Surface water Treatment for the attendance of Riverside Communities of the Brazilian Amazon

Márcio de Freitas Velasco

Master in Science and Environment – INCRA, Brazil

Abstract — The present study allowed to verify the efficiency of the water treatment proposed by the INCRA - National Institute of Colonization and Agrarian Reform, to the riverside communities in the Agroextractive Projects Onças Island and Arapiranga Island, in the Municipality of Barcarena, State of Pará. Of treated water and one of raw water for each island, aiming to calculate the efficiency in the treatment through the evaluation of the parameters turbidity, apparent color, residual chlorine and total coliforms. With the results obtained, the good physical quality of the water provided through the low levels of turbidity and apparent color was verified, besides the absence of microbiological contamination and low residual chlorine content, guaranteeing water free of taste and odor. The good quality of the treated water and the high efficiency of the treatment proposed for sources of surface water abstraction can be verified.

Keywords — Water quality. Onças Island. Arapiranga Island.

I. INTRODUCTION

The Amazon region presents a considerable water availability, varying between 100,000 and 1,000,000 m³/hab.year depending on the State, when compared to the national average, close to 50,000 m³/hab.year. Due to this abundance, it becomes common to install water supply systems that use rivers and streams as a source of capture, a situation very common in most Amazonian municipalities [3].

The absence of basic sanitation, a recurring situation in the great majority of the riverside municipalities located in the Amazon Region, contributes annually to the deaths of thousands of people, mainly children and elderly people, with frequent outbreaks of waterborne diseases, due to the consumption of water without treatment, a situation invisible in the eyes of the great majority of the population in the great centers, because they occur in completely geographically isolated places. [2].

In general, surface water contains several components from the natural environment itself, as well as those introduced through anthropogenic activities, and the main impurities found in surface waters are dissolved solids in the ionized form, dissolved gases, dissolved organic compounds and materials in suspension, such as microorganisms and colloids, being kept in stable suspension for long periods of time, as a function of the negative charges, which provoke repulsion between these particles [13].

Such situations produce physical changes in water, visually characterized by increased turbidity, defined as the degree of reduction of the passage of light by water, and the presence of color, caused mainly by the decomposition of materials from residues of human activities. In addition, water serves as a vector for the transmission of diseases caused by bacteria, fungi and viruses [7].

There are common outbreaks of waterborne diseases in rural areas, due to the consumption of water without any previous treatment. The absence of basic sanitation contributes annually to the deaths of thousands of people, especially children and the elderly, and this situation is very common in the Amazon [2].

The Citizenship Territories Program was launched in 2008 to promote sustainable development in areas of low human development, with one of its guidelines being to guarantee access to sanitation and quality water [12].

The National Institute for Colonization and Agrarian Reform - INCRA, through its technical staff at the Regional Superintendence in Belém (SR-01), designed in 2009 a model of micro-water treatment plant - META, in order to guarantee the communities rivers within the potability standards established by current legislation. [4].

The treatment operation is based on the abstraction of water from rivers and streams of the region, to be treated and distributed individually or collectively, according to the local population density, as shown in Figures 1 and 2:
Fig. 1 – Collective META Layout.
Source: Own Author

Fig. 2 – Individual META Layout.
Source: Own Author
The proposed water treatment operation consists of the following steps, as shown in Figure 3:

![Operation flow diagram for the proposed water treatment.](image)

Source: Own Author

The collective treatment system shown in Figure 1 basically consists of the capture of raw water directly from rivers and streams, and it is repressed to a high reservoir, installed on the top of the support structure and storage, in hardwood, with 6.40 m in height. The subsequent stage consists of chlorination and flocculation, aiming at the disinfection and clarification of the raw water, through the implantation of a chlorinator installed in the entrance barrel of the upper reservoir, in which flocculant and chlorine are added, obeying this order. Then the super-chlorinated water will fall by gravity and pass through an inlet filter, located at the base of the support structure, and later stored in an intermediate reservoir. In each residence there is installed an individual treatment center, to remove excess residual chlorine and suspended matter, guaranteeing the supply of treated water, according to the standards established by Ordinance No. 2,914, of 12/12/2011 of the Ministry of Health [8].

The individual treatment system shown in Figure 2 presents practically the same characteristics of the collective, differing in the height of the elevated reservoir, 3.00 m in height, besides the fact that super-chlorinated water falls by gravity directly to riverside residence, where an input filter is installed in series, followed by an individual treatment center, responsible for the clarification, polishing and removal of excess residual chlorine, guaranteeing the supply of treated water, in accordance with the standards established by Ordinance No. 2,914, of 12/12/2011 of the Ministry of Health [9].

Agroextractive Projects Onças Island and Arapiranga Island, located in the municipality of Barcarena, in the State of Pará, have several rivers and streams, which are strongly influenced by the waters of Guajará Bay, which have a high turbidity, are muddy and yellow-green coloration, a very evident situation in its tributaries, observed mainly under low tide [6].

