Portable Mobile Water Purifier Design for Natural Disaster

Fang-Lin Chao and Bo-Sen Tseng

***Abstract*—The turbidity water in the disaster area is unusable and requires long periods of precipitation and filtration. A simple portable water filter is designed to solve the problem of drinking water for the victims. The method to solve the problem: a 2-in-1 motor powered by a DC battery provided extracted and pressurized on turbid rainwater. We choose the suitable filters set to reduce costs. The Prototyping model made by 3D printing used to verify the user's requirement. Both piggyback and handheld are suitable for rescuer's body condition. The result shows the turbid water can be continuously extracted and released to the drinking water of acceptable quality during the pressurization process. We achieved a portable water purifier which improved the water quality and provided a short-term drinking water supply. It can place in local community office during the disaster.**

***Index Terms*—Water purifier, product design, portable, disaster.**

I. INTRODUCTION

Water is an essential part of life, accounting for about 70% of the human body [1]. If people do not drink water for more than 48 hours, they will die, so water is indispensable. The typhoon is a common natural disaster in Taiwan, although it brings rainfall; but the flash floods also cause turbid water in the disaster area. Besides, the typhoon may also be powered off, and the general pressurized water filter cannot operate. Even after the windstorm, the turbidity of the raw water at the tap water level is also high, and it is necessary to improve the short-term and appropriate drinking water in the disaster area.

After the windstorm in 2015, the turbidity of the raw water soared, and the people rushed to buy water after the disaster. The Taipei Water Supply Division said that Typhoon Sudile made the water turbidity hit a record high, and the turbidity of the Xindian River slid to 39,300 degrees, causing households to use water and yellow. The short-term effluent water quality is not good, the water also contains more micro-organisms, and resident's drinking water with impurities may cause gastroenteritis. During this period, the water purification is difficult to have, and the amount of disinfectant used in the water plant will also increase.

Recently, many people killed in a landslide in the Philippines following typhoon Mangkhut [2]. People living at the village in Naga had evacuated. Heavy rains saturated the soil of a slope above the cluster of houses, causing it to give way. More than 20 to 25 homes have buried. Many injured villagers rescued from the massive mound of earth and debris.

Frequent typhoons are proving a challenge for utilities in the Philippines to ensure consistent water supply. Almost a quarter of the country's population of 92 million still does not have access to potable water on a sustained basis.

The traditional method of purifying water is first to settle the sediment, but it takes a long time. Alum powder can also be used to aid in the precipitation of impurities. It is also filtered through activated carbon to remove odor from water. Activated carbon has a large surface area and a large number of pore structures so that it can absorb some heavy metal particles. Although it can solve some problems; but the traditional clean water, the victims, need to be boiled before they can drink. It is still inconvenient for disaster-stricken areas.

II. SAMPLE COLLECTION OF TURBID WATER

A. *Sample Collection*

After the heavy rain, we took samples of turbid water (5 in total) to the river in the suburb of Wufeng Township, Taichung. The sample water was placed in a PET bottle. We can see that there are many tiny particles in the water and the turbidity is very high. After the heavy rain, many small particles were washed out. Because it is not easy to sink by gravity, it does not become noticeable after one day of placement. Secondly, we use alum powder, which causes most tiny particles to sink and improves the turbidity of the water. But the taste of water has also changed.

B. *Use Gravity to Filter*

We tried to purify the turbid water with gravity. First, the turbid water placed in the upper bucket, and a channel provided between the upper and lower buckets. The water in above container drive by gravity and flow downward. We found that the filtration works well, but the speed is relatively slow. Therefore, we need to find other ways which provide stable drinking water.

III. DESIGN PROPOSAL

The design goal is to provide relatively safe drinking water within a limited budget. The poor conditions in the disaster area, there is often no tool to boil water, so we hope to propose s design which drinks directly after filtration.

A. *Power Consideration*

The source of water is not a problem, because tap water usually stored before the typhoon comes, and rainwater is also available. Since the power line is affected after the windstorm, there is often a blackout. We hope to use mobile power to provide short-term drainage. The battery charging

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Fang-Lin Chao and Bo-Sen Tseng are with the Department of Industrial Design, Chaoyang University of Technology, Taichung, 436, Taiwan (e-mail: flin@cyut.edu.tw).

