, especially swimming; 6.7% (n = 6) fishing; 4.5% (n = 4) for agriculture; 1.1% (n = 1) for washing clothes.

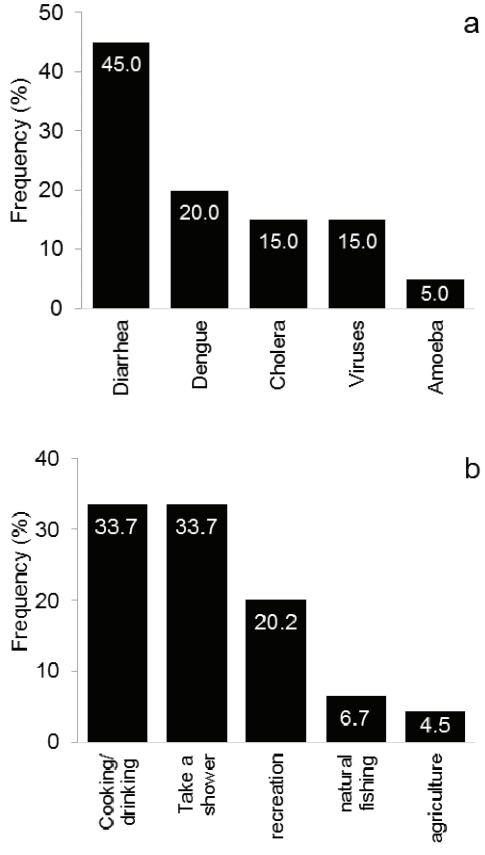

Figure 2. Frequency (%) of the main diseases vectored by water and mentioned in the interview (a) and the main uses of water (b) of the River Piancó by riverine inhabitants.
Source: Authors.

The microbiological parameters showed that the water of the River Piancó within the urban parameter of the municipality of Pombal is not fit for drinking and improper for human consumption. According to CONAMA Resolution 20 (CONAMA, 1986), fresh water may be classified into five classes, or rather, special class and classes 1, 2, 3 and 4, according to quality and end.

The water of the River Piancó exceeded the limits of Class 1 water, which should not be above 200 fecal coliforms per 100 mL, or rather, water for home supply, protection of water communities, primary recreation, irrigation of vegetables and aquaculture. Following CONAMA Resolution 54 (Conama, 2000a), all samples collected throughout the period at the four sites provided unsatisfactory fecal coliform rates. In fact, fecal coliforms may not exceed 100 mL.

Similar results were reported by Vieira et al. (2013) at the collection sites of the River Bonzinho in the state of Roraima, Brazil. These authors reported fecal coliforms rates between 400 and 700 NMP 100 mL^{-1}, which failed to comply with those given by the Brazilian Health Ministry, or rather, more than 100 mL of fecal contamination. In the case of total coliforms, water samples were inadequate by CONAMA Resolution 54 (CONAMA, 2000a) allowed in only one sample but not exceeding the limit < 1.1 MPN 100 mL^{-1}, or its absence.

Studies conducted by Guedes, Simão, Dias and Braga (2015) on the people´s perception and on public exposure to the water of the River Doce in Tumiritinga, Minas Gerais State Brazil, showed that in 352 homes visited, there were 173 cases of waterborne diseases, especially skin diseases (126 cases) and schistosomiasis (11 cases), typhoid fever and other diseases not specified by respondents.

Studies by Scapin, Rossi and Oro (2012), 64.1% of 298 (n = 191) of samples evaluated on several farms in the western region of the state of Santa Catarina, Brazil, were improper for human consumption due to total coliform rates.

Studies by Luna et al. (2011) revealed that chances of transmission of diarrheal diseases increased in populations without access to water of good quality. It is actually one of the main problems that affect life quality, especially for the elderly and children.

Research on the microbiological quality of public supply water in Pelotas, state of Rio Grande do Sul, Brazil, showed positive results in all samples, or rather, between 170 and 7,900 MPN 100 mL^{-1} for total coliforms (Peil, Kuss, & Gonçalves, 2015). In fact, rivers that run through urban perimeters

receive a greater contamination load due to waste and drainage disposal, compromising quality by coliform contamination and other pollutants (Silva, Migliorini, Silva, Lima, & Moura, 2014).