This research aims to evaluate the efficiency of the water treatment systems proposed by INCRA through the analysis of physical-chemical and microbiological parameters in treated water samples from micro-water treatment plants installed in riverside residences in Agroextractive Projects Onças Island and Arapiranga Island, belonging to the Municipality of Barcarena, in the State of Pará, taking as a basis the water potability parameters established by the current legislation.

II. METHODOLOGY

2.1-Sampling.

Forty samples of treated water were collected in META’s installed in Agro-extractive Projects belonging to the Municipality of Barcarena, distributed as follows:

- Twenty samples from collective META’s installed at Agroextractive Project Ilha das Onças, where a raw water sample was collected from the common source of abstraction for all treated water samples. In this case, the Igarapé Piramanha. Sampling period: June 5 to 15, 2016.

- Twenty samples from individual META’s, installed in Agroextractive Project Ilha Arapiranga, and a sample of raw water from the main source of abstraction was collected, in this case the Cutaju-mirim river. Sampling period: September 5 to 15, 2016.

The sampling plan was defined according to the location of the META’s installed in the same drainage, according to the maps shown in Figures 4 and 5. Each of the sectors had twenty sampling points, plus a point for collecting raw water in the drainage. The parameters adopted to evaluate the efficiency of the proposed system are directly related to the characteristics of the surface spring used as source of gross water capture, whose turbidity and the apparent color of the water present high values, as well as the presence of total coliforms characteristic of area without basic sanitation. The presence or absence of free residual chlorine is related to the last step of the treatment, the dechlorination. The protocol adopted obeyed Portaria no. 2,914, dated 12/12/2011 of the Ministry of Health, which provides for
procedures to control and monitor the quality of water for human consumption and its drinking water standard [4]. From the results obtained, the two proposed modalities were compared: individual and collective.

The location maps of the sampling points are shown in Figures 4 and 5, which were constructed using the GPS TrackMaker 13.8 software, used to georeference and identify the sampling points, and then finalize the map generation with the aid of the QGIS 2.4 software.

Fig. 4 – META’s individual sampling map (Arapiranga Island).
Source: Own Author

Fig. 5 – META’s collective sampling map (Island of Onças).
Source: Own Author
2.2- Assessment of the efficiency of the proposed water treatment.

The collected samples were analyzed in a laboratory contracted, Monitora Laboratories LTDA-ME, taking into account that the proposed water treatment follows the conventional methodologies of most of the processes adopted by water supply companies in cities spread throughout the national territory, which consists of the clarification and disinfection of raw water, and the parameters defined for the evaluation of the efficiency obeyed physical and microbiological determinants for acceptance of the final product of the operation: turbidity, through the method SMWW 22° Ed., 2130B 2012; apparent color, through the method SMWW 22° Ed., 2012 - 2120 C and total coliforms, through the method SMWW 22° Ed., 2012 - 9221 D; as well as residual free chlorine by the method SMWW 22° Ed., 2012 - 4500 Cl, since the treated water supplied will be used for human consumption [1].

The results obtained were then compared with the potability standards established in the current legislation. Subsequently, the treatment efficiency for each of the collection points was calculated. Then, the average efficiency for the individual and collective system was calculated.

In order to determine the treatment efficiency in relation to each parameter evaluated, the following relation was used:

\[
\text{Efficiency (\%)} = \left(\frac{\text{gross water value} - \text{treated water value}}{\text{gross water value}}\right) \times 100
\]

Where:
- gross water value = before treatment;
- treated water value = after treatment, ready for human consumption.

### III. RESULTS AND DISCUSSION

#### 3.1- Collective water treatment plants.

##### 3.1.1- Efficiency in the removal of turbidity.

Through the results obtained, the efficiency in the removal of turbidity from the raw water in the collective META’s was determined, whose results are presented in Table 1:

Table 1 – Results for efficiency in turbidity removal in the collective system - PAE Onças Island

