Requirement of Outdoor Water Filtration System

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Abstract. Presently, outdoor water filtration (OWF) system becomes one of home appliances that is a must-have for every house in Malaysia. Even though the tap water is a guarantee can be consumed directly, Malaysians still need the appliances. These home appliances become popular nowadays, however the requirement of the OWF is never determined. This study focuses on OWF system which improves quality of water from the plant treatment at point of entry before it gets to consumers. The purpose of this study was to understand qualitatively the requirement of OWF system through awareness of the consumers. In addition, residual chlorine was also measured to determine the performance of the system. Seven houses that have been using OWF were asked on their awareness on the technology used in their system and mostly said they knew the technology used. However, they are less aware on types of filter media and water parameter that are related to quality of effluent water. Based on the measurement of residual chlorine, the percentage removal after the system was in the range of 76% to 96%. This high removal was reduced the chlorine concentration far below the recommended, thus the safety of water effluent is uncertain. This study shows that requirement of using the system can still be disputed and therefore the large number of sample may require for further study to obtain the real need of OWF system in Malaysia.

1. Introduction
Tap water in Malaysia, as elsewhere in the world, may be polluted with traces of various chemicals, heavy metals, hormones, pharmaceuticals, and other pollutants. This pollution may be due to the water travels a long way to reach tap and other external factors [1]. Thus, it is advisable to invest in water filtration system in household. The pollution may threat to human health which leads to appropriate design of water filtration system [2]. According to the Department of Statistics, 98% of the urban Malaysian population and 92% of the rural community used tap water as water resource in household.

According to [3], the high number of consumers in Malaysia using water filtration system is due to high turbidity, high colour and presence of foreign particles, taste and odour due to traces of chlorine. There are several types of water filter system used in Malaysia such as indoor, outdoor, and portable [4]. This study focuses on outdoor water filtration (OWF) system which purifies the tap water that supplies to entire home for examples bathe, shower and wash clothes. As compared to indoor water filtration system, the use of treated water are mainly for drinking and cooking. Whereas, portable water filter used the simple design of filtration system which was easier to carry out from source of water [4].

OWF is also known as point-of-entry water filter which is installed at a property’s main water supply connection point where it traps sediment before it enters the property’s indoor water supply. The advantages of using OWF system is based on the quality control aspects, which is extending the life of appliances of indoor water filtration system. Thus, OWF installation is reducing the indoor water filtration maintenance and subsequently reduces the maintenance cost. OWF does not require pump and electricity to operate the system. Several of OWF used membrane technology to remove the specific...
contaminants. The system is a low-pressure driven type of membrane without needing pressure tank and pump for filtration process [5]. The common media in outdoor water filter system are activated carbon, zeolite, fine silica sand, medium silica sand, and coarse silica sand [6]. The routine maintenance for OWF are carbon cartridge (POE only), backwashed (flushed) or discarded if non-toxics have been adsorbed [7]. In removing taste and odor-producing chemicals, the POE unit can be backwashed manually or automatically depending on the device's capabilities.

By using OWF, it may reduce the concentration of free chlorine in household. Free chlorine (the sum of hypochlorous acid and hypochlorite ion) is widely used for water disinfection [8]. The World Health Organization recommends 0.2 mg/l of free chlorine as a safe level for a water supply. The free chlorine concentration should be accurately monitored for the water safety, especially for drinking, recreational, and food processing water [9]. For recreational activities, free chlorine concentration in a swimming pool should be maintained between 1.5 to 2 mg/l. For food processing, the water should contain 50 to 200 mg/l free chlorine [10]. The accurate monitoring of free chlorine concentration is challenging because it is correlated with the temperature and pH of the water sample [9].

The study of consumer perception on the OWF is very limited as compared to the study of indoor water filter, thus this study was carried out to evaluate the household perceptive on requirement of outdoor water filter system. In addition, this study also determine the concentration of residual chlorine before and after outdoor water filter system for household.

2. Methodology
This section is divided into two parts, namely, design and distribution of questionnaire and sampling and analyses of free chlorine in laboratory. A total of seven households in Selangor were selected based on OWF that was installed in their house for distribution of questionnaire and measurement of free chlorine. As preliminary study, small number was chosen in this study. In addition, the qualitative analysis was used in this study.

