University of Southern Queensland
Faculty of Engineering and Surveying

The Usage of Domestic Water Filtration Systems in Malaysia

A dissertation submitted by

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ABSTRACT

Water is closely related to human health as there is about 70% of water found in human bodies. In the recent years, consumers are concern about the quality of tap water due to the water pollution issues published in the mass media. Manufacturers and distributors of domestic water treatment systems took this opportunity to promote their own water filtration systems. Different types of domestic water treatment systems have been introduced to the public.

In this research project, six types of domestic treatment methods were identified, namely activated carbon filter, membrane filter, reverse osmosis system, distillation system, ultraviolet light system and combination unit. The theories and technologies involved in each type of water treatment system are being studied. From the literature review, the mechanisms involved are convincing and almost ideal. In order to investigate the effectiveness of each water treatment system, laboratory experiments have been conducted to justify the reported results.

The laboratory experiments take into account parameters such as apparent colour, turbidity, total free chlorine, total aluminium, total iron and total chromium. Three samples of each treatment method are collected in order to obtain the average value. The percentage removal of each parameter is obtained by taking readings before and after treatment. Then, the average value of percentage removal is calculated to evaluate the efficiency of each treatment method. Hopefully this research project can raise the interest of consumers to be more aware of the water quality that they consume everyday and in choosing a correct domestic water treatment system that suits their lifestyle requirement.

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Limitations of Use

Certification

I certify that the ideas, designs and experimental work, results, analyses and conclusions set out in this dissertation are entirely my own effort, except where otherwise indicated and acknowledged.

I further certify that the work is original and has not been previously submitted for assessment in any other course or institution, except where specifically stated.

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Signature

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Date

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I also want to thank all my readers who had spent their time in reading this report patiently. Hopefully this report will provide them some knowledge in various treatment systems and their filtration process.

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CHAPTER 1

INTRODUCTION

Water is very important to human beings. We can live for a while without food but we can not survive without water as there is about 70 % of water in our bodies. Since water is closely related to our life, therefore we are concerned with the quality of our supplied drinking water. In the past, consumers used the supplied water without any doubts. In recent years, consumers focus on the safety of their tap water due to the increasing numbers of complaints of water contamination.

In Malaysia, highland forests act as the natural water towers providing a clean supply of fresh water for domestic, agricultural and industrial demands. There are many unplanned and unsustainable developments in the highland forests in Malaysia such as road building and excessive highland resort development. Excessive clearing of forests and construction of highland road have lead to the contamination of water supply.(Source:http://www.tve.org)

Manufacturers and distributors of domestic water filter systems have mushroomed in the market. They have advertised their products in the mass media in order to attract more consumers in buying it. Consumers are willing to spend money on the water filter systems to assure that the tap water is always clean and safe for human consumption.

1.1 Project Aims

The aim of this research project is to investigate the current use of domestic water filters and compare the technologies of the various filtration systems.

This study will investigate various types of commonly used water filter such as activated carbon filter, membrane filter, reverse osmosis system, distillation system, ultraviolet light system and combination unit (i.e. combination of few treatment methods into one unit).

This project also aimed at investigating the effectiveness of various water filters through laboratory experiments.

1.2 Specific Objectives

The objectives of this research project are as below:

- Literature review about the water quality and method of measurement.

- Study the mechanism and technology behind a few popular types of domestic water filter available in Malaysian market. Comparisons will be made based on quality, technology, price and maintenance.

- Conduct a survey on public's opinion about the supplied water quality, the reasons households install water filter systems and gauge public attitude towards these systems.

- Collect water samples and conduct lab tests to compare the quality of water before and after treatment.

1.3 Background

Water filters have been introduced for many centuries; they are closely related to the history of water. Water has become more contaminated with the growth of industry and increase in population; human beings realized that water filters are needed in order to provide pure and clean water for drinking and cooking purposes. This is because we want to ensure that only the clean water is being consumed. Several treatment alternatives have been introduced for water treatment.

According to the history, the use of water filters began more than 4000 years ago. Early Sanskrit writings outlined some methods to generate pure water such as boiling, placing hot metal instruments in water, exposing to sunlight and filtering water through crude sand or charcoal filters. As early as 1500 years ago, Egyptians recommended the application of coagulant alum to settle out the suspended solids from water. (Source: www.historyofwaterfilters.com)

The famed father of medicine, Hippocrates conducted his own crude water filter. The filter was a cloth bag used to trap any sentiments in the water when water was poured through it. Several experiments in water purification were carried out during the Middle Ages. However, there is lack of scientific innovations in this period of time. Sir Francis Bacon in 1627 began the experiment of desalination of seawater; his experiment did mark rejuvenation in water filter experimentation.
(Source: www.historyofwaterfilters.com)

During the 1800s, European began using slow sand filtration to remove taste and odour from water. During 1960s, standard drinking water treatment techniques such as aeration, flocculation and granular activated carbon adsorption were used for removal of organic contaminants. In the 1970s and 1980s, membrane filtration was used in reverse osmosis system.

Throughout the centuries, new technologies have developed and emerged in the water treatment. The popular types of water filter used nowadays are activated carbon filter, membrane filter, reverse osmosis system, distillation system, ultraviolet light unit and combination unit. Currently, lead and disinfection byproducts are the major concerns in regard to water quality. Chlorine byproducts are harmful chemicals to humans' health as they are cancer causing compounds. The future of water filtration will focus on removal of both chemical substances and microorganisms from drinking water.

1.4 Dissertation Overview

Chapter two of this research project focuses on the safety of drinking water for human consumption. Sources of water, physical quality and chemical quality of drinking water are discussed in this chapter. In chapter three, six types of domestic water filtration systems are investigated, namely activated carbon, membrane, reverse osmosis, distillation, ultraviolet light and combination. Comparisons of various filtration systems are made based on the technologies, price, maintenance and limitation.

The public survey results are analyzed in the chapter four based on the random questionnaire of 100 respondents. The survey is to identify the public's opinion about the supplied water quality and the use of domestic water filtration systems in Malaysian market nowadays.

Laboratory experiments such as apparent colour, turbidity, total iron, total chromium, total aluminium and total chlorine are set out in chapter five. The equipments used, materials required and test procedures are discussed in this chapter. The experimental results of those parameters are outlined in the chapter six. Then, the discussion and analysis of the experimental results of each parameter are given in chapter seven.

CHAPTER 2

SAFE DRINKING WATER

Quality of drinking water depends on where we live, the source of the raw water, the water supplier and exposure to contamination as the water travels from its source through distribution system to our faucet. In Malaysia, water pollution is an alarming issue to the public.

Quality of water becomes worse due to rapid development of the country. As scientific techniques became more sophisticated, industries pumped more harmful chemicals into the river and hence more impurities were found in drinking water.
Cities are the polluters of water with disposal sewerage, industrial effluent and polluted urban runoff. Pesticides and animal wastes from farming also pollute the water. Water pollution disrupts the water supply services, affects the human health and destroys the aquatic lives and habitat. Drinking water should be colourless,

odourless, free from pathogenic organisms, not saline and free from chemical compounds that may affect human health.

Due to the poor water quality, consumers often resort to the use of domestic water filters. Therefore, to safe guard public health we need to know about the quality of water in terms of physical and chemical properties. We have the technology and ability to treat water to a high standard. However, owing to deteriorating water delivery infrastructures i.e. reticulation, trunk mains and storage tanks, water delivered at the household may be of a diminished quality due to intervening contamination.

2.1 Sources of Water

Water is known as the universal solvent due to its ability to slowly dissolve anything that comes into contact with. The total volume of water in the world remains constant through the hydrological cycle. There is about 97.5 % of the world's water is sea water and only 2.5 % of the total volume is non-saline. Although it appears that plenty of water in the world, but there is only very little which is readily available for human consumption.

There is about 75 % of the fresh water locked up as ice-caps and glaciers, 24 % of it appears as groundwater and less than 1 % of the total volume is found in lakes, rivers and the soil. Public drinking water is generally taken from streams, rivers, lakes or underground.

In general, water supply in Malaysia comes from two main resources, i.e. surface water and groundwater. Each of these resources has its own advantages and disadvantages as a source of drinking water.

2.1.1 Surface Water

Surface water is any water which is found flowing or standing on the surface such as river, streams, ponds, lakes and reservoir. Origin of surface water is surface runoff, direct precipitation, interflow and water table discharge.

Quality of surface water is dependent upon the geological factor. Waters from chalk and limestone catchments result in hard waters, whereas impervious rocks such as granite result in soft waters. Suspended solids content of surface water vary widely depending on the season and flow.

During periods of heavy precipitation, the river water may be muddy and high in bacterial content. Clay soils tend to produce muddy streams resulting in a change in water quality due to the washing of silt into the streams. Forests retard run off and tend to equalize stream flow.

In Malaysia, surface water is readily available throughout the year; it is abstracted mainly for irrigation and domestic uses. Surface water represents 97 % of the total water use. Pollution of surface water is inevitable; therefore it needs to be treated carefully before being supplied to the consumers. The Figure 2.1 below shows the withdrawals of surface water by different sectors in Malaysia.

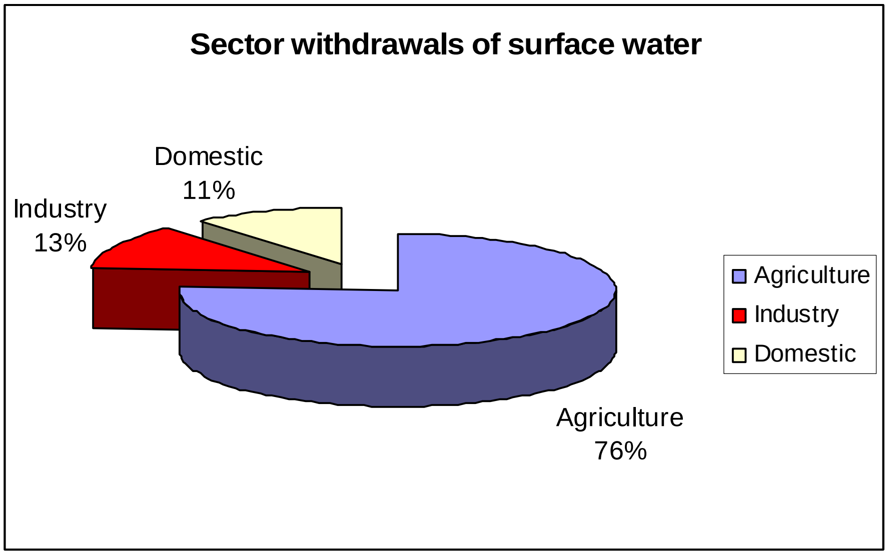


Figure 2.1: Sector withdrawals of surface water [www.pemsea.org]

2.1.2 Groundwater

Groundwater is the precipitation that seeps down through the soil until it reaches rock material that is saturated with water. In general, groundwater is much cheaper than surface water as it does not require construction of reservoir or long pipelines. Groundwater usually has better quality than surface water; it is usually free from suspended solids, bacteria and other pathogens except in areas where it has been affected by pollution.

Groundwater is not commonly used in Malaysia; it is limited to some pockets of the coastal region and is generally exploited by rural people to supplement their piped water supply. Groundwater only represents 3 % of the total water use.

In Malaysia, the potential aquifers may be found in alluvium and hard rock. In alluvium, the aquifer occurs in layers of sand and gravel. This kind of aquifer is capable to supply water in the range from 45 m^3 to 100 m^3 of water/ hour/ well.

In consolidated sediment, the aquifer occurs in openings form as a result of chemical dissolution and in fractures in the rock body. Besides that, the aquifer also occurs in rock fractures, bedding and voids between grains. In igneous and volcanic rock, the aquifer occurs in rock fractures including joints and faults. This is not a good aquifer as the discharge rate seldom exceeds 10 m^3/ hour/ well. The Figure 2.2 below shows the withdrawals of ground water by different sectors in Malaysia.

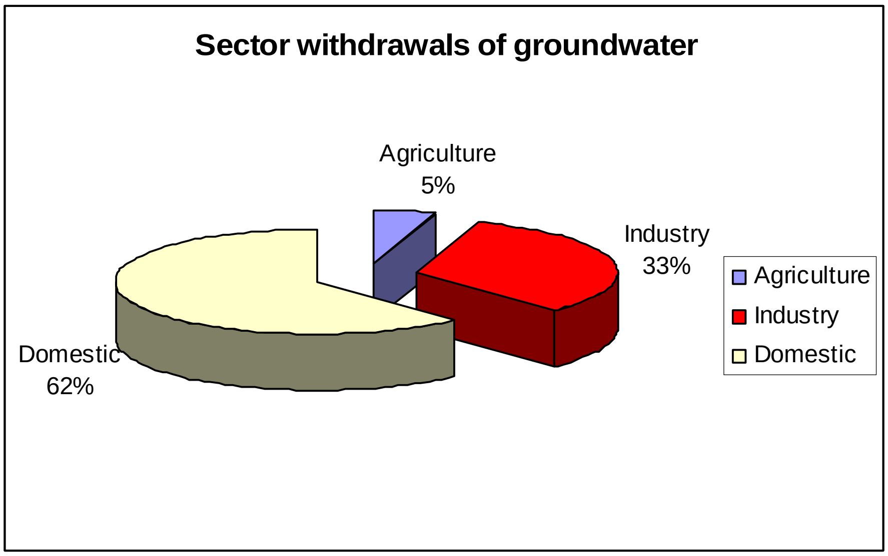


Figure 2.2: Sector withdrawals of groundwater [www.pemsea.org]

2.2 Physical quality

Physical parameters define those characteristics of water that respond to the senses of sight, touch, taste or smell. Physical quality of water is referred to the measurement of parameters such as colour, turbidity, taste, odour, suspended and dissolved solids. Majority of the consumers always make sure that they only consume water which has good physical quality.

Physical quality of water may not seriously affect human health in short term. However, if we consume poor quality of water for long period of time, then there will be detrimental effect to our health as the contaminants accumulated. Therefore, we need to know about the causes and health effects of some physical parameters of drinking water.

2.2.1 Colour

Drinking water should be colourless. Presence of colour in drinking water indicates the presence of complex organic compounds, colloidal forms of iron and manganese, or highly coloured industrial wastes from textile and dyeing operations, paper production or food processing.

Iron oxides cause reddish water and manganese oxides cause brown or blackish water. Presence of yellowish-brown colour may cause by organic debris such as leaves, weeds or woods, where water picks up tannins, humic acid and humates.

Less than 2.5 mg/l of humic and fulvic acid in drinking water is considered safe for human consumption. The acceptable colour in drinking water is less than 15 TCU (True Colour Units). However, about half of Malaysian rivers contain more than 50 TCU. Colour in water can be reduced to acceptable level by conventional treatment if the raw water does not contain more than 75 TCU.

2.2.2 Turbidity

Turbidity in drinking water is due to organic or inorganic impurities suspended in water. The predominant suspended solids in Malaysian waters are consist of silt, clay and finely divided organic matter. Household and industrial wastewater may contain a wide variety of turbidity-producing material. Soaps, detergents and emulsifying agents produce stable colloids that result in turbidity.

Maximum turbidity level allowed in drinking water is 5 NTU (Nephelometric Turbidity Units) whereas maximum acceptable raw water turbidity level is 1000 mg/l. Malaysian river waters have high turbidity, mostly of silt with 47 % of them having more than 50 mg/l of suspended solids. The process of coagulation, flocculation, sedimentation and filtration are able to reduce the turbidity in raw water to acceptable level.

2.2.3 Taste and odour

Inorganic substances are likely to produce tastes unaccompanied by odour but organic material is likely to produce both taste and odour. Chlorination products are also potential causes of taste and odour in water. Ammonia reacts with chlorine would produce three chloramines, which are more odourous than free chlorine.

Chlorination of phenol can cause odour problems due to the formation of chlorophenols. Algae can produce extra cellular products which are themselves odourous. Taste and odour can be measured in unit of TON (Threshold Odour Number).

2.2.4 Suspended Solids and Total Dissolved Solids

A suspended solid is the quantitative measurement of amount of particulate material in water sample. It includes both organic and inorganic matters such as plankton, clay and silt. These materials are often natural contaminants resulting from the erosive action of water flowing over surfaces.

Other suspended materials may come from domestic wastewater which contains large quantities of organic suspended solids and industrial wastewater. Suspended material is aesthetically unpleasant and provides adsorption sites for chemical and biological agents.

A total dissolved solid is the quantitative measurement of dissolved salts in water. Total dissolved solid has influence on quality of water in terms of taste and hardness. Total dissolved solids in water are mainly due to calcium, magnesium, sodium, potassium, iron and manganese. Excessive total dissolved solids give water an unpalatable mineral taste and hardness whereas extremely low total dissolved solids may give flat taste. The acceptable value of total dissolved solids is 1000 mg/l.

2.3 Chemical quality

In the supplied drinking water, presence of inorganic substances at concentration above certain levels may give rise to actual danger to human health. Inorganic chemicals are generally found naturally only in certain groundwater or when industrial contamination is present. Inorganic chemicals are derived from both natural processes of chemical weathering, soil leaching and human activities.

Harmful inorganic chemical pollutants include arsenic, cadmium, chromium cyanide and mercury. Arsenic is known to cause cancer and serious damage to the circulatory system. Cadmium can damage kidneys whereas chromium can affect the liver.
Organic substances from industry, agriculture and municipal effluents contribute extensively to the pollution of water sources. Many contaminants are found through chemical transformations of naturally occurring organic matter during water disinfection like chlorine will convert humic substances to trihalometahnes.

2.3.1 Arsenic

In certain types of metalliferous ore area, the surface waters contain certain amount of arsenic. It is mainly due to pollution of weed killers, pesticides containing arsenic compounds or runoff from mining waste tips. The maximum allowable content of arsenic is 0.05 mg/l. Arsenic concentration in Malaysian rivers and lakes are well below 0.01 mg/l but some instances can be as high as 1.0 mg/l.

2.3.2 Cadmium

Cadmium is the environment results from industrial sources such as electroplating facilities, textile manufacturing and chemical industries. Cadmium occurs as an impurity in zinc and may enter tap water as a result of galvanized pipe corrosion.

Excessive exposure to cadmium has resulted in severe health effects. The maximum allowable content of cadmium is 0.005 mg/l. Cadmium can be removed effectively by coagulation at pH greater than 8.0 during water treatment.

2.3.3 Chromium

Chromium is widely distributed in soils and plants, but it is rare in natural waters. Concentration of chromium in household tap water may increase due to plumbing materials. Other potential sources are including fossil fuel combustion, solid waste and sewage sludge incineration and cement plant emission.

Chromium (VI) is much more toxic than chromium (III) and does not have any nutritional value. Chromium (VI) causes hemorrhage of the gastrointestinal tract, ulceration of the nasal septum and respiratory cancer. The maximum allowable value is 0.05 mg/l.

2.3.4 Fluoride

Fluoride is the most electronegative element; small amounts of fluoride are present in most soils. Fluoride has been added to drinking water to reduce the potential for dental caries. Fluoride content in Malaysian surface water is in the range of 0.02 to 0.78 mg/l.

Dental fluorosis appears when fluoride in drinking water is in the range of 1 to 2 mg/l. Fluoride levels of 0.6 to 0.9 mg/l can reduce dental caries formation. Crippling fluorosis occurs when fluoride is in the range of 10 to 40 mg/l. The maximum allowable value is in the range of 0.5 to 0.9 mg/l.

2.3.5 Lead

Lead concentration in natural waters is rarely more than 0.02 mg/l except in areas where soft and acidic waters come into contact with galena or other lead ores. Lead contamination in drinking water is mainly results from corrosion of lead pipes and solders especially in areas of soft water.