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before the storm supplies the electrical power.

Therefore, it is provided with an additional action power source to provide a water purification device for drinking. Such a water filtration device can operate independently after using the portable DC battery source.

B. Design Goal

The facility has to transport to a suburb or a specific location in the disaster area, so we want to design it to be portable. This requirement means that the weight of the product should be within the range that people can bear. In the previous considerations: the price also needs to be controlled within the acceptable range of the public, and it is easy to promote and use. The product can be easily carried, using existing filtration technology, and can independently produce water for drinking. Additional movable power can apply in the disaster area. The overall design is portable and back-type, which is convenient for users to transport and carry.

IV. FILTRATION TECHNOLOGY

A. Available Approach

Case 1: Straw type, the advantage is easy to carry, easy to use; but cannot filter heavy metals and viruses. Among them, the activated carbon will gradually decrease with the increase of the attachment and the dissolution of iodine (Fig. 1). Therefore, the number of uses is limited. In [3], the water passed through the unit was composed of 80% dechlorinated (passage through activated charcoal Tucson City tapwater and 20% primary sewage. "The units exceeded the requirements for highly protective water treatment." None of the challenge organisms detected in the water treated by the LifeStraw Family units. The Vestegard LifeStraw units exceeded the criteria for "High Protective" Microbial water purifiers.

Fig. 1. Life Straw products use a hollow fiber membrane.

Case 2: Filter jug, commonly used in household tea kettles (Fig. 2), the capacity is usually 1.7L; the flow rate is 0.28-0.3 L / min. The advantages are plug-in, chlorine removal, and some heavy metals. However, the frequency of filter replacement is high, and it is not sterilizable.

The advantage of the portable water filter bottle is that it penetrates through the activated carbon filter core and the ceramic filter core after being pressurized by air pumping; it is convenient to carry and does not require a power source. Water filtered by applying pressure manually [4] at a slow rate. The water purification capacity is small.

Case 3: Tzu Chi's "Q Water"

Taiwan’s Tzu Chi merits is an internationally renowned humanitarian organization. Tzu Chi's "Q Water" emergency water purifier can make five tons of drinking water per day. In 2012, the Water Resources Department of Taiwan commissioned the ITRI to research and solved the problem of water purification in the disaster area after the typhoon. The machine is fast assembly providing high-quality drinking water [5]. When the typhoon Haiyan invaded, the Tzu Chi volunteers contacted the ITRI; the water purifier could be used by 2,000 people in a harsh environment (Fig. 3). The unit is installed in a frame for easy mechanical transport. When fixed in the disaster area, use a gasoline-electric generator to provide motor power to extract rainwater for filtration. The filter screen includes activated carbon, a membrane, and a filter that filters the bacterial molecules.

Fig. 2. Filter jug.

Fig. 3. Tzu Chi designed Q Water – mobile water purification equipment. The concentrate water plant, combined filtration integrated into the container. With the power generator, the system achieves high-quality purification up to fifteen tons of water in a day.

Case 4: hollow fiber membrane

The hollow fiber membrane, also known as the ultrafiltration membrane, is shaped like a group of tiny straws (Fig. 4). The thin tubular wire has a smaller pore size than bacteria, so it can remove most bacteria in the water and even filter mold spores. The disadvantage is that it cannot remove odor, chlorine, pesticides, heavy metals or organic chemicals in the water.

Asymmetric PVDF fiber membranes, "with an inner diameter of 0.05–0.06 cm, an outer diameter of 0.07–0.08 cm, and a dense layer (≈ 3 μm in thickness) on the inner fiber wall", have been tested for the removal of concentrations [6]. The newly developed membranes consist of a functional selective polyamide layer formed by highly reproducible interfacial polymerization on a polyethersulfone (PES) hollow fiber. They employed dual-layer extrusion technology to design and effectively control the phase inversion during membrane formation [7].

Fig. 4. Hollow fiber membrane [7].

Case 5: Reverse osmosis RO membrane

On one side of the semipermeable membrane, a pressure higher than the osmotic pressure is applied to pores of the membrane (pore size is about 0.1 nm). It can filter bacteria, viruses, chemical pollutants, and heavy metals, and is the most effective filtration method at present. It is suitable for areas with poor quality but at a higher cost. Because it is pure water after filtration, it is pure and safe. A summary of the significant advances in RO performance and mechanism modeling presented. Moreover, the two crucial issues of RO brine discharge and energy costs and recovery methods discussed in [8]. However, the disadvantage is that it requires 24 hours of power supply, and the wastewater generated in the process reaches 75%, resulting in a waste of water resources.

