DESIGN OF A PRE-WATER FILTER TO PROVIDE AERATION IN FILTRATION PROCESS

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ABSTRACT

Occasionally, the tap water of housing area at Gambang, Pahang is detected to have the presence of odour and brownish in colour. The water filter cartridge turns brown rapidly. This issue has harassed the residents and caused doubtfulness by using the water supply. In order to verify this perception, tests of colour, turbidity, Biochemical Oxygen Demand (BOD), total solids (TS), total suspended solids (TSS) and total dissolved solids (TDS) were carried out by using the water supply from five houses in Gambang area. The results obtained were compared with the water quality standards. A pre-water filter was designed to solve this problem, which included an aeration and filtration process. The aeration process was induced by a free-fall in the system. Hence, the relationship between the height of the fall and dissolved oxygen level was determined to obtain the best and most feasible height in the aeration process. A high rate dual media filter with filter media of graded sand and activated carbon made from coconut shells; and a support layer of gravel was used for the filtration process. By the completion of pre-water filter design, a running of the water filter was carried out and water after passed through the filter was then tested with colour, turbidity, BOD, TS and TSS amount, along with the confirmation of increased in dissolved oxygen value to ensure the water freshness. The results obtained were compared with the results of water before induced to the pre-water filter, and also the water quality standard. From this research, the final model of the pre-water filter was able to decrease above 50 % of the colour, turbidity, BOD, TSS and TDS; and increased the dissolved oxygen level for 5.31%.

ABSTRAK

Kadang –kala, air paip di kawasan perumahan Gambang, Pahang dikesankan terdapat bau dan berwarna keperangan. Kartrij penapis air bertukar menjadi perang dengan cepat. Isu ini telah mengganggu penduduk setempat dan menyebabkan keraguan semasa menggunakan bekalan air. Untuk mengesahkan tanggapan ini, ujian warna, kekeruhan, Biochemical Oxygen Demand (BOD), jumlah pepejal (TS), jumlah pepejal terampai (TSS) dan jumlah pepejal larut (TDS) telah dijalankan dengan menggunakan bekalan air dari lima buah rumah di kawasan Gambang. Keputusan yang diperolehi dibandingkan dengan standard kualiti air. Sebuah pra-penapis air telah dihasilkan bagi megatasi masalah ini, yang terdiri daripada proses pengudaraan dan penapisan. Proses pengudaraan dihasilkan melalui jatuhan bebas dalam sistem. Oleh itu, hubungan antara ketinggian jatuhan dengan aras oksigen larut telah ditentukan bagi mendapatkan ketinggian yang terbaik dan paling sesuai dalam proses pengudaraan. Satu dwi-media penapis kadar tinggi dengan media penapis daripada pasir yang digred dan aktif karbon yang dibuat daripada cangkerang kelapa; dengan satu lapisan kelikir digunakan untuk proses penapisan. Dengan hasil rekabentuk pra-penapis air yang lengkap, ujian penapisan air telah dijalankan dan air selepas ditapis oleh penapis tersebut telah diuji dengan warna, kekeruhan, BOD, jumlah TS dan jumlah TSS, bersama dengan pengesahan kenaikan aras oksigen larut bagi memastikan kesegaran air. Keputusan yang diperolehi telah dibandingkan dengan keputusan air sebelum ditapis dengan pra-penapis air, dan juga dibandingkan dengan standard kualiti air. Daripada penyelidikan ini, model akhir pra-penapis air dapat mengurangkan lebih 50 % warna, kekeruhan, BOD, TSS dan TDS; dan meningkatkan aras oksigen larut sebanyak 5.31 %.

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LIST OF SYMBOLS

$\forall_{S}$	Volume of sample
$\forall_{DW}$	Volume of dilution water
μm	Micrometer
y	Depth

LIST OF ABBREVIATIONS

AC	Activated Carbon
Av	Average
AWWA	American Water Works Association
BOD_5	Biochemical Oxygen $Demand_5$
$CaCl_2$	Calcium Chloride
COD	Chemical Oxygen Demand
DO	Dissolved oxygen
EPA	Environmental Protection Agency
F	Froude number
FKASA	Fakulti Kejuruteraan Awam & Sumber Alam (Faculty of Civil Engineering & Earth Resources)
NTU	Nephelometric turbidity units
PtCo	Platinum-cobalt unit
RVF	Rapid Varied Flow
TCU	True colour unit
TDS	Total dissolved solids
THM	Trihalomethane
TS	Total solids
TSS	Total suspended solids
TU	Turbidity unit
UV-VIS	Ultraviolet-visible
WHO	World Health Organization

CHAPTER 1

INTRODUCTION

1.1 INTRODUCTION

Clean water is essential for human life. Human make use of clean water especially for basic daily activities. Approximately 30 to 50 liters of water is needed for one person of daily fundamental usage like drinking, cleaning and cooking.

