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DESIGN OF A PORTABLE DUAL PURPOSES WATER FILTER SYSTEM

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Abstract

The quality of water flows through the taps for drinking is gaining attention from public. There are still bacteria and minerals that exist in the tap water that can damage human's health. Hence, the objective of this work is to develop a personal, portable dual purposes handy water filter to provide an easier way to get safe, clean and healthy drinking water for human wherever they go. The designed system can be used in filtering water taken from public drinking fountains or other public water sources. The work is started by conducting a preliminary research. First, the constraints and criteria of the problem are identified and discussed in detail. Analysis of the mechanism performance is conducted as inputs for calculation, modelling, testing and other designing methods. Finally, several possible solutions of the problems are generated.

Keywords: Water quality, Dual proposes water filter, Testing and analysis.

1. Introduction

Water is the main component in our body. Human being body consists mainly of water (on average about 70%). Human being liver, for example, is about 90% water, brain 85%, blood 83% and even the bones 35%. Therefore, consuming enough water in our daily life is a must to stay hydrated and healthy.

According to the World Health Organization (WHO) in 2007, over 1 billion people lack access to safe water supplies. This has led to widespread microbial con-

Abbreviations

COD	Chemical oxygen demand
DOE	Department of environment
NTU	Nephelometric turbidity units
PAHs	Polycyclic aromatic hydrocarbon
PCBs	Poly chlorinated biphenyls
THM	Trihalomethanes
WHO	World Health Organisation

tamination of drinking water. Water-associated infectious diseases claim up to 3.2 million lives each year, approximately 6% of all deaths globally. The burden of disease from inadequate water, sanitation, and hygiene totals 1.8 million deaths and the loss of greater than 75 million healthy life years. It is well established that investments in safe drinking water and improved sanitation show a close correspondence with improvement in human health and economic productivity. Each person needs 20 to 50 litres of water free of harmful chemical and microbial contaminants each day for drinking and hygiene [1].

The quest for pure, abundant potable water is not a modern idea, as the beginning of recorded history confirm. The old treatment tells of the danger of 'bitter' water and of a desperate search for life-sustaining, pure water. Sanskirt and Greek writings dating back 6,000 years describe early water treatment [2].

Water in Malaysia is treated in two stages. The first stage is the wastewater treatment process. This process is specifically for the usage of water from the toilet/human discharge which can be called wastewater. The water is treated in the wastewater treatment process before letting the water into the stream. Water that is used in the industry such as product washing or reaction mediums is also considered as wastewater but the factory that responsible producing the wastewater have to clean the water first before letting the water flow in the stream. The second process is for water from the river/lake. The water from the river is treated in the water treatment plant to free the water from colloids/suspended solids and dangerous microorganisms. However, some part of the industry do not follow the regulation and standards provided by Department of Environment (DOE) and thus discharging dangerous/hazardous chemicals into the river and the plant is unable to filter them. The consequence of this is that the chemicals will pass through the treatment process and into the water supply tanks that supply the supposed 'cleaned' water to the public.

Tap water is the major supply of our drinking water but it is actually not safe to consume it regularly as it contains high level of chlorine, leads, fine microscopic which causes cloudiness, bad taste and smell, and also micro bacteria. The used water is being treated to be reused which means large amount of chlorine is used in order to cleanse it. Tap water that is consumed everyday is not safe as it contains high level of chlorine, leads, fine microscopic which causes cloudiness, bad taste and smell, and also micro bacteria. However, this matter can be encountered by first, filter the water and after that boil it.

A water filter is a device which removes impurities from water by means of a fine physical barrier, chemical process and/or biological process. Water filters have certainly come a long way in the past few years. Distillation is probably the oldest method of water purification. Water is first heated to boiling.

