Water Quality of the “Água Limpa” stream in the State Park Biribiri, Minas Gerais State, Brazil

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Aim: This study aims to evaluate the quality of water based on physical-chemical and microbiological conditions of the stream called Água Limpa, located in the Biribiri State Park, Diamantina-MG.

Method: On a stream of about 4 km, were conducted in each of the four points, six collections in the period from March to September/2009. The month of March was representative of the rainy season, with precipitation of 15 mm, and the month of August was representative of the dry season, with precipitation of 170 mm. The characterization in the different sampling points was conducted in accordance with the limits established by CONAMA Resolution 357 of March 17, 2005. The differences between the estimates of mean physico-chemical and microbiological obtained between points and sampling dates were tested statistically by the F test estimated from the analysis of variance (ANOVA). When the ANOVA showed significant differences at 5% Tukey test was applied.

Results: It was noted that points 1, 2 and 3 are presented as similar to physical-chemical conditions, however, as fecal coliforms, only the point 1 framed within the limits allowed. Higher concentrations of total phosphorus, nitrite, nitrate and iron occurred at point 4. At this point, values of turbidity and thermo tolerant fecal coliforms were also higher and rates of dissolved oxygen was lower during all collection time and analysis of waters.

Conclusion: Point 4 have contributed to the quality decline of stream water and exacerbate eutrophication processes, species extinction and propagation of aquatic diseases. Physico-chemical and microbiological monitoring is much important to determine water classes and their applicabilities.

INTRODUCTION

A group of factors like using natural resources without distinction, high scales of deforestation, sewage dropped in natura and inadequate use of soil added to fertilizers and pesticides are causing severe environmental problems to drainage basins headwaters [22]. Frequently the results are changes on quality and quantity of their water (Andrade Pinto et al., 2004), that may be irreversible for years. Water is a renewable resource, but it is needed to optimize its use, being it an excellent factor to guarantee hydrological cycles equilibrium. Human population increase justifies this search because it contributes with increasing quantity of industrial and domestic pollutant thrown at water bodies.

Controversially to valid laws in Brazil, monitoring continental water is being neglected, considering many bodies of freshwater are under horrible conditions to human intake, animal drinking water, aquatic communities protection, irrigation and others. Only the principal rivers from hydrographic basins are some way physico-chemical and microbiologically monitored, being streams, which are important because their utilization, not considered as priorities. Initiatives to monitor water courses are kept by academic groups [23].

Water quality parameters may indicate environmental degradation, one of the factors that reinforce freshwater bodies monitoring [35]. This monitoring provides subsidies to create management plans in order to mitigate pollution effects, as well as to protect ciliary forests and riparian vegetation which protect water courses of external stress.

Besides its several utilizations, being human intake the prior one, water also disseminates agents associated with some illnesses. Then, it is necessary to create set of laws to determine limits of water contamination. In this case, physico-chemical and microbiological characteristics should follow the ones proposed by World Health
Organization (WHO) [31]. In Brazil, the responsible to classify freshwater bodies is Conselho Nacional do Meio Ambiente - CONAMA. Its last resolution relating hydric resources is number 357, from March 17th of 2005, being freshwater under special classes, 1, 2, 3 and 4. The ones in class 4 may not be used for human intake, or for any other living being because of its bad quality. In the case of treatment, onerous expenses cause the impracticability to reuse it. Other classes are different, mainly because of treatment applied to disinfect, before distributing to population.

Hydric monitoring is important, that is why this study aimed to evaluate physico-chemical and microbiological conditions of Agua Limpa stream in Biribiri state park /MG. Also classify the stream water according to CONOMA Resolution 357/2005, indicating their application and reach hypothesis to possible reasons of variation among estimates observed.

MATERIAL AND METHODS

Characterization of study area:

The basin of Jequitinhonha river is at the bounds Minas Gerais/Bahia between parallels 15º 30’ and 18º 30’ S and the meridians 38º 50’ and 43º 50’ W. it has a drainage area of 65.850 Km², 60 cities, urban population of de 429.861 people and rural area of 344.253 people [14].

The area analyzed is a stream known as Agua Limpa, in Biribiri State Park (BSP), at Serra do Espinhaço, Alto Jequitinhonha. Their boundaries are between Agua Limpa source and its junction with João de Barro stream.

