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Research paper

A new approach to production of mass suppliable water purifier

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Abstract

Potable water can be produced from untreated water sources using variety of water purification techniques. In a critical situation such as flood, some of the technique such as heating the water might not be possible especially when the water level had increased to an alarming rate. The flood victims might be threaten by water-borne diseases which make them to suffer from illness, and in a worst case might lead to death. The development of low cost and simple water purifier without the use of fuel energy is very helpful in this situation. A simple sand and charcoal filter such as PAK filter together with solar disinfection (SODIS) method has been proven effective in killing the micro-organism and blocks the chemical contaminants which are dangerous from being consume by the flood victims. This paper will introduced some of the methods such as water filtration technique and sterilization that can be practiced by the flood victims in order for them to survive during flood.

Keywords: *Water Purifier; Flood Management; Water Technology.*

1. Introduction

Flood is a natural disaster which happened almost every year in Malaysia. It is often associated with the change of climate and poor drainage system despite of heavy rain which falls continuously for a long period of time. The average rainfall for all states in Malaysia is approximately 2,500 mm a year, making it the one of the countries with the heaviest rainfall in the world [4]. Heavy seasonal rain and strong wind affected most parts of Malaysia starting in mid-December 2014 and continuing in to the first weeks of January. The rain caused severe flooding in the East Coast of Peninsular Malaysia – the states of Terengganu, Pahang, and Kelantan. In addition to the three most affected states, four other states in Peninsular Malaysia (Perak, Johor, Selangor and Perlis states) and one state in East Malaysia (Sabah) also experienced floods due to the heavy rainfalls [2].

The need for clean water during flood has become a serious issue as it will affect the daily routine and health of society. Lack access to safe water due to the broken water piping system and failure of the water treatment plant to operate normally has forced the people to rely on rainwater as a primary source of clean water. People suffer from illnesses caused by water-borne bacteria in the water that they consumed, thus worsen the condition that they are already in.

One of the common method usually used to purify the water is by boiling the water. Although boiling water is the most effective method of purification, fuel shortages or lack of a heat source especially during the flood might mean that this is not always possible. Furthermore, boiling the untreated water does not guaranteed that it is safe to drink as it may contained chemical contaminants that have been associated with a broad array of adverse health effects, including cancer, cardiovascular disease, neurological disease, and miscarriage.

Impurities in water can be removed through a chemical process and/or biological process using a water filter. There are various kind of water filtration technologies which can be apply during the flood. As for example, a charcoal bucket filter designed by J. Kearns can purify 1 liter of water using 0.1~1g of charcoal. [3] Other filtration system as proposed by El-Harbawi et al. proves that featuring a heating element using the electrical component as part of the portable water filter would help to heat the water thus killing all the bacteria found in that water [5].

Some aspects must be considered when building a water purification system on site since it is harder for the victims to gather all the materials needed and to acquire the energy sources. Alternatively, sterilization process can be consider as another method to deactivate the bacteria in such situation when heating of water is impractical, since it can be done by using a renewable solar energy. Therefore, it is required to develop certain water purification system with high reliability especially in terms of sterilization. By converging low cost filtration technology and sterilization technology, a more reliable and versatile water purification system can be build.

2. Experimental design

The water purifier system is made up of two parts, namely the water filter and the water sterilizer. Most of the materials needed to build up the water filter can be obtained easily from the nature such as sand, pea-size stone, charcoal and a fairly clean water source. Meanwhile for the water sterilization part, the process which helps to disinfect the water will be further explained in this section.

2.1. PET assembly kit (PAK) filter

- PET (polyethylene terephthalate) 1.5L bottle

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The bottle will be used as the container for the water filter since it is relatively easy to find it especially at the landfill. Two PET bottles with a volume of 1.5L will be used to build the filter, in which it will be tied to a poll or a tree with one positioned at top and the other at bottom. The top bottle will act as the input source for the water and the output is the filtered water which flow out from the bottle at the bottom. These two bottles is connected to each other by the hose or tubing that has been glued to the cap of both bottles.