| SAMPLE | LOCALITY | COORDINATES (DATUM WGS84) | GROSS WATER TURBIDITY (μT) | POTABLE WATER TURBIDITY (μT) | EFFICIENCY OF TREATMENT (%) |
|--------|----------|----------------------------|-----------------------------|-----------------------------|-----------------------------|
| ON1    | ONÇAS ISLAND | 22M 0770562 9840785 | 32 0 | 100,00% |
| ON2    | ONÇAS ISLAND | 22M 0770435 9840590 | 32 0 | 100,00% |
| ON3    | ONÇAS ISLAND | 22M 0773899 9840776 | 32 0 | 100,00% |
| ON4    | ONÇAS ISLAND | 22M 0773191 9838580 | 32 0 | 100,00% |
| ON5    | ONÇAS ISLAND | 22M 0772813 9838788 | 32 0 | 100,00% |
| ON6    | ONÇAS ISLAND | 22M 0773331 9837671 | 32 0 | 100,00% |
| ON7    | ONÇAS ISLAND | 22M 0773246 9837443 | 32 0 | 100,00% |
| ON8    | ONÇAS ISLAND | 22M 0768912 9839803 | 32 2 | 93,75% |
| ON9    | ONÇAS ISLAND | 22M 0768624 9840046 | 32 1 | 96,88% |
| ON10   | ONÇAS ISLAND | 22M 0768605 9840259 | 32 0 | 100,00% |
| ON11   | ONÇAS ISLAND | 22M 0768935 9841418 | 32 2 | 93,75% |
| ON12   | ONÇAS ISLAND | 22M 0769171 9841499 | 32 1 | 96,88% |
| ON13   | ONÇAS ISLAND | 22M 0770855 9840410 | 32 2 | 93,75% |
| ON14   | ONÇAS ISLAND | 22M 0771254 9840458 | 32 0 | 100,00% |
| ON15   | ONÇAS ISLAND | 22M 0771342 9840517 | 32 0 | 100,00% |
| ON16   | ONÇAS ISLAND | 22M 0771681 9841120 | 32 2 | 93,75% |
| ON17   | ONÇAS ISLAND | 22M 0772220 9841235 | 32 0 | 100,00% |
| ON18   | ONÇAS ISLAND | 22M 0772497 9841321 | 32 1 | 96,88% |
| ON19   | ONÇAS ISLAND | 22M 0773519 9840865 | 32 0 | 100,00% |
| ON20   | ONÇAS ISLAND | 22M 0774228 9840675 | 32 0 | 100,00% |

| ZONE | E | N |
|------|---|---|
| ON1  | 22 | M |
| ON2  | 22 | M |
| ON3  | 22 | M |
| ON4  | 22 | M |
| ON5  | 22 | M |
| ON6  | 22 | M |
| ON7  | 22 | M |
| ON8  | 22 | M |
| ON9  | 22 | M |
| ON10 | 22 | M |
| ON11 | 22 | M |
| ON12 | 22 | M |
| ON13 | 22 | M |
| ON14 | 22 | M |
| ON15 | 22 | M |
| ON16 | 22 | M |
| ON17 | 22 | M |
| ON18 | 22 | M |
| ON19 | 22 | M |
| ON20 | 22 | M |

AVERAGE EFFICIENCY 98,28%

Source: Own Author
3.1.2 - EFFICIENCY IN REMOVING APPARENT COLOR.

Through the obtained results, the efficiency in the removal of apparent color of the raw water in the collective META’s was determined, whose results are presented in Table 2:

Table 2 – Results for efficiency in apparent color removal in the collective system - PAE Onças Island

| SAMPLE | LOCALITY   | COORDINATES (DATUM WGS84) | GROSS WATER APPARENT COLOR (uH) | POTABLE WATER APPARENT COLOR (uH) | EFFICIENCY OF TREATMENT (%) |
|--------|------------|----------------------------|---------------------------------|-----------------------------------|----------------------------|
| ON1    | ONÇAS ISLAND | 22M 0770562 9840785      | 178                             | 1,0                               | 99.44%                     |
| ON2    | ONÇAS ISLAND | 22M 0770435 9840590      | 178                             | 1,0                               | 99.44%                     |
| ON3    | ONÇAS ISLAND | 22M 0773899 9840776      | 178                             | 1,0                               | 99.44%                     |
| ON4    | ONÇAS ISLAND | 22M 0773191 9838580      | 178                             | 1,0                               | 99.44%                     |
| ON5    | ONÇAS ISLAND | 22M 0772813 9838788      | 178                             | 0                                 | 100.00%                    |
| ON6    | ONÇAS ISLAND | 22M 0773331 9837671      | 178                             | 0                                 | 100.00%                    |
| ON7    | ONÇAS ISLAND | 22M 0773246 9837443      | 178                             | 0                                 | 100.00%                    |
| ON8    | ONÇAS ISLAND | 22M 0768912 9839803      | 178                             | 1,0                               | 99.44%                     |
| ON9    | ONÇAS ISLAND | 22M 0768624 9840046      | 178                             | 5,0                               | 97.19%                     |
| ON10   | ONÇAS ISLAND | 22M 0768605 9840259      | 178                             | 0                                 | 100.00%                    |
| ON11   | ONÇAS ISLAND | 22M 0768935 9841418      | 178                             | 1,0                               | 99.44%                     |
| ON12   | ONÇAS ISLAND | 22M 0769171 9841499      | 178                             | 2,0                               | 98.88%                     |
| ON13   | ONÇAS ISLAND | 22M 0770855 9840410      | 178                             | 6,0                               | 96.63%                     |
| ON14   | ONÇAS ISLAND | 22M 0771254 9840458      | 178                             | 6,0                               | 96.63%                     |
| ON15   | ONÇAS ISLAND | 22M 0771342 9840517      | 178                             | 4,0                               | 97.75%                     |
| ON16   | ONÇAS ISLAND | 22M 0771681 9841120      | 178                             | 6,0                               | 96.63%                     |
| ON17   | ONÇAS ISLAND | 22M 0772220 9841235      | 178                             | 0                                 | 100.00%                    |
| ON18   | ONÇAS ISLAND | 22M 0772497 9841321      | 178                             | 5,0                               | 97.19%                     |
| ON19   | ONÇAS ISLAND | 22M 0773519 9840865      | 178                             | 0                                 | 100.00%                    |
| ON20   | ONÇAS ISLAND | 22M 0774228 9840675      | 178                             | 0                                 | 100.00%                    |