Biribiri State Park was created by State enactment # 39.909, of September 22nd of 1998 and it protects 16.998,66 hectares in Diamantina/MG [15]. To create this conservation unit was necessary because it is a region with remaining vegetation of Cerrado, a great number of water sources and occurrence of endemisms with species seriously threatened with extinction [34].

The climate in the region is tropical altitude (Cwb) by Koppen’s classification. The annual mean precipitation varies from 1.250 to 1.550mm and annual mean temperature is around 18º, 19ºC. The relative air humidity is frequently high, with annual means of 75.6% [24]. Dry and rainy seasons are well defined, being the first one from June to August and the second from November to march, approximately. The main basin that maintains water courses is Jequitinhonha River, which indicates the park boundary by its confluence with Pinheiros River [15].

The Serra do Espinhaço geography is North-South directed and it has more than 1.200 km from North of Belo Horizonte to North of Bahia. Its characteristics include high plateau interspersed by huge rock formation, and it is an important water divisor in Minas Gerais, because it separates São Francisco River basins at west from basins of Doce, Mucuri, Jequitinhonha rivers and Pardo Rivers at east. The tectonic movements which determined relieve provided, together drain system, waterfall formation and riverbeds inside failures and fractures [8].

Sampling:

Water samples were collected from Agua Limpa stream in four different points which extent for four kilometers according to coordinates in Universal Transverse Mercator (UTM), – Zone 23 K: Point 1: 645137 / 7987876; Point 2: 646261 / 7985574; Point 3: 646485 / 7985554 and Point 4: 648140 / 7985305. The points of collection were established basing on characterization of the stretch studied where the source, represented by # 1, has no direct anthropic influences. Points 2 and 3 are well preserved relating to riparian vegetation and their water are basically used to entertain with a primary contact of visitants. In spite of being set in conservation unit, point 4 receives high quantity of leachate provided by a landfill there was near the stream. At this point it is added sewage dropped because of inadequate occupation of population around the affluents in the park area.

In each point there were six collections from March to September of 2009. March represented rainy period, with precipitation of 15mm, and August represented dry period, with precipitation of 170mm.

Water samples were collected in vials, previously sterilized and covered with a top wrapped in a protector paper. They were kept in a polystyrene Box with ice for approximately two hours to keep low temperature until arriving at the lab [9]. Water temperature was taken at collection with a mercury thermometer. Other analysis were accomplished in a lab at Universidade Federal dos Vales do Jequitinhonha e Mucuri.

Variables analyzed, analytical methodologies and references:

PHmeter AT-300 and Turbidimetry Microprocessor Plus were used to measure pH and turbidity, respectively. Nitrite, Nitrate, Iron, Phosphorous and Ammonia were analyzed by photocolorimeter At-100PB according to methodologies presented in table 1. Dissolved oxygen was determined by a Compact Kit with redox titration. Quantitative analysis of fecal coliforms was accomplished by using Microbiological Kit E.Coli, Coliforms and Salmonellas. All these kits and equipments were acquired through Alfakit enterprise and its methodologies are adapted to American Public Health Association [2].
**Classification of Agua Limpa water:**

At the different sampling points the characterization was according to CONAMA 357 Resolution of March 17th, 2005 (ATTACHMENT 1), which establishes the classification of fresh, brackish and saline waters and their preponderant use.

**Statistical Analysis:**

Estimates differences of means of physico-chemical and microbiological variables and zoobenthic organisms were obtained between points and collection dates by F test beginning from variance analysis (ANOVA). It was used a model for cross-classifying \( y_{ij} = M + d_i + p_j + e_{ij} \), being \( M \) = general mean; \( d_i \) = date effect; \( p_j \) = point effect; \( e_{ij} \) = residue effect. When ANOVA showed significant differences at 5%, Tukey test was applied. Correlation analysis measured the degree of relationship among variables evaluated at 10% of significance by bilateral t test. All calculation were done in Excel program- Office 2007.