Filtration operates entirely on particle or droplet size (and, to some extent, shape), such that particles below a certain size will pass through the barrier, while larger particles are retained on or in the barrier for later removal [3].There are a number of tap water filtration systems available in the market, but not all of them are of good quality. The technology is greatly improved and the water produced by these filters is much safer and cleaner than ever before. However, recently it is hard to find a portable water filter where consumers can carry it anywhere and used it for more than one purpose. Hence, we have come out with a solution to design a portable water filter with extra feature, which is the heating element to boil the water. That means the filter can be use for cold and hot water. In terms of scientific point of view boiling would be able to kill all the germs and microorganism in the tap water. There are a few aspects that needed to be considered in the design process which are economical, convenient and user friendly.

Many types of portable water filters available, with varying degrees of effectiveness, can be used together with chemical purification. Portable water filters are usually small, portable and light (0.5-1.0 kg) and usually filter water by working a mechanical hand pump, although some use a siphon drip system to force water through while others are built right into water bottles.

There are several methods of water purification. The main ones are:

- Distillation,
- Ion exchange
- Reverse osmosis
- Microporous filtration
- Ultra-filtration
- Photo-oxidation

2. The Methodology

The methodology of the design is starting from selecting the materials, design the filter, testing the filter and the water quality and finally obtain the result. The portable water filter design consists three parts; the filter medium, the housing and the heater. Figure 1 shows the filter design stages.

2.1. Filter medium

The filter medium is a porous (or at the very least semipermeable) barrier placed across the flow of a suspension to hold back some or all of the suspended materials. If this barrier were to be very thin compared with the diameter of the smallest particle to be filtered (and perforated with even sized holes), then all the filtration would take place on the upstream surface of the medium. Any particle smaller than the pore diameter would be swept through the pores and any particle larger than that (assuming the particles to be rigid) would remain on the upstream surface [3]. The cylindrical hollow filter cartridge is having a combination of filter pads consists five layers; activated carbon, silica sand, zeolite, bioball, and mineral sand as shown in Fig. 2. Each layer has advantages and proposes of use as described below:

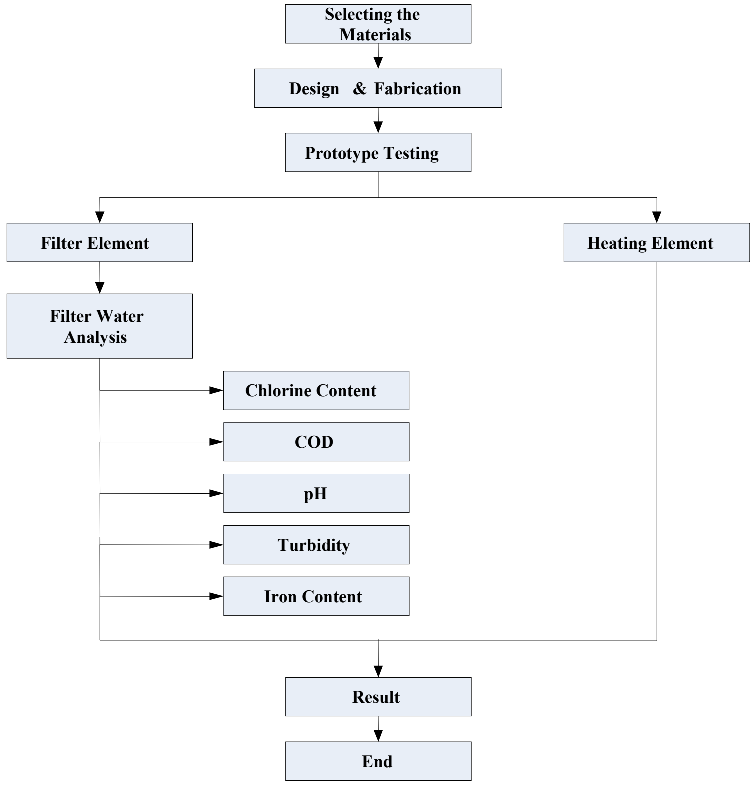

Fig. 1. Filter Design Stages.