AVERAGE EFFICIENCY 98.88%

Source: Own Author

3.1.3- EFFICIENCY IN DECLORATION.

In the chlorination operation carried out in the initial stage 2.5 mg / l of active chlorine is added to the disinfection of the raw water, and the dechlorination is carried out in the final stage of the process, thus generating the data shown in Table 3, proving the efficiency in this stage of treatment:
### Table 3 – Results for dechlorination efficiency in the collective system – PAE Onças Island

| SAMPLE | LOCALITY     | ZONE | E   | N   | GROSS WATER CHLORINE (mg/l) | POTABLE WATER CHLORINE (mg/l) | EFFICIENCY OF TREATMENT (%) |
|--------|--------------|------|-----|-----|----------------------------|-------------------------------|----------------------------|
| ON1    | ONÇAS ISLAND | 22M  | 0770562 | 9840785 | 2.5                        | 0                             | 100.00%                   |
| ON2    | ONÇAS ISLAND | 22M  | 0770435 | 9840590 | 2.5                        | 0.01                          | 99.60%                   |
| ON3    | ONÇAS ISLAND | 22M  | 0773999 | 9840776 | 2.5                        | 0                             | 100.00%                   |
| ON4    | ONÇAS ISLAND | 22M  | 0773191 | 9838580 | 2.5                        | 0                             | 100.00%                   |
| ON5    | ONÇAS ISLAND | 22M  | 0772813 | 9838788 | 2.5                        | 0                             | 100.00%                   |
| ON6    | ONÇAS ISLAND | 22M  | 0773331 | 9837671 | 2.5                        | 0                             | 100.00%                   |
| ON7    | ONÇAS ISLAND | 22M  | 0773246 | 9837443 | 2.5                        | 0                             | 100.00%                   |
| ON8    | ONÇAS ISLAND | 22M  | 0768912 | 9839803 | 2.5                        | 0                             | 100.00%                   |
| ON9    | ONÇAS ISLAND | 22M  | 0768624 | 9840046 | 2.5                        | 0                             | 100.00%                   |
| ON10   | ONÇAS ISLAND | 22M  | 0768605 | 9840259 | 2.5                        | 0                             | 100.00%                   |
| ON11   | ONÇAS ISLAND | 22M  | 0768935 | 9841418 | 2.5                        | 0                             | 100.00%                   |
| ON12   | ONÇAS ISLAND | 22M  | 0769171 | 9841499 | 2.5                        | 0                             | 100.00%                   |
| ON13   | ONÇAS ISLAND | 22M  | 0770855 | 9840410 | 2.5                        | 0                             | 100.00%                   |
| ON14   | ONÇAS ISLAND | 22M  | 0771254 | 9840458 | 2.5                        | 0                             | 100.00%                   |
| ON15   | ONÇAS ISLAND | 22M  | 0771342 | 9840517 | 2.5                        | 0                             | 100.00%                   |
| ON16   | ONÇAS ISLAND | 22M  | 0771681 | 9841120 | 2.5                        | 0                             | 100.00%                   |
| ON17   | ONÇAS ISLAND | 22M  | 0772220 | 9841235 | 2.5                        | 0                             | 100.00%                   |
| ON18   | ONÇAS ISLAND | 22M  | 0772497 | 9841321 | 2.5                        | 0                             | 100.00%                   |
| ON19   | ONÇAS ISLAND | 22M  | 0773519 | 9840865 | 2.5                        | 0                             | 100.00%                   |
| ON20   | ONÇAS ISLAND | 22M  | 0774228 | 9840675 | 2.5                        | 0                             | 100.00%                   |