2.1. Design and distribution of questionnaire
The questionnaire was developed in three sections, namely, Section A: Background information of respondents, Section B: Information and Perception on Outdoor Water Filter System and Section C: Awareness on technology in water filter system. The questionnaire consist of 15 questions. Sociodemographic data such as address and number of household were included in Section A. Awareness on OWF was assessed based on eight questions in Section B as follows:

1. What brand of outdoor water filter use in your house?
2. How long have you use that brand?
3. How much of water do you use per month?
4. How much capacity does your water purifier have?
5. Do you conduct the maintenance service (e.g. backwash) in your outdoor water filter system?
6. If yes, how long the duration of maintenance service was conducted?
7. Are you satisfied with the quality of your water after use the outdoor water filter?
8. Are you aware of the technology used in your outdoor water filter?

In section C, respondents were asked on familiarity of filter components such as activated carbon, zeolite, fine, medium and coarse silica. In addition, the respondents were also asked on familiarity with several water parameters, namely, pH, turbidity, dissolved solid, heavy metal and total coliform. The questionnaire was developed based on the results from previous studies and was reviewed and validated by lecturer from Faculty of Science Technology and Human Development which have expertise in development of questionnaire.

To address the research questions, a mixture of qualitative and quantitative methods were used to consider the “multiplicity of meanings, representations and practices” [11]. This includes one method of data collection by face to face with households. The questionnaires were distributed to selected seven households that own an OWF in Selangor and face to face method was used in distribution of
questionnaire. After the fieldwork and data collection are completed, a single data file was compiled from the individual hardcopy surveys from all of the households.

2.2. Measurement of Free Chlorine
A total of 42 water samples were collected from seven houses. Three samples from each before and after the OWF were collected for every week for each house. Water samples were obtained from two sources, namely, treated piped water from water treatment plants which is before it goes through OWF and tap water after it goes through the OWF extensively used by the households. Standard Methods for the Examination of Water and Wastewater was referred for sampling procedure and sample handling for measurement of free chlorine. Samples were stored in pre-cleaned glass bottles, not exposed to sunlight or strong artificial light and was not aerated for mixing. Free chlorine were analyzed using DR6000 Method 8021. Powder pillow (chlorine free-DPD) was used as reagent in this method.

3. Results And Discussion
Relation of awareness and requirement of outdoor water filtration system was evaluated for each house. User of house 1 used their OWF system more than 6 years, which can be categorized as long duration. The long duration could be due to regular maintenance which is within one to two months. Thus, the system can perform effectively to remove contaminant that passed through. In addition, this user was very satisfied with the water quality and decide to prolong the use of the system. This house was occupied by 8 adults who use water more than 50 m$^3$/month. This high volume requires regular maintenance service to maintain the system’s performance. This user really cares about the system’s performance. However, this user does not know the capacity of the filtration system. In addition, this user knows a little bit on the technology used and only heard on a few of filter media. This perception shows that this user take less care on what inside the filtration system.

Characteristics of house 1 is mostly similar to house 3. The difference between these houses was the duration of using the filtration system, which is owner of house 3 used their system more than 10 years, longer compared to house 1. Compare to house 1, user of house 3 told that they concerned on their system, which they know the technology used. However, the owner only heard on mostly filter media. They were familiar with activated carbon but did not know about zeolite. Outdoor filtration media mostly used silica sand to filter water. However, this user only heard on silica sand as filter media. Among parameters, user was very familiar with pH value. They were very concerned if their water in acidic and alkaline condition. Whereas, this user did not know about turbidity, but familiar with dissolve solid. This user was also familiar with heavy metals and only heard on total coliform. This user know the basic of technology used in water filtration system, but further information on the system is very lacking for this user.

From high volume (more than 50 m$^3$), house 5 using smaller water volume which is from 30 m$^3$ to 50 m$^3$ monthly. Even though number of residents is almost similar to House 3, residents of house 5 used their water wisely. This user did not know the capacity of their system, which is similar to house 1, and conduct maintenance service twice a year. They were very satisfied with the quality of the effluent water and know the technology used in their water filter. However, when asking on filter media, they had very little knowledge on activated carbon and other media. This perception was similar when asking on water parameter.