However in the near future, the clean water required for human daily activities are increasing drastically for the enormous amount of global demand, which causes scarcity of available clean water. In additional, with a rising water contamination issues, death problems caused by water disease are also increasing. According to Water Org. (2013), there are 780 million people who are lacking from clean water access in the world, and 3.4 million people died from water borne disease every day. Among this, a United Nations report in 2006 stated that there are almost 2 million children suffered from mortality every year due to water-related disease, therefore, by calculations, there will be a child dies from bad water every 15 seconds (Dahlin & Sheehan, 2010). World Health Organization research stated that, there are 936 Malaysians who died of water, sanitation and hygiene reasons. These dreadful statistics are the best testimony to terrify the publics. Consumers who had little or no idea about the awareness of clean water would be in the high risk group of the victims, whilst majority of the consumer may face to doubtfulness and questioned in using the water supply. This phenomenon shall be reduced and realization of the importance of consuming clean water shall be propagated.

1.2 BACKGROUND OF STUDY

Pollutants in the water can be grouped into several categories such as microorganisms, disinfectants, disinfection by product, and radionuclides, inorganic and organic chemicals. The polluted water may contains bacteria, viruses, organic, non-organic matters, metals, non-matters, odour, taste-causing contaminants, rust and sediments that will cause human health aspect if consumed continuously (EPA, 2013). Along with the increasing water contamination issues, the pollutants in water sources are rising substantially. Hence, this lead to the scarcity of available clean water sources. From here, various types of water treatments are widely practiced in most of the developed and developing countries. Che Osmi and Mokhtar (2013) claimed that, the water treatment process which aims to remove suspended objects, chemical substances, bacteria, viruses, will be able to improve water characteristics by producing clean and safe water under required water quality. However, due to certain unexpected circumstances such as leaking at the water distribution stage, the water quality might be confronted to derogation. With no prevention methods for the circumstances, certain post-guard actions may be done before receiving the water supply. The water filter is the most popular way to overcome this problem. Types of water filters are able to conform the users' needs, for an instant the most commonly seen filters for domestics used, like the under-sink water filter, whole house filter, faucet mounted filter, and pitcher filter. In this research, the designation of a whole house filter, or called a pre-filter will be conducted.

1.3 PROBLEM STATEMENT

The water supply of housing area along Jalan Besar Gambang, in Gambang, Pahang was detected to have an odour and was brownish in colour. The water filter cartridge turns brown rapidly in only two weeks period. This has brought about trepidation to the consumers. In spite of frequent replacement of new water filter cartridge, sustaining consume of water supply is also seems to be doubtful for the user where health problems were suspected to be lead. Hence, this problem not only brings uneconomic effect but also health aspects.

1.4 OBJECTIVES

1. To determine the presence of odour, colour, turbidity, the level of dissolved oxygen, Biochemical Oxygen Demand (BOD), dissolved solids and suspended solids in water supply, and compare with the water quality standards.
2. To determine the relationships between the height of hydraulic fall and dissolve oxygen level.
3. To design a pre-water filter system.
4. To compare the quality of water in terms of odour, colour, turbidity, dissolved oxygen level, Biochemical Oxygen Demand (BOD), dissolved solids and suspended solids amount before and after through the treatment of pre-water filter designation, and with the water quality standards.

1.5 SCOPE OF STUDY

The research was conducted by using water supply from 5 random houses in the housing area along Jalan Besar Gambang, in Gambang. Only the colour, turbidity, dissolved oxygen level, Biochemical Oxygen Demand (BOD), amount of dissolved solids and suspended solids of the water sources were measured and compared with the water quality standards. The presence of odour in water which has no measurable parameter was only determined by judgment of the senses. The design of the pre-water filter system included a rapid varied flow (RVF) with ideal height of channel bed drop in the hydraulic mechanism system to provide an aeration action, and a dual media filter that enhances mechanism of filtration. The dual media filter consists of gravel as support layer; while a layer of graded sand and a layer of coconut shell activated carbon as filter media. The height of channel bed drop with the highest dissolved oxygen level obtained will be determined through laboratory test and will be taken in filter design. The height of filter media will be studied, and three trial model of filter will be tested with different height of filtering media. The best composite of filter media which gave the best water quality of treated water was compared with the suggested height of filtering media components, and applied to the pre-water filter. The result of water before and after treated through the designed pre-water filter was judged of odour presence, and tested for colour, turbidity, BOD, total dissolved solids, total suspended solids and dissolved oxygen level amount only. Results obtained were compared with the parameters of water before treated and with the water quality standards.

