Clean Water for All: Designing Sustainable, Low-Cost Water Filters using Common Household Waste

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The World Water crisis is a very present and serious issue. Even now, 1 in 10 people globally still do not have access to safe drinking water, giving them a greater risk of contracting water-borne diseases and robbing them of valuable time and physical effort used to try and procure clean water. Over a million people die each year from drinking water contaminated with bacteria, chemicals, and heavy metals. In Canada, many First Nations communities also cannot access potable water, being disproportionately affected by water pollution and treatment issues. This causes significant financial strain, as drinking water advisories could last for multiple years. In this project, the aim was to create an effective water filtration system out of everyday items typically found as waste, such as plastic bottles and bags.

The first step that was done to create this filtration system was to research the ways water was commonly filtered with, with the pros and cons of each system. Afterwards, water pollutants and regular landfill materials were researched and planned out. Finally, a blueprint was drawn with the complete system and materials gathered.

The filtration system consists of two parts: the solid filter and a distillation setup. The solid filter was constructed with the idea that coarser pollutants would be filtered out from the top, with the layers becoming finer towards the bottom, as per the common design for these types of filters. The distillation setup would then remove anything the solid filter could not, like dissolved solutes, as well as killing any bacteria and microorganisms with heat.

The solid filter is made up of four major layers (bottom to top): a layer of activated carbon, two layers of fabric from fine to coarse, and a final layer of plastic pieces wrapped in fabric on top. The materials for these layers were gathered from pre existing sources, with the exception of the activated carbon. In real-life scenarios, the carbon can be substituted with biochar, created from burning food waste in a low oxygen environment. The final list of components that were considered common waste were plastic water bottles, plastic lids, clothing, and wet wipes. These materials would filter out the largest solids first to leave more room for the finer filters to filter the smaller particulate matter left.

The second part of the filtration, the distillation system, was constructed out of a steel pot, with an upside-down conical lid that would direct the water condensation that collected on it into a smaller vessel within the pot. This part is primarily used as a finisher for anything that the particulate filter could not remove, as well as a sterilization agent because of the heat that was needed to boil the water. With an absence of steel pots, this system could be created with any type of heat-resistant material that is generally bowl-shaped, such as plastic milk jugs, though the heat used would have to be reduced to prevent melting, with the distillation process taking longer.

In the testing phase, the DIY filtration system was testing on samples pertaining to common water pollutants, such as fertilizer. Each sample of 500mL would be tested with water testing strips, run through the clean filter (components soaked in clean water with some detergent after every trial), tested again, and finally put into the distillation system to be finally purified. At the end of the purification process, the water's final quality was assessed, along with the time taken to fully purify and the amount in contrast from the original. This data was compiled into a Google Sheet (full in project).

After the data was collected, it was then analyzed and graphed into relevant categories, which was then compared to the data outputted by filtering the water using a commercially available water filter (the BRITA Small 6 Cup Metro Water Filter), primarily the effectiveness and efficiency against the same samples. The effectiveness of the DIY filtration system was comparable to that of the commercially available, even outperforming it at times (the average deviation between the two datasets was 0.8), but its efficiency (water retained throughout the filtration process & the total filtration speed) was noticeably lower. However, this was justified, with the DIY water filter having two phases, one of which required boiling, where more water was lost from the steam.

Due to the relatively limited sample size, a basic neural network was also coded to attempt to predict the effectiveness of the DIY filter on other compounds to which the experimenter did not have access to (let's call them predictors). This was achieved using Google Colab, with the data from the existing samples serving as a guide. The learning rate was set to a standard of 0.001 (how fast the data is gone through), with the training cycle taking 5000 epochs (basically how many times the model goes over the data). The samples and predictors were grouped based on compound type to ensure the predictions were as accurate as possible.

The neural network was made to predict the outcome of filtering three additional predictors which were also found commonly in water pollution: lead, chlorine, and industrial-grade oil. The main reference samples used to train the model for these were the fertilizer, disinfection chemical, and 'dirty snow' samples, respectively. The data for these main samples was used as the training set for the network for each predictor, supplemented with choice points from the other samples. One sample, the fluoride one, was set aside (no data used from it) to be used in the testing stage to determine accuracy. After training, the neural network accuracy was tested by making it predict the outcome of filtering the unseen sample, which would be completely new to it. This yielded an accuracy rate of 75%, with a precision of 83.3%. Finally, the expected unfiltered quality data of the predictors were inputted into the network. The new data output was put through a round of Python analysis and graphed, though it was ultimately kept separate from the real-life data.

Overall, this filter could be an accessible option to those in disadvantaged areas with poor water, facing significant financial strain. It can be fully put together in about thirty minutes, and only mainly uses items usually considered waste that can be easily found in landfills. The other non-landfill specific items can be substituted for similar materials still from the consumption of waste, such as creating biochar from food waste as a substitute for activated charcoal. This DIY filter is comparable to commercially available water filters, with near-equal output quality. Though the purification process does take longer, the price is drastically lower and can be assembled on the spot. This filter also provides a use for common waste materials by recycling them into its design, which, if it were mass-produced, could have a significant impact on the waste problems of affected countries.

Possible sources of error for this project include the limited sample size and shortcomings for some data, as well as the experimenter not having access to more sophisticated methods to test water quality. As mentioned, the neural network was not 100% accurate, which may have led to some issues with the newly predicted data. While the research put into this project was reviewed for reliability, there is always the possibility of imprecise metrics and data. Finally, there were some flaws in the experimental process, which could be improved the next time this is done.

To expand this project, more real-world samples could have been collected to be tested on the filter, resulting in more data. This data could be applied to the neural network to create more accurate predictions. More data could also have been collected regarding the distillation system with an absence of metal materials, where the containers had to instead be substituted with plastic that was certainly meltable. A more thorough analysis of the final product, including bacteria levels and potentially microplastic ratings, would have definitely been helpful in determining true drinkability levels. On that note, the DIY filter could be modified to purify a wider range of pollutants effectively, as well as making modifications to increase its current efficiency and effectiveness.

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