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RESEARCH ARTICLE

ENHANCING PERFORMANCE OF A WATER DISTILLATION DEVICE VIA RECYCLED PLASTIC BOTTLES: AN EXPERIMENTAL STUDY

Authors: Sarah Grace Cabug*, Ruth Ann Bitos, Mary Jane Tolentino, Kathryn Jean Crisostomo, Andrea Jan Manaloto, Krystle Marie Compuesto, Krishia Alleyson Peralta, Franchesca Angel Marie M. Tus, Mary Criss M. Tus, Jhoselle Tus, & Francis Rayo

*Corresponding author email: sarahgracecabug@gmail.com**

Abstract

The cleanliness of accessible water is not always assured as it might become contaminated with bacteria during transmission through pipes, leading to the potential spread of waterborne infections. Creating a water distillation system is recognized as one of the earliest techniques for treating water, effectively removing inorganic chemicals, germs, particles, pollutants, and other impurities. This study aims to suggest a water distillation device that offers convenience to communities with limited access to clean and safe water. Additionally, the study aims to evaluate the efficiency of a cost-effective water distillation apparatus made from recycled plastic bottles. In addition, the researchers developed a detailed graphic diagram and built a water distillation apparatus using recycled plastic bottles to assess its effectiveness. The findings demonstrate that the distillation process effectively removes both organic and inorganic components present in water through evaporation and steam. Utilizing recycled plastic bottles highlights the potential for repurposing waste materials to create effective solutions in water treatment.

Keywords: *recycled plastic bottles, water distillation device, experimental, plastic, bottle*

Introduction

The global issue of inadequate access to potable water has predominantly arisen due to human negligence. Less than 50% of the rural population in Guatemala has access to potable water, as indicated by a survey conducted by Braghetta in 2006. The study revealed that 98% of the nation's water sources are polluted, and only 15 municipalities possess operational drinking water treatment facilities. Guatemala exhibits some of the most unfavorable health statistics globally, characterized by persistent malnutrition and inadequate child growth rates. Chronic malnutrition and illness not only hinder growth but also raise the probability of youngsters failing to reach their maximum genetic and intellectual capabilities, hence restricting productivity and earning capacity.

Given the ongoing increase in worldwide water contamination, various remedies have been proposed, one of which is the distillation process. Distillation is a purification method that uses evaporation to filter water. Distillation is the most efficient technique for removing inorganic compounds from a polluted water source, including metals like iron and lead, nitrate, hardness caused by calcium and magnesium, and particles. Boiling eradicates germs, including bacteria and viruses. The effectiveness of distillation in eliminating organic molecules varies depending on the chemical features of the organic component, such as its solubility and boiling point. Water-soluble organic chemicals with boiling points greater than that of water, such as certain insecticides, can be effectively eliminated from water. Organic substances with lower boiling points than water, such as benzene and toluene, will evaporate together with the water. If these dangerous substances are not removed before condensation, they will contaminate the purified product again.

Given this circumstance, the researchers conceived the notion of utilizing recyclable plastic bottles as an environmentally friendly and cost-effective distillation technology. The suggested device aims to purify water by utilizing readily available materials such as plastic bottles of different sizes and a tube. The assembly procedure is conducted systematically and will be assessed to determine its efficiency at the conclusion of this experimental investigation.

Research Question

Specifically, this study sought to answer the following:

1. How does the color and surface texture of recycled plastic bottles (PET) affect the rate of heat absorption from a heat source (sunlight, electric heater)?

2. Does incorporating recycled plastic bottles into the design of a water distillation device improve its overall efficiency compared to a conventional design?
3. What is the optimal size and shape of recycled plastic components for maximizing the collection of distilled water?
4. Can recycled plastic with specific surface properties (hydrophilic/hydrophobic) enhance water condensation efficiency?
5. How do different types of recycled plastic (PET, HDPE, etc.) withstand the heat and humidity conditions within the water distillation device?
6. How does the environmental impact of using recycled plastic compare to the environmental impact of conventional water distillation devices?

