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Evaluation of the drinking water treatment system (STAP) San Fernando – Los Patios urbanization, Colombia. Efficiency and quality

Evaluación del sistema de tratamiento de agua potable (STAP) en la urbanización San Fernando - Los Patios, Colombia. Eficiencia y calidad

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Abstract

The quality of water for human consumption in the municipality of Los Patios in Colombia, depends 60% of the treatment systems for drinking water (STAP) independent, these are adapted according to the population that conforms in 2014 and own resources. Urbanization San Fernando carries out the treatment in an efficient way guaranteeing the quality of water for human consumption, therefore, the field study is based on a quantitative approach and a method that describes the results of the analysis of the samples taken at the entrance and exit of the STAP, to evaluate the efficiency and quality of the system the sample is characterized from the analysis of the physical-chemical and microbiological parameters at the entrance and exit of the system in the Water Laboratory of the Universidad Francisco de Paula de Santander. The physical and microbiological results identify the efficiency of the system and the operator, indicating the quality of the water by the values in the parameters measured according to Decree 1575 of 2007 and 1525 of 2007 by the Ministry of Social Protection in Colombia. The chemical analyses detected a high percentage of calcium hardness in the sample at the system outlet, which is reported to the directors of the urbanization. In accordance with this, the relevant controls and monitoring are carried out in the process for the purification and consumption of water, without neglecting the habits of water storage by the community in each home.

Keywords: quality; efficiency; STAP drinking water treatment system; phisyc-chemical and microbiological parameters.

Resumen

La calidad del agua para consumo humano en el municipio de Los Patios en Colombia depende un 60% de los Sistemas de Tratamiento para Agua Potable (STAP) independientes, estos se adaptan de acuerdo con la población que la conforma en el 2014 y los recursos propios. La Urbanización San Fernando realiza el tratamiento de manera eficiente

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garantizando la calidad del agua para consumo humano, por lo tanto, el estudio de campo se basa desde un enfoque cuantitativo y un método que describe los resultados del análisis de las muestras tomadas a la entrada y salida del STAP, para evaluar la eficiencia y calidad del sistema se caracteriza la muestra a partir del análisis de los parámetros físico-químico y microbiológicos en la entrada y salida del sistema en el Laboratorio de aguas de la Universidad Francisco de paula Santander. Los resultados físicos y microbiológicos identifican la eficiencia del sistema y del operario indicando la calidad del agua por los valores en los parámetros medidos de acuerdo con el decreto 1575 de 2007 y el 1525 de 2007 por el Ministerio de la Protección Social en Colombia. Los análisis químicos detectaron un alto porcentaje de dureza al calcio en la muestra de la salida del sistema, lo cual se reporta a los directivos de la urbanización. De acuerdo con esto se realizan los controles y el seguimiento pertinente en el proceso para potabilización y consumo del agua, sin dejar de lado los hábitos de almacenamiento del agua por la comunidad en cada vivienda.

Palabras clave: calidad; eficiencia; sistema de tratamiento; agua potable STAP; parámetro fisicoquímico y microbiológico.

1. Introduction

The existence of some contaminants in the water, whether in minimum or higher concentrations, reconsiders performing an optimal treatment for water consumption. With each technological advance in Drinking Water Treatment Systems (STAP), a thorough study of these processes is required in order to eliminate these contaminants and adapt them to human consumption, through the implementation of conventional processes (coagulation, rapid mixing, flocculation, sedimentation, clarification, filtration and disinfection) for its treatment [1]. The new challenges in terms of adequate activity for optimal water treatment, from the technical, economic and environmental points of view, without having repercussions and/or effects on health, guarantee the evaluation of the performance of the different approaches for the study and analysis of this [2] [3].

The analysis of the process out by the STAP of the San Fernando Urbanization considers study of physical-chemical, microbiological, parameters, to know their concentration and evaluate the quality and efficiency of the water purification systems; each stages, behavior and conditions determine the fluid at the inlet and outlet. Therefore, the monitoring and control of these systems are the fundamental basis for timely corrections of errors in the process and state of drinking water [4][1].

For this case, the water treatment process is divided into stages: the first was the entrance to the STAP, the second the interval or delivery line, the third stage the fluid outlet and finally the collection and consumption of water. Specifically, the final stage of the STAP process is a vulnerable area prone to breakdowns, damage and leaks due to the condition of the pipe, which can cause contamination in the system, for this reason, the study on quality and current status of the water of the STAP of the San Fernando urbanization.

