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DEVELOPMENT OF A SUSTAINABLE PROTOTYPE FOR ALTERNATIVE RAW WATER TREATMENT

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Abstract: Water is an essential natural resource for the life of plants, animals and human beings, and is essential in all ecosystems on planet Earth. However, there is a large part of the world's population that suffers from diseases acquired through water contamination, due to limited access to safe drinking water. Therefore, this research aimed to develop a sustainable prototype for alternative treatment of raw water, applied to areas with inefficient basic sanitation services. Two prototypes were designed and executed, consisting of the following operational and treatment phases: storage of raw water; continuous water flow piping; filters, with sand and gravel filtering media; microbiological disinfection area using ultraviolet radiation through sunlight; storage of treated water. The first prototype (A) had filters where the water flows by descending and ascending flow and the second (B) was designed with an ascending flow. According to the results obtained, Prototype B, being lighter, achieved better structure stability, with no leaks. It was also observed regarding the organoleptic quality of the treated water, that in Prototype B the characteristics of the water were superior to that of Prototype A. Finally, it can be concluded that based on the evaluations carried out, Prototype B was more successful in terms of the structural stability of the system and also regarding better water treatment.
Keywords: Homemade filters; Potable water; water treatment system

INTRODUCTION

According to the 1992 universal declaration of water rights, water is a heritage of all inhabitants of the Earth, and it must not be polluted, poisoned or wasted, so as not to reach a situation of scarcity or deterioration in the quality of water. existing water. Consequently, all inhabitants of the Earth are responsible for the conscious consumption, maintenance and preservation of such a precious and fundamental asset for our lives, water.

According to Ordinance Number: 518, of March 25, 2004, drinking water is water whose microbiological, physical, chemical and radioactive parameters meet the potability standard and which does not pose any health risks. For this purpose, water quality control is required, which is a set of continuous activities, designed to verify whether the water supplied to the population is drinkable.

The water treatment plant (ETA) is the place where water is collected from a natural reservoir and treated so that it meets the parameters so that it is classified as potable and can be consumed.

The treatment carried out by the Paraíba Water and Sewage Company (CAGEPA) constitutes 1st aeration, which is the exchange of water substance with air; 2nd coagulation, coagulant is added to aggregate suspended particles; 3rd flocculation promotes the collision between coagulated particles to become larger and facilitate removal; 4th decantation, stage in which the flakes, being denser than water, settle at the bottom of the decanter; 5th filtration, the remaining particles are removed using porous granules; 6th pH correction, lime is added to alkalize the water and prevent corrosion of pipes; and 7th disinfection, chlorine is applied, with the aim of destroying microorganisms in the water.

All care is taken so that the precious commodity that is water can reach its final destination in a drinkable form. However, there is a large part of the population that suffers from diseases because they do not have access to safe drinking water. Therefore, it is necessary to search for alternative treatments to increase the population's access to water, especially in rural areas, which do not have water distribution systems, making this population more susceptible to a wide variety of water-borne diseases.

When explaining alternative water treatment sources, the use of homemade filters was identified. There is a wide variety of these filters, with different types of low-cost, accessible and efficient materials. According to a publication by Coelho (2019), a low-cost homemade filter with downward flow was built to improve water quality in São João do Piauí - PI, which consists of a bottle of mineral water with a capacity of 20 (twenty) liters, containing a filter bed of materials found in the environment forming four layers.

Therefore, visualizing the effectiveness in water treatment and the low construction cost of these filters, this research aimed to develop a sustainable prototype for alternative treatment of raw water, in areas with inefficient basic sanitation services.

MATERIALS AND METHODS

The development of the prototypes was carried out and financed in partnership with `` Centro Universitário UNIFACISA``, in the construction materials laboratory, located in the city of Campina Grande-PB.

Due to the semi-arid climate and rainfall characteristics of the region, this study was designed to create alternatives for water purification, aiming to use sustainability concepts and low-cost materials. The population for which the use of the prototype is suggested are the inhabitants of rural areas and other places that suffer from the lack of basic sanitation, making it necessary in these environments to implement an alternative treatment to guarantee the use of drinking water.

Two prototypes were designed and executed, consisting of the following operational and treatment phases: Storage of raw water; Continuous water flow piping; Filters, with sand and gravel filtering media; Microbiological disinfection area by ultraviolet radiation through sunlight; Storage of treated water.

