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Recirculating Shower Filtration System: Utilizing Natural, Cost-Efficient, and Effective Materials to Consolidate the Purification of Water

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ABSTRACT

The objective of this project was to make a recirculating water shower system that creates clean water using natural resources, without the requirement of additional electricity. Due to the use of natural materials, maintenance of the shower will be dramatically reduced. Our shower system filters the used water and integrates it back into the pipes of the shower, to be used again. The filter removes dirt, bacteria, debris, and biodegradable shampoo. It does so with different filtration methods in each part of the filter. As the water moves from top to bottom, the largest to the smallest impurities are removed from the water to ultimately leave it potable. The system purifies the water to below 5 Nephelometric Turbidity Units (NTU), the recommendation for drinking water by the World Health Organization. Cleaned water is collected and sent back to the shower head by a solar paneled water pump. Our economical shower system has the potential to reduce disease and allow for increased hygiene without wasting water.

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Introduction

Only 2.5% of the world's water is freshwater according to National Geographic (NG). The vast majority of that water is not able to be extracted and used. Therefore, only 0.007% of the planet's water is available for use. In an article published by the CDC, it is estimated that 790 million people, 11% of the world's population, do not have access to a freshwater supply (CDC). The CDC also states that 1.8 billion people, 25% of the world's population, do not have adequate sanitation due to a lack of water (CDC). According to Medical News Today, showering can improve immune function, kill off germs, and provide numerous other benefits (MNT). Today, with the spread of COVID-19, the importance of staying clean has never been more prominent, but many still lack the means to do so. In recent years, the idea of a recirculating water shower system has started to come into play. The clean tech company, Orbital Systems, makes a recirculating water shower system for the modern home that conserves up to 90% of its water (OAS). Their product is expensive, costing $2,500. Additionally, almost all of the parts of the shower have to be replaced three times a year for an average family, leading to more additional costs. The shower may help conserve water, but it is not affordable or efficient enough to help those suffering from water shortages as lack of water is a problem mainly seen in poverty stricken areas. The purpose of this experiment is to address the problems in the Orbital Systems shower by using natural resources, no additional electricity, and being cost effective while providing potable water. By accomplishing these tasks, the shower will be affordable and provide people with the necessary hygiene one requires, while conserving water and money.

Importance of Turbidity and pH

Turbidity measures the amount of particles in a sample of water in Nephelometric Turbidity Units or NTU. Turbidity is caused by chemical and biological particles in water and is a measure of both safety and aesthetic. It is measured on a scale of 0-800. A water with a Turbidity of 0 would have no excess particles within it and the WHO recommends water to be below 5 NTU. Turbidity indicates pathogens and other dangerous particles within water. In water with higher turbidity, pathogens are more likely to be found as particles can often host microorganisms. pH is also another measurement needed for determining whether water is potable. pH shows water solubility as well as resources for aquatic organisms. Solubility is important as it can reveal the toxicity of water regarding metals such as lead and copper. Metals in water at a lower pH are more toxic, because the water is more soluble. The pH levels must be between 6.5 - 8.5 for the water to be considered potable.

Methodology

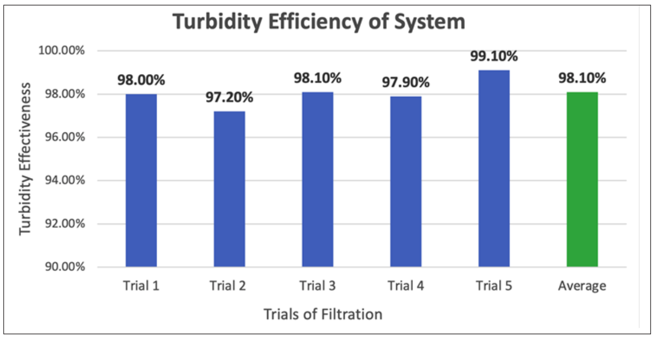
Stage One: To create a shower filtration system, different materials were found and incorporated. The system used PVC pipes, metal mesh, coffee filters, dirt, soil, sand, fine charcoal, and diatomaceous earth. These materials were chosen due to their specific role in the filtration process of the water. Each material was placed into separate PVC pipes with metal mesh and a coffee filter at the bottom to hold the materials from traveling with the water.