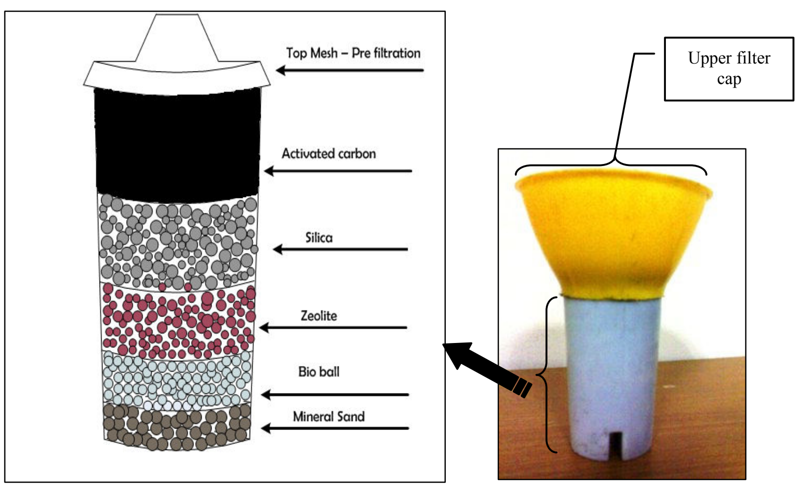

Fig. 2. Filter Cartridge and its Layers.

2.1.1. Activated carbon

Active carbon is unique and versatile adsorbents, and they are used extensively for a removal of undesirable odour, colour, taste, and other organic and inorganic impurities [4]. Activated carbon is a form of carbon that has been processed to make it extremely porous and thus to have a very large surface area available for adsorption or chemical reaction. Adsorption is a removal process where particles are bound to an adsorbent particle surface by either chemical or physical attraction. It is most effective in removing organic contaminants and other particles from water. Activated carbon also removes taste, odour and colour problems of the water. Most importantly, activated carbon filtration will remove chlorine from the water where chlorine is greatly used in water treatment as disinfectant. Other than that, activated carbon does remove some organic chemicals such as trihalomethanes (THM), pesticides, industrial solvents (halogenated hydrocarbons), polychlorinated biphenyls (PCBs), and polycyclic aromatic hydrocarbons (PAHs). Activated carbon is not suitable for removing suspended biological material. This can be done in an element that combines adsorption with biological activity [3].

2.1.2. Silica sand

Ceramic water filter is one of the types of water filter, commonly used in a household, which purify water by passing the water through pores in ceramic with the pressure of the tap water. In this way, the undesired materials found in water such as dirt, rust, clay materials and even pathogens are removed and the water is safe for drinking [5]. Silica sand (quartz) is pure crystalline sand, the most common mineral on the earth's surface. Silica sand has been used in water filtration systems for many years to put finishing touches on clean water. It removes the acidic components from the water, and thereby brings about a pH-balance of body fluids. Besides, it also removes toxic chemicals and other hazardous materials from water much more effectively and at lower cost.

2.1.3. Zeolites

Zeolites are micro porous crystalline solids with well-defined structures. Generally they contain silicon, aluminium and oxygen in their framework and cations, water and/or other molecules within their pores [6]. Zeolite crystal structures from highly porous, nanoscale “cages” that can filter and trap small molecules. Zeolite removes bacteria, viruses, heavy metals, detergents and harmful chemicals such as desolvate, phenol and agricultural chemicals. It also removes toxic ions such as nitrate, nitrite, mercury and arsenic-continuing ion from water.

2.1.4. Bio-Balls

Bio-Balls are compact polyethylene media designed for biological filtration. Bio-Balls are used to maximize flow of water and air, and to avoid retention of liquid. Bio-Balls are used inside pond filters to house bacteria, helping to keep water clear. Bio-Balls will form to any shape container and are hard so they will not compact. Bio-Balls are extremely easy to clean and will last forever.

2.1.5. Mineral sand

Mineral sands contain suites of minerals with high specific gravity known as 'heavy minerals', which include economically important minerals rich in titanium, zirconium and rare earths. Mineral sand is used in water filtration because it releases minerals to the water. Furthermore, it adjusts the water pH to mildly alkaline. Thus, healthy water can be obtained.