AVERAGE EFFICIENCY 99.98%

Source: Own Author

3.1.4. EFFICIENCY IN THE DISINFECTION OF GROSS WATER.

In the chlorination operation carried out in the initial stage 2.5 mg/l of active chlorine is added to disinfect the raw water, thus generating the data shown in Table 4, proving the efficiency in this treatment step:
Table 4 – Results for the efficiency of disinfection of raw water in the collective system – PAE Onças Island

| SAMPLE | LOCALITY     | SAMPLE LOCALITY | COORDINATES (DATUM WGS84) | GROSS WATER TOTAL COLIFORMS (P-A/100 ml) | POTABLE WATER TOTAL COLIFORMS (P-A/100 ml) | EFFICIENCY OF TREATMENT (%) |
|--------|--------------|-----------------|---------------------------|-------------------------------------------|-------------------------------------------|-----------------------------|
| ON1    | ONÇAS ISLAND| 22M             | 0770562                  | 9840785                                   | PRESENCE                                  | ABSENCE                     | 100,00%                    |
| ON2    | ONÇAS ISLAND| 22M             | 0770435                  | 9840590                                   | PRESENCE                                  | ABSENCE                     | 100,00%                    |
| ON3    | ONÇAS ISLAND| 22M             | 0773899                  | 9840776                                   | PRESENCE                                  | ABSENCE                     | 100,00%                    |
| ON4    | ONÇAS ISLAND| 22M             | 0773191                  | 9838580                                   | PRESENCE                                  | ABSENCE                     | 100,00%                    |
| ON5    | ONÇAS ISLAND| 22M             | 0772813                  | 9838788                                   | PRESENCE                                  | ABSENCE                     | 100,00%                    |
| ON6    | ONÇAS ISLAND| 22M             | 0773331                  | 9837671                                   | PRESENCE                                  | ABSENCE                     | 100,00%                    |
| ON7    | ONÇAS ISLAND| 22M             | 0773246                  | 9837443                                   | PRESENCE                                  | ABSENCE                     | 100,00%                    |
| ON8    | ONÇAS ISLAND| 22M             | 0768912                  | 9839803                                   | PRESENCE                                  | ABSENCE                     | 100,00%                    |
| ON9    | ONÇAS ISLAND| 22M             | 0768624                  | 9840046                                   | PRESENCE                                  | ABSENCE                     | 100,00%                    |
| ON10   | ONÇAS ISLAND| 22M             | 0768605                  | 9840259                                   | PRESENCE                                  | ABSENCE                     | 100,00%                    |
| ON11   | ONÇAS ISLAND| 22M             | 0768935                  | 9841418                                   | PRESENCE                                  | ABSENCE                     | 100,00%                    |
| ON12   | ONÇAS ISLAND| 22M             | 0769171                  | 9841499                                   | PRESENCE                                  | ABSENCE                     | 100,00%                    |
| ON13   | ONÇAS ISLAND| 22M             | 0770855                  | 9840410                                   | PRESENCE                                  | ABSENCE                     | 100,00%                    |
| ON14   | ONÇAS ISLAND| 22M             | 0771254                  | 9840458                                   | PRESENCE                                  | ABSENCE                     | 100,00%                    |
| ON15   | ONÇAS ISLAND| 22M             | 0771342                  | 9840517                                   | PRESENCE                                  | ABSENCE                     | 100,00%                    |
| ON16   | ONÇAS ISLAND| 22M             | 0771681                  | 9841120                                   | PRESENCE                                  | ABSENCE                     | 100,00%                    |
| ON17   | ONÇAS ISLAND| 22M             | 0772220                  | 9841235                                   | PRESENCE                                  | ABSENCE                     | 100,00%                    |
| ON18   | ONÇAS ISLAND| 22M             | 0772497                  | 9841321                                   | PRESENCE                                  | ABSENCE                     | 100,00%                    |
| ON19   | ONÇAS ISLAND| 22M             | 0773519                  | 9840865                                   | PRESENCE                                  | ABSENCE                     | 100,00%                    |
| ON20   | ONÇAS ISLAND| 22M             | 0774228                  | 9840675                                   | PRESENCE                                  | ABSENCE                     | 100,00%                    |

Source: Own Author

3.2- Micro-individual water treatment plant.

3.2.1- EFFICIENCY IN THE REMOVAL OF TURBIDITY.