**Table 1:** Variables, analytical methodologies and references.

<table>
<thead>
<tr>
<th>METHODOLOGIES</th>
<th>VARIABLES</th>
<th>REFERENCE</th>
</tr>
</thead>
<tbody>
<tr>
<td>Colorimetric Method (thioglycolic acid)</td>
<td>Iron (mg L(^{-1}))</td>
<td>FRIES, 1977</td>
</tr>
<tr>
<td>Colorimetric Method (Vanadomolibdo)</td>
<td>Total Phosphorus (mg L(^{-1}))</td>
<td>DAVINO, 1976</td>
</tr>
<tr>
<td>Colorimetric Method (Indotest)</td>
<td>Ammonia (mg L(^{-1}))</td>
<td>APHA, 2005</td>
</tr>
<tr>
<td>Colorimetric Method (alphanaphthylamine)</td>
<td>Nitrite (mg L(^{-1}))</td>
<td>FRIES J., 1971</td>
</tr>
<tr>
<td>Colorimetric Method (Brucine)</td>
<td>Nitrate (mg L(^{-1}))</td>
<td>FRIES, 1977</td>
</tr>
<tr>
<td>Titration by the method of Winkler</td>
<td>Oxygen Dissolved (mg L(^{-1}))</td>
<td></td>
</tr>
<tr>
<td>nephelometric Method</td>
<td>Turbidity (NTU(^{\ast}))</td>
<td></td>
</tr>
<tr>
<td>Potentiometric</td>
<td>pH</td>
<td></td>
</tr>
<tr>
<td>thermometry</td>
<td>Temperature (°C)</td>
<td></td>
</tr>
<tr>
<td>Microbiology Kit</td>
<td>Fecal Coliforms (UFC(^{\ast}/)100mL)</td>
<td>ALFAKIT, 2007</td>
</tr>
</tbody>
</table>

* NTU = Nephelometric Turbidity Unit, CFU = Fecal coliforms in colony forming units, pH = hydrogen potential

**Results:**

Higher concentrations of total phosphorous, nitrite, nitrate and iron occurred at point 4 (Figures 1A, 1B, 1C and 1E, respectively). At this point, values of turbidity and thermo tolerant fecal coliforms were also higher (Figure 2A and 2B, respectively) and rates of dissolved oxygen was lower (Figure 1F) during all collection time and analysis of waters. Higher pH appeared frequently at points 1 and 4 (Figure 2D). High ammonia concentration occurred in the collection done in March (Figure 1D). Temperature was constant in all collection points in March and lower in June (Figure 2C).

There was no significant difference to total phosphorous means among collection points. Point 1 showed smaller concentration means to total phosphorous, nitrite, iron, temperature and fecal coliforms being that it did not happen to nitrate, ammonia, dissolved oxygen, pH and turbidity. To nitrate, ammonia, turbidity and fecal coliforms point 1 was similar to points 2 and 3, but different from point 4. Points 2 and 3 showed concentration values that may be considered intermediate among the ones found at points 1 and 4. Results to nitrate were similar between points 1 and 2 and 3 and 4. Point 4 had higher means observed to most of variables, except dissolved oxygen and temperature. Its values of nitrite, iron, pH and temperature were similar to point 3, however, there were significant difference to nitrate, ammonia, turbidity and fecal coliform. The four collection points were similar to values of total phosphorous.

Considering collection dates, higher mean values of ammonia, dissolved oxygen, turbidity and temperature occurred in March 31st. Collections accomplished in August 03rd, May 6th, April 25th, September 14th, June 26th and August 3rd had higher quantities of total phosphorous, nitrite, nitrate, iron, pH and fecal coliforms, respectively. Smaller means were nitrite, pH and fecal coliforms in March 31st, turbidity in April 25th, total phosphorous and nitrate in May 6th, iron and temperature in June 22nd and ammonia and dissolved oxygen in August 3rd. There was no significant difference among collection dates to dissolved oxygen, pH, turbidity and fecal coliforms. March 3rd and May 6th were different relating to ammonia and nitrate. Mean values of temperature were the ones that distinguish the collection dates, and June 22nd is the one that shows the most different value. (Table 3).