Lead in solution is odourless, tasteless and colourless, which makes high levels in drinking water undetectable unless chemically analysed. Lead is a cumulative body poison to humans. Children, infants, foetuses in utero and pregnant women are most sensitive to lead exposure. Lead can attack the nervous system and result in mental retardation and behavioural abnormalities in the young and unborn. The maximum allowable content of lead is 0.05 mg/l.

2.3.6 Mercury

Mercury occurs in drinking water as an inorganic salt and it is poorly absorbed into the adult, but it is highly absorbed in infants and young children. Mercury is a toxic element and has no beneficial physiological function in man.

Organic forms of mercury are readily absorbed and easily enter the central nervous system, causing death or mental and motor dysfunctions. The maximum allowable value is 0.001 mg/l. Organic mercury may be removed by activated carbon adsorption.

2.3.7 Pesticides

Pesticides such as insecticides, herbicides and fungicides are widely used in agriculture and public health. They include inorganic compounds such as DDT dieldrin, aldrin and lindane; organophosphorus compound such as parathion and malathion.

Pesticides include organic compounds which are potentially toxic even in small amounts. Some organic compounds particularly the chlorinated hydrocarbons are very resistant to chemical and biochemical degradation. Accidental discharges of pesticides in bulk to water courses can be more serious causing fish death and making it necessary for a temporary shut down of water intakes.

2.3.8 Trihalomethanes (THMs)

Chlorine has been used to disinfect drinking water since the beginning of the century. Some of the organic compounds in water could react with the chlorine during disinfection process at the treatment plant to form new, complex and dangerous chemicals. Trihalomethanes (THMs) is one group of these which has attracted considerable attention.

Four common THMs found in drinking water are chloroform, bromodichloromethane, dibromochloromethane and bromoform. THMs are only found in raw water or treated water which are disinfected using chlorine. They are considered carcinogens and therefore undesirable in drinking water. The most effective ways of reducing THMs in drinking water are to reduce organic levels before disinfection with chlorine and to restrict the use of chlorine prechlorination.

2.4 Other parameters

2.4.1 pH

Value of pH is the measurement of acidity and alkalinity of waters. Most of the natural waters have pH value range from 4 to 9. Acidic water of low pH tends to be more corrosive, water results a sour taste if the pH value is very low. Malaysian river waters have pH value less than 7 with 60 % of them having value between 6.5 and 8.5. The recommended value for pH of water is in the range of 6.5 to 9.0.

2.4.2 Hardness

Hardness is the measure of polyvalent cation contents present in water due to calcium, magnesium, strontium and barium. Total hardness consists of temporary hardness and permanent hardness. Temporary hardness is precipitated by boiling and forms the scale found inside kettles. Permanent hardness is due to calcium, magnesium sulphates and chlorides which are not precipitated by heating.

According to the research, consumption of hard water may have some health benefits. Consumption of water without mineral in long term may result in the lowering of the bone calcium saturation level. In Malaysia, most of river waters are soft with less than 60 mg/l of hardness. In raw water, hardness of up to 500 mg/l is permitted.

2.4.3 Iron

Iron is found in raw water as a colloid in suspension or as a complex with other mineral or organic substances. Iron is also found in distribution systems where the water ha been in contact with iron pipes. Iron is likely to be precipitated in ferric state, causing brown stains on laundry and plumbing fixtures. Large amounts of iron result a bitter taste in drinking water and make water unpalatable. Iron can lead to the accumulation of large deposits in a distribution system which can give rise to iron bacteria and further deteriorate the water quality.

Levels of iron in most of the Malaysian river water are in the range of 1 to 5 mg/l. However, the maximum allowable value is 0.3 mg/l. Therefore, water exceed the acceptable limit needs to be treated. Iron salts can be reduced to the permissible level by standard water treatment processes of aeration, coagulation and filtration, pH adjustment, oxidation with chlorine and lime softening.

2.5 Water quality standards

Water for drinking and cooking should meet certain standards before it is supplied to the consumer to ensure the human health. World Health Organization (WHO) has outlined a standard for safe drinking water; all the parameters should not exceed the maximum acceptable levels. Many countries have their own standards and WHO standards are only a guideline to them. The parameters measured are divided into a few categories. The comparison of WHO standards and Malaysian standards is shown as below.

2.5.1 Comparison of Malaysian Drinking Standard and WHO Drinking Standard

Parameter	Malaysian standard	WHO standard
Group I - Physical		
Turbidity	5 NTU	5 NTU
Colour	15 TCU or HU	15 TCU
pH	6.5 – 9.0	6.5 – 8.5
Free residual chlorine	Not less than 0.2 mg/l	Not less than 1.0 mg/l
Combined residual chlorine	Not less than 1.0 mg/l	Not less than 1.0 mg/l
Group II - Inorganic		
Total dissolved solids	1000 mg/l	1000 mg/l
CCE	0.5 mg/l	0.5 mg/l

Chloride	250 mg/l	250 mg/l
Anionic detergent MBAs	1 mg/l	1 mg/l
Ammonia as N	0.5 mg/l	1.5 mg/l
Nitrate as N	10 mg/l	10 mg/l
Iron	0.3 mg/l	0.3 mg/l
Fluoride	0.5 – 0.9 mg/l	1.5 mg/l
Hardness as CaCo3	500 mg/l	500 mg/l
Aluminium	0.2 mg/l	0.2 mg/l
Manganese	0.1 mg/l	0.1 mg/l
Group III		
Mercury	0.001 mg/l	0.001 mg/l
Cadmium	0.005 mg/l	0.003 mg/l
Selenium	0.01 mg/l	0.01 mg/l
Arsenic	0.05 mg/l	0.01 mg/l
Cyanide	0.10 mg/l	0.07 mg/l
Lead	0.10 mg/l	0.01 mg/l
Chromium	0.05 mg/l	0.05 mg/l
Silver	0.05 mg/l	0.05 mg/l
Copper	1.0 mg/l	-
Magnesium	150 mg/l	150 mg/l
Zinc	5 mg/l	5 mg/l
Sodium	200 mg/l	200 mg/l
Sulphate	400 mg/l	400 mg/l
Mineral oil	0.30 mg/l	0.3 mg/l
phenol	0.002 mg/l	0.03 mg/l
Chloroform	0.03 mg/l	0.03 mg/l
Group IV		
Total biocides	0.1 mg/l	0.1 mg/l
Organochlorine pesticides:		
Aldrin / dieldrin	0.03 µg/l	0.03 µg/l
Chlordane	0.3 µg/l	0.3 µg/l
DDT	0.001 mg/l	0.001 mg/l
Heptachloro & heptachloro epoxide	0.1 µg/l	0.1 µg/l
Hexachlorobenzene	0.01 µg/l	0.01 µg/l
Lindane	0.003 mg/l	0.003 mg/l
Methoxychlor	0.03 mg/l	0.03 mg/l
Herbicides:		
2, 4-D	0.1 mg/l	0.1 mg/l
Radioactivity:		
Cross α	0.1	0.1
Cross β	1	1

Table 2.1: Comparison of Malaysian Drinking Standard and WHO Drinking Standard

CHAPTER 3

TYPES OF DOMESTIC WATER FILTER

In recent years, manufacturers and distributors of water treatment system have mushroomed in the market. They introduced various types of water filters to consumers. Most of the manufacturers claimed that their water filters are the most effective system to remove contaminants from the supplied water. The development of the nation and increase in standard of living become the important factors for marketing these products.

Actually, each type of water treatment system is designed to treat specific water quality problems. No single water treatment system is able to treat all the water problems as all systems have their own limitation. Some of the common type of water treatment systems sold in the market will be discussed here. The name of the filter systems and the manufacturers will not be revealed as to protect their confidentiality.

3.1 Activated Carbon Filter

The most common base materials used to produce carbon are wood, coal, and coconut shell. These materials are subjected to carbonization process where the base material is heated to the high temperature. In order to activate the carbon, base material is subjected to a second heat and steam treatment.

Activated carbon is an adsorption medium where substances are attracted and attached to the surface of the carbon particles. Household activated carbon filters can be divided into granular activated carbon and powdered activated carbon. Granular carbons made from coal are hard and dense; hence it can be pumped in water slurry without appreciable deterioration. Powdered activated carbon is a coal-based product activated at high temperature and then pulverized to a powder form.

The effectiveness of activated carbon filter depends on the following factors:

i) Physical properties:

The amount and distribution of pores determine how well contaminants are filtered. Size of pores must large enough to admit contaminant molecules because contaminants come in all different sizes.

ii) Chemical properties:

The surface of filter interacts chemically with organic molecules. The chemical nature of adsorbing surface will affect the adsorption effectiveness. Different chemical properties of carbon filters make them more or less attractive to various contaminants.

iii) Contaminant properties:

Adsorption process is affected by concentration of organic contaminants. Most organic chemicals are effectively adsorbed to carbon surface due to the similarity of materials. Smaller organic molecules are held the tightest because they can fit into smaller pores.

iv) Water temperature and pH:

Low pH value and low temperature result in better adsorption because organic chemicals are in more adsorb able form.

v) Exposure time:

The longer the contact time of carbon surface with contaminants in water, the greater amount of contaminant will be removed from water. Contact time can be improved by increasing the amount of activated carbon and reducing the flow rate of water through filter.

3.1.1 Adsorption Mechanism

Activated carbon is a porous material which has a high surface area for the contaminant adsorption. Activated carbon removes contaminants in two mechanisms, namely as adsorption process and catalytic reduction reaction.

Adsorption process is a process where the contaminants in water attached to the surface of carbon. Adsorption involves both adsorbent and adsorbate. Adsorbent is the adsorbing phase (carbon) and the material concentrated or adsorbed at the surface is adsorbate. The most important characteristic of an adsorbent is the quantity of adsorbate it can accumulate.

There are two principal types of adsorption, i.e. physical and chemical adsorption. Physical adsorption is caused by Van der Waals forces and chemical adsorption is commonly resulting in a transformation of the adsorbate.

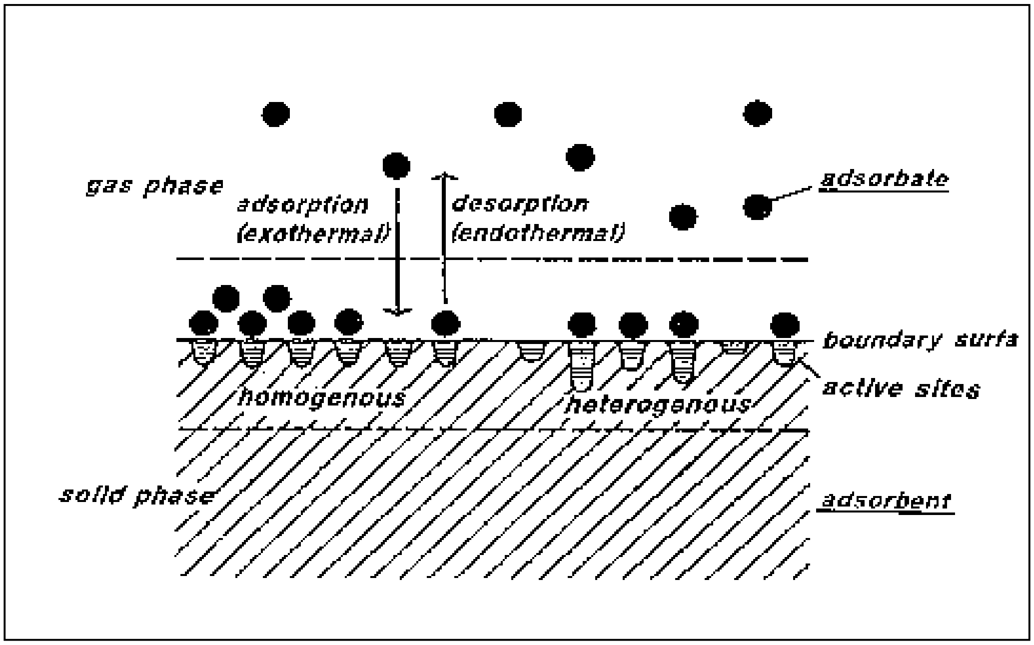


Figure3.1: Adsorption process of activated carbon [www.activated-carbon.com]

Van der Waals forces are extremely short- ranged and sensitive to the distance between carbon surface and adsorbate molecule. The attractive forces can be altered by increasing the density of carbon or reducing the distance between carbon surface and substance being adsorb.

When attractive forces between carbon surface and contaminant are stronger than forces keeping contaminant dissolved in water, the organic materials will be attached to the surface of carbon and therefore adsorption takes place.

Adsorption capacity is increases with surface area of the carbon adsorbent. Therefore, larger surface area is preferable for providing larger adsorption capacity. The resulting bond from chemical adsorption is usually greater than the bond that derived from the physical van der Waals forces.

The degree of insolubility or degree of 'dislike' for water (hydrophobicity) of an organic compound can influence the extent of adsorption significantly, where increasing hydrophobicity usually increases the extent of adsorption. The greater the solubility of the organic compound results in stronger bond and smaller extent of adsorption.

The residual disinfectant such as chlorine can be removed by activated carbon through a catalytic reduction reaction. Activated carbon acts as a reducing agent to reduce chlorine to a non-oxidative chloride ion. Chemical reaction is involves in transferring the electrons from carbon surface to chlorine. As carbon surfaces become filled up, the effectiveness of removal will be reduced. The filter needs to be replaced with a new cartridge.

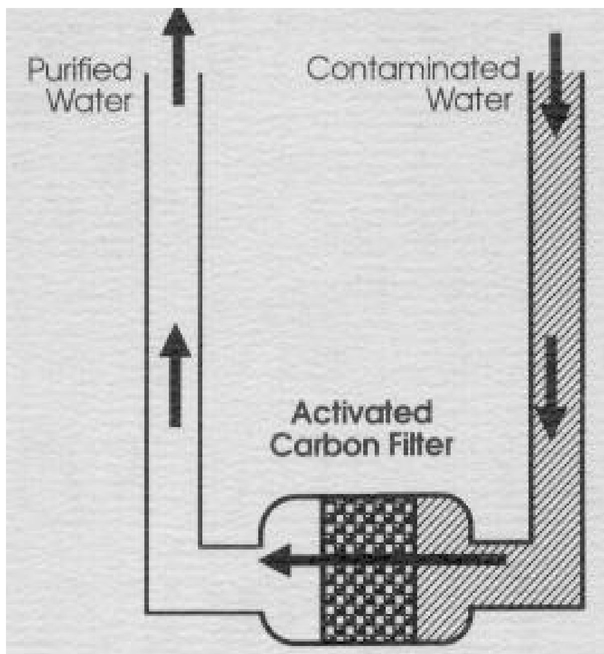


Fig 3.2: Activated carbon filtering process [web1.msue.msu.edu]

3.1.2 Case Study 1: Granular Activated Carbon Filter

Figure 3.3: Arrangement of granular activated carbon filter [www.ionlight.com]

Mechanism:

Activated carbon surface are both hydrophobic (water hating) and oleophilic (oil loving), where they hate water but love oil. This type of filter is used with a sediment filter to remove larger particles such as dust and rust and therefore protects the carbon filter from being clogged. Water flows through the sediment filter before entering carbon filter. When water flows through the carbon filter, dissolved organics in water are adsorbed to the carbon surface.

Cost:

This type of carbon filter costs about RM 130 per unit.

Maintenance:

Granulated activated carbon is not cleanable, therefore high solids or turbidity in raw water will reduce its useful life. The filtering capacity of granular activated carbon is about 6800 L. Therefore, the granulated activated carbon should be replaced at intervals of 6800L usage to maintain at its optimal performance. The cartridge of this filter costs about RM 20 per unit.

3.1.3 Case Study 2: Powdered Activated Carbon Filter

Figure 3.4: Powdered activated carbon cartridge

Mechanism:

This is a simple filtration system where only one cartridge is used to treat the water. Carbon in powder form is fixed into a cartridge. Water enters the filter from the bottom end and flows through the cartridge. The contaminants are attracted and attached to the surface of carbon particles.

Cost:

This kind of powdered activated carbon filter costs about RM 150 per unit.

Maintenance:

Powdered activated carbon is also not cleanable. The filtering capacity of the cartridge is 12800 L or it can last about 6 months, and then the old cartridge should be replaced by a new one. The cartridge costs about RM 40 per unit.

Advantages and disadvantages:

Activated carbon is not a universal treatment, only limited number of contaminants will be removed. Carbon filter can be used to remove organic contaminants, chlorine, some organic chemicals such as trihalomethanes (THM), pesticides and industrial solvents.

Carbon filters do not remove iron content and heavy metals such as silver, copper and lead. Offensive taste, odour and colour in supplied water also can be removed by carbon filter.

Activated carbon filters can be a breeding ground for microorganisms. Non-pathogenic bacteria that do not cause diseases have been regularly found in carbon filters. In order to flush out the bacteria that have been built up in the filter, let the water run for 30 seconds prior to use especially if filter is not used for several days. Some manufacturers add silver to carbon filters to prevent bacteria growth. Activated carbon filters only suitable for use on bacteria free water.

3.2 Membrane Filter

Membrane filtration process has been used for many years in water treatment process. The typical membrane materials used are polymer and ceramic.

Membrane is a thin film of porous material that allows water to pass through and traps contaminants larger than pore size on the top surface of the membrane.

Membrane can be used to prevent larger and undesirable molecules such as virus, bacteria, salt and metal.

Membranes are increasingly being used in water treatment process because:

- Membranes remove particulates by physical staining above a target size, so they are able to remove microbial contaminants such as Giardia, Cryptosporidium and viruses.

- Membranes may reduce the disinfection chemicals.

- Membranes are able to remove organic precursors and leading to more biologically stable water.

Membranes can be classified into three main types, namely as micro filtration, ultra filtration and nano filtration. Nano filtration (NF) is a lower pressure process that removes substances with molecular weight above 100-500 and is capable of removing hardness, pathogens and originally derived colour. Ultra filtration (UF) is a low pressure process for removal of microorganisms, colloids, and high molecular weight compounds while salts and water will pass through. Micro filtration (MF) is similar to ultra filtration except that the pore size is slightly larger and operating pressures are lower. Micro filtration can remove contaminants in the range of 0.025 to 10.0 μm from fluid by passage through the micro- porous medium.

There are two forms of separation in membrane filtration. One form is cross flow separation and the other form is dead end filtration.

In cross flow separation, the fluid stream runs parallel to the membrane. There is pressure differential across the membrane and the filtrate passes through the membrane and the remainder continues across the membrane.