Through the obtained results, the efficiency in the removal of turbidity of the raw water was determined in the individual META's, whose results are presented in Table 5:
Table 5 – Results for efficiency in turbidity removal in the individual system – PAE Arapiranga Island

| SAMPLE | LOCALITY     | COORDINATES (DATUM WGS84) | GROSS WATER TURBIDITY (μT) | POTABLE WATER TURBIDITY (μT) | EFFICIENCY OF TREATMENT (%) |
|--------|--------------|---------------------------|----------------------------|----------------------------|-----------------------------|
| AR1    | ARAPIRANGA ISLAND 22M 0769920 9847573 25 0 100,00% |
| AR2    | ARAPIRANGA ISLAND 22M 0769524 9847056 25 0 100,00% |
| AR3    | ARAPIRANGA ISLAND 22M 0767156 9846277 25 0 100,00% |
| AR4    | ARAPIRANGA ISLAND 22M 0767186 9846273 25 0 100,00% |
| AR5    | ARAPIRANGA ISLAND 22M 0768187 9847503 25 0 100,00% |
| AR6    | ARAPIRANGA ISLAND 22M 0768164 9847508 25 0 100,00% |
| AR7    | ARAPIRANGA ISLAND 22M 0768201 9847423 25 0 100,00% |
| AR8    | ARAPIRANGA ISLAND 22M 0768218 9847394 25 0 100,00% |
| AR9    | ARAPIRANGA ISLAND 22M 0768156 9847393 25 0 100,00% |
| AR10   | ARAPIRANGA ISLAND 22M 0768151 9847386 25 0 100,00% |
| AR11   | ARAPIRANGA ISLAND 22M 0767535 9847208 25 0 100,00% |
| AR12   | ARAPIRANGA ISLAND 22M 0767277 9847157 25 0 100,00% |
| AR13   | ARAPIRANGA ISLAND 22M 0767229 9847168 25 0 100,00% |
| AR14   | ARAPIRANGA ISLAND 22M 0766962 9846960 25 0 100,00% |
| AR15   | ARAPIRANGA ISLAND 22M 0767337 9847187 25 0 100,00% |
| AR16   | ARAPIRANGA ISLAND 22M 0767461 9847223 25 0 100,00% |
| AR17   | ARAPIRANGA ISLAND 22M 0768018 9847315 25 0 100,00% |
| AR18   | ARAPIRANGA ISLAND 22M 0767414 9847215 25 0 100,00% |
| AR19   | ARAPIRANGA ISLAND 22M 0767520 9847199 25 0 100,00% |
| AR20   | ARAPIRANGA ISLAND 22M 0767368 9847229 25 0 100,00% |

AVERAGE EFFICIENCY 100,00%

Source: Own Author

3.2.2- EFFICIENCY IN REMOVING APARENT COLOR.

The efficiency of the removal of apparent color from the raw water in the individual system was determined by the results obtained. The results are presented in Table 6:
Table 6 – Results for efficiency in apparent color removal in the individual system - PAE Arapiranga Island.

| SAMPLE | LOCALITY          | COORDINATES  | GROSS WATER APPARENT COLOR (uH) | POTABLE WATER APPARENT COLOR (uH) | EFFICIENCY OF TREATMENT (%) |
|---------|------------------|---------------|---------------------------------|-----------------------------------|-----------------------------|
| AR1     | ARAPIRANGA ISLAND| 22M 0769920   | 9847573                         | 146                               | 100.00%                     |
| AR2     | ARAPIRANGA ISLAND| 22M 0769524   | 9847056                         | 146                               | 100.00%                     |
| AR3     | ARAPIRANGA ISLAND| 22M 0767156   | 9846277                         | 146                               | 100.00%                     |
| AR4     | ARAPIRANGA ISLAND| 22M 0767186   | 9846273                         | 146                               | 100.00%                     |
| AR5     | ARAPIRANGA ISLAND| 22M 0768187   | 9847503                         | 146                               | 100.00%                     |
| AR6     | ARAPIRANGA ISLAND| 22M 0768164   | 9847508                         | 146                               | 100.00%                     |
| AR7     | ARAPIRANGA ISLAND| 22M 0768201   | 9847423                         | 146                               | 100.00%                     |
| AR8     | ARAPIRANGA ISLAND| 22M 0768218   | 9847394                         | 146                               | 100.00%                     |
| AR9     | ARAPIRANGA ISLAND| 22M 0768156   | 9847393                         | 146                               | 100.00%                     |
| AR10    | ARAPIRANGA ISLAND| 22M 0766962   | 9847056                         | 146                               | 100.00%                     |
| AR11    | ARAPIRANGA ISLAND| 22M 0767337   | 9847187                         | 146                               | 100.00%                     |
| AR12    | ARAPIRANGA ISLAND| 22M 0767461   | 9847223                         | 146                               | 100.00%                     |
| AR13    | ARAPIRANGA ISLAND| 22M 0768018   | 9847315                         | 146                               | 100.00%                     |
| AR14    | ARAPIRANGA ISLAND| 22M 0767414   | 9847215                         | 146                               | 100.00%                     |
| AR15    | ARAPIRANGA ISLAND| 22M 0767520   | 9847199                         | 146                               | 100.00%                     |
| AR16    | ARAPIRANGA ISLAND| 22M 0767368   | 9847229                         | 146                               | 100.00%                     |

Source: Own Author

3.2.3- EFFICIENCY IN DECHLORINATION.