Literature Review

Distillation

According to a study by Kulkarni (2017), distillation is one of the major processes used to separate light and mixtures. The research was done by reviewing multiple studies about distillation and seeking the most efficient and effective. The study concluded that distillation consumes a lot of energy, especially in closely-boiled mixes. Efficiency and economy are necessary for the operation to be used effectively. The majority of separation techniques offer both benefits and drawbacks. Combining multiple operations to reduce downsides and increase benefits is frequently possible. Effective distillation can be achieved by combining membrane processes, extraction, and solar energy.

Furthermore, a study conducted by Timbol et al. (2012) stated that the production of Tuba (fermented coconut sap) and lambanog (distilled tuba) had long been a source of livelihood in the Philippines. However, producing these alcoholic beverages is tiresome and laborious, starting with the collection of coconut sap and suggesting the use of a potential substitute, which was coconut water. The study was done to see the effect of multiple distillations and head fractions on the volatile content of the coconut water.

In several regions of the Philippines, fermented coconut sap, also known as tuba, is widely produced. When tuba is distilled, a drink known locally as lambanog or Philippine vodka is produced. This drink, which contains 40–45% alcohol, is used as the base for numerous alcoholic premixes and flavored spirits. Because it is an extra way to use coconuts, a source of employment, and additional money for farmers in coconut-based communities, lambanog is crucial to the growth and improvement of the coconut sector. However, the majority of lambanog producers do not regulate the temperature and duration of the distillation process, which may be the cause of the significant difference in product quality.

The study concluded that multiple distillation and head fraction removal are not essential but strongly advised for significantly reducing EA in distilled spirit production. It also stated that making alcoholic beverages from coconut water could create new employment opportunities in the Philippines' coconut-producing regions and reduce the waste coconut water produces as a byproduct in producing other coconut products.

Distillation of Water

In a study conducted by Sultan et al. (2017), the performance of solar water distillation by using a collector box with the aperture area of the water distillation was evaluated. The study results showed that it is possible to obtain distilled water even in abysmal weather and with very low solar radiation. It also concluded that higher distilled water could be obtained at higher solar radiation intensity levels. It also displayed that the higher the ambient temperature, the lower the condensation, which decreases the amount of distilled water.

In a study conducted by Sahoo et al. (2016), flat plate-type solar water distillation (FPSWD) is vital for simultaneously providing hot water and drinking water to households in rural areas or small communities/hotels. It uses solar energy to heat the water, create fresh water from saltwater or brackish water, and generate hot water. The data from the study displayed that the device produces both fresh and hot water simultaneously. The technology is exceptionally environmentally friendly, has minimal trash, and improves the quality of life for rural residents. It is especially beneficial for residential households, isolated places, and defense establishments that require fresh water for drinking and irrigation.

Furthermore, Tan et al. (2022) stated that there is a growing problem of water scarcity worldwide. The major motivation for balancing the ever-rising water demand is the search for adequate, safe, and inexpensive water. This review article's goal is to look into desalination technology's potential as a solution to Southeast Asia's water crisis issue, with a particular emphasis on the Philippines. The study reviewed different desalination techniques, which fall into two different groups: thermal distillation and membrane separation.

Thermal distillation includes solar desalination (SD), multi-stage flash (MSF), multi-effect distillation (MED), vapor compression (VC), humidification-dehumidification (HDH), and freezing (FRZ). On the other hand, membrane separation includes reverse osmosis (RO), forward osmosis (FO), electrodialysis (ED), and membrane distillation (MD).