In the Department of Norte de Santander in 2015, information on the status and quality of water in its 40 municipalities was reported to the platform of the Water Quality Surveillance Information System for Human Consumption (SIVICAP) [5]. The evaluation of water quality using the IRCA Water Quality Risk Index [6] showed that 5.00% (2 municipalities) of the municipalities are at a risk-free level, the equivalent to 17.50% (7 municipalities) a low risk level and finally 65% (26 municipalities) a medium risk level (table 1). On the other hand, a total of 894 samples were reported to SIVICAP, 687 samples (76.8%) came from the urban area and 176 samples (19.7%) from the rural area, 31 samples were observed without information on the area of collection.

Table 1. Adapted Water Quality Assessment Summary IRCA

IRCA water quality assessment		
Level	**Percentage**	**N° Municipalities**
No Risk	5.0%	2
Low Risk	17.5%	7
Medium Risk	65.0%	26
Risk Not identified	12.5%	5

Source: modified from National quality report of water for human Consumption year 2013 based on IRCA

In Colombia it is regulated by, the Ministry of Health and Social Protection (MPS), the Ministry of Environment and Sustainable Development, the Ministry of Housing, City and Territory of Colombia (Decree 1575 of 2007[6]), and Resolution 2115 of 2007[7] describe the characteristics, basic instruments and frequencies of the control and monitoring system for water quality with recommended drinking water levels for human consumption.

In the present study a physical-chemical and microbiological analysis of the state of the water that flows through the STAP in the San Fernando Urbanization, located in the municipality of Los Patios was conducted to determine the efficiency of the system and the quality of the product. Laboratory tests were conducted to determine the state of the physical, chemical and microbiologicals properties of the tributary in the initial stage of the process and of the final product when it leaves the STAP, thus revealing the current state of operation of the system and the quality of the water for human consumption.

The main contribution of this document is to present the current status of the Drinking Water Treatment System of the San Fernando Urbanization, located in the department of Norte de Santander with the purpose of verifying the quality of the water treated in it, which through this study seeks to encourage the community to restructure in terms of storage habits and water use.

2. Methodology

The study in each stage of the process details the aspects of the variables related to the physical-chemical and microbiological parameters of the water of the natural tributary supplied by the Duplat Intake (STD) and the final product of the STAP consumed by the population. For the evaluation of the efficiency of the system and the quality of the drinking water, the analyses are carried out in the water laboratory of the Universidad Francisco de Paula de Santander who is certified by the IDEAM.

2.1. Sampling procedure for water quality analysis

The methodology used to collect the sample manually is acceptable for the control and surveillance critera, the sample must be representative to analyze the water quality of the systema, some unstable parameters such as dissolved oxygen, pH and temperature are measured in situ [8],[9].

Samples were taken every 2 days at different points (entry and exit) of the STAP, with a periodicity of 2 samples (morning and afternoon), every other day, for a total of 45 samples [10]. Thus allowing the conformation of a representative sample for the corresponding analyses. Following the laboratory conditions for their transfer to the Water Laboratory of the Universidad Francisco de Paula Santander (UFPS), complying with the standards in reference to the color of the containers properly purged and with an optimal temperature, for the performance of the analyses described in the following sections.

2.2. Physical analysis

For the purposes of the study, it was necessary to determine the physical parameters on site and others laboratory. Turbidity is onethem to identifity the degree of transparency that water loses due to the presence of suspended particles upon entering the STAP. It is determined by the nephelometric method.

The turbidity formula in the diluted sample is A, the volume of dilution water in milliliters is B, and volume of sample in milliliters is C.

$$Turbidity\ (\boldsymbol{NTU}) = \frac{A(B-C)}{C} \tag{1}$$

The Conductivity measurement identifie the ionics content on the water, and from this the total solids or non-filterable residues of the inlet and outlet water sample of the STAP are determined. This is done by the evaporation method with gravimetric analysis.

$$Total\ solids\ {}^{\boldsymbol{mg}}\!/_{\boldsymbol{L}} = \frac{(A-B)1000}{V} \tag{2}$$

Where A represents the weight of the capsule plus the weight of the residue in grams, B is the weight of the pure capsule in grams and V is the volume of sample used in liters.