In the chlorination operation carried out in the initial stage, 2.5 mg / l of active chlorine is added to the disinfection of the raw water, and the dechlorination is carried out in the final stage of the process, thus generating the data shown in Table 7, proving the efficiency in this step of treatment:
### Table 7 – Results for dechlorination efficiency in the individual system - PAE Arapiranga Island

| SAMPLE | LOCALITY             | COORDINATES (DATUM WGS84) | GROSS WATER CHLORINE (mg/l) | POTABLE WATER CHLORINE (mg/l) | EFFICIENCY OF TREATMENT (%) |
|--------|----------------------|---------------------------|-----------------------------|------------------------------|----------------------------|
| AR1    | ARAPIRANGA ISLAND    | 22M 0769920 9847573       | 2,5                         | 0                            | 100,00%                    |
| AR2    | ARAPIRANGA ISLAND    | 22M 0769524 9847056       | 2,5                         | 0                            | 100,00%                    |
| AR3    | ARAPIRANGA ISLAND    | 22M 0767156 9846277       | 2,5                         | 0                            | 100,00%                    |
| AR4    | ARAPIRANGA ISLAND    | 22M 0767186 9846273       | 2,5                         | 0                            | 100,00%                    |
| AR5    | ARAPIRANGA ISLAND    | 22M 0768187 9847503       | 2,5                         | 0                            | 100,00%                    |
| AR6    | ARAPIRANGA ISLAND    | 22M 0768164 9847508       | 2,5                         | 0                            | 100,00%                    |
| AR7    | ARAPIRANGA ISLAND    | 22M 0768201 9847423       | 2,5                         | 0                            | 100,00%                    |
| AR8    | ARAPIRANGA ISLAND    | 22M 0768218 9847394       | 2,5                         | 0                            | 100,00%                    |
| AR9    | ARAPIRANGA ISLAND    | 22M 0768156 9847393       | 2,5                         | 0                            | 100,00%                    |
| AR10   | ARAPIRANGA ISLAND    | 22M 0768151 9847386       | 2,5                         | 0                            | 100,00%                    |
| AR11   | ARAPIRANGA ISLAND    | 22M 0767535 9847208       | 2,5                         | 0                            | 100,00%                    |
| AR12   | ARAPIRANGA ISLAND    | 22M 0767277 9847157       | 2,5                         | 0                            | 100,00%                    |
| AR13   | ARAPIRANGA ISLAND    | 22M 0767229 9847168       | 2,5                         | 0                            | 100,00%                    |
| AR14   | ARAPIRANGA ISLAND    | 22M 0766962 9846960       | 2,5                         | 0                            | 100,00%                    |
| AR15   | ARAPIRANGA ISLAND    | 22M 0767337 9847187       | 2,5                         | 0                            | 100,00%                    |
| AR16   | ARAPIRANGA ISLAND    | 22M 0767461 9847223       | 2,5                         | 0                            | 100,00%                    |
| AR17   | ARAPIRANGA ISLAND    | 22M 0768018 9847315       | 2,5                         | 0                            | 100,00%                    |
| AR18   | ARAPIRANGA ISLAND    | 22M 0767414 9847215       | 2,5                         | 0                            | 100,00%                    |
| AR19   | ARAPIRANGA ISLAND    | 22M 0767520 9847199       | 2,5                         | 0                            | 100,00%                    |
| AR20   | ARAPIRANGA ISLAND    | 22M 0767368 9847229       | 2,5                         | 0                            | 100,00%                    |

Source: Own Author

### 3.2.4 - Efficiency in the Disinfection of Gross Water.

In the chlorination operation carried out in the initial stage 2.5 mg / l of active chlorine is added to disinfect the raw water, thus generating the data shown in Table 8, proving the efficiency in this treatment step:
Table 8 – Results for efficiency of raw water disinfection in the individual system - PAE Arapiranga Island