- Charcoal

Charcoal consists of elemental carbon in its graphite configuration. Carbon has been used for water purification for centuries, possibly dating back as far as ancient Egypt and India [3]. Carbon filters are effective for removing chlorine, mercury, iodine, and some inorganic compounds as well as many problematic organic contaminants. As a general rule, carbon will bind non-polar materials while polar materials will tend to remain in aqueous solution. Most pesticides are organic and strongly non-polar and thus should display an affinity for adsorption onto the carbon surface [3]. The purpose of crushing the charcoal is to provide a large surface area thus increasing the effectiveness of the filtration process. The crushed charcoal must be clean several times with water as to prevent the debris that will certainly causes clogged to the system.

- Sand

Sand effectively removes turbidity and micro-organisms through various biological, physical and chemical processes by passing the water slowly through the filter [1]. The selection of sand texture is important as it will affect the filtration of water. Fine sand normally takes longer time in water filtration process compared to the coarse-textured sand. However, fine sand can still be used as an acceptable medium for filter because it helps to block micro-organisms that cannot fit through the pore spaces between sand grains.

- Pea-size stones

The pea gravel serves two purposes in the water filter medium. First, it provides support to the layers of charcoal and sand in the bottle. Second, the pea stones will prevent the sand from entering the water hose, which will cause the water flow suspended. As any other medium, the pea gravel must be washed thoroughly to get rid of silt from accumulate in the water hose.



Fig. 1: Top Bottle Serves as the Input for the Water Sample.



Fig. 2: Filtered Water Flow through the Outlet.

PAK filter must not be used alone for heavily contaminated water. It can be applied as a complimentary method for a more reliable method such as solar disinfection (SODIS), since PAK filter does not remove micro-organism in water completely. The filter performance should be depends on the situation. The filter medium should be replaced time to time under good maintenance.

2.2. Water sterilization using solar disinfection (SODIS) mmethod

Solar Water Disinfection (SODIS) is a sterilization method which make use of renewable solar energy to destroy pathogenic micro-organisms in untreated water.[6] This method is very simple and easy to understand since the people only need to fill the water into a bottle and exposed it to direct sunlight for a certain period of time. Pathogenic microorganisms are vulnerable to two effects of the sunlight: radiation in the spectrum of UV-A light (wavelength 320-400nm) and heat (increased water temperature) [6].
The effectiveness of SODIS is strongly dependant on the weather, which means a sunny day is preferable for this process. Intense sunlight and high temperature is the best condition to conduct the activity as it will reduce the time required to sterilize the water and also improves the water quality.



Fig. 3: A Bottle Filled with Water Sample Is Sterilized Using.

2.3. SODIS method

For this purpose, the polyethylene terephthalate (PET) bottle will be used instead of polyvinylchloride (PVC) bottle. This is because PET particles would not melt due to higher melting point of PET. Plus, the PET bottle is chemically stable and transparent which make it the best container to be used for SODIS.[6] Usually the bottle which has been filled with water will be placed on the roof or any hard and reflecting surfaces such as wood and aluminum. This will ensure the UV-A light to bounce back as it hits a hard surface and to maintain high temperature within the bottle, thus increasing the efficiency of SODIS. It is important to make sure that there is no bubble formed in the bottle as this will cause the UV-A lights to scatter hence reducing the potential of solar energy to disinfect the water.

2.4. Water quality analysis

A proper water quality analysis may require long time and high cost facilities such as in laboratory test. In many cases, the water quality test must be able to be conducted on site, to be more specific, during the flood. The water quality test is primarily concern about the presence of micro-organisms in water. All living organisms use ATP (adenosine triphosphate) as energy source. For that reason, a portable ATP detector is the best solution for the expensive laboratory test since it estimates the amount of micro-organism by measuring amount of ATP in the water sample.
ATP stick is used together with the ATP detector. The ATP stick contains firefly luciferin which generates light when there is a reaction with ATP in water sample which indicates the presence of micro-organisms. The ATP detector will measure the light intensity emits by ATP stick that contained the water sample. The ATP reading will be appear in 10 seconds after the analysis. Nevertheless, the detector only gives estimation of energy but not the actual number of micro-organisms in that particular water sample.



Fig. 4: ATP Stick Is Used to Take Water Sample.



Fig. 5: Portable ATP Detector Shows the ATP Reading for the Water Sample.