Figure 2 shows the filter cartridge and its pads layers. The filter cartridge includes an upper filter cap with water inlet adapted for fluid communication with a tap water supply. The upper filter cap is received inside an open top portion of the cartridge. The cartridge also includes a lower filter cap with a water outlet. The lower filter cap is received inside an open bottom portion of the cartridge.

2.2. Heating unit

Water heating is a thermodynamic process using an energy source to heat water above its initial temperature. Domestically, water is traditionally heated in vessels known as kettles, cauldrons, pots or coppers. The aspirations of the dual purpose handy water filter were to provide a method of heating water in a small time frame within a domestic environment using electricity. Electric heating is any process in which electrical energy is converted to heat. An electric heater is an electrical appliance that converts electrical energy into heat. The heating element inside every electric heater is simply an electrical resistor, and works on the principle of Joule heating: an electric current through a resistor converts electrical energy into heat energy. Most heating elements use Nichrome wire or ribbon as the conductor. Nichrome is an ideal material, as it is inexpensive, has relatively high resistance, and does not break down or oxidize in air in its useful temperature range.

The main component of the cylindrical casing, the part that has to hold the heating element, water gauge, electric conductors, switch, rubber seal, and water in place. Therefore the properties that the component has to fulfil are: withstand changes in temperature from minus temperatures in some cases to just over 100^0C for boiling water, good rigidity, resistance to cleaning chemicals, low deformation, reasonable impact resistance, and electrical non conductivity.

2.2.1. Electrical component housing

This component is situated at the rear of the cylindrical casing and its task is to hold the switch, electrical control unit, and kettle lead housing in place. Electrical component housing is made from reinforced stainless steel. The casing was manufactured by fabricated the steel. It is determined by the complexity of the component and the fact that a sprue hole, split line, and injector pin marks were found on the surface of the moulding.

2.2.2. Water gauge

This component is situated on the side of the kettle and its function is to measure the water level in the kettle. The properties that the part needs to conform are similar to the previous parts: Broad range of temperatures from minus values up to just over 100°C, clear so that water level can be seen through material, rigidity, dimensional stability, impact resistance and clarity. The chosen component for all these characteristics was polycarbonate (PC). Polycarbonate is a thermoplastic with outstanding characteristics, it is amorphous and is a polyester polymer in which is a repeating structural unit of the carbonate type. The polycarbonate water gauge was manufactured using injection moulding. This was determined by the components complexity, symmetrical lines, sprue, split lines, and injector pin marks on the artifacts surface.

2.2.3. Seal

This component is used to seal the gap between the electrical components in the electrical housing and the water in the main body of the kettle. Its main properties are resistance to cleaning chemicals and water, resistance to variable temperatures from minus to just above 100°C, non-conductivity to electricity and the most importantly is sealing ability. The material that was chosen for this part was silicone rubber, which is based on polymers. The main polymer chain of silicone consists of alternating silicone and oxygen atoms. They derive from sand and methyl chloride. Silicone rubber parts can be made from a number of different methods these being: compression, transfer, and injection moulding. In this case it is evident that the seal was manufactured using transfer moulding due to the complexity of the part and the varying wall thickness.

2.2.4. Electrical control unit

This unit is made up of several parts, which come together to from the main control unit for the kettle. These parts are: the switch mechanism, spring, conductive pins, and automatic cut off mechanism. The switch mechanism and housing for the rest of the control unit needs to be non- conductive with electricity, rigid, reasonable strength, good stability and heat resistance. Therefore the material that was chosen was polyphenylene oxide (NORYL), which is a thermoplastic resin capable of having all the properties and more listed above. The component made from NORYL has been manufactured by injection moulding with three brass pins for conducting electricity from the mains kettle lead inserted into the mould for the thermoplastic to form around them. The manufacturing technique has been determined by the high complexity of the part and the split line, and sprue marks found on the surface.

