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Artisanal Filter with Geo-Materials: A Basic Water Treatment Alternative for Human Consumption in Marginal Areas

Daniela Martínez Yañez[1], Álvaro Pedroza Rojas[1] and Carlos Acevedo Peñaloza[2]

[1] Civil Engineering Program, Engineering Faculty
Universidad Francisco de Paula Santander, Colombia

[2] Mechanical Engineering Program, Engineering Faculty
Universidad Francisco de Paula Santander, Colombia

Abstract

The article presents the design and development of filters (easy to implement in homes) that have the capacity to eliminate microorganisms and chemical substances; therefore, they act as handmade water purifiers. It constitutes a reasonable alternative solution to the problem of contaminated water consumption, which can be applied in places of low economic resources.

Keywords: Supply of water, aqueduct, drinkable water, quality of the water, pollution of the water, disinfection, filtration, served population, reparation, treatment

1 Introduction

In the capital city of Norte de Santander, the reality in some marginal sectors is far from the frequently socialized message that there is full coverage of drinking water service. Still, there are neighborhoods where water arrives in tank cars, collected directly from nearby surface streams, and there are places where rainwater is collected from rooftops. This problem suggests the need to look for

alternatives to improve the quality of drinking water in such sectors, as a way to contribute to the reduction of morbidity from contamination by ingestion of contaminated liquid.
The formative research carried out was experimental - descriptive, developed laboratory tests and the design of homemade water filters with stone materials of easy attainment in Cúcuta.
The design, construction and installation of handmade filters in homes are relatively easy tasks to implement and the accessibility to the materials used as raw material in the manufacture of the filter, the relative ease of installation and maintenance, are essential characteristics of the solution.
The basic investigation of this article [1] was framed in the objective to design and to develop a prototype of artisan filter with materials of the region for the treatment of water of human consumption, that can be implemented in marginal zones of the city of Cúcuta. This purpose was achieved by the following specific objectives:
To characterize, in terms of public services and infrastructure, the human settlement selected as an object of evaluation, in the city of Cúcuta, Norte de Santander.
To make a bibliographic revision on the design of filters for water treatment that makes possible the definition of the variables that determine the design and, therefore, the efficiency, of the mentioned filters elaborated by hand.
To select and characterize the basic materials for the construction of a prototype of handmade filter for the treatment of water for human consumption.
Physically construct the artisanal filter and evaluate its level of efficiency in terms of turbidity reduction, microbiological removal and physical-chemical improvement of the filtered water.
To propose the cost-benefit relation of the "in situ" implementation of the prototypes of artisanal filters.

2 Methodology

2.1 Evaluation of the current water supply system for human consumption.

A pre-diagnosis of the urban complex “The Talent”, which does not have an improved drinking water service; the aqueduct network of the neighborhood is made up of hoses connected to the main network and the supply of the liquid is not continuous.
In the absence of a constant water service, its inhabitants must collect the water that falls on their roofs when it rains. In the sector, water is stored in plastic containers, metal tanks, there is no disinfection system and the stored liquid is in contact with the air. People show signs of contagious infectious diseases through consumption and contact with contaminated water.

2.2 Random statistical analysis to define the number of samples.

Given the difficulty of studying all the elements that comprise a research problem, it is usual to do it with a small significant group and then generalize the result. Following this process of statistical inference, we proceeded to define the number of evaluable subjects, as proposed [2].

The case of the project alludes to the inhabitants of the influenced area formed by "The Talent" Neighborhood, one of the new human settlements developed on the western ring road of Cúcuta.

The sample, understood as the subset of the population with defined properties and characteristics and on which the control was carried out in the research is a small significant quantity of that universe; in this case, thirteen water samples were chosen taken from three randomly selected houses of the set that integrate "The Talent" Neighborhood.

The procedure followed to determine the size of the sample consisted essentially of the following steps:

Obtaining the desired level of confidence (Z). A confidence level of 90% was adopted, equivalent to having a margin of error of 10%. For this confidence level, a value of $Z = 1.65$ was obtained.

Estimate the characteristics of the problem being investigated. The probability that an event will occur will be called "p" in this document and the probability that such an event will not occur will be called "q", so that the sum $p + q$ is invariably equal to the unit (1). Even though the water they receive is pre-treated, its storage and what is observed in situ suggests, for the purposes of this research, that there is a 95% probability (p) that all the houses that make up the population are consuming polluted water and that there is a 5% probability that they are not (q). Consequently, $p + q = 0.95 + 0.05 = 1.0$

Define the maximum acceptable degree of error (e). In the results of the research, it is assumed that variations in the range $0\% \leq e \leq 10\%$. The authors of this research proposal estimate that variations greater than 10% reduce the validity of the information.

Applying equation 1 to estimate the sample size if the population is unknown and correct with equation 2 if the population is known.

$$\eta_o = \frac{z^2 * p * q}{e^2} \quad (1)$$

$$\eta' = \frac{\eta_o}{1 + \frac{\eta_o - 1}{N}} \quad (2)$$

Being, o: sample size, if the population is unknown or the population is too large to be considered "infinite".