The most significant correlations among variables were: nitrate with nitrite, iron with total phosphorus and nitrate, dissolved oxygen with nitrate and iron, turbidity with nitrite, nitrate, ammonia and iron, fecal coliforms with nitrite, dissolved oxygen with turbidity, temperature with iron, pH with total phosphorous, nitrite, nitrate, dissolved oxygen and turbidity (Tables 4 and 5).
Fig. 1: Chemical values of stream water samples from the Água Limpa, State Park Biribiri, MG: Total Phosphorous (A), Nitrite (B), Nitrate (C), Ammonia (D), Iron (E) and Dissolved Oxygen (F).

Fig. 2: Physical Chemical values of stream water samples from the Água Limpa, State Park Biribiri, MG: Turbidity in Nephelometric Turbidity Unit (NTU) (A), Fecal coliforms in colony forming units (CFU) (B), Temperature degrees celsius (ºC) (C) and pH (D).
**Discussion:**

Several factors as climate, geology, shoreline vegetation, different uses and soil occupation contribute to physical, chemical and microbiological characterization of lotic aquatic environment [33]. However, altering space and time by biotic and abiotic interactions result in the actual conditions of water body [30]. Knowledge about these factors becomes pertinent because they are going to determine water qualities and its applicability.

**Total Phosphorous:**

Phosphorous shines through its importance on energy conversion process that takes place during living being metabolism. It has been considered as the main factor that limits productivity in aquatic ecosystems and it is directly associated to eutrophication process in freshwater [6]. Phytoplankton, bacteria and benthic plants assimilate phosphorous and it is remineralized by animals and heterotrophic microorganisms [32].

All total phosphorous values in all points and dates of collection are above the one allowed by CONAMA Resolution of 2005 (0.1 mg L\(^{-1}\) to waters of classes 1, 2, and 0.15 mg L\(^{-1}\) to waters class 3 (table 2)).

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**Table 2:** Estimates of mean physico-chemical and microbiological analyzes at each point of collection of the Água Limpa Stream in the period from March to September 2009.

<table>
<thead>
<tr>
<th>Point</th>
<th>P</th>
<th>Nitr(\dot{e})</th>
<th>Nitr(\dot{a})</th>
<th>Ammonia</th>
<th>Iron</th>
<th>DO(^{-})</th>
<th>pH</th>
<th>Turb</th>
<th>Temp</th>
<th>FC</th>
<th>pH</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>0,756</td>
<td>0,007</td>
<td>1,582</td>
<td>0,777</td>
<td>0,401</td>
<td>2,400</td>
<td>b</td>
<td>18,58</td>
<td>50</td>
<td>b</td>
<td>345</td>
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<tr>
<td>2</td>
<td>0,800</td>
<td>0,010</td>
<td>1,433</td>
<td>0,634</td>
<td>0,817</td>
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<td>a</td>
<td>5,377</td>
<td>a</td>
<td>b</td>
<td>345</td>
</tr>
<tr>
<td>4</td>
<td>0,919</td>
<td>0,304</td>
<td>1,342</td>
<td>1,603</td>
<td>1,510</td>
<td>6,883</td>
<td>b</td>
<td>7,008</td>
<td>a</td>
<td>b</td>
<td>345</td>
</tr>
</tbody>
</table>

1. P: Total Phosphorous; DO: Dissolved Oxygen; Turb: Turbidity; Temp: Temperature; FC: Fecal coliforms.

**Table 3:** Estimates of mean physico-chemical and microbiological analyzes on each collection date in the four points of the Agua Limpa Stream.