According to Faveri (2013), intake of water linked to the city sewage treatment (and thus unfit for consumption) is one of the main causes of death in less than 1-year-old babies, featuring one of the most common diarrheal diseases causing dehydration of newborn.

Since all samples from the River Piancó were positive for *E. coli*, with rates up to 2,095 UFC 100 mL^{-1}, its water was classified as improper. All samples exceeded the limit 800 UFC 100 mL^{-1} and failed to comply with criteria of CONAMA Resolution 274 (CONAMA, 2000b) for water fit for drinking.

Similar results were also retrieved from lake Igapó III in Londrina, Paraná State, Brazil, where 3 samples (25.0%) had rates higher than 800 UFC/100 mL, and classified the lake as improper for primary recreation, following CONAMA Resolution 274/2000 (Schuroff, Lima, Burgos, Lopes, & Pelayo, 2014).

In a study on 27 shallow wells and respective consumption sites, Scalize et al. (2014) showed that *E. coli* occurred in all collected samples. CONAMA Resolution 54 (CONAMA, 2000a) states that all natural water should not harm the consumer´s health due to lack of pathogenic microorganisms, such as *E. coli*. All rates were above the accepted standard for human consumption. The presence of *E. coli* in natural water for human consumption may cause simple gastroenteritis (diarrhea) and more seRious diseases (Silva, Oliveira, Simões, & Ferreira, 2013).

The social and environmental assessment measured the population's knowledge on issues related to the river water. The inhabitants of the district that margins the river perceived the impact on the water environment throughout the years. Most of the population was concerned on the water quality but unaware of the consequences caused by pollution and by the diseases transmitted by contaminated water.

Only 11 homes visited use a water filter for the previous treatment of water received in the home; though it had been already treated by the CAGEPA, most did not state that the water quality was good. In similar research work, Visser, Giatti, Carvalho and Guerreiro (2011) evaluated water treatment for drinking and cooking and verified that 49.8% (n = 146) of the 191 homes visited did not undertake any treatment and the filter is only used by 7.1% (n = 21) of the homes.

Studies by Silva, Strapação, Yamanaka, Ballão and Monteiro (2013), showed that water consumed in 36.3% of the homes visited was not previously treated pRior to consumption; just 14.6% employed some type of treatment.

Scapin et al. (2012) also verified that most of the population visited failed to use water filters or any other type of treatment, such as boiling the water prior to use.

In fact, 80.0% (n = 24) of the visited homes admit their responsibility in the pollution of the river. Similar reports are dealt with in studies on collection sites by Souza, Moraes, Sonoda and Santos (2014), on bad uses, such as washings and the disposal of food, near the River banks.

Water is actually a determining factor for the social and economic development of a town or city. Its water quality and quantity are basic issues that may determine the growth of populations. Each item is not only highly relevant but also a revenue involving the commercialization of fish, vegetables, fruits for public supply and for industries, sports and leisure (Oliveira et al., 2012).

Good conservation practices, such as a decrease in the occupation of river margin areas, are required so that water quality may be preserved. Correct ecological thinking and proper sanitation ideas for each region are needed since the preservation and conservation of this finite natural resource is urgent and mandatory (Silva et al., 2014).

Conclusion

All sampling sites selected on the River Piancó fail to comply with Brazilian legislation on microbiological quality and are improper for primary use. All analyzed sites are contaminated by total and fecal coliforms, covering high pathogenic microorganisms, mainly *E. coli*.

The social and environmental assessment of riverine populations show that they perceive the environmental impacts on the river. They are not satisfied with the treated water they receive in their homes. However, the populations fails to take any action for the river's preservation.

Although water is considered inadequate, many inhabitants use it for their needs, for livestock, fishing, washing of clothes and recreation. In fact, they are exposed to contaminated water without being warned on the consequences of drinking water with high concentrations of pathogenic microorganisms. Among its several uses by the population, the water from the river is mainly used for cooking, drinking (duly treated) and primary recreation. Recovery and monitoring of the water's

microbiological quality should be drastic whilst the community requires great care for its sensitiveness in the preservation of the water environment.

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