2.3. Chemical analysis

For the analysis of the samples in this study it was necessary to interpret the levels of Ion Concentration, by means of the determination of pH with the metric potency method, the total Alkalinity in order to determine the total alkalinity in natural waters and waste waters using volumetric procedures.

$${}^{\boldsymbol{mg}}\!/_{\boldsymbol{L}}\, \boldsymbol{C_aCO_3} = \frac{VNM_{eq}C_aCO_3}{V_m} * 1000 \tag{3}$$

Where V is the volume of H_2SO_4 spent in the valuation in milliliters, N normality of H_2SO_4, Meq of $CaCO_3$ equivalent of 0.05 and Vm is the volume of the sample used in liters.

With the calculation of the total Acidity, the acidity in the sample is determined by the volumetric method (4).

$${}^{\boldsymbol{mg}}\!/_{\boldsymbol{L}}\, \boldsymbol{C_aCO_3} = \frac{VNM_{eq}}{V_m} * 1000 \tag{4}$$

Where V is the volume of NaOH spent in the valuation in milliliters, N normality of NaOH, Meq to an equivalent of 0.05 and Vm the volume of the sample in liters. In the case of total hardness, Calcium Ca and Magnesium Mg are determined by volumetric methods and mathematical expression.

Where V represents the volume of EDTA spent in the titration in milliliters, N the Normality of EDTA, Meq a constant equivalent to 0.05 and Vm the volume of the sample in liters.

Table 2. Measurement of Water Hardness in mg/L or ppm

mg/L $CaCO_3$	Water quality
0 – 75	Soft
75 – 150	Moderately hard
150 – 300	Hard
More than 300	Very hard

Source: adapted IDEAM, 2007.

Calcium hardness is obtained with the same mathematical expression mentioned in the previous item.

Where, in the same way V represents the volume of EDTA spent in the titration in milliliters, N the Normality of EDTA, Meq a constant equivalent to 0.05 and Vm the volume of the sample in liters, but the Hardness to magnesium is obtained from the subtraction of the total hardness, the hardness to calcium.

$$\boldsymbol{D_{Mg}} = D_T - D_{Ca} \quad (5)$$

In the case of other minerals present in water such as Iron, it is determined quantitatively by its concentration and obtained by the spectrophotometric method. Chelating agents ilustrating the formation of coloured iron (II) complexes with sulphate is determined with l the amount of sulphate ions in a given water sample using the spectrophotometric method, Nitrates is determined with the nitrogen content, in various oxidation states: nitrates, ammoniacal and organic; both in natural waters and in waste waters, nitrites is obtained with the concentration in waters of different origins and phosphates are generally present in natural waters in the form of phosphates.

2.4. Microbiological analysis

To determine the percentage or number of fecal coliforms predominant is the Escherichia coli. This Microbiological analysis of the water includes 3 parts:

Table 3. Expected values of phosphates in water

Phosphate level (ppm)	Water quality
0.0 – 1.0	Excellent
1.1 – 4.0	Good
4.1 – 9.9	Acceptable
10.0	Bad

Source: adapted IDEAM, 2004.

2.4.1. Presumptive test

It consists of investigating the fermentation of lactose with gas production. Using the Most Probable Number (MPN) technique, the sample is inoculated with bright green bile lactose broth (BRILA) of MERCK and incubated at 37°C for 24 to 48 hours.

2.4.2. Confirmatory test

To confirm the presence of coliforms in the positive lactosed broth tube, from this one, it is sowed in a differential medium or indicator, to facilitate the recognition of the typical colonies of E. Coli. EOSINE-METHYLENE BLUE (EAM or EMB) agar is the one used in this analysis, which contains peptone, lactose and the dyes eosine and methylene blue.

2.4.3. Definitive proof

Outside the appearance of the colonies, the tests carried out do not allow us to conclude that the isolated organisms are effectively E. coli or other coliform microorganisms fermenting the lactose; for this, it is necessary to carry out additional biochemical tests with pure cultures, which allows us to identify Escherichia coli and Aerobacter aerogenes. (see table 4).

Table 4. Values to identify the presence of bacteria

Reaction Bacteria	I	M	Vi	C
E. coli	+	+	-	-
A. aerogenes	-	-	+	+

Source: adapted MERCK (cultive media manual).

