COMPARISON OF NUTRIENTS CONTENT AND PHYSICAL PROPERTIES IN FILTERED DRINKING WATER BY VARIOUS BRAND OF WATER FILTER MACHINE

By

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DECLARATION

I declare that this thesis entitled "Comparison of Nutrients Content and Physical Properties in Filtered Drinking Water by Various Brand of Water Filter Machine" is the result of my own research except as cited in the references. The thesis has not been accepted for any degree and is not concurrently submitted in candidature of any other degree.

Signature : ______________________________

Name : ______________________________

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LIST OF ABBREVIATION

AAS	Atomic absorption spectroscopy
CONTAM	Panel on Contaminants in the Food Chain
DRI	Dietary Reference Intakes
EPU	Economic Planning Unit
FDA	United States of Food and Drug Administration
FNB	Food and Nutrition Board
FRWC	Flint River Watershed Coalition
FWPCA	Federal Water Pollution Control Act
GDWQ	Guidelines of Drinking Water Quality
HA	Health Advisory (HA) Program
HWT	Household Water Treatment
ICP-MS	Inductively Coupled Plasma Mass Spectrometry
KDF	Kinetic Degradation Fluxion
MCL	Maximum Contaminant Level
MCLG	Maximum Contaminant Level Goal
MLS	Mandatory Level of Service
NSDWQ	National Standard for Drinking Water Quality
NSDWR	National Secondary Drinking Water Regulations
NSF	National Sanitation Foundation
OW	Office of Water for USEPA
POE	Point of Entry
POU	Point of Use
QAP	Quality Assurance Programme

RO	Reverse Osmosis
SYABAS	Syarikat Bekalan Air Selangor
TDS	Total Dissolve Solid
USEPA	United States Environmental Protection Agency
VOC	Volatile organic compounds
WCC	World Chlorine Council
WECAM	Water and Energy Consumer Association of Malaysia
WHO	World Health Organization

LIST OF SYMBOLS

µg/L	Microgram per litre
As	Arsenic
Ca	Calcium
Cd	Cadmium
Cu	Copper
Cl	Chlorine
F^-	Fluoride
FAU	Formazin Attenuation Units
Fe	Iron
Mg	Magnesium
mg	Milligram
mg/L	Milligram per liter
ml	Millilitre
Mn	Manganese
Ni	Nickel
NTU	Nephelometric Turbidity Units
Pb	Lead
ppm	Parts per million
Se	Selenium
Zn	Zinc

Comparison of Nutrients and Physical Properties in Filtered Drinking Water by Various Brand of Filter Machine

ABSTRACT

In these recent years, the awareness among public about the good quality and clean water have been increased. Therefore, to ensure the water that will be consumed is clean, many people have installed water filter machine that filter the tap water at their premises before it being drank. As the awareness increasing, the manufacturer of various brand of water filter machine also increasing in terms of numbers and products. These companies are competing with each other to win people's heart by offering variety of function of the water filter machine. The result from these water filter machine is either mineral water or reverse osmosis water. This study is carry out to determine the level of nutrients (Cu, Ca, Mg, Zn, F^-, Cl and Ni) and physical properties (pH, TDS and Turbidity) in filtered drinking water by various brand of water filter and compared with the drinking water standard from USEPA and the GDWQ by WHO. The results obtained from this research showed that the level of each element that have been analysed are within the guidelines except for turbidity and TDS. Therefore, the best drinking water can be obtained from water filter C as the there are many nutrients contents in water filter C are higher than other water filter and have physical parameters that still under the limitation of standard from both standards. The results obtained through this study is hoped to give baseline information to the public in order to choose which the best filter machine in the market. It is also hoped to give awareness to the public to have a good practices in maintaining the filter machine.

Perbandingan Kandungan Nutrien dan Parameter Fizikal dalam Air Minuman yang Ditapis oleh Pelbagai Jenama Mesin Penapis

ABSTRAK

Dalam beberapa tahun kebelakangan ini, kesedaran di kalangan orang ramai mengenai air yang berkualiti dan bersih telah meningkat. Oleh itu, bagi memastikan air yang akan digunakan adalah bersih, ramai telah memasang mesin penapis air untuk menapis air paip di premis masing-masing sebelum ia dijadikan air minuman. Kesedaran yang semakin meningkat ini menyebabkan pengeluar pelbagai jenama mesin penapis air juga semakin meningkat dari segi bilangan dan produk. Syarikat ini bersaing antara satu sama lain untuk memenangi hati masyarakat dengan menawarkan pelbagai fungsi mesin penapis air. Mesin penapis ini akan mengeluarkan air sama ada air mineral atau air osmosis berbalik. Kajian ini dijalankan adalah untuk menentukan tahap nutrien (Cu, Ca, Mg, Zn dan F^-, Cl and Ni) dan sifat fizikal (pH, TDS dan kekeruhan) dalam air minuman yang ditapis oleh pelbagai jenama penapis air dan dibandingkan dengan standard air minuman dari USEPA dan GDWQ oleh WHO. Hasil daripada kajian ini mendapati tahap setiap elemen yang telah dianalisis berada dalam garis panduan kecuali kekeruhan dan TDS. Oleh itu, air minuman yang terbaik boleh diperolehi daripada penapis air C kerana terdapat banyak kandungan nutrien dalam penapis air C adalah lebih tinggi daripada penapis air yang lain dan mempunyai parameter fizikal yang masih di bawah had standard dari kedua-dua standard. Keputusan yang diperolehi melalui kajian ini diharapkan dapat memberi maklumat asas kepada orang ramai untuk memilih mesin penapis air terbaik di pasaran. Ia juga diharap dapat memberi kesedaran kepada orang ramai untuk mempunyai amalan yang baik dalam sentiasa menyelenggara mesin penapis air.