In dead end filtration, all the fluid will pass through the membrane; those particles that cannot fit through the membrane pores are being stopped. The efficiency of filtration is dependent on the pore size of the membrane. There are several mechanisms by which a ceramic element filters out particles as a dead end filtration.

i) Direct interception or sieving:

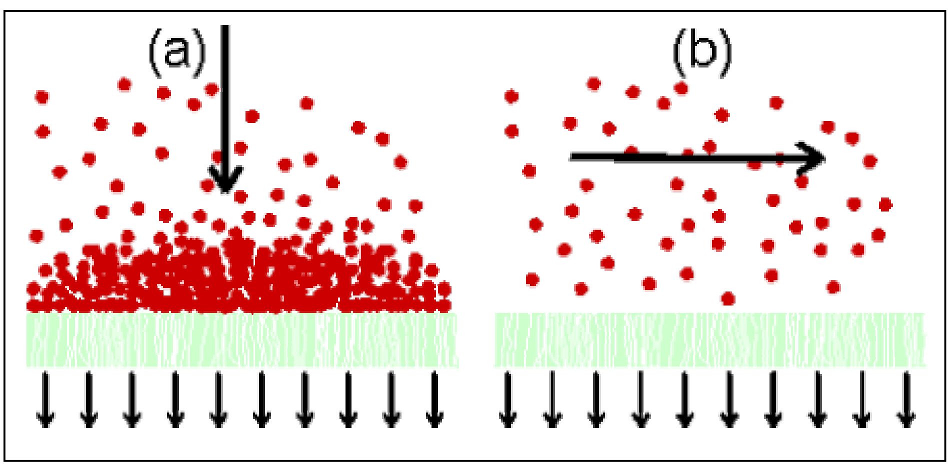
Particles of 0.5 µm and larger run into a pore that is smaller than the topmost layer particle of the ceramic are captured.

ii) Bridging:

Particles that smaller than 0.5 µm may be too small to be intercepted, however two particles hitting the obstruction at the same time will form a bridge across the pore adhering to each other. The topmost blocked layer can be removed with brush for many times before the filter has to be changed.

iii) Initial impaction:

Particle flowing through the filter hits none porous surface barrier, it becomes captured while the water flows around the barrier. (Source: Doulton Water Filter Ceramic Candle and Cartridge Technologies)



(a) Dead end filtration (b) Cross flow separation

Figure 3.5: Two forms of separation in membrane filtration [www.Isbu.ac.uk]

Micro filtration has the largest pore size of membrane and it is operated at low pressure. Micro filtration can remove Giardia and Cryptosporidium but is less effective at removing viruses. Ultra filtration can remove microorganisms, colloids, high molecular weight compounds, trihalomethane, disinfection products and some ionic material. Nano filtration can remove hardness, pathogens and organically derived colour.

Membrane filter can be used both at point of use (POU) and point of entry (POE). Ceramic is the common material used as the membrane for point of use filter which is located in the kitchen. Whereas fiber is the common material used as filter stem for point of entry.

Fiber filters are usually made of cellulose, rayon or other thread like material spun into a mesh with small pores. Fiber filters are designed to remove suspended solids from fluid. This kind of filter is usually installed at the main pipe outside the house to filter out the big particles before entering the piping systems in the house.

2.2.1 Case Study 1: Point Of Entry (POE)

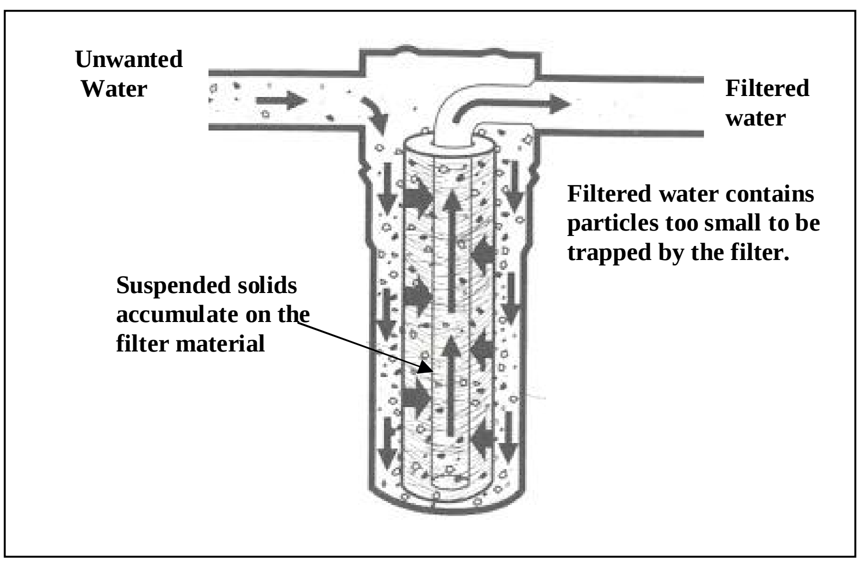


Figure 3.6: Fiber membrane filtration process [http://ianrpubs.unl.edu]

Mechanism:

Water flows into a cartridge at high pressure and makes its way into the fiber stem. The tightly wrapped fibers form a cylinder around a tubular opening and pressure forces water through the wrappings to the inner opening that leads to the faucet. The fiber will then filter out the larger particles such as organic matter, sand, mud and silt. After that, filtrate will pass to the opening that leads to the faucet. Normally, the flow rate is high with higher pressure as it is on the main pipe.

Cost:

Membrane filter is quite cheap where the cost ranges from RM 75 to RM 200 per unit.

Maintenance:

When the old fiber stem is worn out, then a new fiber stem has to be replaced. Clogged filter can reduce the flow pressure of water and interrupt the water flow into the house. The fiber stem is costs about RM 39 per unit. The life expectancy of the filter is depends on the quality of feed water. More particles will be trapped in finer mesh membrane compared to coarse mesh; therefore more frequent filter change is required.

Advantages and disadvantages:

Fiber filters remove suspended solids in the water. They may not be effective in removing dissolved solids, organic and chemical pollutants. The fiber used can retain large amounts of suspended matter if maintained properly. However, drinking water may contain very fine suspended material, which may be too small to be removed by fiber filters.

Since this filter is exposed to the sunlight, it might encourage bacteria and algae growth. This will contaminate further the water flowing through it. Bacteria will affect health of the users and hence fiber filters need frequent replacement. If proper attention is given to the filter, then it can stop the unwanted larger particles flow into the house piping system. This system is economical since no electric energy is being used during the filtration process.

Case Study 2: Point Of Use (POU)

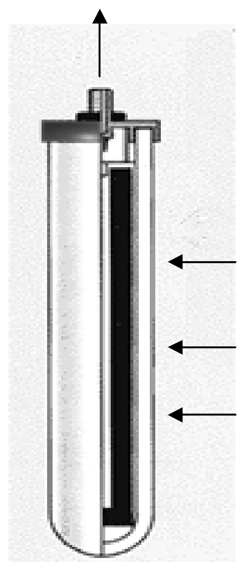


Figure 3.7: Typical ceramic membrane [www.doultonusa.com]

Mechanism:

This filter used ceramic as the membrane to filter the feed water. The pressure and flow rate of the water are relatively lower than the point of entry. Tap water will flow into the filter via an input hose, and then the pressure in the cartridge will force water into the ceramic stem to retain the unwanted contaminants. Ceramic filtration technology is often called dead end filtration. The filtrate in the stem will flow out through the output hose and use for cooking and drinking purposes.

Cost:

This kind of filter costs in the range from RM 165 – 300 per unit dependents upon the brand of the filter.

Maintenance:

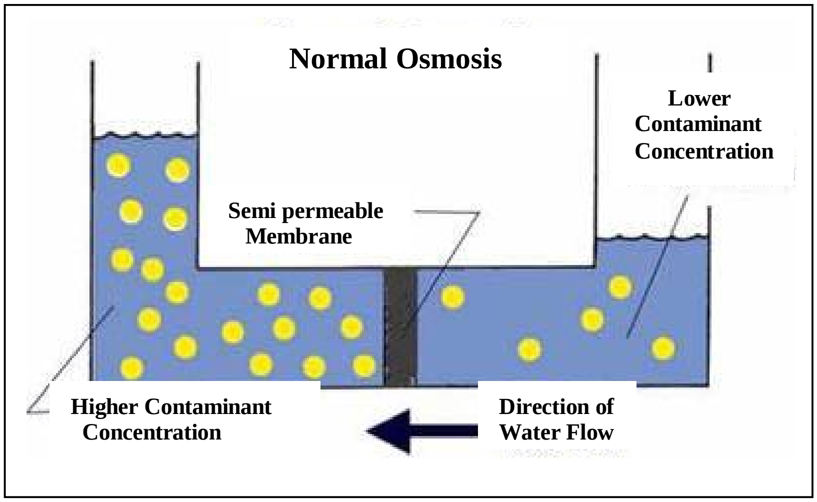
The ceramic stem should be brushed and washed regularly to prevent it from being clogged. The ceramic will become thinner and thinner, and then users need to replace the old stem with a new one. Normally, a ceramic stem can last for about 12 months depends on how frequent is the cleaning process.

Advantages and disadvantages:

This kind of filter is small in size; therefore it can fit easily at the kitchen. This filter has simple mechanism and straightforward application; therefore it is very easy to use by the consumers. It is also affordable and available in the current market.

The tiny pores of a ceramic filter element make it an extremely efficient filter for removal of particulate matter and fine sediment from the water. This ceramic filter is effective in removing mud, silt and other suspended matter. It is less effective in removing dissolved solids, organic and chemical pollutants.

3.3 Reverse Osmosis



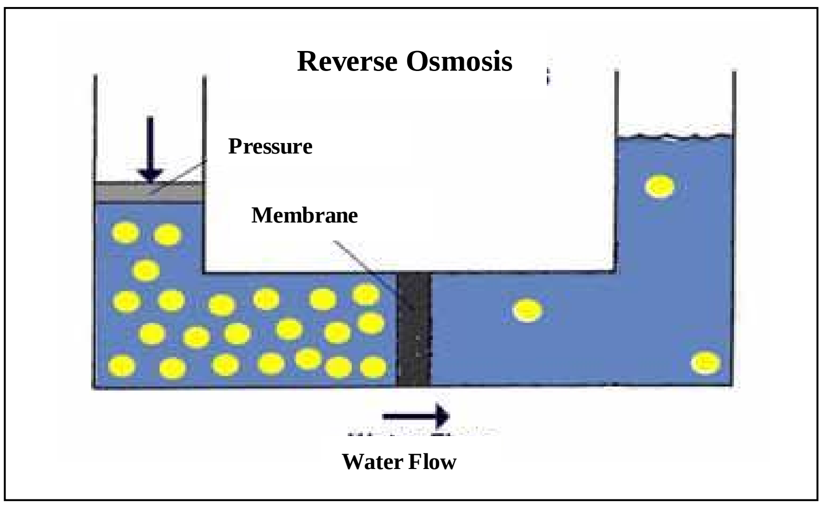


Figure 3.8: Osmosis and reverse osmosis process [www.wqa.org]

Reverse osmosis is a water purification process where untreated water flows thorough several filters and elements, and one of them is semi-permeable membrane. Reverse osmosis system is effective in removing impurities in water such as heavy metals, chemical toxin, pesticides, bacteria and viruses. This system is used to separate the pure water from salt and other contaminants.

In order to understand the reverse osmosis system, we need to know about the osmosis process first. For two aqueous solutions of different concentrations of dissolved solids which are separated by a semi-permeable membrane, water will pass through the membrane in the direction of more concentrated solution until both sides of concentrations are reaching at equilibrium state. This process is called osmosis.

In reverse osmosis process, pressure is applied to the more concentrated liquid in order to reverse the direction of osmosis. Normal osmotic flow is forced through semi- permeable membrane into less concentrated solutions. The flow is reversed mechanically and concentrated solution is separated into water and dissolved solids.

Dirty water left behind is drained off at a constant rate capillary waste water controller. Rejection efficiency of R.O. system is affected by both ionic charge and concentration gradient. Rejection rates of single-charged ions are ranged in 90 to 96 %, whereas multi-charged ions having rejection rates exceeding 99 %. Rejection efficiency is reducing as the concentration gradient increasing.

3.3.1 R.O. Membrane

The membrane used in R.O. system is a thin micro- porous surface that rejects all impurities but only allows water molecules to pass through. The three types of commonly used membranes are tubular, spiral wound and hollow fiber.

The two most common base materials used to produce membranes are cellulose acetate and polyamide polymers. Polyamide polymer membranes produce both higher rejection and flux; tolerate a wider pH range and higher continuous temperature than cellulose acetate.

i) Spiral wound membrane:

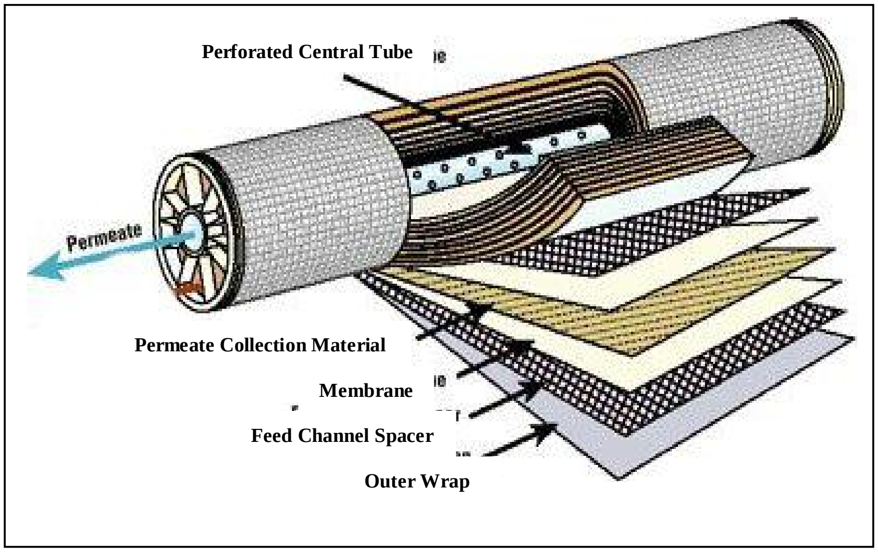


Figure 3.9: Spiral wound membrane [http://trisep.com]

Spiral wound membrane is the most popular membranes used in household R.O. systems. In the design of spiral wound, two flat sheets of membrane are placed back to back to form an envelope that contains a porous sheet of material called a permeate carrier. Then, envelope is glued together on three sides only. The fourth side is attached to a perforated tube.

Water that passes through membrane is then flows along the permeate carrier toward open end of envelope and leaves through permeate tube. The pores of membrane can range from atomic dimensions (<10 angstroms) to 100+ microns. Membrane can reject bacteria and 85 to 95 % of inorganic solids but it allows dissolved solids to pass through.

ii) Hollow fiber membrane:

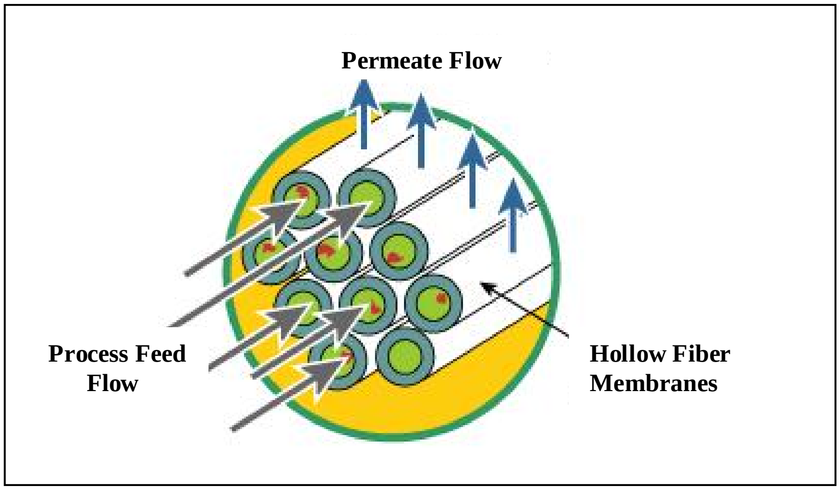


Figure 3.10: Hollow fiber membrane [www.kochmembrane.com]

Hollow fiber is one of the semi permeable membranes used in reverse osmosis system. It is usually produced using aromatic polyamides or cellulose triacetate. Membrane material is spun into hair like hollow fibers with outer diameter of between 85 to 200 microns. The fibers are bundled together in either a U-shaped configuration or straight configuration.

Pressure is applied to pump raw water through the distributor tube and flows outward through the fiber bundle. The pressurized feed water permeates through the wall of each hollow fiber and leaving the dissolved solids, organics and bacteria to discharge as reject water.

The major disadvantage of the hollow fiber membrane is its susceptibility to fouling. Therefore, feed water that containing turbidity, iron and manganese need to be treated before passing through the hollow fiber.

The performance and life of membrane will be affected by the influent water supply.

i) Pressure:

Both the quantity and purity of product water will be affected by the pressure of feed water. Lower product flow rate and lower product purity is caused by lower feed water pressure.

ii) pH:

If the feed water is basic, acidic or unstable, it is recommended to use the wider pH range membranes.

iii) Free chlorine and bacteria:

Cellulose acetate membranes require constant free chlorine to prevent bacteria growth and damage. Polyamide and thin film membrane will be damaged by free chlorine; therefore pre-carbon filter is used to remove chlorine from water.

iv) Temperature:

The performance of membrane is based on temperature of 25 ˚C. Quantity of product water is reduces by 3 % for every 1 ˚C below 25 ˚C. Feed water should not exceed 35 ˚C because most membranes damage at that temperature.

Household reverse osmosis systems in the market can be classified as undersink and tabletop. Undersink system is much cheaper than tabletop. Household R.O. systems usually can treat between 1 to 9 gallons of water. R.O. system is also equipped with a booster pump to apply high pressure to the water and a tank is needed to store pure water due to its slow operation.

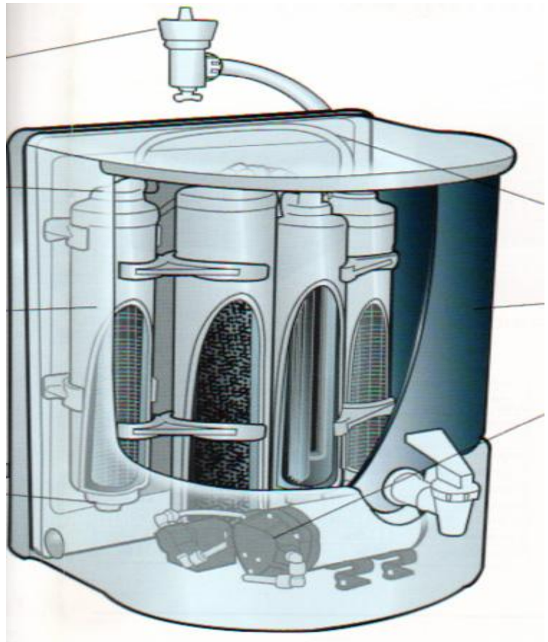


Figure 3.11: Typical counter top R.O. system [http://yourwaterneeds.com]

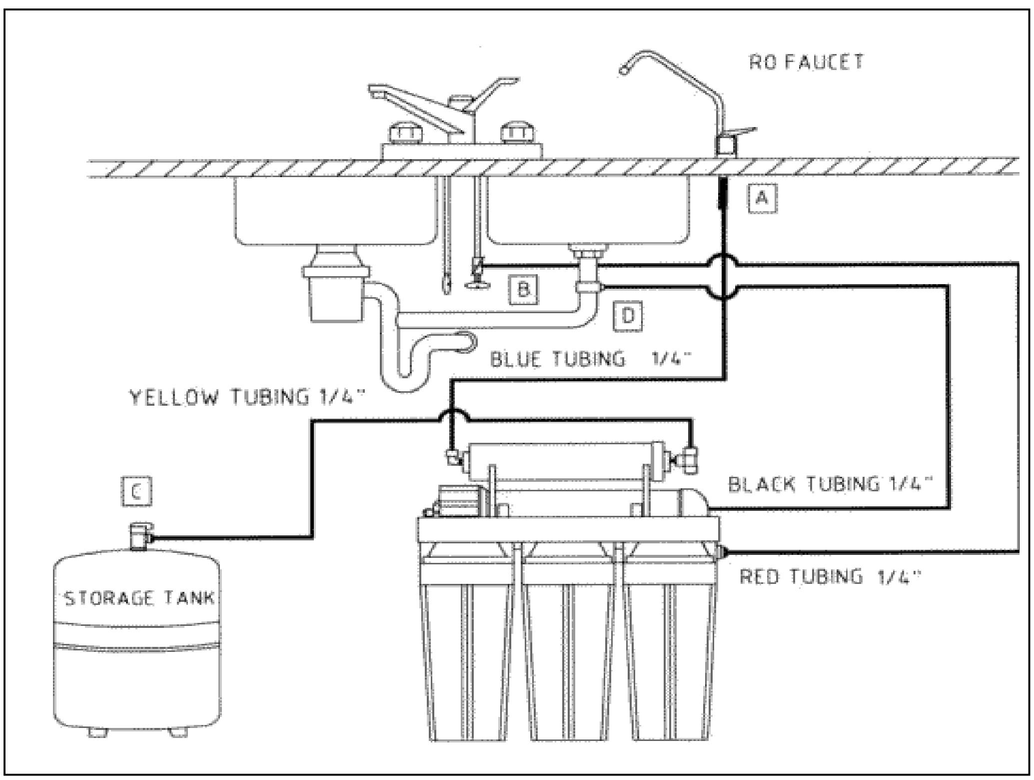


Figure 3.12: Typical under sink R.O. system arrangement [www.edenengineering.com]

Figure 3.13: Typical arrangement of R.O. system [www.jousui-souchi.com]

3.2.2Case Study 1: RO1

Mechanism:

This reverse osmosis system consists of five elements as below:

- Stage 1: 5 micron sediment filter – this sediment filter is used to extract larger sediment such as dirt and mud. It also used to prolong the life span of the other elements in water filtration system.