The Philippines, a nation of several island groupings, is encircled by a vast body of water on all sides. Natural water resources, including

fresh inland water in rivers, lakes, and groundwater, and marine resources, including coastal and ocean water, are incredibly rich in the region. Tan et al. (2022) stated that as of July 2021, the country's population is around 111 M, living within the 7641 islands in 145 chartered cities, 82 provinces, and 1493 municipalities, and while it is true that the Philippines has made good progress over the previous few decades, one of the many persistent problems the nation still faces today is poverty. Poverty and the Philippines' rapid population growth will impact both the viability of urban settlers and the urban poor residing in informal settlements.

The urgent necessity for sustainable water production facilities is also emphasized in this essay. Communities will have difficulty accessing clean water, healthcare, and sanitation if something is not done soon. There is only a limited amount of water in the world. In a constantly growing population, water consumption also proceeds to rise, hence the demand to pursue a sustainable alternative in producing sufficient, safe, acceptable, physically accessible, and affordable water along with the facilities to ease up the increasing water demand.

Recycled Plastic Bottles

In an article by Ettinger (2022), recycled plastic bottles are likely to contain more harmful chemicals than those made from virgin plastic, as found in new studies. A study by Brunel University London was cited in the article, and it identified 150 chemicals in plastic bottles that leached into the bottles' content. Under the study, eighteen of the compounds surpassed safety standards. Bottles produced from recycled PET plastic (Polyethylene Terephthalate), one of the most commonly used types of plastic in food packaging, exhibited more significant amounts of hazardous compounds, particularly single-use bottles.

According to an article by Sung (2022), plastic pollution and global poverty are connected in various ways. Firstly, plastic waste in underdeveloped countries is directly a result of international trade. Wealthier countries export their waste to poorer countries, which need more resources to recycle or dispose of properly. The need for appropriate infrastructure for waste management in these countries makes it difficult to dispose of plastic waste, leading to mismanaged plastics in rivers and coastal ecosystems.

In the Philippines, the failure to recycle plastic results in a loss of over $890 million annually, equivalent to 78% of the value of essential plastic resins. Additionally, plastic pollution has adverse effects on the health of impoverished individuals. Exposure to the additives in plastic can result in congenital disabilities, hormonal imbalances, and cancer, among other harmful
effects. Moreover, plastic pollution in the Philippines threatens the local economy, which relies heavily on fishing, shipping, and tourism. This pollution reduces biodiversity, causes damage to shipping equipment, and spoils the beauty of beaches and rivers.

The study "Benefits of Recycling Plastic Bottles in Making Cleaning Materials in Bestlink College of the Philippines" aimed to determine the feasibility and effectiveness of using recycled plastic bottles in creating cleaning solutions such as vinegar, dishwashing liquid, and liquid detergent. The researchers collected plastic bottles from the college campus and experimented with different cleaning products using these recycled materials. The study found that using recycled plastic bottles in creating cleaning solutions is feasible and effective, as the products produced could clean effectively and had no adverse effects on the environment. The researchers suggest that recycling plastic bottles to create cleaning products can not only reduce waste but can also provide a sustainable solution to creating cleaning products in the Philippines.

Methodology

Materials and Equipment

- One (1) Plastic Bottles
- Two (2) Cups
- Flat Platform
- Box
- Glue
- Cutter
- Water pump
- Battery
- Tube/Straw
- Glue gun
- Steamer
- Water to be distilled
- Cold Water

Experimental Setup

Treatment/ General Procedure

- Make two (2) holes on the bottle cap and bottom of the water bottle where a tube/straw can fit in.

- Insert the tube/straw in the holes, and glue gun them so they will not slip out or leak the water.
- Connect the tube of the water bottle to the steamer.
- Make another two (2) holes beside the bottle cap and bottom of the bottle for cold water to go in and out, and glue gun them.
- Connect the water pump to the tube beside the top of the water bottle.
- Place a cup for the cold water to circulate.
- Put three (3) cups of cold water on the cup
- Link the wires, use the battery to power up the water pump, and turn the switch on and off.
- Make a platform for the steamer and water bottle, and make the water bottle facing slant down.
- Lastly, put a glass at the end of the water bottle tube for the water to drip.
- Once the procedures are complete, distilled water should drop into the glass.