CHAPTER 1

INTRODUCTION

1.1 BACKGROUND OF STUDY

Water filter machine is a machine that has the ability to filter water from the tap water before it is consumed by consumers either for drinking or other purposes in daily life. This water filter machine has been very popular among Malaysians since 2010 as it is very compatible and easily to handle as a home appliance. Nowadays, most residences in Malaysia have at least one water filter either it is installed inside or outside of the house by being connected with the main piping system of the house. There are two types of installations of water filter system which are the point of use (POU) device that is installed at a single tap or limited numbers of taps for directly consumption of water such as for cooking and drinking and also the point of entry (POE) device that functions to treat water that is supplied to one premise which provide more protection to the consumers (EPA, 2006). This is to ensure that all contaminants or pollutants are removed before the water is safe to be consumed.

Nowadays, people have gained their awareness about their drinking water which is not only safe to be consumed, but also supply minerals for a healthier body. Because of that, the companies that produce water filters take this opportunity to promote their own water filter machines with high technology that can meet the needs of the consumers. Based on a previous research, 85% of Malaysians purchased domestic water filters, while 41% of Malaysians used the boiling method to get drinking water from the tap, and 17% of Malaysians bought bottled water, either drinking or mineral water (Aini *et al.*, 2007). Research done by the Water and Energy

Consumer Association of Malaysia (WECAM) in 2008/2009 showed that only 3.68% out of 363 houses installed the water filters and the residence knew the type of the water filters as well as their functions, which resulted that their awareness regarding the system and the function of this water filter machine was low (WECAM, 2010). Nowadays, the water filters systems at the markets have been upgraded in terms of the components and membrane technology. Their functions are not only filtering the water from contaminants and pollutants, but also give minerals and nutrients to human body.

Generally, there are many membranes or types of filters that have been used in each water filter machines. There are water filters that use reverse osmosis (RO) membrane in them, which filter all the nutrients in the water such as salt, Manganese (Mn), Iron (Fe), Fluoride (F^-), Lead (Pb) and Calcium (Ca) (Binnie *et al.*, 2002). This RO water is good to be consumed once a while in order to flush unwanted elements in the body while mineral water is very important to be consumed every day in order to fulfil the capacity needed for the body to develop (Soetan *et al.*, 2010). Recently, there are lots of companies produce water filter machines that have their own system of filtration which provides nutrients in the filtered water.

Based on the previous study, the essential minerals or nutrients that should be taken by the human body is Ca, Mg and Zn (Schwalfenberg & Genuis, 2015). World Health Organization (WHO) have been stated that human body needs important nutrients such as F^-, Mg, Zn, Ca and Copper (Cu) by consuming water or milk (Sievers, 2005). These kind of minerals can be taken by human through drinking water in order to sustain the minerals contain in the human body system. But, everything has pros and cons. The consumption of minerals is essential for human, but if the concentration of each minerals is too high, there will be an adverse effect to the human body as the minerals will act as toxics to the human body system (Nouri *et al.*, 2014).

This research is conducted to determine the selected nutrients (copper, calcium, magnesium, fluoride, zinc, chlorine and nickel) and physical properties (pH, TDS and turbidity) in drinking water that have been filtered by various brand of water filter machine and compared the result with the drinking water standard in order to get the best water filter that provide the best drinking water for the consumers.

1.2 PROBLEM STATEMENT

A safe drinking water is essential to the human. By drinking the polluted water, it could affect the human's health and it may lead to serious disease and death. This can be related with the term water-borne disease. Water-borne diseases are infectious diseases which can spread primarily through contaminated water and also through other medium such as via clothes, hands, foods, materials used for cooking, eating and drinking where the pathological microorganisms can enter the body through an open wound, eyes and nose as well (Deepali & Joshi, 2014). Typhoid fever, dysentery, diarrhea, cholera, hepatitis, worms and polio are some of the widespread water borne diseases (Fonyuy, 2014).