The Determination of Fecal Coliforms, is necessary to differentiate fecal coliforms (from the intestine of man and warm-blooded animals) from coliforms of other origins in this two types of tests are stipulated for the study and / or analysis of these in water.

2.4.4. Differentiating test 1: Presumptive test

Outside the appearance of the colonies, the tests carried out do not allow us to conclude that the isolated organisms are effectively E. coli or other coliform microorganisms fermenting the lactose; for this, it is necessary to carry out additional biochemical tests with pure cultures, which allows us to identify Escherichia coli and Aerobacter aerogenes. (see table 4).

The corresponding dilutions are taken with a sterile pipette 10ml of the sample, to be transferred and obtain a 1:10 or 10-1 dilution.

For the interpretation of the results, after 48 hours, the gas action observed by the displacement of the medium in the Durham tube was recorded. If after 24 hours, all the tubes show gas production, proceed to the confirmatory test.

2.4.5. Differentiating test 1: Confirmatory test

A roast of each of the tubes is sowed on the surface of an EMB plate, by means of the implementation of the following mathematical expression for the calculation of the NMP of coliform organisms, per gram or milliliter, as appropriate:

$$\boldsymbol{NPM}/_{\boldsymbol{g\ o\ MI}} = \frac{NMP\ de\ la\ table\ x\ IDF}{100} \qquad (6)$$

Where, *IDF* is the intermediate dilution factor.

3. Result

Physical-chemical parameters found during the development of the study to the sample of the tributary and the product are described. (See table 5 and 6).

According to the norm established in Colombia Resolution 2115 of 2007, the concentration of calcium hardness is acceptable up to 60 ppm as the maximum limit. However, in this case the concentration is higher than this 109 ppm range (Table 5); which indicates a slight hardness of the water at the entrance of the treatment system. The water that is taken at the exit of the treatment system shows a lower value 86 ppm than the initial value (Table 6) optimized for consumption. According to the study carried out, the treated water contains 110 ppm of total hardness (sum of the hardness to calcium and hardness to Magnesium in ppm of CaCO3), being below the recommended value that is 300 ppm indicating that there is no risk for consumption.

Table 5. Values to identify the presence of bacteria

Parameter	Units	Decree 1575/07	Laboratory analysis result UFPS Water outlet to the system
Turbidity	mg Pt-Co Unit of Cobalt platinum	2 - 5	46
Conductivity	µs/cm	1000	232
Concentration of H+ ions	pH	6.5 – 9.0	7.91
Total solids	mg/L	1500	63
Total alkalinity	mg/L $CaCO_3$	200	98
Acidity	mg/L $CaCO_3$	50	0.0
Total hardness	mg/L $CaCO_3$	300	135
Calcium hardness	mg/L $CaCO_3$	60	109
Magnesium hardness	mg/L $CaCO_3$	36	27
Iron	mg/L Fe	0.3	0.18
Sulphates	mg/L SO4	250	51
Nitrates	mg/L NO3	10	0.85
Nitrites	mg/L NO2	0.1	0.02
Phosphates	mg/L PO4	0.5	0.12

Source: Castrillón, Acevedo & Rojas (2015).

Table 6. Result of the physicochemical test of the water at the STAP outlet

Parameter	Units	Decree 1575/07	Laboratory analysis result UFPS Water outlet to the system
Turbidity	mg Pt-Co Units Platinum cobalt	2 - 5	1.32
Conductivity	µs/cm	1000	174
Concentration of H+ ions	pH	6.5 – 9.0	7.70
Total solids	mg/L	1500	76
Total alkalinity	mg/L $CaCO_3$	200	79
Acidity	mg/L $CaCO_3$	50	0.0
Total hardness	mg/L $CaCO_3$	300	110
Calcium hardness	mg/L $CaCO_3$	60	86
Magnesium hardness	mg/L $CaCO_3$	36	14
Iron	mg/L Fe	0.3	0.14
Sulphates	mg/L SO4	250	61
Nitrates	mg/L NO3	10	0.80
Nitrites	mg/L NO2	0.1	0.0
Phosphates	mg/L PO4	0.5	0.01

Source: Castrillón, Acevedo & Rojas (2015)

Within the microbiological parameters, the results obtained in the initial measurement (table 7) shows bacterial presence of origin from the genus of facultative anaerobic gram negative bacteria of the family Enterobacterriaceae, such as Escherichia coli and Enterobacter aerogenes in the water entering the system, indicating that it is not suitable for human consumption, which leads to a thorough treatment that reduces the total microbial contamination present in the water sample that leaves the system (table 8).