Both were composed of reusable or low-cost materials, such as PVC pipe, filtration layers with sand and gravel of different particle sizes to check changes in the organoleptic characteristics of the water and a disinfection channel made with PET bottles to receive UV radiation.

The materials used were:

- Reused 20L buckets: Responsible for water storage;
- 1/2” PVC pipes: Responsible for water flow;
- 100 mm PVC tubes and covers: Sand and gravel filter;
- Connections: connection between pipes;
- Pet bottles: Water storage for UV exposure;
- Nylon mesh: Used to prevent the passage of small particles and plant remains;
- Epoxy putty: Used to seal plumbing;
- Pipe glue: used to prevent leaks at connections;
- Crushed stone and sand: Material used to make the filter.

PROTOTYPE A DETAIL

The operation of Prototype A, which is detailed in Figure 1, happens as follows: raw water is poured into the first bucket, identified in Figure 1 as process number: 1, and then passes through a continuous flow pipe (process number: 2 and 3) being sent to the gravel filter, process 4. At the entrance to the gravel filter, a nylon net was inserted glued to the pipe, to block solid materials that could be contained in the water. The objective of this gravel filter was to remove the largest solid particles present in raw water, being characterized as a physical treatment of water. After this, the water passes through the sand filter, process 5, where some microorganisms and smaller solid sediments are filtered (physical and microbiological treatment). Next, the water passes through PET bottles, process 7, aiming to carry out microbiological treatment through exposure to sunlight. And finally, the treated water is deposited in another bucket, process 8, used for storage.

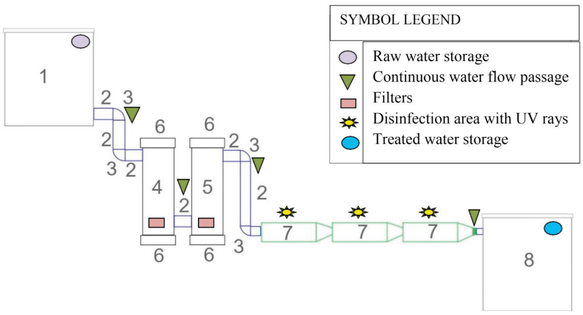

Figure 1: Prototype A Schematic

ITEM LEGEND	
1. A 20-liter bucket, raw water tank	5. Upflow sand filter
2. Pipe Ø1/2" or Ø20mm	6. Cap for 100mm tube
3. 90º knee diameter 20mm	7. Pet bottle
4. Downflow gravel filter	8. A 20-liter bucket, treated water reservoir

Prototype A, illustrated in Figure 1, is made up of several segments that are represented by numbers, they are:

- Segment 1 - shows the prototype's supply reservoir, which consists of a 20 L bucket. This container is located at a certain height, above the filters, in order to guarantee adequate pressure so that the water flows constantly throughout system;
- Segment 2 – represents the ½" pipes, which are used to conduct the water flow and connect the reservoirs to the filters;
- Segment 3 – these are the connections used to interconnect the pipes. In this prototype, 4 90º knees with a diameter of ½" were used.
- Segment 4 and 5 – represents filters that were made with 100 mm PVC pipes and aim to remove solid particles from the water. Tube 4 is composed of crushed stone #6.30, #9.5, #12.5. Tube 5 is composed of medium sand with diameters of #16, #30 and #50.
- Segment 6 – These are sealing caps with a diameter of 100 mm, their function is to contain the material inside the filter;
- Segment 7 – consists of 3 transparent PET bottles, which are intended to expose the water to UV rays. The objective of this exposure is to eliminate disease-causing microorganisms;
- Segment 8 – Constitutes the final reservoir, where it will receive the water treated by the system.

The prototype has filters where water flows through a downward and upward flow. In the first filter, in Figure 1, the water flows in a downward flow, that is, the water is introduced into the upper part of the filter and percolates through the filter bed using gravity as the driving force of the system. In the second filter, the flow is reversed and the water flows upwards, that is, from bottom to top using the dynamic pressure exerted by the water.

In the production process, cuts were made in the PVC pipes to the measurements established in the project. These measurements were made with the aim of having a piezometric line that would guarantee adequate pressure for the water to flow.