1.6 SIGNIFICANCE OF STUDY

From this research, the odour of the treated water was reduced, which can then bring relief to the users. Along with that, the dissolved oxygen level of the water was increased, which improved the water freshness, and hence creates healthier water for used. Besides, the colour, turbidity, Biochemical Oxygen Demand (BOD), total dissolved solids and total suspended solids amount were reduced. Therefore, this can reduce the frequency of changing water filter cartridge, and can be replaced with the changing of relatively low-cost and environmental friendly top layer filter media of the dual media filter in the pre-water filter. Thus, this research can bring cost effective sequel, improvement of water quality and also the elimination of the suspected health aspect that may cause by the doubtful quality of water.

CHAPTER 2

LITERATURE REVIEW

2.1 INTRODUCTION

In this chapter, various related journals, articles and pass researches will be studied. Based on the research objectives in the previous chapter, four scopes were implemented to be studied, which are: the type of filter to be chosen for the filtration process, the relationship between aeration process and related hydraulic mechanism, the details of the filter, and the water quality which the treated water targets to be complied with. Therefore, with the aids of the literatures, the pre-water filter designation process and idea enhancement of methodology will be carried out without a hitch.

2.2 TYPES OF FILTER FOR FILTRATION PROCESS

A typical water filter can be categorized into two types, which is gravity filter system and pressure filter system. The gravity filter system is where the filtration process is conducted through the filter system by means of only gravitational pulls. Whilst, the pressure filter system is directed by pressure induces to the filtration system to enhance the rate and efficiency of filtration. From here, only various types of gravity filter will be studied, for it has a distinct advantage of being more reliable and cost effective in terms of maintenance and operation.

2.2.1 Slow Sand Filter

Slow sand filter is the most age-old method used to filter water, but up until now, it is still widely used in various countries to produce clean water. Salvato et al. (2003);

Lahlou (2000); and Huisman and Wood (1974) recommended that the use of a slow sand filter is the most suitable and popular filtration method to be chosen for small communities, and industrialized city in a developing area. The first instance of a slow sand filter was originated by John Gibb in Paisley, Scotland in 1804. The surplus of the sequel was peddled to the residents and had also supported the Gibb's bleaching business (Baker, 1948).

Based on Che Osmi and Mokthar (2013), and Tan et al. (1994), the filtration mechanism of a slow sand filter included microbiological action, straining, and adsorption. Slow sand filter enables water to permeate slowly through the filtering media of sands which will then enhance to water quality. The slow sand filter had shown advantages in the simplicity of designation and operations. From here, Che Osmi and Mokthar (2013); McGhee (2009); and Davis and Masten (2009) both asserted that the slow sand filter is reliable with low technical operation required, where the sophisticated operational control are not a necessity. The Environmental Protection Agency, EPA (2013) also claimed the usefulness of slow water filter by having the strength of the minimal cost of installation and operation is required. Huisman and Wood (1974) had concluded the forte of a slow sand filter, which are economic in construction and operation time and cost, quality of water after being treated, conservation of water from its water-free cleaning operation, and ease of disposing sludge management. Besides, Bourke et al. (1995) had stressed on the usefulness of a slow sand filter with strength of good hydraulic characteristics, inert, ease of cleaning, and of good durability. By using only means of gravitational force, the slow sand filter is able to remove up to 50 to 60 ppm of turbidity, 25 percent of colour, and 95 percent of bacteria (Basak, 2003). The biological active layer which is the *schmutzdecke* layer, where the microbial activity of bacteria removal can be carried out on the top surface of the filter media acted distinctive from other types of filter. Tan et al. (1994) had claimed that the suspended particles and bacteria are not only restrained at the *schmutzdecke* layer, but up to a certain circumstance, ammonia nitrogen, iron, manganese, phosphate, phenol, taste and also odour can also be removed. This process enables the slow sand filter to get rid of harmful substances like bacteria rather than turbidity removal only. This statement has been proven by Tiwari et al. (2009), where diarrhea problems of children in Kenyan household were proven can be reduced by an intermittent slow sand filter.