- Stage 2: Pre-carbon – coconut based activated carbons are used to trap large sediments and extract excessive contents of chlorine from the water supply.

- Stage 3: 1 micron sediment filter – this sediment provides a good filtration level for extracting large and microscopic sediment. This element protects and prolongs the life span of membrane.

- Stage 4: R.O. membrane – the membrane consists of a skin about 0.0001 microns and a support layer about 100 microns. This element only allows water molecules to pass through.

- Stage 5: Post-carbon – this element removes the residue unpleasant smell and maintains fresh water taste.

Cost:

This R.O. system costs about RM 2500 per unit.

Maintenance:

The frequency and cost of replacing parts are shown in the table below.

Filter	Frequency	Price
Sediment 5 micron	Every 3 months	RM 30
Pre-carbon	Every 8 months	RM 60
Sediment 1 microns	Every 6 months	RM 35
R.O. membrane	Every 18 months	RM 200
Post-carbon	Every 8 months	RM 70

Table 3.1: Replacement parts of RO1

3.3.3 Case Study 2: RO2

Mechanism:

This R.O. system is similar to the previous system, but this system consists of six filters instead of typical five filters.

- Stage 1: Plus-sediment filter – reduces undissolved particles like dust and rust from existing water supply and protects membrane and pre-carbon filter from being clogged.

- Stage 2: Pre-carbon filter – reduces chlorine to prevent hydrolysis of membrane and absorbs volatile organic compounds from water supply.

- Stage 3: TFC membrane filter – thin film composite membrane with pores of up to 0.0001 micron used to reduce heavy metals and waterborne microorganisms such as viruses and bacteria. Chlorine will destroy TCF membrane; therefore it is always equipped with carbon pre-filter to remove chlorine.

- Stage 4: Post-carbon filter – improves taste and odour in drinking water as well as enhances anti-bacterial functions through its silver granular activated carbon.

- Stage 5: Fine filter – minimizes contamination and reduces fine dust that flows into storage tank by passing it first through post-carbon filter.

- Stage 6: Bio-ceramic – restraints breeding of any microorganisms inside water tank and enhance sanitation.

Cost:

This six filtration system costs about RM 3100 per unit.

Maintenance:

The frequency and cost of replacing parts are shown in the table below.

Filter	Frequency	Price
Sediment filter	3 months	RM 60
Pre-carbon filter	6 months	RM 70
TFC membrane filter	24 months	RM 300
Post-carbon filter	8 months	RM 80
Fine filter	9 months	RM 75
Bio-ceramic	12 months	RM 80

Table 3.2: Replacement parts of RO2

Advantages and disadvantages:

Reverse osmosis treatment system can provide consumers with pure water, free from any dissolved solids, organic and chemical matter and mineral. Some typical removal rates for R.O. system are shown in the table below.

Chemical	Rejection (%)
Sodium	85 – 93
Calcium	96 – 98
Magnesium	96 – 98
Iron	95 – 98
Lead	96 – 99
Fluoride	87 – 93
Nitrate	60 – 92
Copper	98 – 99
Arsenic	94 – 96
Mercury	96 – 98

Table 3.3: Typical R.O. contaminant rejection (source: www.cetsolar.com)

As R.O. system removes large amounts of beneficial minerals from the water, we might lack of minerals in our body if we consume R.O. water for a long period of time. Removal of alkaline mineral will produce acidic water. This may result in pulling of minerals from our bone and teeth to form bicarbonates to neutralize the acid in the body.

R.O. system wastes a lot of water, it only recovers 5 to 15 % of the water that entering the system, and the remainder is discharged as waste water. The waste water is contains rejected contaminants in supplied water.

R.O. system takes time in the treatment process, most of the point-of-use systems produce less than 1 gallon of water per hour. R.O. system requires regular maintenance and monitoring to perform satisfactorily over an extended period of time. The maintenance cost can be considered very high.

3.4 Distillation

Distillation is a natural process that exists since the earth began. In natural, distillation is responsible for the hydrologic cycle. Surface water on the earth's surface such as lakes, oceans and streams is evaporates into the atmosphere when it is heated up by the sun. Impurities of the water are leaving behind during evaporation process. As the vapor is cools, it is condenses and falls back to the earth as rain, snow or other forms of precipitation.

Distillation is one of the earliest types of water treatment systems, and it is still a popular treatment system until today. Distillation process is easy to understand and it is one of the effective treatments to remove the water contaminants. Distillation in water treatment also applied the same theory as natural distillation.

Distillation is a process to produce pure water by removing almost all impurities from the water. Distillation process is able to remove nitrate, bacteria, sodium, hardness, dissolved solids, most organic compound and heavy metals from water. This process used distiller which is made of stainless steel, aluminium or plastic materials, this is because they do not absorb impurities from water and easy to clean.

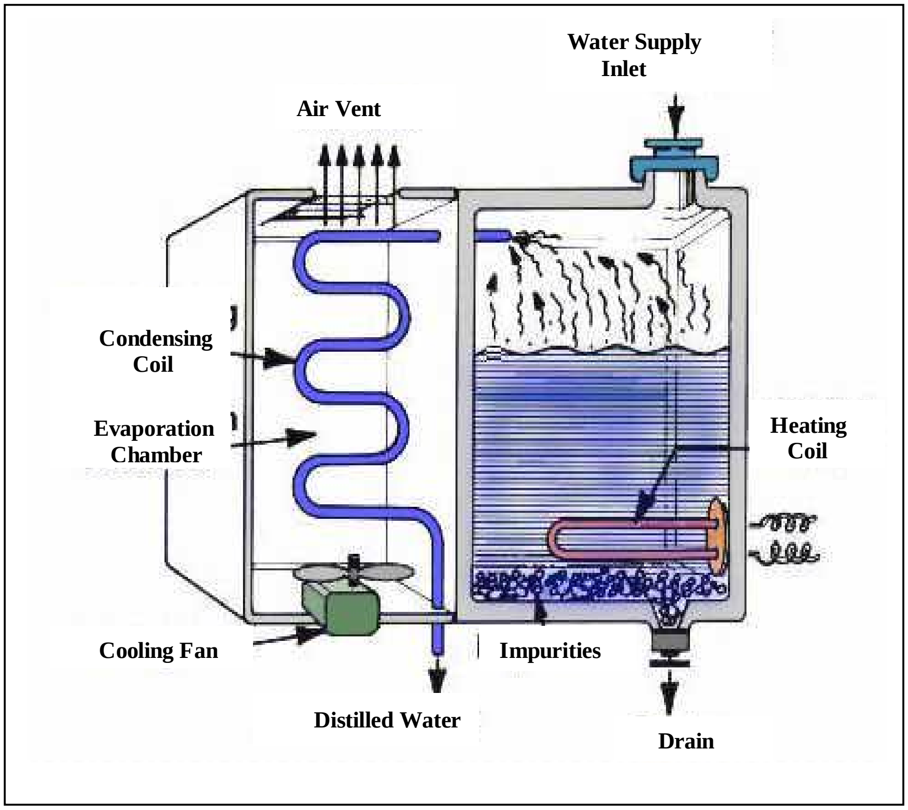


Figure 3.14: Components and process of a distiller [www.wqa.org]

Most of the household distillation systems use single stage distillers which are simple in design and effective in contaminants removal. Tap water is heated to 100 ˚C to kill bacteria and viruses by continuous boiling. Then, steam is rises and leaving behind the impurities of water in the boiling chamber.

The low boiling gases will escape through the gaseous vent. Rising steam is then passes into cooling section and condenses back into liquid. The condensed liquid will flows into a storage container for drinking and cooking purposes. Household distillers are not economical to distill water for other uses like flushing toilets, bathing, washing clothes and cleaning due to its slow operation.

Figure 3.15: Typical countertop distiller [www.happyherbalist.com]

3.4.1 Case Study 1: Distillation 1

Mechanism:

Tap water is fed into the distiller, and then water is heated by heating element to the boiling point. When the water reaches boiling point, steam is rises and contaminants are leaves behind. Steam is rises and enters cooling coils, where it is cooled and condensed back to the water. The pure water then flows into storage container. Electric power is used to heat the tap water into steam.

Cost:

One set of distiller costs about RM 1000.

Maintenance:

Mineral and other residues accumulated in boiling chamber during boiling process need to be removed periodically to ensure optimal performance. Mineral scales build up from hard water need to remove by using acid type cleaner. The life span of a distiller is depends on the levels of impurities in raw water supply, how often distiller is operates and how often distiller is cleaned. Common repair for a distiller is replacing of heating element.

Advantages and disadvantages:

Distillation process provides pure water that free of total dissolved solids, contaminants, heavy metals, chlorine, pesticides, inorganic particles and minerals. Distillation also removes bacteria and viruses from tap water at boiling point. No filter cartridges need to be replaced in a distiller.

Similar to R.O. system, distillation process also removes large amounts of minerals that needed by our human body such as calcium and magnesium. If we consumed distilled water over a long period, it is detrimental to health of bones, teeth and tissues. Since distilled water contains no minerals, it may taste flat when we consume.

However, distilled water can help to dissolve the toxic poisons that accumulate in our bodies, clean out the body cells and organs. Distilled water is suitable to consume by patients who need to dissolve kidneys or gallstones. Distilled water is enters the body and picks up mineral deposits accumulated in the joints or artery walls and carry them out. This can help to decrease gallstones and kidney stones until they can safely pass through their ducts.

Distillation can produce almost 99.5 % extremely pure water, but it is not effective at removing volatile organic compounds because many of them re-condense back into liquid. Bacteria can also accumulate in the cooling coils when a distiller has not been used for a period of time.

Distiller uses electric power all the time to keep it operating, therefore the operating cost for distillation units are generally higher than other forms of home water filter such as activated carbon and membrane. Distiller takes time to purify water, it takes about 8 hours to produce a few gallons of water; therefore it is limited to point-of-use systems.

3.5 Ultraviolet Light (UV light)

Ultraviolet light is also one of the common techniques used in water treatment systems. UV light has been used for many years as an environmental friendly route to water disinfection. Sun is the main source of natural UV light on the earth. Apart from sun, stars also produce some amount of UV light.

Earth's atmosphere produces natural UV light when the very energetic particles from sun strike the air molecules. UV light is invisible to human eye, the short wave light having wavelength ranging from x-ray region (100 nm) to blue end of visible light (400 nm).

The three distinct wavelengths of UV light are as below:

UV-A (400 nm – 315 nm):
It is referred to as 'black light'. It represents the largest region portion of natural UV light. It has the longest wavelength and the lowest energy.

UV-B (315 nm – 280 nm):
It is partially blocked by ozone layer. It is the most aggressive component of natural UV light which responsible for sunburn.

UV-C (280 nm – 100 nm):
It is only encountered from artificial light sources since it is totally absorbed by earth's atmosphere.

Ultraviolet light used in water treatment system is aimed to kill the bacteria, viruses and microorganisms in supplied water. The recent research in USA shown that 271 nm light to 263 nm light are the most effective UV wavelengths for deactivation of particular target organisms. (Source:http://www.hanovia.com)

3.5.1 Mechanism of UV Light

A microorganism is made up of cell wall, cytoplasmic membrane, cells genetic material and nucleic acid. When harmful microbes are exposed to the UV rays, their nucleic acid will absorbs the UV energy which then scrambles their DNA structure. DNA (deoxyribonucleic acid) of microorganisms is the main target of the UV light.

DNA is consists of a linear chain of nitrogen bases known as purines (adenine and guanine) and pyrimidines (thymine and cytosine). Sugar-phosphate components are used to link these compounds along the chain. Adenine is always linked with thymine in opposite by hydrogen bond and guanine is always paired with cytosine by hydrogen bond.

Purine combines with pyrimidine to form base pairs. Hydrogen bond will be ruptured when UV light is absorbed by pyrimidine bases. Disruption in DNA chain means cell undergoes mitosis (cell division) and DNA is not be able to replicate again. Therefore, microorganism is considered dead and it is harmful less to human health.

Figure 3.16: Disruption of DNA structure [www.hanovia.com]

UV light is generated either from low pressure or medium pressure lamp. Low pressure lamp usually has a single line output at 253.7 nm and medium pressure lamp has a continuous output from 200 nm up to long wave visible light.

Most of the commercially available units use low pressure mercury vapor lamps. The operation of these lamps is very similar to the fluorescent lighting with which we are all familiar.

The effectiveness of UV light depends on quality of the feed water:

i) Suspended solids:

Suspended solids in feed water cause a shielding problem during the treatment process, where microbes may pass through the sterilizer without actually expose to the direct UV penetration. This problem can be resolved by using pre-filtration of at least 5 microns.

ii) Iron and manganese:

Iron or manganese will cause staining on the lamp or quartz sleeve at levels as low as 0.3 ppm of iron and 0.05 ppm of manganese. In order to eliminate the staining problem, proper pretreatment is required.

iii) Calcium and magnesium:

Hard water will allow scale formation on the lamp or quartz sleeve. When there is low flow rate, calcium and magnesium ions will tie up with carbonates and sulfates to form hard scale which is builds up inside the sterilizer chamber and deposited on lamp or sleeve.

iv) Other absorbing compounds:

The amount of UV energy that available to penetrate through the water is being reduced when the feed water is contains humic and fumic acids.

v) Temperature:

The optimal operating temperature of UV lamp must be approximate 40 ˚C. UV levels will fluctuate with excessively high or low temperature levels.

In water treatment systems, UV light is always enclosed in the quartz sleeve. There are three purposes of using quartz sleeve:

- It is used to isolate the UV lamp from water, so that electrical contacts are not shorted out by water.

- It is used to create a thermal barrier in order to allow the UV lamp to maintain its ideal operating temperature.

- It is also used to allow optimum transmission of UV energy into the water.

Figure 3.17: Typical UV treatment arrangement [www.pure-pro.com]

3.5.2 Case Study 1: UV1

Mechanism:

This UV ray treatment system has three different components; they are control circuit, power electronics and UV chamber. Consumer can control the intensity of UV ray through the control circuit. UV lamp is enclosed in quartz sleeve. Water enters one end of the sleeve, flows through the sleeve around UV lamp and then exits the other end within a few second.

Water must flow very close to the UV light in a thin layer and at slow flow rate to assure that bacteria and viruses are destroyed. Bacteria and viruses exposed to the UV ray will be killed or rendered inactive.

Cost:

The ultraviolet light treatment system costs about RM 1300 per unit.

Maintenance:

Ultraviolet light water treatment system does not require much maintenance. The sleeve does not need to replace unless it gets broken, but outside of the sleeve need to be cleaned several times per year. UV lamp requires replacement once a year to ensure its optimal performance.

Advantages and disadvantages:

UV light disinfection process does not use chemicals; therefore it leaves no smell or taste in the treated water. It does not affect the minerals in water, so that consumers are able to obtain the beneficial mineral from water. This system is effective in killing all the bacteria, viruses and microorganism in water; therefore it can produce bacteria free drinking water.

UV water treatment does not effective against lead, asbestos, chlorine and many other organic chemicals. This system does not suitable for water with high levels of suspended solids as these materials could shade bacteria from the direct UV rays. Therefore some bacteria could still pass through the water and this is harmful to human health if the water is consumed directly.

UV water treatment system requires electric current for operation, and it is also need regular inspection and maintenance to ensure that the treated water is bacteria. This system should use with other forms of water filter to provide clean and safe water to consumers.

3.6 Combination Filter

Combination water treatment systems use a few kind of treatment into one. Filtrate from these kinds of systems usually can be consumed straight away. The combination filter consists of several cartridges, water need to pass through those cartridges one by one and finally reach at consumers.

3.6.1 Case Study 1: Combination 1

Mechanism:

This treatment system consists of six filters as below:

- Filter1, ceramic membrane filter- pore size of 0.9 micron with silver element used to filter the residues and bacteria in supply water.
- Filter 2, activated carbon filter- remove chlorine, odour, colour, organic chemicals and remaining residue inside the water. It also prevents growth of bacteria.
- Filters 3, silver carbon- enhances remove chlorine, organic chemicals and prevent bacteria from breeding.
- Filter 4, sediment- resin bond cellulose used to filter multi chemical compounds and suspended particles.
- Filter 5, post carbon- further improves any unpleasant smells of traces of organic waste.
- Filter 6, bio-energy converter- to break molecules structure and provide energy rays that regulate and active cells.

Cost:

One set of the treatment unit costs about RM 2500.

Maintenance:

Filter 1, 2, 3, 4 and 5 need to be changed once a year. Consumers only need to change filter 6 every two years.

Advantages and disadvantages:

This treatment system added silver to the activated carbon filter to prevent bacteria growth, therefore boiling is not necessary. This system used activated carbon repetitively; there are three activated carbon filters in the whole system of six filters. With so many times of carbon filtration, no doubt the water is clean.

Mineral stones used in filter 6 are said to provide minerals and calcium to the drinking water, but it is not sure that the stones are really omit minerals. It may become the bacteria breeding ground which is harmful to human health.

3.6.2 Case Study 2: Combination 2

Mechanism:

This combination treatment system is combining carbon filter with the ultra-violet light. Carbon filter is shaped into a block stem and inserted into a cartridge. When water flows into the cartridge, carbon filter is removes the chlorine, lead and organic chemicals such as trihalomethanes. Besides that, carbon also improves the taste and odour of drinking water.

After that, water will flow through the ultra-violet cartridge which puts out up to 80 millijoules of ultra-violet light to destroy the bacteria and viruses in drinking water. Ultra-violet light is switches on when electro-magnetic connection is activated by turning the tap.

Cost:

This type of water treatment system costs about RM 3000 per unit.

Maintenance:

The frequency and cost of replacing parts are shown in the table below.

Parts	Frequency	Price
Carbon block	Every 12 months	RM 275.00
UV light	Every 12 months	RM 344.00

Table 3.4: Replacement parts of COM2

Advantages and disadvantages:

This treatment system used only the activated carbon filter; therefore it does not remove the beneficial minerals such as calcium, magnesium and fluoride from drinking water. Bacteria and viruses are destroyed by ultra-violet light, so water can be consumed directly.

Ultra-violet light is not on all the time; therefore it does not waste energy. This system is equipped with monitor technology; it gives both audio and visual indication when it is time for replacement.

The initial cost of this water treatment system is high; the maintenance costs are also very high too. Not many consumers afford to invest in this type of water treatment system due to its high cost.