$'$: corrected sample size

N: population

z: value of the desired level of confidence for a degree of certainty

e: acceptable error rate
p: probability of occurrence of a phenomenon
q: probability of occurrence of a phenomenon

For the present investigation it was required to select a sample of a population of 900 houses built and inhabited at the time of determining the size of the sample. To see Table No.1

Parameter	Description	Data
N	Population	900
E	Error	10%=0.10, or reliability of 90%
Z	Confidence level for 90% reliability	1.65
P	Probability in favor of finding that drinking water is contaminated	95%
Q	Probability against not identifying contaminated water for human consumption	5%
η_o	Sample size for infinite population for 90% reliability (approximate to the near integer)	12.92
η'	Corrected sample size, for the finite population for 90% reliability (approximate to the near integer)	12.75

Table 1. Calculation of a sample size for a 90% confidence level.

In this way, a sample size of 13 elements (contaminated water samples) was obtained, which were randomly taken from three dwellings, trying to gain representativeness of the different housing models of the sector.

2.3 Use of filters as a proposal to improve the quality of water for human consumption.

Slow sand filtration is a technique that follows design parameters and is commonly used [for its simplicity, efficiency, economy, easy operation and maintenance] to eliminate pathogenic bacteria in human drinking water treatment processes.
The slow sand filtration device has a minimum flow rate; therefore, the water flows slowly through the effect of gravity. The efficiency to clarify the water, the

ease of obtaining the components (materials and accessories) and the simplicity of the simple construction process are significant advantages of this type of filter [3].
By correctly passing the water through a slow artisanal silica sand filtration device (DFALA), the fluid undergoes the following processes: i. Elimination of suspended solids and some colloidal substances (by sifting, sedimentation, biological degradation and biochemical oxidation that removes particles of different sizes); ii.
Elimination of colloidal substances and solutions associated with the absorption process; iii. Reduction of turbidity (by eliminating suspended solids).
This research shows the design of this artisanal filtering element and provides the relevant guidelines for the community to duplicate its construction. In the proposal developed here, a plastic tube has been used as the basic container for the design of the DFALA (very easy to operate and maintain), and geomaterials and local accessories are easy to obtain.

2.4 Design.
The conception of the DFALA proposal presented here was analyzed from the following dimensions: the selection and characterization of the target population of the solution, the pre-diagnosis of the drinking water, the technical constructive aspects of the element, the commitment and participation of the community in the project as a fundamental step for the acceptability of the solution by future users of the filtering element, and the positive impacts of the use of DFALA on the health and well-being of the population.
Constructively, it begins by inserting inside the container or body of the filter [a PVC tube, with a diameter of 4" and 30 cm in length] a base nipple of 5 cm of PVC and on it, to arrange a perforated plastic plate (in this way a support is prefabricated to the layers of draining bed that will be arranged and an empty chamber that receives the percolated water through the sequence of filtering materials); additionally the internal wall of the container is covered with a filter cloth; such elements will help to retain material and to eliminate the turbidity of the water; consequently to improve the transparency of the same one. See Figure 1.

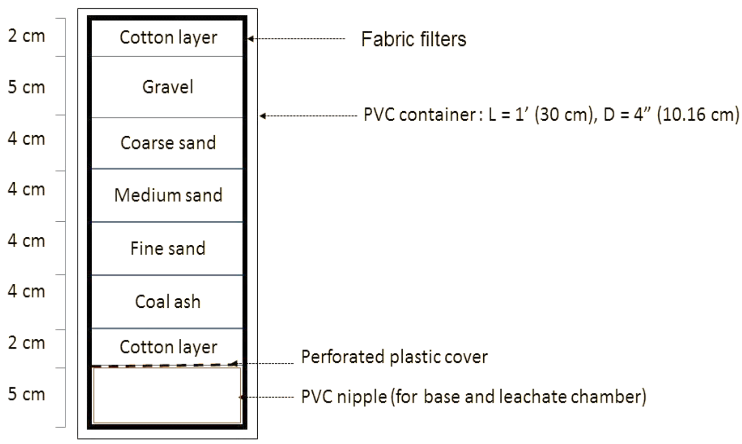

Figure 1. Designed slow sand filter scheme.

In ascending form, the filter is constructed, placing the layers of draining granular geomaterial in the thicknesses indicated in the figure (from greater to smaller diameter). A layer of mineral coal (or, failing that, a layer of ash) was placed on the most superficial layer of fine sand, with the aim of eliminating unpleasant odor and reducing the taste of chlorine or any other substance. Such layers of coal or ash purify water for human consumption [4]

The filter bed inserted inside the tube consists of four (4) layers of geomaterial, as follows: a lower layer of 0.05m of gravel thickness (coarse particles PT3" - RT3/8"), on this, an intermediate layer of 0.04m (coarse sand PT4 - RT10), then another layer of medium sand (PT10-RT40) and a higher layer of 0.04 m of fine sand (fine sand PT40-RT100). As a cover for the fine sand layer, 2cm of cotton were placed and then a layer of 0.04m of coal ash (model 1) and granulated coal (model 2). On top of this layer of activated material a new 2cm cotton layer was laid out. The whole system is covered with a plastic cover, which is opened in the center, a hole with a diameter of ½" capable of housing the feed pipe.