However, for the small pore size of a slow sand filter media, which is a fine sand layer, the filter rate is very slow. Therefore, for larger demand capacity, a bigger filtration area shall be complied. According to Huisman and Wood (1974) the weakness of a slow sand filter can be categorized into four categories, which is a large land requisite, the initial quality of water to be treated, environment temperature, and cleaning operation. Tan et al. (1994) also pointed out the disadvantage of a slow sand filter where a large land area of approximately 50 – 2000 m^2 and a deeper depth is required for a slow sand filter construction. From here, Selecky et al. (2003); Bourke et al. (1995); Barrett et al. (1991); and Engelhardt (n.d.) also supported that an operation of a slow sand filter needed a large land area and the weakness of only feasible when treating on high water quality with low turbidity. The cleaning process of a slow sand filter requires manually scraped off the top most layer of the sand, therefore, or a larger filtration area, the process of cleaning becomes uneconomical compared to other types of filter. Also for the filter function which aimed for bacteria removal by the *schmutzdecke* layer, the restoration duration after cleaning process or a new filter takes a few months to reach the ideal removal efficiency. The process of *schmutzdecke* maturation which is called the "ripening" period takes from several weeks to several months is necessary (Selecky et al., 2003).

2.2.2 Rapid Sand Filter

The rapid sand filter is widely said to be an improvement of a slow sand filter. Based on the different effective size of filtering sand, a rapid sand filter possesses a faster rate of filtration compared to the slow sand filter. Tan et al. (1994) had claimed that the filtration rate of a rapid sand filter has approximately 30 to 40 times higher than the slow sand filter. According to Bernardo (n. d.) and Basak (2003), the different rate of filtration of rapid sand filter is for the reason of coarser filtering sand layers applied than that of a slow sand filter. The typical filtration rate of a rapid sand filter is 40 times of that of a slow sand filter. (Engelhardt, n.d.). The South Pacific Applied Geoscience Commission (n. d.) had proven that the rapid sand filtration method is widely used for large demand. Che Osmi and Mokthar (2013) stated that one of the rapid sand filter's advantages, which is smaller in size and more compact in capacity. For the sake of this reason, certain country like Seychelles had chosen rapid sand filter rather than the slow sand filter for water treatment due to the insufficient land area for slow sand filter construction (South Pacific Applied Geoscience Commission, n. d.).

For the strength of rapid sand filter, Basak (2003) also mentioned that the high efficiency of colour removal. McGhee (2009) suggested that the filtering material in a rapid sand filter could me dual media or even multimedia, such as crushed glass, coconut husks and burned rice husks. There are also various types of rapid sand filtering media like anthracite coal, sand and garnet. Due to the larger pore size of the lighter upper most layer coal, comparatively bigger substances were effectively trapped above the filtering media (Davis and Masten, 2009). From here, Metcalf and Eddy (1979) had shown that the filtration rate of a multimedia filter is 50 percent more than that of a single-medium filter; and the filtration rate of a dual media filter is relatively 25 percent more than that of a single-medium filter.

For cleaning mechanism, rapid sand filter had shown advances in terms of technology improvement. With no manual cleaning needed, backwashing is the only cleaning method for a rapid sand filter. The larger pore size of the filtering sand media in rapid sand filter cause deeper penetration of the suspended substances into the filter bed, therefore a thorough and more frequent cleansing method shall be employed. Backwashing is a process where a clean or filter water is flowing directly upwards back through the filter bed for a few minutes (Bernardo, n. d.). This cleaning process results in more cost and time saving compared to the manually cleaning process of a slow sand filter in terms of large areas of the filter. However, this operation and maintenance require skillful technicians which consequently results in non-feasibility and uneconomic in certain circumstances especially for household filter units. Besides, the backwashing process also inhibited the formation of a *schmutdecke* layer on the filtering sand for microbial activity. Hence, this reduces bacteria and microorganism removal in the rapid sand filter. The less efficiency of bacteria removal of the rapid sand filter compared to the slow sand filter that requires an additional disinfection process where chlorination or ozonation process is carried out to remove the harmful bacteria sustained in the filtered water. This final treatment action will aid the rapid sand filtration process to produce bacteriologically safe water (Bernardo, n. d.). Thus, this also causes an uneconomical effect on the rapid sand filter.

Based on McGhee (2009); and Che Osmi and Mokthar (2013), the rapid sand filter possesses a prerequisite which is the pre-treatment of the water. The process of treatment such as coagulation, flocculation and sedimentation are required to remove flocs that exists the raw water. This shows a higher cost for more processes in rapid sand filter than a slow sand filter. However, the rapid sand filter will then be able to treat a wider range of water quality with the furtherance of these processes.

As additional, Basak (2003) also mentioned that the troubles in a rapid sand filter, where the presence head loss and negative head. Besides, the problems such as mud balls and filtering layer cracks will also appear due to the backwashing process.