Then, holes with a diameter of 20 mm were made in the PET bottles, in the 100 mm tubes and in the 20 L buckets, with a metal saw. Next, 20 mm PVC piping was installed to transport the water, connecting the bucket to the filters and the filters to PET bottles.

To have a good seal at the plumbing connections and avoid leaks, it was necessary to use Epoxy glue on all fittings. Where connections were needed, pipe glue was used.

Regarding the composition material of the filters, a filter with varying sand grain size and another with varying gravel grain size was used.

To separate the particles according to diameter, a vibrating table and sieves with standardized openings were used.

After placing the material in place and sieving, the sand that was retained in the sieves was removed: #50 with a mesh opening of 0.297 mm, #30 with a mesh opening of 0.59 mm, #16 with a mesh opening of #1.19 mm, 10(2 mm) as can be seen in Figure 2.

Figure 2: Sifted sand

Source: Personal files

Then, the gravel was sieved and the portion of material retained in the sieves was removed: #6.30, #9.5, #12.5 as illustrated in Figure 3.

Figure 3: Sifted gravel

Source: Personal files

Then, the materials were placed in the two 150 mm PVC tubes, in ascending and descending order in relation to their diameters.

In the first filter, the gravel was placed from the smallest diameter to the largest, while in the second, it was placed from the largest diameter to the smallest. This happened so that the water followed a decreasing order in the filter in relation to the particle sizes used.

PROTOTYPE B DETAIL

Prototype B (Figure 4) follows practically the same idea as Prototype A, what changed was the number of filters and how they were arranged in relation to the granulometry of the gravel and sand. In it, the water flow continued upwards, from bottom to top, where the dynamic pressure of the water ensures flow in the prototype. The prototype works as follows: Water is placed in the upper reservoir; then, the water flows, gaining pressure due to the piezometric bead and reaching the filter; the filter, the flow occurs upwards; after passing through the filter, the water gains strength again, due to gravity until it reaches the pet bottles, which will serve as a reservoir for the incidence of light; Finally, the already treated water is deposited in the lower reservoir.

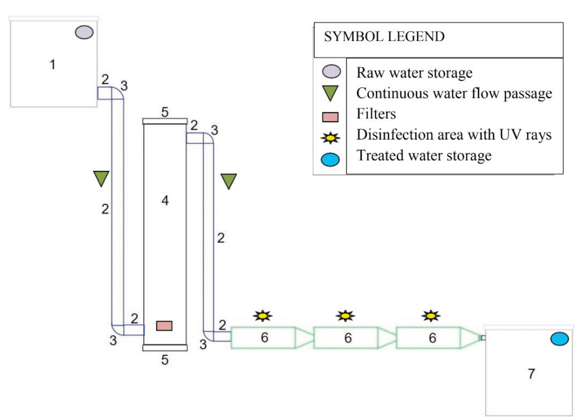

Figure 4: Prototype B Schematic

ITEM LEGEND	
1. A20 liter bucket, raw water tank	5. Cap for 100mm tube
2. Pipe Ø1/2" or Ø20mm	6. Pet bottle
3. 90º knee diameter 20mm	7. A 20-liter bucket, treated water reservoir
4. Upflow filter	

According to Figure 4, the segments that make up Prototype B are:

- Segment 1 – Upper reservoir, where raw water will be deposited;
- Segment 2 – PVC pipe with a diameter of ½", responsible for water flow;
- Segment 3 – PVC connections with a diameter of ½", used to interconnect the system;
- Segment 4 – Corresponds to the filter made with PVC pipe with a diameter of 100 mm, which is composed of crushed stone 19, gravel, medium sand and coarse sand retained in sieves #10 and #16.
- Segment 5 – These are PVC seals with a diameter of 100 mm, used to seal the filter;
- Segments 6 – Transparent PET bottles, where water will be stored for exposure to UV rays;
- Segment 7 – Final reservoir, place where treated water is deposited;

In relation to the first prototype, the second will consist of a single filter, as shown in Figure 4. However, this filter will be much larger, as it will contain sand and gravel of different diameters. The composition of this filter was first made with smaller diameter materials, that is, fine and medium sand was added first and then came the gravel. This happened so that a filter could be made, arranged according to the particle size in an increasing manner, that is, the water will flow through this filter first through medium sand, coarse sand, then through gravel.