3.6.3 Case Study 3: Combination 3

This whole filtration system consists of three cartridges. The first cartridge is a ceramic pre-filter while the second cartridge is consists of activated carbon filter. The third cartridge totally has four different layers, namely KDF, calcium ionized clay, energizing ceramic and natural mineral stones.

Mechanism:

- The first cartridge, ceramic pre-filter is used to block the suspended solids like silt and clay in the supplied water just like any normal ceramic membrane filter.

- The second cartridge, activated carbon is used to remove organic contaminants, chlorine and some organic chemicals like explained previously.

- In third cartridge, the mineral stones are generally to replenish the essential minerals like calcium into the water. This water filter is not only removes water pollutants, chlorine, bacteria and harmful heavy metals in the water, but it also further energizes the water by releasing essential minerals and calcium ions into the water.

Cost:

One set of this filtration system costs about RM 1600.

Maintenance:

The changing frequency of cartridges is depends on the water quality and water consumption rate. First cartridge needs to be clean frequently by using toothbrush once the sediment is covering its surface.

Ceramic pre-filter will become thinner and thinner, consumers need to change it when the carbon block inside ceramic pre-filter exposes to the surface. Normally, ceramic pre-filter can last about one year. The second cartridge needs to be changed every one year while the third cartridge needs to be changed every three years.

Advantages and disadvantages:

The application of KDF in this filtration system can remove contaminants such as chlorine, hydrogen sulfide, iron, lead, calcium, mercury, arsenic and other inorganic compounds.

KDF together with GAC can partially remove hardness, destroy fungi and algae, and control bacteria growth. If contact time is sufficient, both GAC and KDF will clean the feed water from most of the contaminants.

It is wondering that why this filtration system needs to be equipped with calcium ionized clay, mineral stones and energizing ceramic. The manufacturer claimed that these substances are able to provide minerals and release energy to the water. It is probably a marketing tactic to lure in customers into believing its benefits to health. This system is overpriced considering the technology involved.

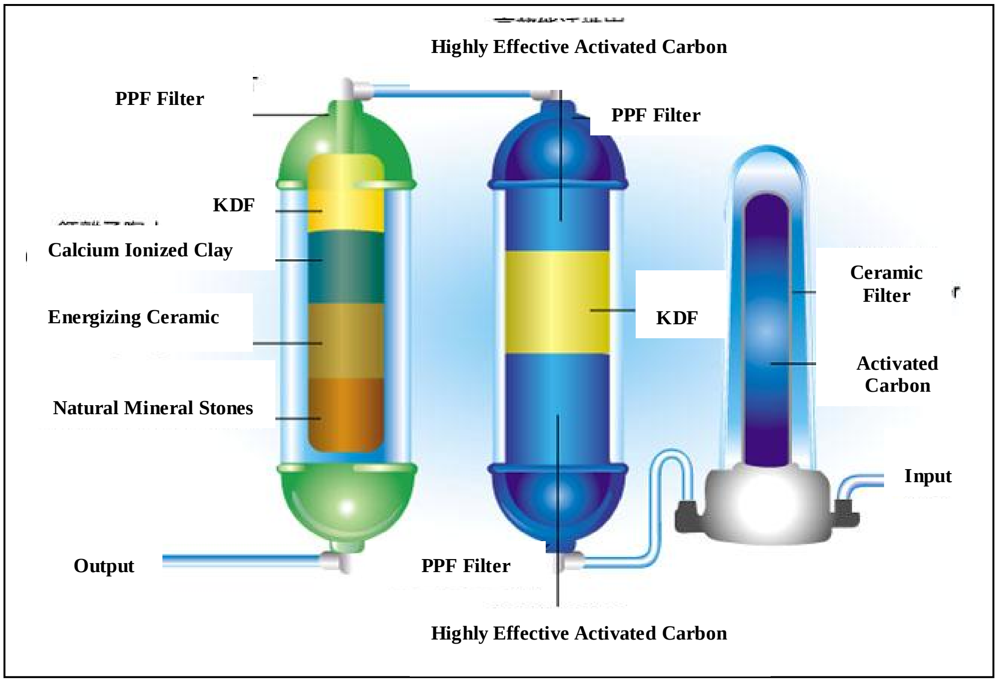


Figure 3.18: Arrangement of COM3 [www.nesh.com.my]

Required Function	R.O.	Ultraviolet unit	Granular activated carbon	Carbon block	Powdered activated carbon	Distillation unit
Absolute filtration to 0.2 microns	Yes	No	No	No	No	Yes
Removes chlorine	Yes	No	Yes	Yes	Yes	Yes
Removes lead and other heavy metals	Yes	No	No	No	No	Yes
Removes organic chemicals	Yes	No	Yes	Yes	No	Yes
Removes harmful bacteria	Yes	Yes	No	No	No	Yes
Removes Protozoan Cysts	Yes	No	No	No	Yes	Yes
Removes foul tastes and odours	No	No	Yes	Yes	Yes	Yes
Leaves essential minerals intact	No	Yes	Yes	Yes	Yes	No
Purifies on demand, no tank required	No	Yes	Yes	Yes	Yes	No
Operates at 25 psi line pressure	No	Yes	Yes	Yes	Yes	No
Operates without chemicals	Yes	Yes	Yes	Yes	Yes	Yes
Operates without wasting water	No	Yes	Yes	Yes	Yes	Yes
Low running cost per gallon	No	Yes	Yes	Yes	Yes	No
Operates without electricity	No	No	Yes	Yes	Yes	No

Table 3.5: Brief comparisons of various types of water treatment systems [www.bacfree.com]

CHAPTER 4

SURVEY RESULTS

A public survey was conducted in order to collect public's opinion about the supplied water quality and their understanding about the domestic water filtration systems. There were 100 respondents.

This community questionnaire survey also aimed to study the reasons why households install water filter systems and gauge public attitude towards these systems. The public survey was done in the form of questionnaire. The questionnaire form was delivered directly to the public to collect their feedback in order to do the analysis. The results of the questionnaire are discussed further in this chapter.

4.1 Statistical Results

Question 1: Are you satisfied with the quality of tap water in your house?

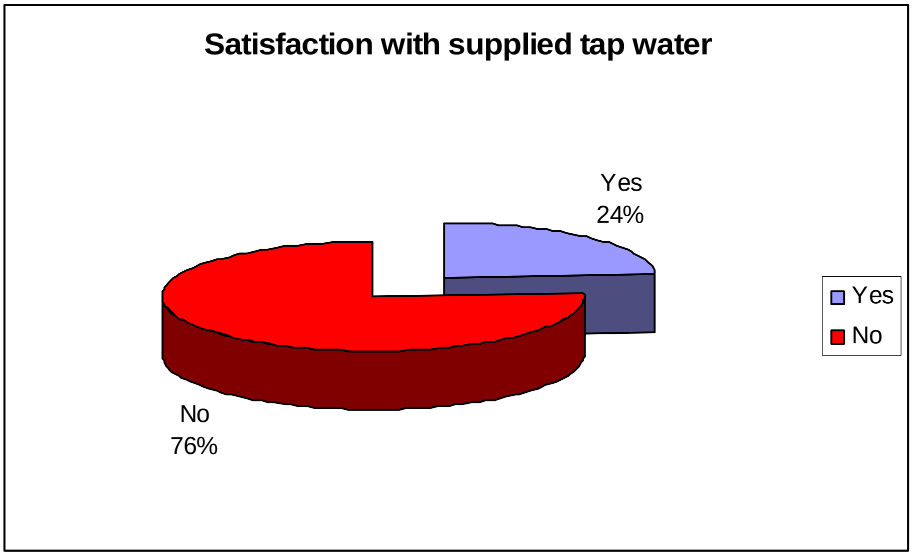


Figure 4.1: Satisfaction with supplied tap water

From the Figure 4.1 above, 76 % of the respondents are not satisfied with the supplied tap water and only 24 % of the respondents are satisfied with the current supplied tap water. Quality of tap water is differs from place to place. The results show that there is only small percentage of consumers satisfied with the quality of water supplied by government.

The unsatisfied water quality issue may due to several reasons. Water pollution is the main reason that causes unsatisfied water quality. Pollution rate in city is higher than rural area; therefore water contamination problem is more serious than rural area. Unsatisfied supplied water might also due to the distribution system that carrying water to consumers at home rather than efficiency of treatment process at water treatment center.

Question 2: Do you boil the tap water before consuming it?

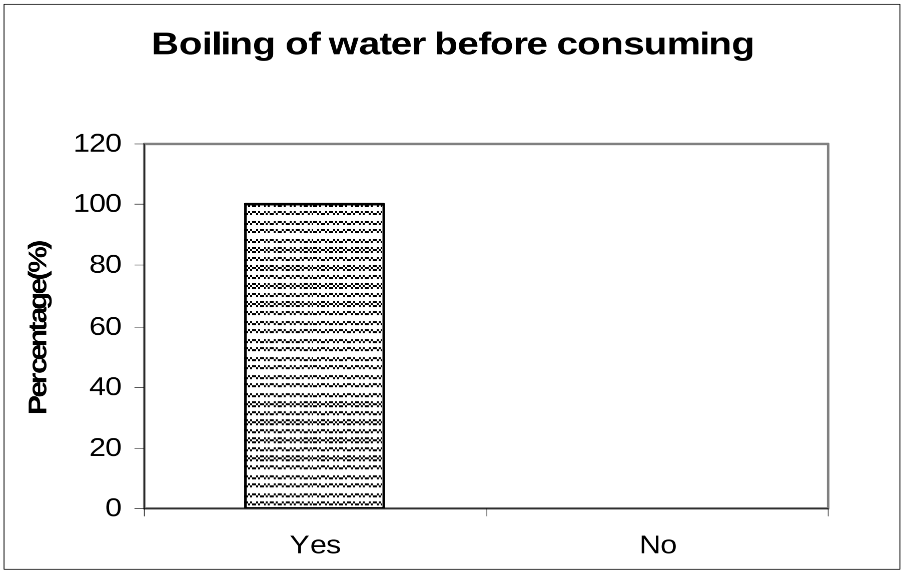


Figure 4.2: Boiling of tap water before consuming

Refer to the Figure 4.2 above, the survey results show that all the respondents boil the supplied tap water before consuming it and they would not drink water directly from the water tap.

The result shows that consumers in this country do not trust the quality of tap water. In Australia, majority of the consumers drink water directly from the tap, they are confident with the tap water quality and drink water without boiling it.

Question 3: What are the problems with the locally supplied tap water do you encountered?

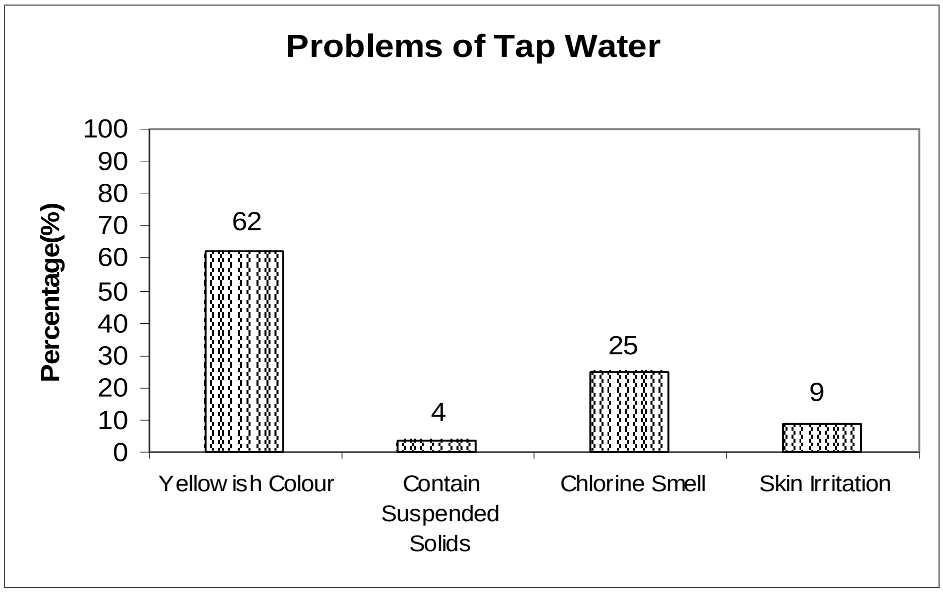


Figure 4.3: Problems of tap water

From the Figure 4.3 above, 62 respondents complained that the supplied tap water is in yellowish colour. Presence of colour in water may due to the presence of organic compounds and colloidal forms of iron and manganese. Other complaints are chlorine smell 25 %, skin irritation 9 % and contain suspended solids 4 %.

Chlorine is the common disinfection used in the water treatment process in order to disinfect the tap water. However, byproducts of the chlorine in drinking water might bring side effects to the body systems as Thrihalomethane is the cancer-causing compound.

Question 5: Do you use water filter at home?

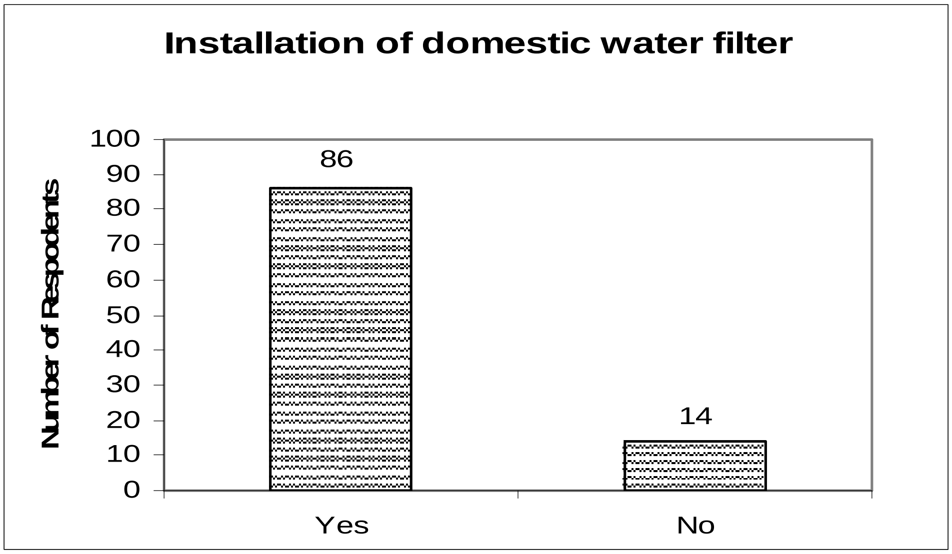


Figure 4.4: Installation of domestic water filter

Refer to the Figure 4.4 above, the results show that 86 respondents have household water treatment appliances at home, only 14 respondents do not install water filter at home. More and more households installed domestic water filters to treat the supplied tap water before consuming it.

In recent years, consumers begin to focus on the safety of their tap water due to the increasing number of complaints on water contamination issue. This result shows that in the consumers' point of view, the supplied drinking water is no longer safe to consume due to the water pollution issue.

Question 6: How many water filters do you installed in your house?

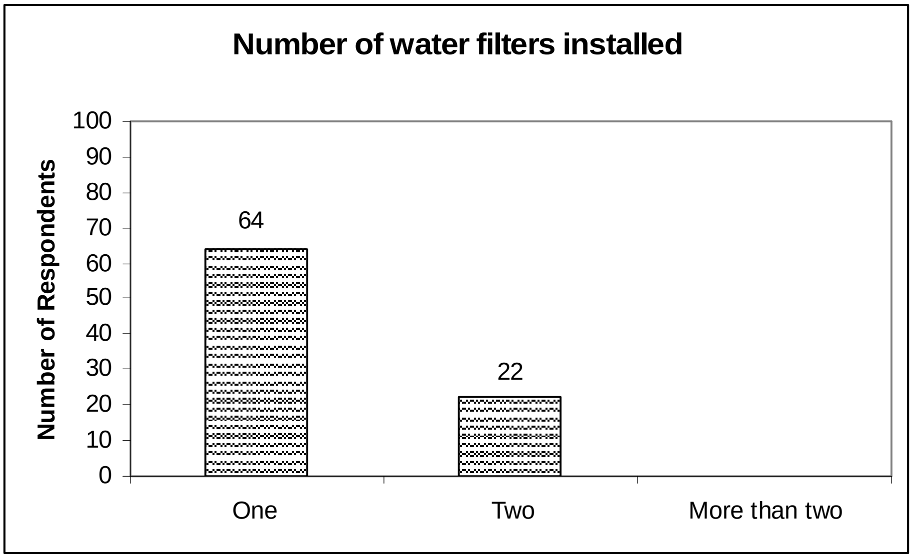


Figure 4.5: Number of water filters installed

From the Figure 4.5 above, 64 respondents of the total users have installed one unit of water filter, 22 respondents have installed two water filters and no respondent installed more than two units of water filter at home.

For the respondents with two units of water filters at home, one unit is installed at the main pipe outside the house and the other unit is installed in the kitchen. Respondents with one unit of water filter at home are installed their filters in the kitchen. All of the consumers installed water filters in the kitchen; this is probably because that kitchen is the main source of water for drinking and cooking.

Question 7: Do you test the tap water before purchasing the water filter?

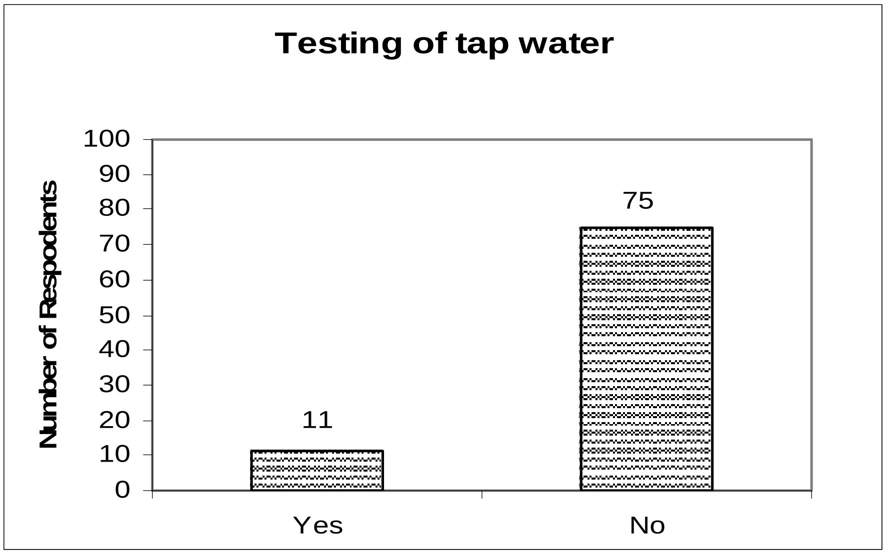


Figure 4.6: Testing of tap water before purchasing water filter

From the figure 4.6 above, most of the consumers did not carry out water testing before purchasing the water filter. Actually, laboratory tests should be conducted on the current supplied tap water in order to find out the water contamination level. Base on the experimental results, consumers can make decision and choose a correct water filter to overcome the water quality problems that encountered by them.

It is very important in choosing a correct water filter to suit the requirement. Purchasing of wrong water filter is not only failed to remove the water contaminants, but it will even worsen the water quality. However, identification of water quality through laboratory experiments is not commonly practice in Malaysia.

Refer to the Figure 4.6, the results show that 11 respondents have been tested the tap water before purchasing the water filter. However, they only carried out the simple chlorine test. This simple test is not sufficient in determination of a correct water filter to suit their requirement.

Question 10: What kind of water filters you are using?