B. *Filter Technology Selection*

This design uses the most widely used raw-grade RO reverse osmosis filter, and the water can be drunk through this filtration step. To adequately reduce the weight and cost requirements, we have limited the amount of drinking, so we chose two filters.

To meet the price requirements, we have modified from the household water filter. The commonly used household water filter uses four screens with a maximum flow rate of 5/min. The four-channel hollow fiber membranes have the following functions [9]:

- first filter: 5 micron PP fiber filter
- second filter: CTO activated carbon filter
- third filter: 1 micron PP fiber filter
- fourth channel: UF hollow fiber membrane filter + silver added activated carbon

In these four filters, it can effectively remove sediment, rust, lead removal, bacteria filtration, active adsorption of odor in water. Which one should be used first in the disaster area? The conditions that need to be selected are:

- What are the main impurities of turbid water produced in heavy rain?
- What is the most effective filtration method for the composition of rainwater?
- The filter life is about nine months. Is the green quality deterioration during the standby period?

The two filter elements will be complemented to simplify the design and meet the requirements of a lightweight as shown in the above, the composite first filter element used for coarse filtration of stream water. The second filter element is the RO reverse osmosis filter for disaster relief use.

V. PROPOSED FILTER MECHANISM

A. *Motor Selection*

Rainwater in the disaster area is often placed in the water storage tank and needs to transfer into the water filter module. Since the turbid water does not exist in the existing pipeline, we need to use a pumping motor to send the water into the water filter. The home RO reverse osmosis motor has only a pressurizing function and is not able to pump water. We used a two-in-one motor that can simultaneously pump and pressurize, which is tailored by the motor manufacturer. An AC outlet at home directly charges the motor powered by a DC battery.

The battery is expected to be designed and installed in the water filtration equipment; later, considering the volume is large, we utilized an external mobile power supply. The size of the custom filter will reduce. There is an opportunity to placed power supply inside the main chassis and integrated into one (Fig. 5, 6).

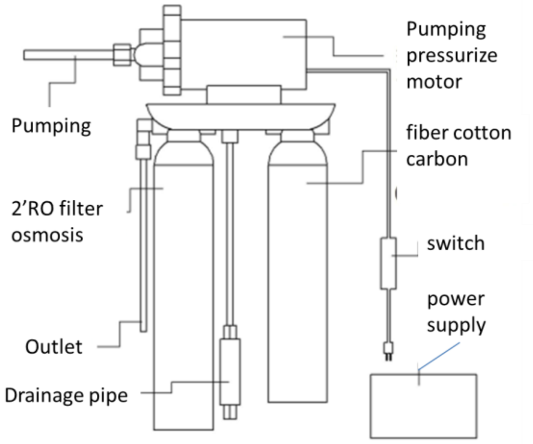

Fig. 5. Pump (top) and pressurize and filter mechanism.

(a) (b)

Fig. 6. System chassis design: (a) product form (b) internal placement by 3D computer modeling.

B. *System Chassis and Prototyping*

The Prototyping model made with 3D printing equipment. With the inner stainless frame, the pumper and filter pack installed successfully. Fig. 7 demonstrates the portable water purifier transport by a rescuer during a disaster. Both piggyback and handheld are suitable for rescuer's body condition. Fig. 8 presents the continuous operation of the water supply in the local community. The traditional precipitation purifying applied firstly with an ordinary bucket.

A small amount of Alum powder can also be used to accelerate precipitation of impurities. They can bring it to the village's office for further purifying with electric pressurize.

Fig. 7. Prototyping and user posture: Piggyback or handheld.

Fig. 8. Portable purifier utilized in disaster situation which demonstrates the continuous operation.

C. *Water Quality Test*

"TDS stands for total dissolved solids and represents the total concentration of dissolved substances in water" [10], it is made up of inorganic salts, as well as a small amount of organic matter." Minerals can originate from both natural and human activities. Agricultural and urban runoff carried excess minerals into water sources. The measured results (Fig. 9, 10) indicate TDS level of entry water is 204 ppm, and that of the filtered water is 25 ppm (within ideal drinking level).