Table 7. Result of the physicochemical test of the water at the STAP outlet

Parameter	Units	Decree 1575/07	Laboratory analysis result UFPS Water outlet to the system
Total coliforms	0FC/100 cm_3	0.0	447
Fecal coliforms	0FC/100 cm_3	0.0	245

Source: Castrillón, Acevedo & Rojas (2015).

Table 8. Results of microbiological tests of water at the STAP outlet

Parameter	Units	Decree 1575/07	Laboratory analysis result UFPS Water outlet to the system
Total coliforms	0FC/100 cm_3	0.0	0.0
Fecal coliforms	0FC/100 cm_3	0.0	0.0

Source: Castrillón, Acevedo & Rojas (2015).

In summary, the STAP registers an average of 109 ppm $CaCO_3$, this indicates that the treatment of the water hardness, is in a considerable variation but even so it is allowed by the Department of the health. The results of the microbiological analysis of the system show the efficiency of the disinfection process, which allows identifying that the community is receiviving quality water.

4. Discussion of resultads

The STAP for human consumption, as a source of drinking water supply for the community of San Fernando urbanization, has a conventional system, with unitary processes in sequential form of coagulation, flocculation, sedimentation, filtration and disinfection, obeying the criteria established worldwide.

The analyses issued by the Departmental Institute of Health to the manager of the San Fernando urbanization, and the analyzes carried out at the UFPS water of Laboratory of the STAP water outlet, find a gap in the concentration of the $CaCO_3$ value, indicating that it is outside the range established be decree 1575/07; wich has not caused harm in the population doe to thre recorded history of consumers, this unusual fat determines that the 60 ppm parameter of can increase aproximately 70% in its permited concentration without causing harm to health.

5. Conclusions

The STAP of the San Fernando urbanization guarantees the quality of water for human consumption in terms of compliance with the permitted values for each parameter (physicochemical and microbiological), with an efficient yield for the number of inhabitants (731) within this community. By complying with the process at each stage and the specific characteristics that a drinking water treatment system must have, it is able to operate under favorable conditions for the community, in accordance with the norms established by law, with the expected results for compliance with the sanitation norms issued by the Departmental Health Secretariat, the municipal RAS2000 and Decree 1575 of 2007[11], [12].

The evaluation shows the community's commitment to the care and optimization of the water service in the urbanization, the compliance of the technician in charge of the system and of the directors in the follow-up. Therefore, there is no contamination index that the community and the authorities alarm, according to the results of the analysis of the UFPS Water Laboratory.

In the period of collection of samples for physicochemical analysis, performed at the water outlet of the system, the parameter that reports values outside the standard mentioned is calcium hardness, with a 86 mg/L of $CaCO_3$, established by law between (60 mg/L of $CaCO_3$) resulting in a moderately hard range (75 to 150 mg/L of $CaCO_3$), indicating that it is not within the parameters, but not considered harmful to the health of the community [13].

The study is relevant for the municipality, because the tributary to the treatment system comes from the Duplat intake, a water source that ends at this point of collection of the San Fernando system, decreasing its flow by 95% and considering this point of consumption as the last population that benefits from the water from the intake.

6. Recommendations

With the interest of working for the community, and participate with the directors of urbanization, the actions that must be taken into account to maintain the quality of the process, and link the population in it, makes it improve the quality of life and habits of collection, consumption and storage thereof.

In the socialization of results to managers and community were given under the proposal of: Visits to the facilities of the treatment system, periodically; to know the results of the physical-chemical and microbiological evaluation that is carried out every month; Campaigns of sensitization on the use, storage and treatment of the water, in cases of shortage and lack of supply.

Following the treatment to reduce the hardness in an individual way, it can be carried out with resins found in the free market, such as natural zeolites, which are aluminum and sodium silicates. Zeolites exchange sodium ions for calcium and magnesium ions. The hardness is therefore removed and adhered to the resin while sodium, which does not produce hardness, takes the place of calcium and magnesium in the water making it softer [14].

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