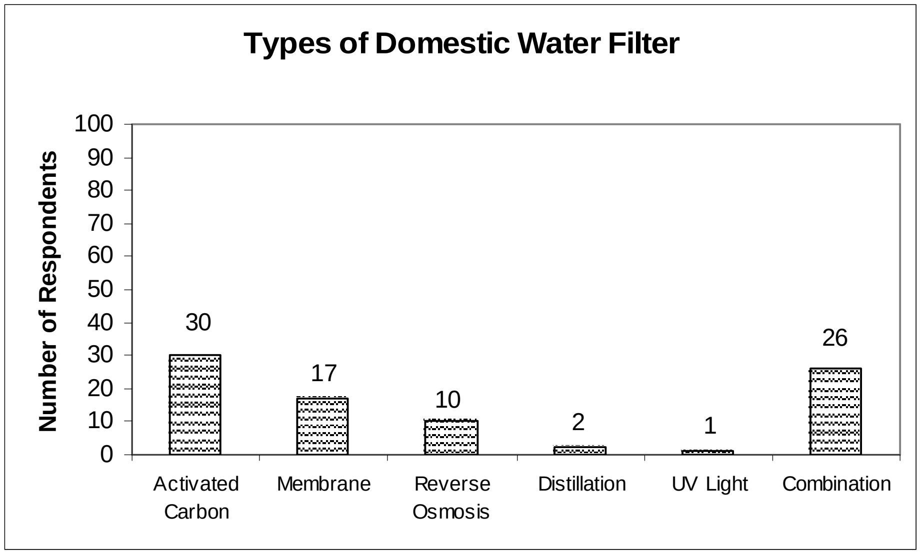


Figure 4.7: Types of domestic water filter

Refer to the Figure 4.7 above; the most popular type of domestic water filter used by consumers is activated carbon with 30 respondents. The second commonly used water filter is combination filter with 26 respondents, followed by membrane, reverse osmosis, distillation and ultraviolet light with 17, 10, 2 and 1 respondents respectively.

There are several reasons that the consumers chose to install activated carbon filter. The main reason might due to its cheaper price compare to other types of water filters, therefore consumers are more affordable to install this kind of water filter. Besides that, activated carbon is the easiest unit to install and maintain, the operating costs are usually limited to filter replacement and their performance in removing contaminants.

Combination filter users are on the rise because of the advertisement on the mass media. Not many consumers install reverse osmosis treatment system at home. This might due to its high initial and maintenance costs. Besides that, the maintenance operation is more complex and it must be done by the operators. Distillation and ultraviolet light treatment systems are remain unpopular in Malaysian market.

Question 11: Why are you buying the water filter?

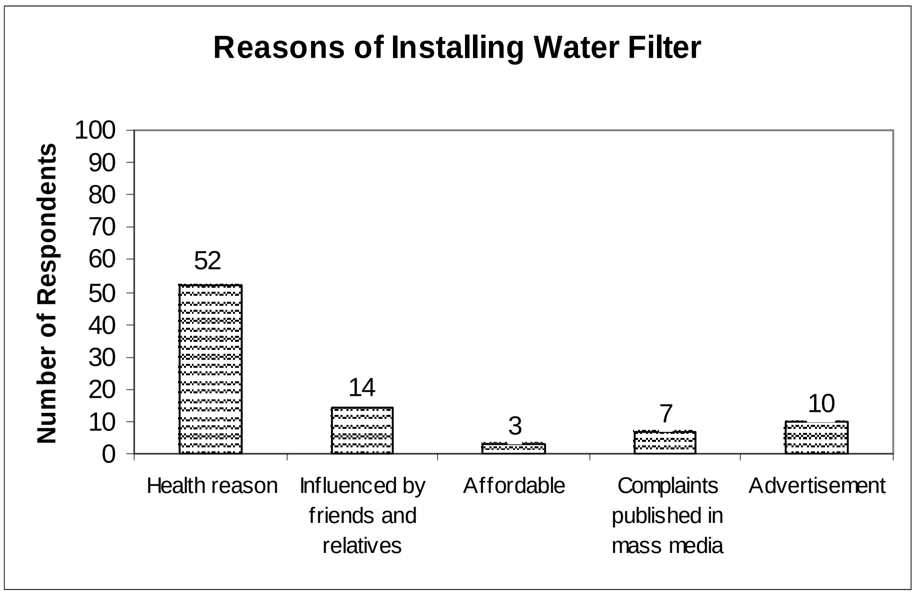


Figure 4.8: Reasons of installing water filter

Refer to the Figure 4.8 above, the results show that 52 of the respondents said that health is their main reason in choosing a water treatment system. As living standard increases, bodies' health becomes a priority in our lives.

We would like to improve our health by consuming clean and safe drinking water. Many consumers aware that clean water plays an important role for our bodies' health, therefore they chose to install water treatment system at home to make sure the drinking water is always clean.

There are 14 respondents said that they are influenced by relatives and friends into buying a water filter and 10 respondents said they bought water filter because of the advertisement published in the mass media. From the figure 4.8 above, the results show that 7 respondents installed water filter because of the water contamination complaints published in the mass media and 3 respondents bought one because it is affordable.

Question 12: How much would you spend on a water filter?

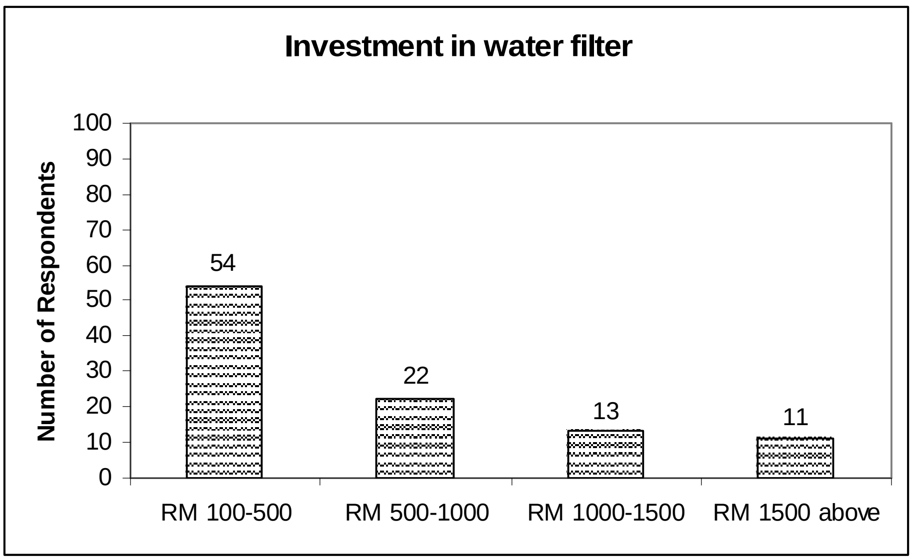


Figure 4.9: Investment in water filters

From the Figure 4.9 above, the results show that 54 respondents would only buy a water filter in the range of RM 100 to RM 500. Most of the membrane filters and activated carbon filters are in this price range. Therefore, membrane filters and activated carbon filters become the main choice among the consumers.

This is followed by RM 500-1000, RM 1000-1500 and RM 1500 above with 22, 13 and 11 respondents respectively. Most of the reverse osmosis, distillation and combination filters are priced above RM 1500 per unit. This high initial cost becomes the reason that those water filters are not as common as membrane and activated carbon filters. For normal uses, membrane and activated carbon filters are sufficient provided that the water must be boiled before consuming.

The survey results also show that many consumers do not clean their water filter often. Many consumers do not really know when the time to replace the filter parts is. This negligence is due to ignorance. For example, a normal membrane filter should be clean as least once a month to get rid of the mud and silt on the membrane surface to maintain the efficiency of the filter. Activated carbon does not need to be clean but the carbon filter need to be replaced every 6 months. All the filter parts need to be changed according to the life span. If the consumers do not change the old filter with a new one, then the efficiency of a water filter would be affected.

CHAPTER 5

EXPERIMENTAL TECHNIQUES

In order to investigate the effectiveness of different types of domestic water filter, laboratory experiments have been conducted to measure several parameters of drinking water. The tested parameters are apparent colour, turbidity, total suspended solids, total free chlorine, total aluminium, total iron and total chromium.

5.1 Sample collection, Preservation and Storage

Correct sampling and storage are critical for accurate testing. Containers and sampling devices need to be thoroughly clean to prevent carryover from the previous samples.

5.1.1 Water Collection

Water samples are collected from various houses in Kuala Lumpur. Water samples are taken from different types of water filter systems. Water is allowed to run for a few minute before collecting the sample. The water samples need to be filled into the containers slowly with a gentle stream to avoid turbulence and air bubbles. A volume of 1.25 liter of treated and untreated water samples are colleted for the laboratory tests.

5.1.2 Types of Containers

i. Polypropylene and polyethylene:

These are the commonly used and the least expensive containers.

ii. Quartz or TFE (tetrafluoroethylene):

These are the best containers but they are also the most expensive containers.

iii. Glass:

Glass is a good general- purpose container. Avoid using soft-glass containers to collect samples for metals testing in the microgram-per-liter range.

5.1.3 Storage and Preservation

Water samples need to be tested as soon as possible after collection because chemical and biological processes continue after collection. Analyzing the sample immediately after collection can reduce the chance for error and hence obtain the more accurate results. The water samples must be preserved if immediate analysis is not possible. These water samples are tested in room temperature of about 25 ˚C to 30 ˚C unless stated.

5.2 Apparent Colour

5.2.1 Introduction

Colour of drinking water can be seen and judged with naked eye. Consumers will consider water is dirty and not suitable for drinking if the water is yellowish or brownish in colour. Pure water for consumption should be clear without any colour. Apparent colour refers to colour of both dissolved and suspended matters in the solution whereas true colour is the colour of solution without suspended matter.

The standard colour solutions are composed of potassium chloroplatine ($K_2 Pt Cl_6$) tinted with small amounts of cobalt chloride. The colour produced by 1 mg/l of platinum in combination with ½ mg/l of metallic cobalt is taken as 1 Standard Colour Unit.

Figure 5.1: Lovibond Colour Comparator

Lovibond colour comparator is the equipment used to compare colour of the samples with standard colour by giving the value in colour units. The water sample is inserted into the holder, and then the value of colour is adjusted until colour of sample equal to the standard colour.

Hach Odyssey spectrometer is a more accurate equipment to measure the apparent colour of collected water samples. Measurement of apparent colour is chosen rather than the true colour because samples colleted are not wastewater. The insignificant amount of suspended solids in water can be ignored.

Figure 5.2: Hach Odyssey Spectrometer

5.2.2 Equipment and Required Materials

The laboratory equipment used is Hach Odyssey spectrometer with a few sample cells. Distilled water is the material used to clean and rinse sample cells. The precision and sensitivity of Hach Odyssey spectrometer are as stated in the tables below.

Precision

Program	95 % confidence limits of distribution
125	245 – 255 units Pt-Co

Table 5.1: Precision of Hach Odyssey spectrometer for measuring apparent colour

Sensitivity

Program	Portion of curve	Δ Abs	Δ Concentration
125	Entire range	0.010	17 Units Pt-Co

Table 5.2: Sensitivity of Hach Odyssey spectrometer for measuring apparent colour

5.2.3 Test Procedures

1. A clean sample cell is rinsed with distilled water before it is filled with distilled water. This cell is called a 'blank'.
2. A second cell is rinsed and filled with collected water sample.
3. Both cells are wiped with a damp cloth followed by dry cloth to get rid of the finger prints on the cells.
4. On the Hach Odyssey front menu, Hach Programs icon is pressed, followed by 125 Colour, 465 nm and Start.
5. The blank cell is inserted into the cell holder in the Odyssey. The cover is closed before Zero button is pressed.
6. The blank cell is removed before the sample cell is inserted into the cell holder.
7. The Read button is pressed and the reading is recorded in units of Pt-Co (Platinum-Cobalt).
8. The procedures are repeated for treated water sample.

5.3 Turbidity

5.3.1 Introduction

Turbidity of water indicates the interference of light passage through the water. Presence of solids, organic particles, microorganisms or other materials in water can block and adsorb the rays of light. Turbidimeter is the apparatus used for measuring turbidity of water. Turbidity is measured as NTU (Nephelometric Turbidity Units).

The turbidimeter is in the range from 0 to 4000 NTU in the nearest three decimal places. Turbidimeter is operates on the nephelometric principle of turbidity measurement. The optical system is consisted of a tungsten-filament lamp, lenses and apertures to focus the light, a 90˚ detector, forward-scatter light detector and a transmitted light detector. The microprocessor of instrument uses a mathematical calculation to ratio signals from each detector.

5.3.2 Equipment and Required Materials

The laboratory equipments used to measure turbidity is Hach 2100N Laboratory Turbidimeter and its standard sample cells. Distilled water is used to clean and rinse the sample cells.

The specifications for Model 2100N Turbidimeter is shown in the table below.

Specifications	**Model 2100N Turbidimeter**
Range	0-4000 NTU
Accuracy	$\pm$2 % of reading plus 0.01 NTU from 0-1000 NTU
Resolution	0.001 NTU on lowest range
Response Time	6.8 seconds with signal averaging off or 14 seconds with signal averaging on.

Table 5.3: Specifications of Model 2100N Turbidimeter for measuring turbidity

Figure 5.3: 2100N Laboratory Turbidimeter

Figure 5.4: Hach 2100P Portable Turbidimeter

5.3.3 Test Procedures

1. In order to measure turbidity, 30 ml of water sample is filled into the sample cell. The sample cell needs to be handled by the top carefully. The sample cell is then capped.
2. The sample cell is rinsed with distilled water before filling with water sample.
3. The sample cell needs to be clean to remove water spots and fingerprints.
4. Then, the sample cell is inserted into the cell holder of turbidimeter.
5. The reading in units of NTU is then recorded.
6. The procedures are then repeated for treated water sample.

5.4 Total Free Chlorine

5.4.1 Introduction

Chlorine is commonly used in disinfection of drinking water. It is effective in preventing the spread of water-borne diseases. However, chlorine is also very reactive towards the natural compounds present in water and therefore forming new, complex and dangerous chemicals.

Hence, it is very important to monitor the concentration of chlorine in the form of hypochlorite ion or hypochlorous acid as it may form harmful by-products. Chlorine is easily detected with DPD (N, N-diethyl-p-phenylenediamine) to form pink colour which is proportional to the concentration of chlorine in the sample solution.

5.4.2 Equipment and Required Materials

The equipment used for measuring the presence of chlorine is Hach Odyssey Spectrometer. The required reagent is DPD Free Chlorine Powder Pillows. The required apparatus is sample cell. The precision and sensitivity of Hach Odyssey Spectrometer are shown in the tables below.

Precision

Program	95 % Confidence Limits of Distribution
80	1.00 – 1.14 mg/l Cl_2

Table 5.4: Precision of Hach Odyssey Spectrometer in measuring free chlorine

Sensitivity

Program	Portion of curve	Δ Abs	Δ Concentration
80	Entire range	0.010	0.02 mg/l Cl_2

Table 5.5: Sensitivity of Hach Odyssey Spectrometer in measuring free chlorine

5.4.3 Test Procedures

1. Firstly, an empty cell is rinsed with distilled water and followed by the sample to increase the accuracy of the test.
2. On the spectrometer, Hach Program button is pressed, and then followed by 80 Chlor.F&T and Start.
3. A sample cell is filled with 10 ml of sample and marked as blank cell.
4. The blank cell is wiped to get rid of fingerprints before placing in the spectrometer.
5. Zero is touched and the display will show 0.00 mg/l Cl_2.
6. Another empty cell is filled with 10 ml of water sample and one sachet of DPD Free Chlorine Powder Pillow.
7. The cell is swirled for 20 seconds to mix the reagent with water.
8. The cell is placed into the spectrometer for reading within one minute.
9. The procedures are repeated for the treated water sample.

5.5 Total Aluminium

5.5.1 Introduction

Aluminium is found in nature as alumino silicates such as kaolin, clay, mica and feldspar. Aluminium is common in treated drinking water especially water treated with alum which acts as coagulant. Besides that, the presence of aluminium in drinking water is also due to corrosion of aluminium tanks, pipes and utensils.

Most experts agree that high levels of aluminium in dialysis fluids and medication are responsible for the dementia. Aluminium has also been associated with severe diseases of the nervous system such as Parkinson's disease, amyotrophic lateral sclerosis (Lou Gehrig's disease) and Alzheimer's disease, but the association is not completely understood. Intake of large amounts of aluminium can also cause osteomalacia (brittle or soft bones), glucose intolerance and cardiac arrest in humans. (Source: http://www.esemag.com)

In this research project, the Hach Odyssey Spectrometer is used to measure the aluminium levels in drinking water. Aluminium indicator combines with aluminium in the water sample to form a red-orange colour. The intensity of colour is proportional to the aluminium concentration. Ascorbic acid is added to remove iron interference. The AluVer3 Aluminium Reagent which is packaged in powder form shows exceptional stability and is applicable for fresh water applications.

5.5.2 Equipments and Required Materials

The equipment used for measuring the presence of aluminium is Hach Odyssey Spectrometer. The required reagents are ascorbic acid, AluVer3 Aluminium Reagent and Bleaching 3 Reagent Powder Pillow. The required apparatus are sample cells and cylinder. The precision and sensitivity of Hach Odyssey Spectrometer are shown in the tables below.

Precision

Program	95 % Confidence Limits of Distribution
10	0.383-0.417 mg/l Al^{3+}

Table 5.6: Precision of Hach Odyssey Spectrometer in measuring aluminium

Sensitivity

Program	Portion of Curve	Δ Abs	Δ Concentration
10	Entire range	0.010	0.008 mg/l Al^{3+}

Table 5.7: Sensitivity of Hach Odyssey Spectrometer in measuring aluminium

5.5.3 Test Procedures

1. Hach Program is touched, program 10 Aluminium is selected and Start is touched.
2. 50 ml of water sample is filled into a cylinder.
3. Then, the content of one Ascorbic Acid Powder Pillow is added. Stopper. The cylinder is inverted several times to dissolve the powder.
4. The content of one AluVer3 Aluminium Reagent Powder Pillow is added. Stopper.
5. The cylinder is inverted repeatedly for one minute to dissolve the powder. Undissolved powder will cause inconsistent results.
6. 25 ml of the mixture is poured into a 25 ml sample cell. This is the prepared sample.
7. The content of one Bleaching 3 Reagent Powder Pillow is added to the remaining 25 ml in the cylinder. Stopper.
8. The cylinder is shaken vigorously for 30 seconds.
9. 25 ml of the solution is pour into a second 25 ml cell. This is the blank cell.
10. The blank cell is wiped and placed into the cell holder after 15 minutes.
11. Zero is touched and the display will show 0.000 mg/l Al^{3+}.
12. The prepared sample is wiped immediately and placed into the holder.
13. Read button is touched and result will appear in mg/l Al^{3+}.

Figure 5.5: Aluminium testing

5.6 Total Chromium

5.6.1 Introduction

Chromium is one of the heavy metals presented in drinking water. Heavy metals such as lead, mercury, arsenic and cadmium are harmful to human's health while small amount of heavy metals such as zinc, copper, chromium, iron and manganese are required in human bodies. However, the latter group can be toxic to our bodies if they exceeded the acceptable limit.

Chromium can exist as Cr (II) through Cr (VI) in the environment, but Cr (III) predominates in natural waters. Large amounts of chromium can cause ulcers, kidney and liver damage and increase the risk of lung cancer.

In this research project, the total chromium content is determined by the 1, 5-Diphenydrazide method. Trivalent chromium in the water sample is oxidized to the hexavalent form by hypobromite ion under alkaline conditions.