3. Results and discussion

A field test for the water purifier system has been conducted in Shiheung City, Korea, July 6, 2015. The water sample is taken from sewer outlet which initially records an ATP reading of 2374. The first experiment was conducted by using only PAK filter that shows a significant reduction in ATP reading to 354, which is in about 85.1% has been reduced from its initial reading. This proves that most of the micro-organisms has been removed out of the water sample by using the water filter.

The next test is performed using the sterilization method alone, often known as solar water disinfection (SODIS). The ATP reading is reduced to 144 when the bottle containing the water sample was left exposed under the sunlight on sunny day for 2.5 hours with a reduction percentage of 93.9%. The SODIS seems much more effective in killing the micro-organism compared to the PAK filter.

However, SODIS does not involved the process of removing chemical contaminants which is harmful to the health of the consumer, whereas it can be done by using the PAK filter. A complementary process of filtration followed by sterilization using the PAK filter and SODIS methods for 2.5 hours in sunny condition has greatly improved the result to 13 which is about 99.5% of ATP has been reduced from the same water sample.

Table 1: The Result for Water Purification of Untreated Water Sample with Various Conditions

Treatment condition	ATP reading	% of reduction
Without Treatment	2374	-
PAK filtered	354	85.1%
SODIS (Sunny, 2.5 hrs)	144	93.9%
PAK filtered, then SODIS (Sunny, 2.5 hrs)	13	99.5%
SODIS (Sunny, 2.5 hrs + Cloudy 4.5 hrs)	71	97.0%
PAK filtered, then SODIS (Sunny, 2.5 hrs + Cloudy 4.5 hrs)	7	99.7%
SODIS (Sunny, 2.5 hrs + Cloudy 4.5 hrs) Followed by 3 days storing at room temperature	466	80.4%
PAK filtered, then SODIS (Sunny, 2.5 hrs + Cloudy 4.5 hrs) Followed by 3 days storing at room temperature	110	95.4%

The second test was carry out once again for the SODIS water sterilization technique with a longer time, and exposing to two different conditions of weather on the same day as shown in Table 1. The ATP reading decrease to 71 and the percentage of reduction is around 97.0%. The integration of PAK filter and SODIS, which made up the whole water purification system also yields a remarkable result when a longer time spend on water sterilization process. Thus it can be concluded that the longer the time water sterilization takes place, the better the result produced from the water purification process. Since the ATP reading is not completely reduced to 0, therefore the micro-organism will start to regrowth when the water sample was left for three days at room temperature, thus showing an increase to the ATP reading as shown in Table 1.

During the flood, it is a common situation when there is no sunlight for the whole day which might caused some water purifying process such as SODIS could not be done. It is almost impossible to sterilize the water using this method because it requires the sunlight to kill the micro-organisms using the UV-A rays and high temperature.

As for the PAK filter, only a fairly clean water is preferable to be treated because some micro-organisms, especially in a heavily contaminated water can pass through the sand and charcoal configuration of the filter. The combination of PAK filter and SODIS sterilization method is suitable for most water quality but still it has to consider about the weather which determines the effectiveness of the water purification system. Each water treatment method must satisfy all of the stated condition as shown in Table 2 so that it can produced a desired result.

Table 2: Method of Water Treatment that Best Works in Some Conditions

Condition	Method of water treatment
Fairly clean water source (e.g. rain water) required Existence of non-biological contaminants Less time consuming Daytime moving Sunny weather required	PAK filter
Longer day time required Non-biological contaminants are not big issue Sunny or Partially cloudy weather	SODIS
Most water quality cases	Combination of PAK filter + SODIS

4. Conclusion

Water purifier system which consist of PAK filter and solar disinfection (SODIS) sterilization can be useful in flood situation. Since water is one of the basic needs for life, thus there is an urgency to develop a low cost and portable water filter with the used of solar as the source of energy to sterilize the water. Generally, the combination of PAK filter and SODIS is recommended as methods to purify the water. The filtration process will help to eliminate the biological and chemical contaminants present in the water, which reduced the risk of water-borne diseases that might threaten thousands of lives during the flood.

The SODIS method has been proven as the best method to kill the micro-organisms due to its capability to decrease the number of ATP reading to an acceptable value. PAK filter can be an auxiliary method to SODIS, while sun light is not intense and it should not be applied alone for heavily contaminated water. Based on the results, there is a significant improvement of the water quality from the filtration and sterilization processes using the PAK filter and SODIS method that is complementary to each other.

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