<table>
<thead>
<tr>
<th>Collection dates</th>
<th>P</th>
<th>Nitr(\dot{e})</th>
<th>Nitr(\dot{a})</th>
<th>Ammonia</th>
<th>Iron</th>
<th>DO(^{-})</th>
<th>pH</th>
<th>Turb</th>
<th>Temp</th>
<th>FC</th>
</tr>
</thead>
<tbody>
<tr>
<td>31/03/09</td>
<td>0,892</td>
<td>0,015</td>
<td>1,255</td>
<td>0,851</td>
<td>10,775</td>
<td>a</td>
<td>21,0</td>
<td>a</td>
<td>555</td>
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</tr>
<tr>
<td>25/04/09</td>
<td>0,690</td>
<td>0,025</td>
<td>4,898</td>
<td>0,950</td>
<td>6,470</td>
<td>a</td>
<td>20,5</td>
<td>b</td>
<td>585</td>
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</tr>
<tr>
<td>06/05/09</td>
<td>0,444</td>
<td>0,145</td>
<td>0,216</td>
<td>0,416</td>
<td>9,725</td>
<td>a</td>
<td>19,0</td>
<td>b</td>
<td>1267,5</td>
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</tr>
<tr>
<td>22/06/09</td>
<td>0,734</td>
<td>0,129</td>
<td>4,346</td>
<td>0,195</td>
<td>8,875</td>
<td>a</td>
<td>13,5</td>
<td>a</td>
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<tr>
<td>03/08/09</td>
<td>1,166</td>
<td>0,075</td>
<td>1,319</td>
<td>0,845</td>
<td>7,575</td>
<td>a</td>
<td>19,9</td>
<td>a</td>
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</tr>
<tr>
<td>14/09/09</td>
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<td>0,067</td>
<td>3,069</td>
<td>0,485</td>
<td>1,560</td>
<td>a</td>
<td>20,0</td>
<td>a</td>
<td>1305</td>
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</tr>
</tbody>
</table>

1. P: Total Phosphorous; DO: Dissolved Oxygen; Turb: Turbidity; Temp: Temperature; FC: Fecal coliforms.

---

**Table 4:** Estimated percentage of the correlations between the variables.

<table>
<thead>
<tr>
<th>P</th>
<th>Nitr(\dot{e})</th>
<th>Nitr(\dot{a})</th>
<th>Ammonia</th>
<th>Iron</th>
<th>DO</th>
<th>Turb</th>
<th>FC</th>
<th>Temp</th>
<th>pH</th>
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</thead>
<tbody>
<tr>
<td>P</td>
<td>-0,09</td>
<td>0,13</td>
<td>0,17</td>
<td>0,42</td>
<td>-0,26</td>
<td>0,26</td>
<td>-0,12</td>
<td>0,15</td>
<td>0,52</td>
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<tr>
<td>Nitr(\dot{e})</td>
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<td>0,61</td>
<td>0,77</td>
<td>-0,16</td>
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<tr>
<td>Nitr(\dot{a})</td>
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<td>0,36</td>
<td>-0,38</td>
<td>0,35</td>
<td>0,19</td>
<td>-0,17</td>
<td>0,44</td>
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<tr>
<td>Ammonia</td>
<td>0,18</td>
<td>0,28</td>
<td>0,15</td>
<td>0,30</td>
<td>-0,05</td>
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<tr>
<td>Iron</td>
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<tr>
<td>DO</td>
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<td>-0,37</td>
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<td>-0,58</td>
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<tr>
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<td></td>
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<td></td>
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<tr>
<td>pH</td>
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<td></td>
</tr>
</tbody>
</table>

The shaded cells highlight the values with 10% significance by t test.

**Table 5:** Significance level as a percentage of the correlations between the variables assessed by t test bilaterally.

<table>
<thead>
<tr>
<th>P</th>
<th>Nitr(\dot{e})</th>
<th>Nitr(\dot{a})</th>
<th>Ammonia</th>
<th>Iron</th>
<th>DO</th>
<th>Turb</th>
<th>FC</th>
<th>Temp</th>
<th>pH</th>
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<tbody>
<tr>
<td>P</td>
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<td>0,54</td>
<td>0,42</td>
<td>0,04</td>
<td>0,22</td>
<td>0,59</td>
<td>0,48</td>
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<tr>
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<td>0,00</td>
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<td>0,06</td>
<td>0,09</td>
<td>0,38</td>
<td>0,42</td>
<td>0,03</td>
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<tr>
<td>Ammonia</td>
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<td>0,18</td>
<td>0,04</td>
<td>0,48</td>
<td>0,15</td>
<td>0,88</td>
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<td></td>
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<tr>
<td>Iron</td>
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<td>0,02</td>
<td>0,18</td>
<td>0,04</td>
<td>0,28</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>DO</td>
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<td>0,08</td>
<td>0,69</td>
<td>0,003</td>
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<td></td>
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</tbody>
</table>