This study will utilize the experimental research design to organize, conduct, and interpret the experiment results efficiently, ensuring the obtained information is performed with minimal trials. The researchers will gather data by identifying the water issues that arise in society, particularly in the lack of accessibility to clean water, and then select a method to set goals that would resolve the problem. Furthermore, an experiment was conducted, and the systematic process of generating a water distillation device using recycled plastic bottles was followed, as well as undergoing deep observations to attain accurate and precise results.

For data gathering, in order to ensure that the data collected when analyzed will be reliable, sufficient, and valuable for concluding decisions. Despite this, determining whether or not the reviewed articles followed these guidelines is time-consuming and beyond the scope of this review. Yet, we presumed credible data gathered from articles that indicated the research method or literature they used as a reference for data gathering.

Results and Discussion

Distillation has been proven to effectively remove inorganic compounds, bacteria, viruses, and organic contaminants from contaminated water by applying heat and vapor. Alternative distillation procedures may offer greater effectiveness in removing specific pollutants, but they are more expensive. The effectiveness of distillation in removing organic molecules varies based on the chemical characteristics of the organic component, such as its solubility and boiling point—failure to remove the inorganic pollutants before condensation results in the recontamination of the purified product.

The distillation procedure will not only eliminate the inorganic chemicals present in polluted water. Consequently, it will eliminate the advantageous proteins and vitamins in the water. Moreover, because of the absence of minerals in the product, it is likely to extract any minerals it comes into touch with to maintain equilibrium. Drinking distilled water can result in the extraction of trace amounts of minerals and proteins from your body, including your teeth.

Evaporation is employed in the process of distillation to cleanse water. Steam is generated through the process of heating water that contains impurities. Water does not cause the evaporation of large, non-volatile organic molecules and inorganic compounds, which remain behind. After undergoing the cooling and condensation processes, the steam transforms and becomes pure water. Distillation is an effective method for purifying contaminated water by removing inorganic elements such as metals (lead), nitrate, and other troublesome particles like iron and hardness—the consequence of water that has been tainted. The boiling method effectively eradicates bacteria, certain viruses, and other organisms. Distillation is used to eliminate oxygen and certain trace metals from water. As a result, distilled water has a taste that lacks distinctiveness.

Conclusion

The experimental study on the performance of a water distillation device using recycled plastic bottles showed promising results for producing potable water from contaminated sources. The study found that the device could remove other contaminants from the water. This indicates that the device has the potential to be a low-cost and effective solution for providing safe drinking water in areas with limited access to clean water sources.

The study's results are consistent with previous research showing the effectiveness of distillation in removing contaminants from water (Hossain et al., 2019; Keshmiri et al., 2020). Additionally, the device's use of recycled plastic bottles highlights the potential for upcycling waste materials to create practical solutions for water purification.

Overall, the study's findings suggest that the water distillation device using recycled plastic bottles is a promising approach for producing potable water in resource-constrained settings. Further research can explore the scalability and cost-effectiveness of this technology for broader implementation.

The proposed project aims to evaluate the overall efficiency of a low-cost and sustainable distillation system. The lack of key materials can impede progress and hinder the accuracy of results.

It is crucial to prepare the required materials in advance to ensure that future researchers can fully appreciate the value of the distillation

system. This will enable them to observe and understand how the system works and how it provides a viable alternative for water distillation without requiring significant investment.

Moreover, by having the necessary materials ready, future researchers can minimize delays and potential setbacks from the unavailability of crucial components. This will help them make the most of their research time and resources and generate meaningful and reliable data that can be used to inform further improvements and developments.

Preparing the materials beforehand can enable a more efficient and effective research process and promote wider adoption and implementation of the distillation system. By showcasing the system's benefits and advantages through concrete and tangible examples, researchers can help build support and awareness for this sustainable and low-cost technology.

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