Fig. 9. Water quality test with the sample from the outlet, the TDS is 25 ppm.

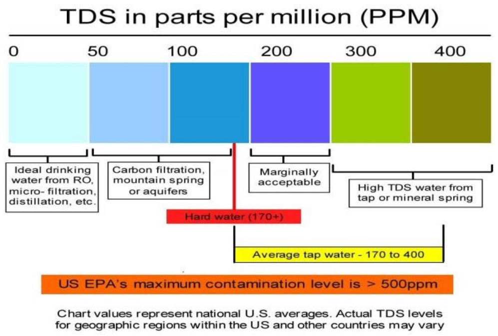

Fig. 10. Digital TDS, EC & Temperature Meter classify the safety range of water [11].

VI. CONCLUSION

The portable water purifier placed in a local office can be a helpful rescuer. The turbidity of the raw water at the tap water level is high; this design improved the water quality and provided a short-term and appropriate drinking water in the disaster area. The 2-in-1 motor powered by a DC battery and can be directly charged by an AC outlet when in use at home. The motor provided extracted and pressurized on rainwater through the filters set. The Prototyping model made with 3D printing with the inner stainless frame. Both piggyback and handheld are suitable for rescuer's body condition. The overall functional design was successful.

In the future, it is possible to make a small filter core and a pressurized pump motor, and the overall size can reduce. In mass production, it is also necessary to think about lightweight and change the design and configuration. The external power can be replaced with an embedded battery under the condition and power supply permit to minimize the volume.

CONFLICT OF INTEREST

The authors declare no conflict of interest.

AUTHOR CONTRIBUTIONS

Chao conducted the research; Tseng designed the system; all authors had approved the final version.

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REFERENCES

[1] F. Hansen and J. Bent, "Total body water in children," *Pediatrics*, vol. 7, no. 3, pp. 321-327, 1951.

[2] Spotlight. [Online]. Available: https://www.waterworld.com/articles/wwi/print/volume-26/issue-6/regional-spotlight/philippines-water.html

[3] N. Jaime and C. Gerba, "Assessment of the LifeStraw family unit using the world health organization guidelines for evaluating household water treatment options: Health-based targets and performance specifications," M.S. thesis, University of Arizona, 2011.

[4] Newly carried mud water filter directly drink - People's News. [Online]. Available: https://www.youtube.com/watch?v=6JBlEFQG9zE

[5] S. Hang *et al.*, "Elution is a critical step for human adenovirus 40 recovery from tap and surface water by crossflow ultrafiltration," *Applied and Environmental Microbiology*, AEM-00870, 2016.

[6] K. Z. Jian and P. N. Pintauro, "Asymmetric PVDF hollow-fiber membranes for organic/water pervaporation separations," *Journal of Membrane Science*, vol. 135.1, pp. 41-53, 1997.

[7] S. Panu and T.-S. Chung, "High-performance thin-film composite forward osmosis hollow fiber membranes with a macrovoid-free and highly porous structure for sustainable water production," *Environmental Science & Technology*, vol. 46.13, pp. 7358-7365, 2012.

[8] M. Lilian and G. M. Ayoub, "Reverse osmosis technology for water treatment: State of the art review," *Desalination*, vol. 267.1, pp. 1-8, 2011.

[9] Pu-de Clean Water. [Online]. Available: http://buderwater.com/

[10] Safewater. [Online]. Available: https://www.safewater.org/fact-sheets-1/2017/1/23/tds-and-ph

[11] Digital-Aid. [Online]. Available: https://www.amazon.com/Digital-Aid-Professional-TDS-Temperature

Fang-Lin Chao received the Ph.D. degree in electrical engineering from National Taiwan University. He joined the Electronic Research and Service Organization, Industrial Technology Research Institute, Hsinchu, Taiwan, in 1982. In 1994, he was an associate professor with Da-Yeh University. Since September 2004, he joins Chaoyang University of Technology. His research interests include eco-design and design integration.

Bo-Sen Tseng graduated from the Department of Industrial Design at Chaoyang University of Technology, Taiwan in 2017. He was a design assistant in the R&D department of Pu-de Clean Water. His research interests include machine-design, CAD and product development.