The shaded cells highlight the values with 10% significance by t test.
Point 1 is the source, so it is necessary to have attention to high rates of this element. Values above the allowed ones should not happen in this place because phosphorous is frequently associated to sewage and pesticides thrown on water courses [38]. This point concentrates low water volume what can provide higher phosphorous concentration. It is located in sloped relief, in a higher level and near the source is the Road BR 367. Soil recovering with asphalt causes a high concentration of rain water on drain systems, taking it to the streams [39,27]. As they have small drainage capacity, it gets a modifying situation regarding their original conditions [28]. In addition, the lack of vegetal coverage reinforces transferences of sediments and contaminants per erosion.

Polluting agents’ transferences caused high phosphorous concentrations at points 2 and 3. Water at these points is eventually used by people to wash clothes which could have increased this variable content, seeing that soap contributes to phosphorous on water.

High quantities of phosphorous, more frequent in point 4, resulted in higher concentration means. High quantity of this variable evidences antrophic impacts [23]. In this context, external interferences are worse to point 4 than to the others because of sewage and leachate on their Banks. When there is higher oxygen availability, phosphorous is fixed at slimy bottom irreversibly [28]. Point 4 showed worse aerobic conditions, and it favored higher concentrations on water surface. Factors used to elevate this variable content were higher mean value of total phosphorous and dry period. It was possible to observe eutrophication increase by the presence of macrophytes of specie Eichhornia crassipes at point 4 during rainy season in March 31st/2009, and dry season in August 3rd/2009.

Eutrophication is the excessive growth of planktonic or adhered aquatic plants, in levels which can be considered the cause of water quality decrease. It occurs because of high quantity of phosphorous and nitrogen taken from sewage and the pesticides used in crops. Dry seasons are also periods of high luminosity, increasing photosynthetic rates of algae that can reach super populations [41].

Total phosphorous values above the allowed by CONAMA and the non significant difference among those values indicate that waters of all area studied are negatively changed. Then, it is necessary to have special attention to this water course because of the importance of increased levels of phosphorous to continental waters.

**Nitrogen Compounds – Nitrite, Nitrate and Ammonia:**

The determination of nitrogen compounds in water is extremely important because they indicate recent contamination and, in superficial water, nitrate indicates partial decomposition of organic matter [36].

To contents of nitrite, nitrate and ammonia (figures 1B, 2B and 2B), all values obtained from their concentrations are on the limits established by CONAMA resolution of 2005 (Table 2).

Nitrite is the most common nitrogen compound on superficial water and in very low content. It is an unstable molecule on oxygen, an intermediate compound on nitrification process, when ammonia is oxidized by bacteria in the aquatic environment, forming nitrate. Nitrite is used by aquatic plants as nitrogen source and indicates biological process with organic pollution influence [11].

At points 1 and 2 nitrite rates were low because there are no sewage deposit and no crops to use pesticides around them. Therefore, these sources of nitrogen compounds associated to their input to water bodies are not in that place.

For receiving water from points 1 and 2, point 3 accumulates nitrite from spaces before, which increase mean concentration. Point 4 has its mean higher because of receiving higher quantity of pollution; however waters from point 4 are according to CONAMA. The maintenance of these values is related to higher quantity of microorganisms that process nitrite on oxygen converting it into nitrate [40]. Correlation between nitrite and nitrate is powerful.

In point 4 it is also found absolute values of nitrite that are worrying because they are near the maximum allowed. Higher nitrate concentrations at his place are because it is related to organic mater input.

Smaller nitrate concentration in May 6th matches with the higher nitrate concentration at the same date, and probably, nitrification process did not reach the final stage on sampling taken at this date.

Ammonia is a toxic substance non persistent in aquatic environment, non cumulative and in low concentrations does not cause physiological damage to [29]. It is the first substance from nitrogen cycle and it is a consequence of accumulated organic matter as food, excrement and urine.