| SAMPLE | LOCALITY        | COORDINATES (DATUM WGS84) | GROSS WATER TOTAL COLIFORMS (P-A/100 ml) | POTABLE WATER TOTAL COLIFORMS (P-A/100 ml) | EFFICIENCY OF TREATMENT (%) |
|--------|----------------|---------------------------|------------------------------------------|-------------------------------------------|----------------------------|
| AR1    | ARAPIRANGA ISLAND | 22M 0769920 9847573        | PRESENCE                                  | ABSENCE                                   | 100.00%                    |
| AR2    | ARAPIRANGA ISLAND | 22M 0769524 9847056        | PRESENCE                                  | ABSENCE                                   | 100.00%                    |
| AR3    | ARAPIRANGA ISLAND | 22M 0767156 9846277        | PRESENCE                                  | ABSENCE                                   | 100.00%                    |
| AR4    | ARAPIRANGA ISLAND | 22M 0767186 9846273        | PRESENCE                                  | ABSENCE                                   | 100.00%                    |
| AR5    | ARAPIRANGA ISLAND | 22M 0768187 9847503        | PRESENCE                                  | ABSENCE                                   | 100.00%                    |
| AR6    | ARAPIRANGA ISLAND | 22M 0768164 9847508        | PRESENCE                                  | ABSENCE                                   | 100.00%                    |
| AR7    | ARAPIRANGA ISLAND | 22M 0768201 9847423        | PRESENCE                                  | ABSENCE                                   | 100.00%                    |
| AR8    | ARAPIRANGA ISLAND | 22M 0768218 9847394        | PRESENCE                                  | ABSENCE                                   | 100.00%                    |
| AR9    | ARAPIRANGA ISLAND | 22M 0768156 9847393        | PRESENCE                                  | ABSENCE                                   | 100.00%                    |
| AR10   | ARAPIRANGA ISLAND | 22M 0768151 9847386        | PRESENCE                                  | ABSENCE                                   | 100.00%                    |
| AR11   | ARAPIRANGA ISLAND | 22M 0767535 9847208        | PRESENCE                                  | ABSENCE                                   | 100.00%                    |
| AR12   | ARAPIRANGA ISLAND | 22M 0767277 9847157        | PRESENCE                                  | ABSENCE                                   | 100.00%                    |
| AR13   | ARAPIRANGA ISLAND | 22M 0767229 9847168        | PRESENCE                                  | ABSENCE                                   | 100.00%                    |
| AR14   | ARAPIRANGA ISLAND | 22M 0766962 9846960        | PRESENCE                                  | ABSENCE                                   | 100.00%                    |
| AR15   | ARAPIRANGA ISLAND | 22M 0767337 9847187        | PRESENCE                                  | ABSENCE                                   | 100.00%                    |
| AR16   | ARAPIRANGA ISLAND | 22M 0767461 9847223        | PRESENCE                                  | ABSENCE                                   | 100.00%                    |
| AR17   | ARAPIRANGA ISLAND | 22M 0768018 9847315        | PRESENCE                                  | ABSENCE                                   | 100.00%                    |
| AR18   | ARAPIRANGA ISLAND | 22M 0767414 9847215        | PRESENCE                                  | ABSENCE                                   | 100.00%                    |
| AR19   | ARAPIRANGA ISLAND | 22M 0767520 9847199        | PRESENCE                                  | ABSENCE                                   | 100.00%                    |
| AR20   | ARAPIRANGA ISLAND | 22M 0767368 9847229        | PRESENCE                                  | ABSENCE                                   | 100.00%                    |

Source: Own Author

The results showed that both systems present high efficiency for each parameter evaluated.

The collective system showed slightly lower efficiency for the parameters apparent color and turbidity in some samples. This situation may be related to factors such as operating time, reservation volume, among others [13].

Collective systems were installed on Onças Island in the year 2014, with a longer operating time, a fact that generates the need for system maintenance. The higher reservoir volume, 2,000 liters, requires a greater amount of reagent and a longer reaction time to achieve maximum efficiency in the treatment of raw water.

The individual system has a lower volume of reservation, 500 liters, which requires less reagents, as well as a shorter reaction time, besides having a lower installation cost. Another important fact is that individual systems were installed in the year 2016.

Since the proposed treatment is equivalent in both cases, both in the collective and individual systems, we can verify that the pre-chlorination, flocculation, filtration and dechlorination / polishing operations present high efficiency in the clarification and disinfection of raw water coming from and sources of surface abstraction, widely used by riverine populations [9].

It is worth highlighting the fact that the reagents used in the proposed treatment are easy to acquire and of proven efficiency [10].

IV. CONCLUSIONS

The two varieties of the water treatment system proposed by INCRA evaluated are distinguished subtly as to the efficiency level for turbidity and apparent color
parameters, but both present maximum efficiency in the disinfection of raw water. The dechlorination and the polishing of the treated water in the final stage of the process guarantees a final product with appreciable organoleptic properties for the human consumption, being this very important characteristic for its acceptance by the main interested ones, the riverside ones.

It was evidenced the need for a stronger monitoring of the units already installed in order to ensure maximum efficiency in the process of obtaining treated water within the standards of potability required by current legislation.

In general, the water provided by the micro-water treatment plants designed by INCRA, used for domestic consumption in the riverside communities living in PAE Onça Island and PAE Arapiranga Island presents good physical quality evidenced by the low levels of turbidity and apparent color, both in the individual and in the collective mode.

The absence of microbiological contamination evidenced in the results can contribute to the reduction in the cases of waterborne diseases, so common in the rural environment. The low levels of residual chlorine ensure water free of taste and odor, which, most of the time, causes distrust in consumption by the riverside, which has the organoleptic parameter of mineral water.

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