2.2.5. Kettle lead housing

The kettle lead housing has to have the same properties as the electrical control unit and is therefore made and manufactured from the same material and technique NORYL and injection moulding respectively.

2.2.6. Heating element

The function of this component is to heat the water to boiling point using electricity and resistance causing heat to fulfil the function. The required properties are not to contaminate the water inside the kettle, non-reactive, electric conductive, and relatively efficient. With these issues in mind the chosen material for the element was copper nickel (Cu-Ni). It is manufactured by having the copper tube bent into shape with a resistive wire core insulated by magnesium oxide. The element was then brazed to a brass head and nickel-plated.

2.2.7. Screws

The three screws that hold the electrical components together are manufactured form brass with chromium plating. Figure 3 shows the overall prototype drawing of the portable water filter.

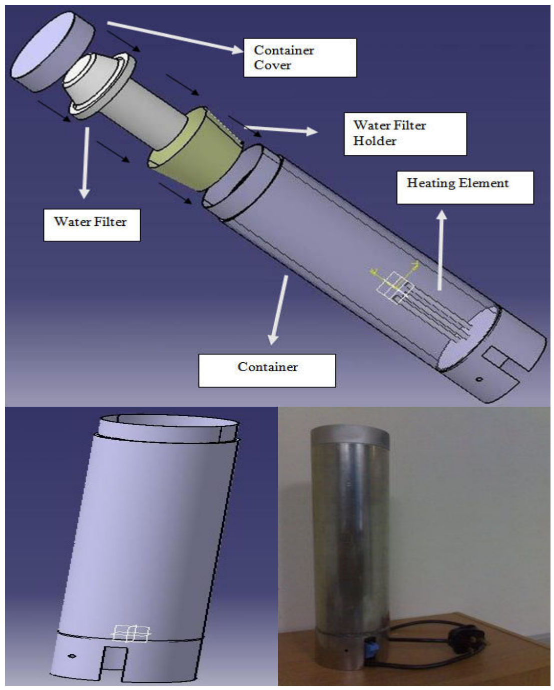

Fig. 3. Portable Water Filter Assembly.

3. Results and Discussion

The water quality from the filter has to be determined to prove that it is working in a stringent environment. There are several tests that have been conducted. Among the tests are Chemical Oxygen Demand Test, *E-Coli* Test, Turbidity test, and Iron Test.

3.1. Chemical oxygen demand (COD) test

Chemical Oxygen Demand or more known as COD test is used as an indicator of water quality. The COD test indicates the amount of organics in the water. The COD is measured by determining the oxygen consumed in degrading the organic matter (biodegradable or non biodegradable). In drinking water, the value of the COD should be 0 mg/litre as there should be no organic matter in the water. If the test is conducted and there is some COD value, it means that the water contains organic matter that might be harmful towards us. Figure 4 below shows how the COD test is conducted. Table 1 shows the results of the COD experiment.

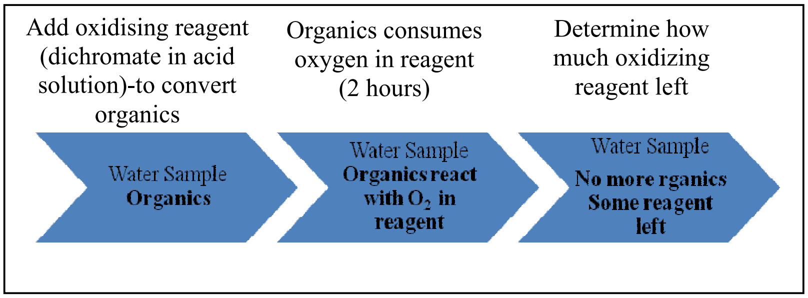

Fig. 4. Steps of the COD Test.

Table 1. COD Content in Water in mg/L.