Users of house 2, 4, 6 and 7 used their water wisely (10 – 30 m$^3$ monthly) even though the number of households was mostly higher compared to house 1, 3 and 5. User of house 2 used their system between 1 to 5 years. This user know their capacity of their system and conduct maintenance service more than 5 months. This user was also satisfied with water quality from effluent of the system. This user was aware on technology used to treat the water. However, the user did not know the water filter component, which only heard on activated carbon. Further question on parameter, this user was only familiar with heavy metals and did not know on pH, turbidity, dissolve solids and total coliform. This user had heard on water filter component such as activated carbon,
zeolite and silica sand. This user was also familiar with a few parameter such as pH, dissolve solid and heavy metals. Only total coliform, user of house 6 did not familiar with.

Users of house 4 and 7 used their OWF system longer compared to house 2 and 6, but in similar water used per month. Both users did not know the capacity of their system. User of house 4 regularly conduct maintenance service, i.e., less a month. Whereas, user of house 7 conduct the service between 2 to 5 months. Both users were satisfied with water quality of water effluent of their system. By comparing on knowledge of the system, user of house 4 said they know little bit on technology. Whereas user of house 7 did not know the technology used. User of house 4 had heard on activated carbon and medium silica sand used in outdoor water filtration system. This user did not know on zeolite, fine silica sand and coarse silica sand. Whereas user of house 7 did not know all filter media, which is consistent with previous statement (did not know the technology used). Based on knowledge on water parameters, user of house 4 only heard on pH and did not know on turbidity, dissolve solid, heavy metals and total coliform. Whereas, user of house 7 familiar with pH, had heard on turbidity, dissolve solid and heavy metals and did not know on total coliform. Knowledge on water parameter for user of house 7 higher compared to user house of house 4.

In evaluating the knowledge of all users, they were asked if they know the technology used in their OWF system. This question can be categorized as first level of awareness and mostly said they know except for two users (house 6 and house 7). Then, all users were asked on water filter media, if they are familiar with. This question was designed to evaluate the further knowledge and can be categorized as second level of awareness on the filter system. In this question, mostly users know on activated carbon but know less on silica sand. By comparing activated carbon and silica sand, mostly OWF systems were designed with coarse, medium and fine silica sand as filter media [12]. Supposedly consumer of OWF system must be familiar with silica sand as filter media. By referring to information from supplier (brochure) and website, less information on type media that used in their filter media [5]. Information that brings to customer is mostly on advantage of using outdoor water filtration system.

Beside filter media, users were also asked on a water parameter such as pH, turbidity, dissolve solid, heavy metals and coliform. These parameters were selected due to high relation with quality of water especially for household. Based on user’s respond, they are less familiar with these parameters. For example, user house 4 never heard or have any information for all parameters. Based on responses from all users, knowledge on filter media and parameter of water quality did not affect the requirement of purchasing the outdoor filter system.

Households prefer alternative treatment of water source instead of relying in the city’s quality supply services. In 2004, the World Health Organization estimated that improvements in drinking water quality through household water treatment, such as chlorination at point of use, can lead to a reduction of diarrhea episodes by up to 39% [8]. The issue of access to safe water supplies has recently gained a lot more attention as it has become one of the Millennium Development Goals targets. The use of OWF is already known by consumers but they do not know what is in their water and how the OWF work. The study of household’s health behavior is quite complex since not only socioeconomic but also psychological factors should be taken into account. Theories of health behavior change, and in particular the so-called Health Belief Model, emphasize the role of individual’s perceptions in influencing the probability of performing protective behavior to prevent illness.