RESULTS AND DISCUSSIONS

As it was previously explained, the water to be treated in this prototype must be collected from gutters, wells or springs, with a relatively high initial quality, and is not suitable for treating gray water or domestic and industrial effluents.

Due to the COVID-19 virus pandemic around the world, activities at the Unifacisa Civil Engineering laboratory were halted. For this reason, it was not possible to expose the water to ultraviolet rays and carry out microbiological tests to determine water potability standards. Therefore, only the physical characteristics of the prototypes and the organoleptic characteristics of the treated water were analyzed.

During the tests, after the insertion of water to check the flow flow operation in Prototype A, a series of leaks were noticed that were caused by the instability of the launched structure. The weight of the two filters composed of sand and gravel made the prototype's own weight high, allowing greater vulnerability to any displacement. As a solution to this problem, the filter was placed on a fixed substrate to increase its durability and avoid leakage problems.

With regard to Prototype B, the leakage problem of Prototype A did not occur, as, as it has a single filter, its resistance to displacement was greater, therefore, it has a lower probability of damage and leakage.

The method of water flow through the filters was designed to use the acceleration of gravity and the dynamic pressure of the water. The raw water reservoirs, made up of 20 L buckets, were intentionally placed with the bottom above the height of the filters, thus creating the appropriate height of the piezometric line so that even with pressure losses, flow can be guaranteed up to the final reservoir. In Prototype A, special attention had to be paid to the piezometric level, as the water flow was slow due to the flow in the second filter of the prototype. This occurred because in this filter the flow was against the action of gravity and the sand particles were very compact due to their particle size and the lubrication imposed by the water. Therefore, it was necessary to create a water column height that would allow it to reach the end of the system. In Prototype B, there were not many problems in relation to drainage, as it was made up of a single filter and the height of the reservoir that supplied this filter was greater, which created a satisfactory pressure for the water to flow. The operation after assembly proved to be efficient in both Prototype A and Prototype B, and in the Prototype B the flow speed was higher.

As for the organoleptic characteristics of the water after passing through the filters, it was noticed that it is directly related to the granulometry of the layers of aggregates that make it up. In the Prototype A filter, layers of sand with smaller grain size were used, which directly influenced the final result, as the water carried the fine particles present in the filter. Even after washing the filter to try to remove these tiny particles and the presence of organic matter, the water did not achieve the expected quality for consumption, and the increase in turbidity could be visually identified. As can be seen in Figure 5, the water remained with a certain amount of turbidity after filtering.

Figure 5: Filtered water in the prototype

Source: Personal files

In Prototype B, layers of sand with larger grain sizes were used in the filters. Furthermore, these layers were arranged in such a way that the water flowed first through the finer layers and then passed through the thicker ones. In this prototype, superior results were obtained compared to Prototype A, which can be seen in Figure 4.

Figure 6: Filtered water in Prototype B

Source: Personal files

CONCLUSION

Regarding the structure of the prototypes, it was identified that the greater the structure's own weight, the greater the risk of leaks, thus preventing any possibility of global displacement. This way, Prototype B achieved better physical stability and greater watertightness of the structure, after reducing the number of filters by half when compared to Prototype A.

As for water treatment, the result of Prototype A was lower than that of Prototype B, with such results being attributed to the presence of impurities such as remains of organic matter contained in the material that makes up the finest layers of sand present in the filter. This happened because it was not possible to remove these particles through the mechanical sieving process of the vibrating table. In Prototype B, the effectiveness of filtration can be seen due to the increase in the particle size of the aggregates, thus preventing the transport of smaller particles.

Furthermore, in this prototype, a much higher flow speed was obtained, due to the piezometric quota imposed to overcome the height of the filter.

It is important to highlight that through a visual assessment of the organoleptic characteristics of the water treated in the proposed systems, Prototype B obtained better results when compared to Prototype A. The turbidity index was visually lower in the water treated in this second prototype, being an indication of extreme importance for water potability. Finally, it is important to emphasize that in all evaluated prototypes, it is necessary to discard the first volumes of water resulting from the first filtrations, as it works as a filter wash and is unsuitable for human consumption.

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