According to (Edrochac, 2017) the gravel and sand filter removes suspended solids in the water and helps to release ions of sodium, potassium, calcium, phosphorus, zinc into the liquid, enriching the water with minerals. There are several mechanisms to remove solids in the water being filtered, associated with the existence of cohesion forces between the formed material and the particles in suspension and the manifestation of electrostatic attraction forces.
Additionally, a few drops of Sodium Hypochlorite concentrated at 15% were applied to the filtered water (the amount to be used depends on the volume of filtered liquid), to help the purification process. To see Table No. 2

FFC \ WV	Number of drops of chlorine according to water volume (cc's)			
	2	10	100	1000
0,2	6	30	15	150
0,5	2	12	6	150
0.8	1	7	3	30
1	1	6	3	30
FCC:	Free chlorine concentration per litre			
WV:	Volume of water (Litres)			

Table 2. Dosage of free chlorine per litre of water. Source: (Health on Board, 2017) [5]

3 Evaluation and Analysis of Filtering Device Results

Filtering to two types of water (clean and with high turbidity) was practiced through the two designed filter models. The contrast of the analyses performed (before and after filtration) of the waters through the two filtering device models was acceptably good. The filtered water was again subjected to physical, chemical and bacteriological analyses performed for the characterization of the incoming water. These tests, as well as the first ones carried out, were developed in the Water Laboratories of the Faculty of Agrarian and Environmental Sciences, in the facilities of the Eliseo's Fields of the UFPS. To see Figure 1. Monitoring program.

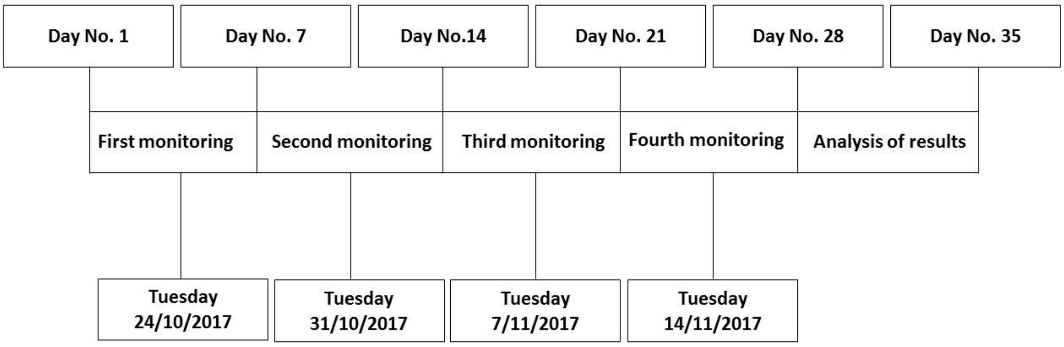

Figure 2. Laboratory Monitoring Program

4 Conclusions

The general objective "To design and develop a prototype of a handmade filter with materials from the region for the treatment of water for human consumption, which can be implemented in marginal areas of the city of Cúcuta", proposed as a guideline for research in the previously approved preliminary project, was achieved in its entirety and, therefore, the objectives outlined as specific were achieved.

"The Talent" Neighborhood, a human settlement located in the western sector of the western ring road of Cúcuta, was characterized in terms of public services and infrastructure.

The basic materials for the construction of artisanal filter models for the treatment of water for human consumption were selected and characterized. The stone drainage material consisted of gravel and sands (fine, medium and coarse) from alluvial dragging of the Pamplonita River, preferably quartz, thus preventing them from deteriorating when in contact with water. Mineral coal and coal ash from mines in the NS region were used. In addition, cotton was used, acquired in shopping centers in the city.

The artisanal filter was physically constructed, and its efficiency level was evaluated in terms of turbidity reduction, microbiological removal and physical-chemical improvement of the filtered water.

Finally, the work was socialized with the community. A workshop was held to teach the community how to make their own filters, install them and periodically maintain the filtering devices. This exercise was carried out with the purpose of stimulating the community to implement the system for improving the quality of drinking water.

To educate the community in the proper use of the filter, the following recommendations, among others, were presented:
In each dwelling, it is necessary to avoid leaving the water storage tanks outdoors (open) or placing them in places prone to contamination by sediments, rodents, livestock, disposal near rubbish or natural pipes on which sewage is poured.
The filtering device should be subject to periodic maintenance. It is advisable to change the cotton that is in the filter, its property of retention of material could potentially become a breeding ground for microorganisms if it is not changed with some frequency.
The recommended dosages for the addition of $NaClO$ in filtered water should adhere to the amounts recommended by the experts.

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