The reasons for being more concentrated in nitrite and nitrate at point 4 may explain the high mean rate of ammonia: directing pollutants and leachate to water. March in Diamantina, the city where Biribiri state park is, is rainy. Higher water volume added to the stream in this period may have caused organic load dilution at point 4. With smaller microorganisms’ concentration, the conversion process ammonia into nitrite and nitrate is slower. To nitrogen compounds Agua Limpa water fit to limit adequate to class 1. In this class water is used to: human consumption after simple treatment; Aquatic communities protection; recreation of primary contact; and to irrigate vegetation and fruits that grow at soil level and they are eaten green without removing the skin.
Iron:
Under aerobic conditions, microorganisms use oxygen to oxidize organic combinations [5] and, when there is no oxygen microorganisms use inorganic substances to receive electrons, as iron. Increasing on Iron concentration (II) indicates hard degradation of contaminants through iron reduction; therefore, iron ions production indicates the existence of processes with low oxygen rates [21]. A decline on redox potential reflects the change on oxidants conditions – favorable to aerobic organisms – to reduce conditions – better conditions to anaerobic processes [20]. It justifies the negative correlation between iron and dissolved oxygen and explains the higher iron content acquired on point 4.

Iron contents are related to phosphorous complex formation that turns iron insoluble [13]. Phosphorous adsorption and the specific surface of iron oxides have direct correlation [7]. On the other hand, predominance of high iron concentrations may be explained also by the presence of this mineral on rocks and soil of Serra do Espinhaço area, being then, considered a natural standard [12].

To this element, points 1 to 4 are out of standards to waters on classes 1 and 2, being classified just to waters of class 3. Waters of this class are used to: human consumption after conventional or advanced treatment; irrigation of tree, cereal and forage crops; amateur fishing; recreation of secondary contact; and animals’ drinking water.

Dissolved oxygen:
Oxygen is primordial to the metabolism of aquatic aerobic beings and, under normal conditions of running water, quantity of oxygen is high and it has variations caused by changes in its environmental characteristics. Therefore, it is extremely important analyze this parameter concentrations in water [19,41].

At point 1, most of the time, dissolved oxygen concentration is smaller than at point 2 and 3. In this case, smaller quantity of dissolved oxygen can be found cause of smaller water volume and smaller running speed. It decreases water whirlpool and, consequently dissolution of atmospheric oxygen. CONAMA does not determine ideal quantities of oxygen in source waters. It has to be emphasized that water has oxygen concentrations near to 0 mg L⁻¹ when it comes out of riverbeds, because before it, it had no contact with atmosphere [1].

Higher quantities of dissolved oxygen in water are predominant in points 2 and, where the stream has a higher volume of water and the riparian vegetation around it is preserved, which protect water courses from possible external negative interferences.

At point 4, oxygen is consumed faster because it presents high quantities of fecal coliforms and organic matter. Furthermore, when inorganic compounds oxidize, they provoke oxygen decrease [41]. These factors determine the correlations between dissolved oxygen with nitrogen compounds and with iron. Mean of dissolved oxygen at point 4, even being the lowest, it is adequate to class 1 waters. However, it was observed absolute values that were lower in dry seasons which classify these waters among the ones of worst quality: classes 2 and 3.

Hydrogen-ion Potential (pH):
$pH$ is a scale that measures the proportion between ions $H^+$ and $OH^-$, in solution and, according to Esteves [6], it is one of the most difficult variable to interpret. Its complexity is because of many variables which influences it. Aquatic being physiology and their membranes permeability are influenced by pH (Lima & Garcia, 2008). One of the worries on water analysis is, also, to know how their values influence concentrations of other substances as nitrite and ammonium [36].

According to limits established to fresh water classes 1, 2 and 3, pH shall be between 6.0 and 9.0. Means obtained among points show soft acidity at point 1, 2 and 3 and null at point 4, however, all points are at standard established by legislation.

With low quantities of nitrogen and phosphorous compounds on water, there is a tendency to pH decrease [6,17]. Because of it, points 1, 2 and 3 showed lower pH. At point 4, near to pollutant sources, pH increased. However, correlation between nitrogen and phosphorous compounds and pH is direct. Correlation between pH and dissolved oxygen is not same way. It was negative because nitrogen and phosphorous compounds reduce oxygen when they oxidize.

From June 22nd, during dry weather, pH means increased cause of smaller water volume and higher concentration those compounds [18].