2.2.3 High Rate Filter

High rate filters are filters which contain a combination of several filter media. Based on Tan et al. (1994), the high rate filter is a modification of different specific gravity filter media to overcome the frequent clogging problems in a rapid sand filter which caused by the backwashing that leads to stratify of granular filter media. A high rate filter may contain coarse single medium, dual media or multi-media. This makes the high rate filter possesses a high filtration rate of 2 to 4 times higher than the conventional filter. The American Water Works Association, AWWA (2010) stated that the most widely used of a high rate filter recently is because of outstanding performance in maintaining good water quality and increasing of treatment plant's capacity.

The high rate filter shows its advance in the filtration action when compared with the conventional rapid sand filter which on top few centimeters of the filter bed is used in the filtration process; the high rate filter uses whole bed efficiently in the filtration process (Tan et al., 1994). AWWA (2010) claimed that for the sake of the arrangement of coarse to fine media from top to bottom of the filter media provides longer filter run and filtration rate. Therefore, the head loss with compared to the rapid sand filter will be lesser and longer to be built up. Tan et al., (1994) also mentioned the strength of using a high rate filter that is lower capital, operational and maintenance cost, and short filter run length.

However, the high rate filter uses more filtered water in backwashing process, furthermore needed special equipment for the backwashing process which is the air-water backwash. From here, the AWWA (2010) claimed that due to the backwash process which may bring about mixing between the filtering layers, therefore the effective size and the specific-gravity-relationships of every single filter media shall be considered attentively before any addition material was added. Tan et al. (1994) stated that additional skilled labor is needed for the operation of the air-wash backwash system that may bring about infeasibility of the usage of high rate filter in small communities. Besides, the high rate filter which possesses a higher depth compared to the conventional filter in order to meet the effluent standard, may lead to construction trouble.

With the aid of anthracite coal or activated carbon, the dual media and multi-media filter shows greater advance in adsorbing organic matters and taste-odor control. The multi-media filter brings about higher filtration rate when compared with the dual media filter; however, the total height of the multi-media filter is consequently higher, caused by the provision of different types of filter media. Furthermore, the filter media selection and arrangement with respective effective size and uniformity coefficient in the multi-media filter is relatively more complicated than the dual media filter in order to achieve the ideal filtration norm.

2.2.4 Conclusion

Based on the study of literatures, the strength and weakness of every filter were understood and the idea of choosing the most suitable and feasible filter had been stimulated. The high rate filter was chosen as filter type for pre-water filter for the outstanding filter efficiency and filter rate. The high rate filter occupied smaller land area and lesser depth of filtering media required when compared to a conventional slow sand filter. Therefore, it is more feasible for being a house whole pre-water filter.

Besides, the lower operating and maintenance cost of a high rate filter compared to the conventional rapid sand filter shows precedence to be chosen. For the reason of excellence dedicated to the filtration process, the dual media filter with the presence of anthracite coal or activated carbon is chosen, along with a shorter height requirement and less complicated filter media selection.

2.3 THE RELATIONSHIP BETWEEN AERATION PROCESS AND RAPID VARIED FLOW (RVF) MECHANISM

According to the AWWA (2010); and Che Osmi and Mokhtar (2013) , the aeration process can be able to remove excessive carbon dioxide, hydrogen sulfide, methane, volatile organic chemicals, radon, iron and manganese, taste and odors, and also increase the dissolved oxygen content of the water. From here, the aeration process and relationship between rapid varied flow (RVF) mechanism and aeration mechanism will be studied to enhance the idea in future pre-water filter oxidation part design.

2.3.1 Aeration Process

Aeration is a process which commonly provided in the water treatment process especially for raw water treatment. Che Osmi and Mokhtar (2013) had emphasized the functions of an aeration process, where unneeded dissolved gasses and hazardous organic constituent can be removed, whilst the dissolved oxygen in the water can be increased. Therefore, a better quality of water with increasing water freshness can be produced. Based on the AWWA (2010), the aeration process is a process of transferring air into the water by desorption, scrubbing and oxidation actions. Tan et al. (1994) mentioned that the aeration process which provide oxygen into the water is able to enhance oxidation of dissolved metals and reduce carbon dioxide level which then able to remove odour from the water. Che Osmi and Mokhtar (2013) indicated that the actions of aeration process can be divided into two categories, which are the scrubbing action and the oxidation process. Scrubbing action is responsible for the removal of gases which subsequently remove the taste and odor in the water; while the oxidation process is responsible for the removal of impurities such as iron and manganese. Figure