Stage Two: The Recirculating shower system was composed of two parts. The first part was the filtration system below the shower. The filter lies inside a 60cm x 60cm x 68cm wood structure with 60cm x 60cm pieces at the top and bottom with four pieces running across the supporting pieces. A 2in diameter hole was cut in these pieces to allow the PVC piping to pass through. These PVCs were blocked on the bottom by a metal mesh that was glued and drilled in place. Several support beams were added. Angled pieces of wood were then glued in place to allow the floor of the shower to be placed on an angle. A layer of plexiglass was added to waterproof the structure. A 7in bucket was placed to collect the water and was connected to the top of the shower via a solar panel powered water pump.

Stage Three: The NTU and pH of the water were tested before and after filtration. The turbidity of the water was tested with a turbidity kit. The water sample consisted of different contaminants during each test with different variations of dirt, mulch, sand, dish soap, biodegradable soap, and other natural materials. pH was tested using compositions of water with materials such as pineapple, lemons, dirt, sand, and mud. All of the pH information was recorded using a pH probe tester and later written down.

Results and Discussion

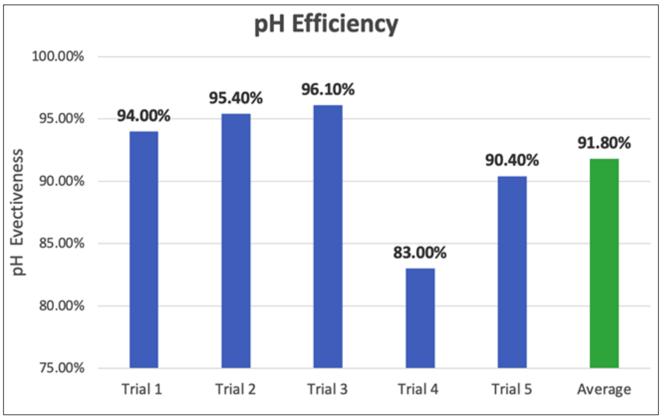
Turbidity Efficiency of System:



	Trial 1	Trial 2	Trial 3	Trial 4	Trial 5	Average	SD
Before Filtration (NTU)	343	179	238	198	318	255.2	N/A
After Filtration (NTU)	6.77	5.10	4.49	4.06	2.92	4.67	1.27%
Eff. %	98.0%	97.2%	98.1%	97.9%	99.1%	98.1%	0.606%

The trials showed large decreases of NTU with an average of around 250 NTU removed from the water. Furthermore, trial 2 included hand soap in the tested water, a contaminant the filter was not made to filter out. A3s seen from the data, hand soap does not affect the filter's ability to remove particles from the water and although it resulted in one of the highest NTU, this was expected and the trial still experienced a decrease of 174 NTU. The trial with the greatest NTU decrease started out at 343 NTU and reduced to 6.77 NTU, a decrease of 336.23 NTU, or 98.02 %. Compared with sink water 3.17 NTU, this trial was only off by around 3 NTU. Trial 5 achieved the lowest NTU of 2.92, even lower than the sink water. The efficiency of this trial was 99.1%. The filter is extremely consistent with a standard deviation of 0.6% regarding the overall effectiveness of NTU decrease.

pH Efficiency:

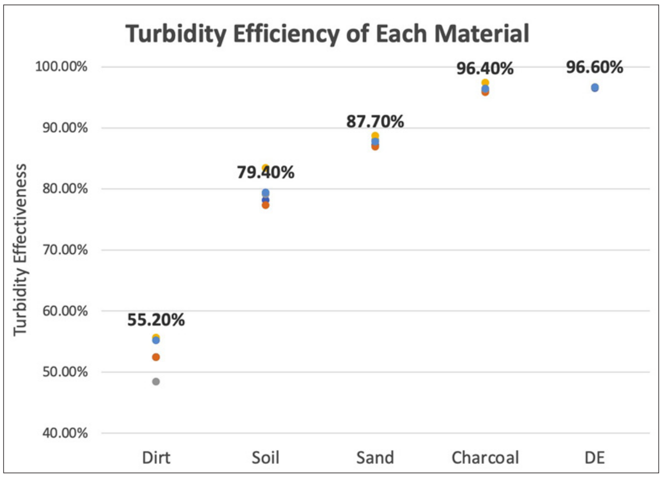


Trials of pH

	Trial 1	Trial 2	Trial 3	Trial 4	Trial 5	Average	SD
Before Filtration (pH)	8.15	7.55	7.68	4.52	2.50	6.08	N/A
After Filtration (pH)	7.42	7.32	7.27	5.81	6.33	6.83	0.64%
Eff. (% to 7pH)	94.0%	95.4%	96.1%	83.0%	90.4%	91.8%	4.81%

It was important to test the effectiveness of the filter to pH as it is an accurate metric for water purity. 5 trials were performed with varying pHs from basic to acidic. Trial 1 had a 94% effectiveness rate. This was determined by using 7 as the target pH. The pH of the water before the trial was 8.15, and after filtration the resulting pH was 7.42. The most effective trial, Trial 3 had a rate of 96.1%. The trial with the most disparity between before and after was Trial 5. Very acidic water was used beforehand at a pH of 2.50. The filter was able to remove the acidic components and bring the pH up to a 6.33. The average pH after filtration was 6.83 with an average 91.8% efficiency throughout all the trials. The standard deviation of pH after filtration was 0.64%, while the standard deviation of the effectiveness rate was higher at 4.81%.

Turbidity Efficiency of Materials



	Start (NTU)	Trial 1 Eff.%	Trial 2 Eff.%	Trial 3 Eff.%	Trial 4 Eff.%	Avg. NTU	Avg. Eff.%	SD
Dirt	225	52.4%	52.4%	48.4%	55.6%	107.5	52.2%	5.68%
Soil	154	78.1%	77.3%	79.1%	83.4%	31.65	79.4%	3.61%
Sand	205	87.2%	86.9%	88.0%	88.7%	25.2	87.7%	1.41%
Charcoal	203	96.1%	95.8%	96.3%	97.4%	7.33	96.4%	1.19%
DE	194	96.5%	96.6%	96.6%	96.6%	6.66	96.6%	0.13%

Before the filter was tested as a whole, each material was tested individually. Dirt had an average efficiency of 52.2%, Soil 79.4%, Sand 87.7% and Charcoal and Diatomaceous Earth were 96.4% and 96.6% respectively. The average final NTUs ranged from 107.5-6.66, and although the Diatomaceous Earth is near potable, the water is only fit for use when filtered through the entire filtration system, and comes up short when just filtered using each material separately. The standard deviation was 5.68% for dirt, 3.61% for soil, 1.41% for sand, 1.19% for charcoal and 0.13% for Diatomaceous Earth, showing how the filtration system involving all of the materials is more consistent than all of the materials excluding diatomaceous earth.

Conclusion

Through the collection of data, it was evident that the filter was able to effectively and significantly reduce the amount of particles in the water. Furthermore, all but one trial resulted in a water with an NTU below the WHO drinking standard. The filter successfully turned dirty and contaminated water into potable water. As the trials suggested, the longer the filter was run the lower the NTU became. This is because as the water runs through the filter it collects particles of the filtration materials such as the diatomaceous earth. This excess diatomaceous earth that is leftover in the water may be seen as a bad thing, but in fact this diatomaceous earth will disinfect the water further and kill any bacteria or parasites making the water even cleaner. In addition, the longer the water is run, the more these excess particles were flushed out. When each stage was tested individually, the final NTUs showed that each material cannot filter out a satisfactory amount of particles and can only do so together. Not only can this filter be quickly assembled and implemented in any climate or region, but it also requires zero additional energy, because the pump runs solely off solar energy. This could be seen as a limiting factor for the system, but a manual pump could also be implemented into the filter eliminating the need for a setting that would provide solar energy. This makes the filter even more versatile [1-11].

Limitations

The project was limited by the testing of the water to make sure that it was potable. Although both turbidity and pH are very important, there are other factors that must be tested to ensure that the water is potable. Additionally, due to the lack of time and materials, the shower system was not easily portable and lightweight. Finally, with more time, the filtration process would be faster as it does take some time for the water to travel through.

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