Turbidity:
When bodies of water receive particles of material carried by erosions, runoff and sloping relief, these particles are kept on water surface. Variable that represents the degree of interference to light penetration on water is the turbidity.

The significant result to turbidity at point 4 is because of anthropic actions on this place. It is a parameter that is directly related to concentrations of nitrogen and iron compounds.
Higher turbidity value occurred in 03/31/2009 date in which the stream was being influenced by rain. Turbidity was increased by material carried out by rain. Even with higher means at point 4 and in March 31, turbidity values obtained were much lower than the limit allowed by CONAMA. Agua Limpa stream waters are not improper to be used considering only turbidity.

**Temperature:**

CONAMA does not specify ideal temperatures to water classes. Higher temperatures increase biological and chemical reactions, raising gas transferences. Consequently, it can release gas with a bad smelling and decrease oxygen solubility of water [40].

At point 1, waters come from riverbed and because of it showed lower temperatures. Points 3 and 4 are at a lower course then, they receive more revolved Waters, and consequently they show higher temperatures. For being at a flat relief, their waters are exposed to the sun for more time [35]. Higher temperature at point 4 could also be caused by the increase on microbial activity.

The most different dates were March 31st and June 6th, with higher and smaller means, respectively. In this case, water temperatures tended to follow environment temperature: in March characterized by summer and in June by winter. Rain during summer provided direct correlation between this variable and iron which, together soil particles, was carried to water course.

**Fecal Coliforms:**

Analyzing fecal coliforms is very important to monitor hydric resources, because this variable is related to pollution by sewage [23]. The main biochemical characteristic used to identify fecal coliforms is its capacity to lactose fermentation, producing gas, at 44.5°C. Then, as higher organic matter available, higher organisms populations which decompose it. Therefore, oxygen consumed is higher [25].

Only point 1 showed mean of fecal coliform according to the accepted, and points 2 and 3, in spite of being statistically similar to point 1, are over values allowed. A higher mean at point 4 was waited because it had great external interferences when compared to interferences on points 1, 2 and 3. Moreover, its Waters showed typical characteristics of Waters which receive sewage and waste. Such characteristics, bad smell, turbidity and eutrophication make clear the direct correlation among fecal coliforms, nitrite and turbidity, and the inverse correlation of this parameter with dissolved oxygen. Similar results were found by Saad et al.,[31]; Oliveira et al., [26]; Souza & Nunes, [37] who observed high values of fecal coliforms in hydric resources with accumulation of waste and pollutant receivers.

Means acquired on different dates of collection were all over the allowed limit and it is notable the increase of these values during dry weather (from May to September). It was because of smaller volume of water and higher amount of organic matter.

Only at point 1 the mean of fecal coliform was adequate to class 1 of waters. Points 2 and 3 are classified to class 2, used for human consumption, after conventional treatment, protection of aquatic communities, entertainment with a primary contact of visitants, irrigation of green vegetables, fruit plants and gardens, agriculture and fishing. Point 4 had means compatible with waters of class 3.

**Conclusion:**

Agua Limpa may not be classified in only one water class, once it presented different mean concentrations for each parameter analyzed, in each point of collection. It happens because this place has different levels of external interference.

In spite of the means of most analyzed parameters being classified to class 1, they were found values that exceeded the limit allowed by legislation. Values that, in any way, may classify waters in drinking water standard or of first contact, as the ones obtained for ammonium, dissolved oxygen and fecal coliforms. Values were, frequently, over these limits at point 4, which indicates that this place is the main responsible for losing water quality in the area studied. It is important to pay attention to the fact that the amount of pollutants at point 4 may cause advancement to process like eutrophication, aquatic communities’ extinction and transmission of diseases transmitted by water.

Results do not make clear the efficiency in creating units of conservation on continental water protection, because Agua Limpa is inside Biribiri State park, an area of integral protection to Serra do Espinhaço. Therefore, creating this area is not a guarantee of integrity of this stream. It is suggested that the management prioritize, equally, preservation of fauna, flora and aquatic environment preservation.

Physico-chemical and microbiological monitoring is much important to determine water classes and their applicabilities. Small water courses should be included on monitoring plans, because if they are neglected, they may provide loss of quality and resilience capacity of rivers water essential to life.
REFERENCES