“Though it is important to use clean water for those activities, many conventional water treatment systems cannot filter chlorine, ammonia and heavy metals as they consist of a single medium such as sand or fibre”

This statement was cited based on brochure from supplier of outdoor water filter system. Based on this statement, the main parameter, free chlorine was measured for all selected houses in this study. The average of three weeks analysis for all houses were shown in Table 1. The highest percentage removal was 94.6% from house 1 with average of 1.12 mg/L for before filter system and 0.06 mg/L for after filter system. The lowest percentage was 76.1% from house 2 with average of 0.88 mg/L for before filter system and 0.21 mg/L for after filter system. Other house, namely, house 4, 5, 6 and 7 show the high percentage removal of 87.3%, 94.4%, 92.5%, and 90.9%, respectively. Only house 3 shows the increasing of chlorine concentration after filtration with percentage increasing was 19.3% with average of 0.88 mg/L for before filter system and 1.09 mg/L for after filter system.
Table 1. Average residual chlorine (mg/L) on outdoor water filter system for three weeks.

| Sample house No | Average Chlorine residual, Cl₂ mg/L for three weeks | Percentage removal (%) |
|-----------------|----------------------------------------------------|-------------------------|
|                 | Before filter Cl₂ mg/L | After filter Cl₂ mg/L |                         |
| House 1         | 1.12                  | 0.06                   | 94.6                    |
| House 2         | 0.88                  | 0.21                   | 76.1                    |
| House 3         | 0.88                  | 1.09                   | 19.3                    |
| House 4         | 0.71                  | 0.09                   | 87.3                    |
| House 5         | 0.72                  | 0.04                   | 94.4                    |
| House 6         | 0.67                  | 0.05                   | 92.5                    |
| House 7         | 0.77                  | 0.07                   | 90.9                    |

To help prevent contamination, the Environmental Protection Agency (EPA) requires treated tap water to have a detectable level of chlorine of 0.2 mg/L to 0.5 mg/L [8]. Based on result, only house 2 shows the chlorine concentration after filter was in EPA range. Whereas, other house shows chlorine concentration after filter system much below than 0.2 mg/L. The differences in residual chlorine concentration for each houses was due to the used of different brands of OWF that has varies filter technology for each brands. Based on the questionnaires distributed, house 2 used 3-stage filter which will get rid of 99% of the chlorine found in the water entering home [13].

From result, house 3 shows chlorine concentration of 1.09 mg/l after the filter which was 50% higher from recommended residual chlorine 0.5 mg/l. Granular activated carbon in filter is to remove chlorine from water, house 3 however has increased in chlorine residual after the filter due to the age of the water filter. It is recommended to replace the filter every 6 months or depends on how much volume of water used, and in addition, the quality of the filter is crucial to show the performance of OWF [14]. From questionnaires, the house 3 OWF was used more than 10 years. The chlorine residual increased maybe due to improper function of the OWF, which filter media that has not been replaced for very long time. Free chlorine can react with ammonium and other compound in water to form chloramines and other combined chlorine compounds that can increase the chlorine concentration readings and affect the human health [15].

In Malaysia, before water pass through the OWF system, source of tap water is from water treatment plant which function to remove colloids, suspended solids and pathogens [4]. In removing pathogens, chlorine gas was commonly used due to economical compare to other disinfectants. Based on the result, residual chlorine concentration before filter system were above the 0.5mg/L for all houses. Thus, installation of OWF system was highly needed. However, the system reduces residual chlorine much below that requirement. Thus, the safety of using the water was uncertain. In addition, the effluent of OWF system will be kept in a storage tank that maybe the water will be used after 1 or 2 days after filtered. In this duration, the pathogen may growth and multiply in high number.

4. Conclusion
Contamination can happen if the water pipes are broken or rusted. Installing OWF system is mainly to remove contaminants like rusts, mud and sand. Even substances like organic chemicals and chlorine exist in minute and permissible concentrations, they might store in our body and lead to health problems in the long run. As to conclude, an OWF system is needed for household and industrial as it improves the water quality from the plant treatment at point of entry before it gets to consumers. From the study, the awareness of the consumers on the requirement of OWF system have been measured. Thus, it showed that further information on the outdoor water filter system by the consumers is very limited. They are less aware on types of filter media and water parameter that are related to quality of effluent water. Consequently, based on the measurement of residual chlorine, the percentage removal after the system was in the range of 76% to 96%. Hence, it indicates that requirement of using the system can still be disputed and therefore the large number of sample may be required for further study to achieve the real need of OWF system in Malaysia.
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