5.6.2 Equipment and Required Materials

Hach Odyssey Spectrometer is the equipment used to determine the presence of chromium in drinking water. The required materials are Acid Reagent Powder Pillows, ChromaVer 3 Chromium Reagent Powder Pillows, Chromium 1 Reagent Powder Pillows and Chromium 2 Reagent Powder Pillows.

In addition, a hotplate, a beaker and a thermometer are also required in order to prepare a hot bath. The precision and sensitivity of Hach Odyssey Spectrometer in measuring total chromium are shown in the tables below.

Precision

Program	95 % confidence limits of distribution
100	0.24 – 0.26 mg/l Cr

Table 5.8: Precision of Hach Odyssey Spectrometer in measuring total chromium

Sensitivity

Program	Portion of curve	Δ Abs	Δ Concentration
100	Entire range	0.010	0.01 mg/l Cr

Table 5.9: Sensitivity of Hach Odyssey Spectrometer in measuring total chromium

5.6.3 Test Procedures

1. Firstly, a beaker is filled half full with pipe water. Water is treated to boiling state by using hotplate.

2. On the spectrometer, Hach Programs button is pressed, followed by 100 Chromium, Total and Start.
3. A round sample cell is filled with 25 ml of water sample and chromium 1 Reagent Powder Pillow is added into it.
4. Then, the sample cell is placed into a boiling water bath. The cap of the cell is tightly closed to prevent water going into it.
5. The timer icon on the spectrometer is pressed to allow a five minutes reaction. When the timer beeps, the cell is removed from the bath and cooled down to 25˚C by using running tap water.
6. After that, one packet of Chromium 2 Reagent Powder Pillow is added into the cell.
7. Then, an Acid Reagent Powder Pillow is added; the cell is capped and inverted.
8. Chromium 3 Reagent Powder Pillow is added into the cell.
9. On the spectrometer, the time icon is pressed for a five minutes reaction.
10. When the timer beeps, a blank sample cell is prepared. The cell is contains water sample only.
11. The blank cell is placed into the cell holder in the spectrometer.
12. Zero is touched and the display will show 0.00 mg/l Cr.
13. Then, the sample is placed into the spectrometer for reading.

5.7Total Iron

5.7.1 Introduction

Iron ions also known as ferrous ions, which are highly objectionable in domestic water usage. Iron ions will produce brownish colour oxides when oxidized and leave an unaesthetic condition with water uses. The most common method to test total iron is by using photoelectric colorimeter or spectrometer to measure the intensity of colour developed in a treated sample, which can be related to the concentration of the test substance.

In this research project, the Hach Odyssey Spectrometer is used. The samples are treated with FerroZinc Iron Reagent that converts all soluble iron and most insoluble forms of iron in the sample to soluble ferrous iron. The ferrous iron reacts with the 1, 10 phenanthroline indicator which gives the sample a slight orange colour with the presence of iron. This orange colour is proportion to the iron concentration in the sample and can be read easily using the spectrometer in the units of mg/l Fe.

5.7.2 Equipment and Required Materials

The equipment used is Hach Odyssey Spectrometer. FerroVer Iron Reagent Powder Pillow is required to convert all soluble iron and most insoluble forms of iron in water sample to soluble ferrous iron. The required apparatus are beaker and sample cells. The precision and sensitivity of Hach Odyssey Spectrometer in measuring total iron are shown in the tables below.

Precision

Program	95 % confidence limits of distribution
265	0.989 – 1.011 mg/l Fe

Table 5.10: Precision of Hach Odyssey Spectrometer in measuring total iron

Sensitivity

Program	Portion of curve	Δ Abs	Δ Concentration
265	Entire range	0.010	0.022 mg/l Fe

Table 5.11: Sensitivity of Hach Odyssey Spectrometer in measuring total iron

5.7.3 Test Procedures

1. Hach Program is clicked on the screen and followed by 265 Icon, FerroVer button and Start button.
2. A sample cell is rinsed with distilled water and then filled with 10 ml of water sample.
3. One sachet of FerroVer Iron Reagent Powder Pillow is added into the sample cell. The cell is swirled to mix the reagent with water.
4. The timer icon is pressed to start a three minutes reaction period.
5. Then, another sample cell is rinsed with distilled water and filled with the same water sample. The cell is labeled as blank.
6. When the timer beeps, the blank cell is placed in the cell holder.
7. Zero is touched and the display will show 0.00 mg/l Fe.
8. The blank cell is replaced with the prepared sample in the cell holder. The reading is taken and recorded.

CHAPTER 6

EXPERIMENTAL RESULTS

From the laboratory experiments, all the raw data was recorded in the table forms. Then, the percentage removal was calculated by using the following formula.

$$\% \text{ removal} = \frac{\text{Value before treatment} - \text{Value after treatment}}{\text{Value before treatment}}$$

The results are tabulated according to the parameters and types of filtration systems used. Three samples are taken from three different locations for a variety of water quality before treatment.

6.1 Apparent Colour

The results for apparent colour for different filtration systems are shown in the table below.

Types of filters	Samples No.	Colour		
		Before	**After**	**% removal**
Activated Carbon	A1	23.00	3.00	86.96
	A2	35.00	9.00	77.14
	A3	25.00	10.00	60.00
Membrane	M1	12.00	7.00	41.67
	M2	24.00	11.00	54.17
	M3	28.00	14.00	50.00
Reverse Osmosis	R1	14.00	5.00	64.29
	R2	6.00	4.00	33.33
	R3	14.00	6.00	57.14
Distillation	D1	8.00	0.00	100
	D2	26.00	0.02	99.92
	D3	22.00	0.04	99.82
UV Light	U1	11.00	8.00	27.27
	U2	15.00	10.00	33.33
	U3	21.00	16.00	23.81
Combination	C1	6.00	4.00	33.33
	C2	10.00	5.00	50.00
	C3	14.00	2.00	85.71

Table 6.1: Experimental results for apparent colour for different filtration systems

6.2 Turbidity

The results for turbidity for different filtration systems are shown in the table below.

Types of filters	Samples No.	Turbidity		
		Before	**After**	**% removal**
Activated Carbon	A1	3.26	0.21	93.56
	A2	4.20	0.40	90.48
	A3	3.29	0.42	87.23
Membrane	M1	2.38	0.90	62.18
	M2	4.85	1.56	67.84
	M3	0.90	0.44	51.11
Reverse Osmosis	R1	2.43	0.47	80.66
	R2	1.69	0.22	86.98
	R3	0.77	0.22	71.43
Distillation	D1	0.82	0.13	84.15
	D2	1.35	0.11	91.85
	D3	1.73	0.30	82.66
UV Light	U1	0.79	0.34	56.96
	U2	2.26	1.23	45.58
	U3	0.61	0.29	52.46
Combination	C1	1.61	0.65	59.63
	C2	3.19	1.52	52.35
	C3	0.61	0.19	68.85

Table 6.2: Experimental results for turbidity for different filtration systems

6.3Total Free Chlorine

The results for total free chlorine for different filtration systems are shown in the table below.

Types of filters	Samples No.	Total Free Chlorine		
		Before	After	% removal
Activated Carbon	A1	0.28	0.03	89.29
	A2	0.43	0.01	97.67
	A3	0.34	0.01	97.06
Membrane	M1	0.37	0.05	86.49
	M2	0.24	0.06	75.00
	M3	0.01	0.00	100.00
Reverse Osmosis	R1	0.18	0.01	94.44
	R2	0.01	0.00	100.00
	R3	0.44	0.02	95.45
Distillation	D1	0.25	0.06	76.00
	D2	0.03	0.01	66.67
	D3	0.02	0.01	50.00
UV Light	U1	0.21	0.09	57.14
	U2	0.15	0.08	46.67
	U3	0.19	0.09	52.63
Combination	C1	0.31	0.01	96.77
	C2	0.18	0.03	83.33
	C3	0.64	0.02	96.88

Table 6.3: Experimental results for total free chlorine for different filtration systems

6.4 Total Aluminium

The results for total aluminium for different filtration systems are shown in the table below.

Types of filters	Samples No.	Total Aluminium		
		Before	After	% removal
Activated Carbon	A1	0.058	0.042	27.59
	A2	0.084	0.053	36.90
	A3	0.073	0.052	28.77
Membrane	M1	0.135	0.048	64.44
	M2	0.069	0.037	46.38
	M3	0.075	0.031	58.67
Reverse Osmosis	R1	0.041	0.005	87.80
	R2	0.015	0.006	60.00
	R3	0.077	0.015	80.52
Distillation	D1	0.083	0.021	74.70
	D2	0.114	0.042	63.16
	D3	0.096	0.038	60.42
UV Light	U1	0.082	0.065	20.73
	U2	0.093	0.062	33.33
	U3	0.035	0.022	37.14
Combination	C1	0.021	0.007	66.67
	C2	0.025	0.014	44.00
	C3	0.028	0.012	57.14

Table 6.4: Experimental results for total aluminium for different filtration systems

6.5 Total Chromium

The results for total chromium for different filtration systems are shown in the table below.

Types of filters	Samples No.	Total chromium		
		Before	**After**	**% removal**
Activated Carbon	A1	0.08	0.06	33.33
	A2	0.08	0.06	25.00
	A3	0.07	0.05	28.57
Membrane	M1	0.07	0.06	14.29
	M2	0.06	0.05	16.67
	M3	0.07	0.05	28.57
Reverse Osmosis	R1	0.06	0.04	33.33
	R2	0.08	0.05	37.50
	R3	0.07	0.05	28.57
Distillation	D1	0.08	0.05	37.50
	D2	0.10	0.06	40.00
	D3	0.09	0.05	44.44
UV Light	U1	0.07	0.07	0.00
	U2	0.09	0.07	22.22
	U3	0.07	0.05	28.57
Combination	C1	0.07	0.04	42.86
	C2	0.08	0.05	37.50
	C3	0.05	0.04	20.00

Table 6.5: Experimental results for total chromium for different filtration systems

6.6 Total Iron

The results for total iron for different filtration systems are shown in the table below.

Types of filters	Samples No.	Total iron		
		Before	After	% removal
Activated Carbon	A1	0.07	0.05	28.57
	A2	0.06	0.03	50.00
	A3	0.07	0.04	42.86
Membrane	M1	0.08	0.05	37.50
	M2	0.12	0.06	50.00
	M3	0.07	0.02	71.43
Reverse Osmosis	R1	0.08	0.03	62.50
	R2	0.07	0.02	71.43
	R3	0.10	0.03	70.00
Distillation	D1	0.28	0.05	82.14
	D2	0.19	0.05	73.68
	D3	0.09	0.03	66.67
UV Light	U1	0.06	0.04	33.33
	U2	0.04	0.03	25.00
	U3	0.07	0.04	42.86
Combination	C1	0.04	0.01	75.00
	C2	0.09	0.04	55.56
	C3	0.03	0.01	66.67

Table 6.6: Experimental results for total iron for different filtration systems

CHAPTER 7

ANALYSIS AND DISCUSSION

From the experimental results tabulated in Chapter 6, the quality of water before and after treatment is analyzed. The analysis is made based on the WHO and Malaysian Drinking Water Standard as a guideline.

The highest and the lowest percentage removal are analyzed according to the method of treatment used. The average percentage removal is calculated from the readings obtained and the results are presented in the bar chart form. It can be seen easily from the bar chart of the effectiveness in removing contaminants for each treatment system.

7.1 Apparent Colour

The lowest, highest and average percentage removals of apparent colour for each treatment method are shown in the table below.

Types of filters	Lowest % removal	Highest % removal	Average % removal
Activated carbon	60.00	86.96	74.7
Membrane	54.17	41.67	48.61
Reverse Osmosis	64.29	33.33	51.59
Distillation	99.82	100	99.91
UV Light	23.81	33.33	24.96
Combination	85.71	33.33	56.35

Table 7.1: The lowest, highest and average percentage removals of apparent colour

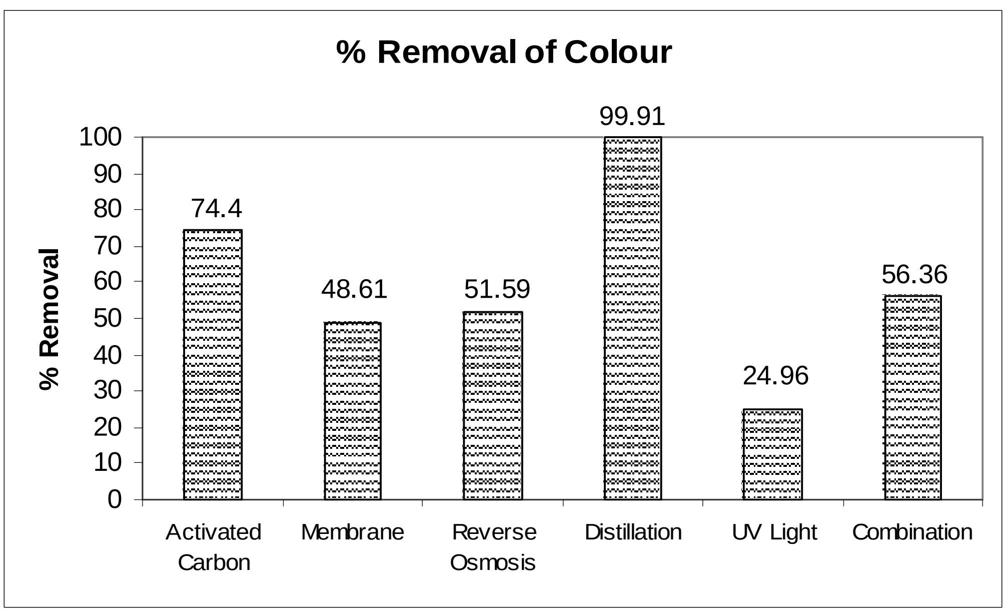


Figure 7.1: Percentage removal of colour for different treatment systems

The results obtained from the laboratory test showed that colour of water samples before treatment is differs from place to place. Water sample in some areas appeared in yellowish colour which gave value above 30 Pt-Co, while water in some areas can be considered clear with value less than 10 Pt-Co. However, the supplied tap water is still considered unsatisfactory as the maximum permissible level in drinking water is 15 True Colour Units (TCU).

The experimental results showed that distillation system is the best treatment method in removing colour from drinking water. Distillation system removes almost 99.9 % of colour and provides colourless drinking water for human consumption. This is followed by activated carbon filter at 74.7 % of colour removal. Activated carbon filter is proven to be an effective method in removing colour from drinking water.

Reverse osmosis system and combination treatment units give unsatisfactory results as both treatment methods consist of activated carbon that should remove colour as good as a simple activated carbon filter. Both treatment methods are expensive and both mechanisms are expected to remove traces of colour.

Ultra violet light unit (UV) uses pre-filter before water is treated with UV light. Therefore, it removes small percentage of colour from water. UV light treatment is not expected to remove colour as the main concern for using UV light unit is to remove microorganisms.

7.2 Turbidity

The lowest, highest and average percentage removals of turbidity for each treatment method are shown in the table below.

Types of filters	Lowest % removal	Highest % removal	Average % removal
Activated carbon	87.23	93.56	90.42
Membrane	36.67	62.18	60.38
Reverse Osmosis	71.43	86.98	79.69
Distillation	82.66	91.85	86.22
UV Light	45.58	56.96	51.67
Combination	52.35	68.85	60.28

Table 7.2: The lowest, highest and average percentage removals of turbidity

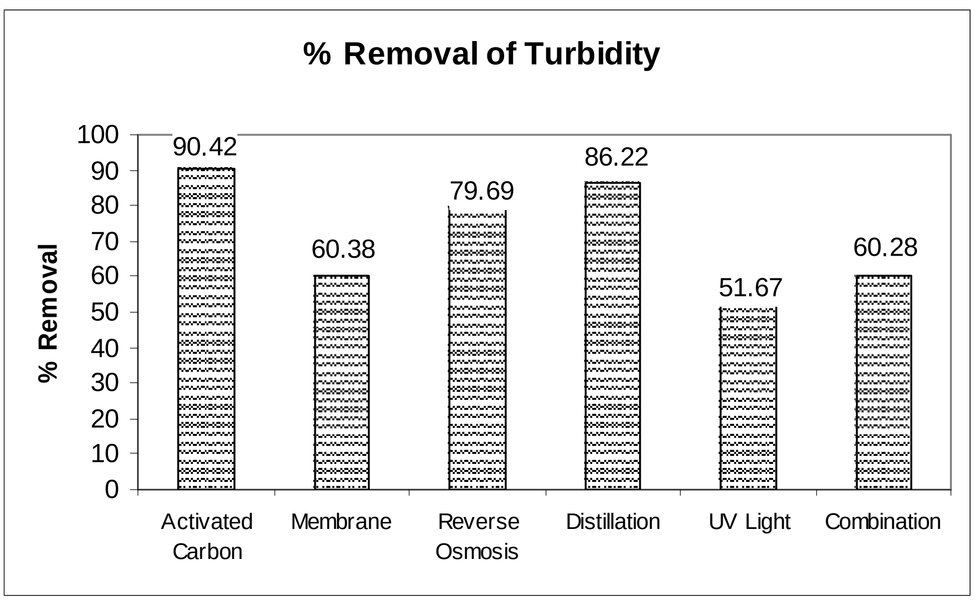


Figure 7.2: Percentage removal of turbidity for different treatment systems

Turbidity level in drinking water should not exceed 5 Nephelometric Turbidity Units (NTU) according to WHO and Malaysian Drinking Water Standard. Turbidity level in water is also varies from place to place. Some samples collected are with high turbidity level which gave value above 4 NTU. However, most of the water samples are fall in the range of 1.00 to 3.00 NTU. Only a few sample give turbidity level less than 1.00 NTU.

The experimental results showed that activated carbon filter is the most effective method in removing turbidity from drinking water. Activated carbon is known as a natural absorbent for dissolved, colloidal and particulate matters that cause turbidity in water. Distillation system is also a good method in removing turbidity from water. Distillation system gives positive result that matches its mechanism of treating water.

Membrane filter gives satisfactory result in removing turbidity as compared with colour. Turbidity may due to silt, clay or colloidal particles; ceramic stem of membrane filter is able to retain those matters at the membrane surface and hence results in low turbidity level in drinking water. Combination treatment unit is also gives satisfactory result in removing turbidity. UV light treatment unit gives the lowest percentage removal at 51.67 % as pre-filter is only able to remove certain amounts of suspended matter from water.

7.3 Total Free Chlorine

The lowest, highest and average percentage removals of total free chlorine for each treatment method are shown in the table below.

Types of filters	Lowest % removal	Highest % removal	Average % removal
Activated carbon	89.29	97.67	94.67
Membrane	75.00	100.00	87.16
Reverse Osmosis	94.44	100.00	96.63
Distillation	50.00	76.00	64.22
UV Light	46.67	57.14	52.15
Combination	83.33	96.88	92.33

Table 7.3: The lowest, highest and average percentage removals of total free chlorine

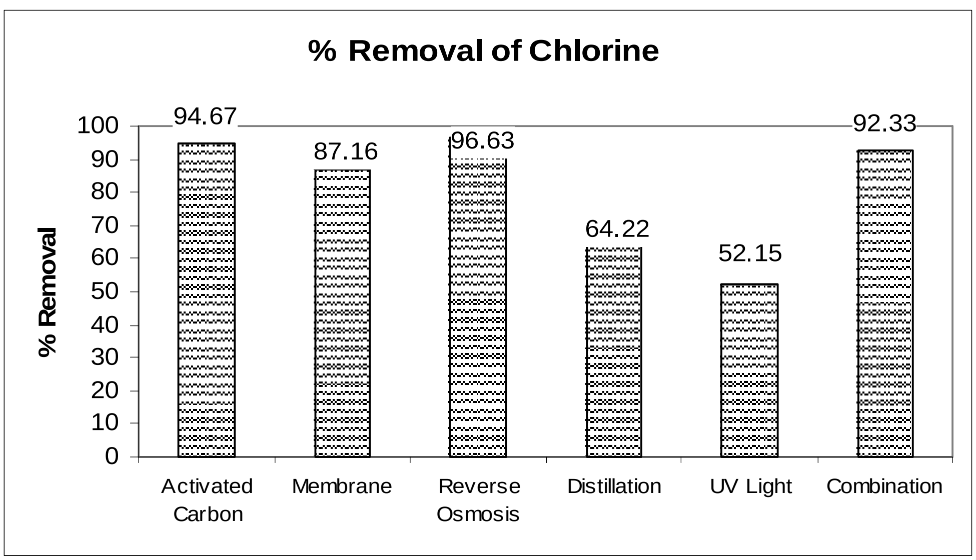


Figure 7.3: Percentage removal of chlorine for different treatment systems

Residual chlorine is maintained in the distribution of water to ensure continues disinfection throughout the distribution. Water samples collected give the free chlorine concentration in the range from 0.01 to 0.64 mg/l.