Test	1	2	3
Without Filter	-2	-3	-6
Normal Filter	-8	-8	-4
Designed Filter	-16	-4	-11

From the result, it can be noted that all the values of COD are negative values. This shows that there is no content of organic matter in the water after the test is conducted. One of the tests is conducted using a sample of normal unfiltered tap water as a benchmark to see that what happens to the water without the filter. All the tests are conducted three times for removing errors and to show consistency in the readings of the result. As all of the tests show negative values, it means that the water is free of organic matter.

3.2. Turbidity test

Turbidity is the cloudiness or haziness of a fluid caused by individual particles (suspended solids) that are generally invisible to the naked eye. The measurement of turbidity is a key test of water quality. Fluids can contain suspended solid matter consisting of particles of many different sizes. While some suspended material will be large enough and heavy enough to settle rapidly to the bottom container if a liquid sample is left to stand (the settle able solids), very small particles will settle only very slowly or not at all if the sample is regularly agitated or the particles are colloidal. These small solid particles cause the liquid to appear turbid.

WHO establishes that the turbidity of drinking water shouldn't be more than 5 NTU (Nephelometric Turbidity Units), and should ideally be below 1 NTU. To test turbidity, all that is needed to do is to collect the water samples and put it inside a vial that is inserted to a Turbidity meter which measures the corresponding value of Turbidity. The result of the Turbidity Test that was conducted is shown in Table 2.

The test results show that the value of turbidity all below 1 NTU which passes the minimum requirement by WHO. However from Table 2, there are some differences in the turbidity level of sample without filter and the ones with filters. The turbidity level seems to be higher in the sample of water without the filter comparing with the filtered ones. This shows that the filters are reducing the turbidity of the water.

Table 2. Turbidity of Water Samples Measured in NTU.

Test	1	2	3
Without Filter	0.85	0.73	0.78
Normal Filter	0.44	0.54	0.39
Designed Filter	0.38	0.63	0.47

3.3. Irons test

Iron can be found everywhere even dissolved in water that we use for drinking, bathing and other chores daily. Excessive iron can be toxic, because free ferrous iron reacts with peroxides to produce free radicals, which are highly reactive and can damage DNA, proteins, lipids, and other cellular components. However, large amounts of ingested iron can cause excessive levels of iron in the blood because high iron levels can damage the cells of the gastrointestinal tract, preventing them from regulating iron absorption. Humans experience iron toxicity above 20 milligrams of iron for every kilogram of mass, and 60 milligrams per kilogram is a lethal dose.

The tap water from the designed filter contains dissolved iron. The density/quantity of the iron can be removed by using a good filtration system. Most of these systems filter various no of trace metals including iron. The testing can be done by using a photo-spectrometer and using a reagent for iron tracing. The results of the test conducted in determining the concentration of iron in water is as indicated in Table 3.

Table 3. Concentration of Iron in Fe mg/L.

Test	1	2	3
Without Filter	0.11	0.12	0.09
Normal Filter	0.06	0.07	0.4
Designed Filter	0.04	0.02	0.02

From the result, it can be seen that the initial level of iron in water is around 0.09-0.12 Fe mg/L. The quantity of iron drops to 0.04-0.07 Fe mg/L after passing through the normal filter. The concentration of iron in the designed filter is even lesser than the rest with the values of iron ranging from 0.02-0.04 Fe mg/L. This shows that the designed filter is even better in removing the iron content in the water, thus making the water safer to drink. This is probably due to the appearance of ceramic and Bio-Balls in the designed filter that proves effective in removing the iron content.

4. Conclusions

The design of dual purposes handy water filter provides state-of-the-art information on the feasibility of using this technology and on design, construction, and operations to best achieve desired production and performance.

An efficient and easy way to make small sized dual purposes handy water filter has been proposed in this paper. The water filter comprises a cylindrical container for holding a quantity of liquid to be treated including, a filter tube to filtrate the water and heating element to heat the filtrated water. The filter tube is connected to the upper end of the cylindrical case and the heating element is connected to the lower end of the cylindrical container.

The designed filter provides an easier way to get safe, clean, and healthy and hot water. The water from this dual purpose handy filter has been tested using various tests to prove that the quality of water is meeting the standards.

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