Chlorine removal is essential in water treatment because chlorine and its by-product, Trihalomethane (THM) is toxic to human's health. Chlorine gives a displeasing odour and it is corrosive when it presents in excessive amount.

All the treatment methods give a good percentage removal of chlorine at above 50 % removal. However, reverse osmosis system is the most effective method in removing chlorine from water at 96.63 % removal. Reverse osmosis system has been achieved the expected result and hence provides drinking water with very low level of chlorine. Activated carbon filter and combination units are also give positive result in removing chlorine at 94.67 % and 92.33 % removal respectively.

Distillation system and UV light system are not very effective in removing chlorine from drinking water as compared to other treatment methods. The result obtained is disappointed because distillation system is expected to get rid of all constituents from water.

7.4 Total Aluminium

The lowest, highest and average percentage removals of aluminium for each treatment method are shown in the table below.

Types of filters	Lowest % removal	Highest % removal	Average % removal
Activated carbon	36.90	27.59	31.09
Membrane	46.38	64.44	56.50
Reverse Osmosis	60.00	87.80	76.12
Distillation	60.42	74.70	66.09
UV Light	20.73	37.14	30.40
Combination	44.00	66.67	55.94

Table 7.4: The lowest, highest and average percentage removals of aluminium

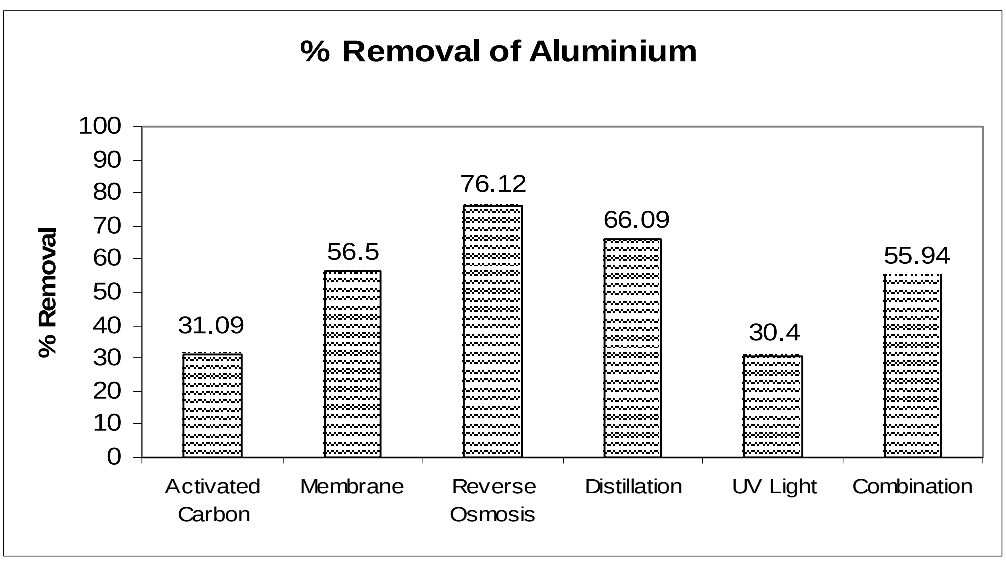


Figure 7.4: Percentage removal of aluminium for different treatment systems

Aluminium level in drinking water should not exceed 0.2 mg/l according to the WHO and Malaysian Drinking Water Standard. The aluminium levels of water samples are in the range of 0.021 to 0.135 mg/l. The experimental results showed that aluminium level in Malaysian tap water has met the Malaysian Drinking Water Standard.

The experimental results also showed that not all the treatment methods give satisfactory result in removing aluminium from drinking water. Among six treatment methods, reverse osmosis system is the most effective method to remove aluminium at 76.12 % removal. This is followed by distillation system at 66.09 %, combination unit at 55.94 %, membrane filter at 56.5 %, activated carbon filter at 31.09 % and UV light system at 30.4 % removal.

Reverse osmosis system and distillation system should give better result in removing aluminium from water as both methods are expected to produce pure water after treatment process. Activated carbon filter and UV light system are not the effective methods in removing aluminium from water.

7.5 Total Chromium

The lowest, highest and average percentage removals of total chromium for each treatment method are shown in the table below.

Types of filters	Lowest % removal	Highest % removal	Average % removal
Activated carbon	25.00	33.33	28.97
Membrane	14.29	28.57	19.84
Reverse Osmosis	28.57	37.5	33.13
Distillation	44.44	37.50	40.65
UV Light	0.00	28.57	16.93
Combination	20.00	42.86	33.45

Table 7.5: The lowest, highest and average percentage removals of total chromium

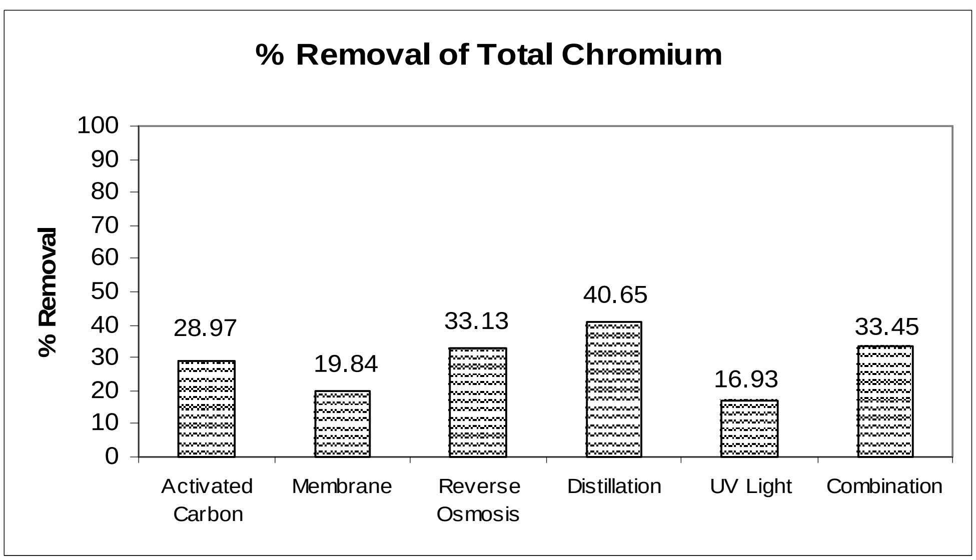


Figure 7.5: Percentage removal of total chromium for different filtration systems

The maximum allowable value for total chromium is 0.05 mg/l according to WHO and Malaysian Drinking Water Standard. The experimental results showed that most of the water samples have exceeded the permissible value. The highest recorded value is 0.10 mg/l whereas the lowest recorded value is 0.05 mg/l. Chromium is a toxic substance and it is detrimental to human health. This is an alarming issue as our supplied tap water does not abide the water drinking standard.

All the treatment methods do not give a satisfactory result in removing total chromium from water. The experimental results showed that distillation system is the most effective method in removing total chromium compared with other treatment methods at 40.65 % removal. This is followed by combination unit at 33.45 %, reverse osmosis system at 33.13 % activated carbon filter at 28.97 %, membrane filter at 19.84 % and UV light system at 16.93 % removal.

Distillation system and reverse osmosis system do not give positive results as expected. Theoretically, both methods should remove chromium from water as they can remove heavy metals and provide pure water for human consumption. The chromium level of some water samples is still exceeded the permissible value even though after treatment process. The mentioned treatment methods are not be able to remove all chromium in drinking water but at least the total chromium level has been reduced.

7.6 Total Iron

The lowest, highest and average percentage removals of total iron for each treatment method are shown in the table below.

Types of filters	Lowest % removal	Highest % removal	Average % removal
Activated carbon	28.57	50.00	40.48
Membrane	37.50	71.43	52.98
Reverse Osmosis	62.50	71.43	67.98
Distillation	66.67	82.14	74.85
UV Light	25.00	42.86	33.73
Combination	55.56	75.00	65.74

Table 7.6: The lowest, highest and average percentage removals of total iron

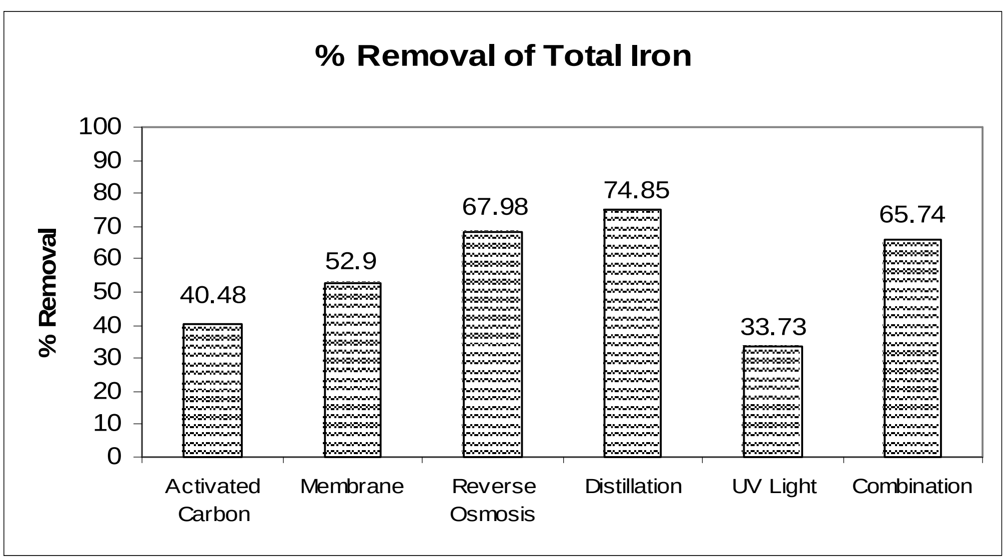


Figure 7.6: Percentage removal of total iron for different filtration systems

The maximum allowable value of iron concentration in drinking water is 0.3 mg/l. The recorded values of water samples before filtration treatment process are well below the permissible value. Most water samples have values lower than 0.15 mg/l. Samples from the same area may differ greatly in iron concentration. Types and conditions of pipes used in the distribution system might lead to the varying concentration in iron. Household with old rusted iron pipes may experience a higher level in iron concentration as opposed to PVC pipes users.

Removal of total iron is more successful than chromium removal as each treatment method gives higher percentage removal. Distillation system is the most effective treatment method in removing total iron from water at 74.85 %. This is followed by reverse osmosis system, combination unit, membrane filter, activated carbon filter and UV light system at 67.98 %, 65.74 %, 52.98 %, 40.48 % and 33.73 % removal respectively.

Reverse osmosis system and distillation system give unsatisfactory results again as both methods should remove higher percentage of iron from water. Theoretically, reverse osmosis system should remove 95 % to 98 % of iron from drinking water. However this method does not achieve the expected result. Activated carbon filter and UV light system are not the effective method for removal of iron.

CHAPTER 8

CONCLUSION

8.1 Conclusion

This research project is focused on the currently used domestic water filtration systems in Malaysian market. There is a need for consumers to have a better understanding of the various filtration systems based on their technologies, price, maintenance and limitation.

Nowadays, many consumers do not satisfy with the supplied tap water quality due to the water contamination problems in the country. Most of the consumers encountered problems such as turbidity, colour, excessive chlorine content, taste and odour.

Both organic and inorganic substances at concentration above the acceptable levels are detrimental to human's bodies. Harmful chemical pollutants in water are arsenic, chromium, cadmium, cyanide, mercury, lead and etc. Hence, manufacturers and distributors of domestic filtration systems took this opportunity to introduce consumers various methods to treat their tap water before consuming it.

Six types of domestic water filtration systems were studied in this research project. These methods are activated carbon filter, membrane filter, reverse osmosis system, distillation system, UV light system and combination unit. Based on the case studies, activated carbon filter and membrane filter are the common and cheaper methods compared to other filtration systems. These types of filtration systems are commonly used by consumers because they are easy to install and maintain. Reverse osmosis system, distillation system, UV light system and combination unit are expensive and require higher maintenance cost.

Laboratory experiments were conducted on water samples in order to rectify the water quality issue. Some parameters of the collected tap water are exceeded the permissible levels of WHO and Malaysian Drinking Water standards. All the parameters should not exceed the allowable levels in order to ensure human's health. According to the experimental results, most treatment methods give high percentage removal in parameters such as colour, turbidity and total free chlorine. On the contrary, parameters such as total aluminium, total chromium and total iron are harder to remove.

The average percentage removal of apparent colour using activated carbon filter, membrane filter, reverse osmosis system, distillation system, UV light system and combination unit are 74.7 %, 48.61 %, 51.59 %, 99.91 %, 24.96 % and 56.35 % respectively. The average percentage removal of turbidity using activated carbon filter, membrane filter, reverse osmosis system, distillation system, UV light system and combination unit are 90.42 %, 60.38 %, 79.69 %, 86.22 %, 51.67 % and 60.28 % respectively.

The percentage removal of total free chlorine using activated carbon filter, membrane filter, reverse osmosis system, distillation system, UV light system and combination unit are 94.67 %, 87.16 %, 96.63 %, 64.22 %, 52.15 % and 92.33 % respectively. The average percentage removal of total aluminium using activated carbon filter, membrane filter, reverse osmosis system, distillation system, UV light system and combination unit are 31.09 %, 56.50 %, 76.12 %, 66.09 %, 30.40 % and 55.94 % respectively. The average percentage removal of total chromium using activated carbon filter, membrane filter, reverse osmosis system, distillation system, UV light system and combination unit are 28.97 %, 19.84 %, 33.13 %, 40.65 %, 16.93% and 33.45 % respectively. The average percentage removal of total iron using activated carbon filter, membrane filter, reverse osmosis system, distillation system, UV light system and combination unit are 40.48 %, 52.98 %, 67.98 %, 74.85 %, 33.73 % and 65.74 % respectively.

From the results obtained, activated carbon filter is the most effective method in removing turbidity from water. Distillation system is the most effective method in removing colour, total chromium and total iron. On the other hand, reverse osmosis system is the most effective method in removing chlorine and total aluminium. Not all the treatment units give expected result as mentioned in the literature review. Reverse osmosis system and distillation system do not remove all the impurities and give only the pure water as mentioned. According to the experimental results, percentage removal of some parameters especially the chemical substances is low.

We can conclude that a single water treatment system is not able to treat all the water problems. Water filter is the simplest way to improve drinking water quality. Although it cannot remove all the impurities from water but at least it can reduce the concentration level in the water. Water filter requires maintenance on a regular basis in order to maintain at its optimum performance. Without regular maintenance, water filter is not able to provide clean water to us.

8.2 Further Work

For further work of this research project, I hope that students who are interested in this topic would be able to carry out deeper research. In this research project, the laboratory experiments are mainly focused on the physical properties and a few chemical properties. For further research, laboratory experiments should focus on the chemical properties of drinking water. This is because chemical substances presented in drinking water are dangerous compounds to human's health. We need to investigate the effectiveness of various domestic filtration systems in removing chemical substances from drinking water.

Besides that, biological aspect of the drinking water also should be taken into consideration. Microorganisms, viruses and bacteria are major concern in regards to the water quality. Drinking water should be free from all pathogenic microorganisms as they are waterborne disease-causing organisms. More water samples should be collected for the experiments in order to obtain accurate results.

On the other hand, consistency test of water parameters can be done to verify the consistency of quality and treatment efficiency over a period of time. In order to carry out the consistency test, one specific water treatment system with a single source should be collected for few days, i.e. five days. Water samples are collect for five consecutive days and test in the laboratory for the same parameters, i.e. colour, turbidity, total aluminium, total chromium, total iron and total free chlorine. These consistency tests are aimed at evaluating the consistency of supplied water quality and treated water quality.

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APPENDIX A

University of Southern Queensland

Faculty of Engineering and Surveying

ENG 4111/4112 Research Project

PROJECT SPECIFICATION

FOR : **LAW BEE BEE**

TOPIC : THE USAGE OF DOMESTIC WATER FILTRATION SYSTEMS IN MALAYSIA

SUPERVISOR : Dr. Ernest Yoong

PROJECT AIM : This project investigates the current use of domestic water filters in Kuala Lumpur. The study will also compare the technologies of the various filtration systems.

PROGRAMME: **Issue A, 11 March 2005**

1. Study the reasons why households install water filter systems and gauge public attitude towards these systems by carrying out a community questionnaire survey.
2. Literature review of similar work by other researchers and show why this investigation is relevant.
3. Collect and present data of supplied drinking water quality. This information will be the basis of baselines values of municipal supplied drinking water.
4. Study different types of water filter available in the market base on their cost, design and maintenance.
5. Make comparisons between the water filter systems.
6. Investigate the effectiveness of filter systems by carrying out lab test on the filtered water.

AGREED:

______________ (Student)
LAW Bee Bee
(dated) 18/03/2005

____________ (Supervisor)
Dr. Ernest Yoong
(dated) 31/03/2005

APPENDIX B

QUESTIONNAIRE

1. Are you satisfied with the quality of tap water in your house?

A. Yes

B. No

2. Do you boil the tap water before consume it?

A. Yes

B. No

3. What are the problems with the locally supplied tap water do you encountered?

A. Yellowish colour

B. Contain suspended solid

C. Chlorine smell

D. Skin irritation

F. Others___________

4. If the water is yellowish colour but told that it is still clean, will you consume it?

A. Yes

B. No

5. Do you use water filter at home?

A. Yes

B. No

6. How many water filters do you installed in your house?

A. One

B. Two

C. More than two

7. Do you test the tap water before purchasing the water filter?

A. Yes

B. No

8. Where is your water filter installed?

A. Outside home on the main pipe

B. In the kitchen

C. In the shower

D. Others____________

9. Do you have an understanding about the water filter you are using?

A. Yes

B. No

10. What kind of water filter you are using?

A. Activated carbon

B. Membrane filter

C. Reverse osmosis

D. UV ray

E. Distillation

F. Combination

G. Others_____________

11. Why are you buying the water filter?

A. Health reasons

B. Advertisement

C. Affordable

D. Influence from friends, relatives or neighbors

E. News and complaints of water contamination in mass media

12. How much would you spend on a water filter?

A. RM 100 – 500

B. RM 500 – 1000

C. RM 1000 – 1500

D. Above RM 1500

13. Are you satisfied with the water filter you are using?

A. Yes

B. No

14. How often do you clean your water filter?

A. Weekly

B. Monthly

C. Every 3 months

D. Others__________

15. How often do you need to replace your filter parts?

A. Every 6 months

B. Every 1 year

C. Others_______________

16. How much do you spend to replace those parts?

A. RM 0 – 100

B. RM 100 – 200

C. RM 200 – 300

D. Above RM 300