Today, safe drinking water has become a priority to the government as well as to the public. The government have establish a lot of policy and action plan in ensuring the people can access the safe drinking water which is clean and free from bacteria. By time, the related waterborne diseases especially in Malaysia has decreased as the water have done the treatment process before it goes to the houses and premises through the piping system. Based on Laporan Kesejahteraan Rakyat Malaysia 2013, the household percentage index throughout Malaysia that have received the treated water has increased from 89.9% in 2000 to 93.9% in 2012 (EPU, 2013). Therefore, the water that we get from our tap has been treated and safe to be consumed for any activities. But, a research have been conducted indicates that the Malaysian did not consume directly from the tap as their perception on that water is poor in quality and have pollution as well as contamination (Aini *et al.*, 2007). Therefore, many Malaysians have chosen to install the domestic water filters at their homes for safer water, especially for drinking purpose.

Since there are various brands of water filter machines in the market that offer different types of filtered water either RO water or mineral water, the consumers become confused and difficult to decide which brands give the best drinking water for their safety and health. People also do not know the differences between the mineral water, the RO water, as well as the zamzam water in terms of the nutrient contents as well as the effects of the consumption of the filtered water to the human body. Therefore, this study is significant in order to determine which water is the best to be consumed based on nutrients that the human body needs.

1.3 OBJECTIVES

i. To determine the level of nutrients (copper, calcium, magnesium, fluoride, zinc, chlorine and nickel) and physical properties (pH, TDS and turbidity) in filtered drinking water by various brand of water filter machine.

ii. To determine the best water filter machine through the best drinking water to be consumed by comparing the level of nutrients and physical properties of the filtered drinking water with the drinking water standard from Environmental Protection Agency of United States (USEPA) and the Guidelines of Drinking Water Quality (GDWQ) by WHO.

CHAPTER 2

LITERATURE REVIEW

2.1 HISTORY OF DRINKING WATER TREATMENT

Water is most vital liquid for maintaining the life on the earth. About 97% water exists in the oceans is not suitable for drinking and only 3% is fresh water wherein 2.97% of it comprises by glaciers and ice caps and the remaining little portion of 0.3% is available as a surface and ground water for human use (Miller, 1997). Access to safe drinking-water is essential for health, a basic human right and a component of effective policy for health protection. Therefore, the good drinking water quality has become the goal to ensure the health of human can be retained. In order to achieve that, water treatment is the biggest concern back then.

During the late nineteenth and early twentieth centuries, the concerns regarding drinking water quality continue to focus mostly on disease-causing microbes (pathogens) in public water supplies (Darby & Tchobanoglous, 2000). Scientists discovered that turbidity was not only an aesthetic problem; particles in source water, such as faecal matter, could harbour pathogens such as Escherichia coli and Vibrio cholera (Cabral, 2010). As a result, the design of most drinking water treatment systems built in the U.S. during the early 1900s was driven by the need to reduce turbidity, thereby removing microbial contaminants that were causing typhoid, dysentery and cholera epidemics. To reduce turbidity, some water systems in U.S. cities (such as Philadelphia) began to use slow sand filtration (Cutler & Miller, 2004). While filtration was a fairly effective treatment method for reducing turbidity, it was disinfectants like Cl that played the largest role in reducing the number of waterborne disease outbreaks (Sobsey *et al.*, 2003). Based on EPA report, chlorine was used for the first time as a primary disinfectant of drinking water in Jersey City, New Jersey in 1908. After that, the use of other disinfectants such as ozone also began in Europe around this time, but were not employed in the U.S. until several decades later (EPA, 2000)

Malaysia also becomes more concern about the treatment of water before it can be supplied to the citizen. For the water treatment, the Malaysia's government has put a lot of efforts to treat the water to make it safe to be consumed as the previous study have resulted that the concentration of inorganic matter in tap water throughout Malaysia is low than standard limit, except for certain areas (Azrina *et al.*, 2011). In Malaysia, according to Syarikat Bekalan Air Selangor (SYABAS), the quality of the water supplied to the consumers is safe for consumption direct from the tap as the water quality is constantly monitored to ensure it is always well within the Quality Assurance Programme (QAP) and National Standard for Drinking Water Quality (NSDWQ) under the Ministry of Health and as being well within the requirements of the Mandatory Level of Service (MLS) under the Concession Agreement, but the consumers must periodically check their home internal plumbing and clean the water tank (SYABAS, 2016).

2.2 GUIDELINES OF DRINKING WATER QUALITY

In order to produce a water filter machine, the product must comply the standards that have been provided. For example, in the US, all companies that produce water filter machines must comply with the standard that have been published by the Environmental Protection Agency of United States (USEPA) (WQA, 2016). For the drinking water standard in Malaysia, the Guidelines of Drinking Water Quality

(GDWQ) that have been provided by the World Health Organization is being used in Malaysia in order to produce the National Standard for Drinking Water Quality (NSDWQ) (Second Version, January 2004) issued by Engineering Services Division, Ministry of Health, Malaysia (SYABAS, 2016). The GDWQ acts as the protection for public health and it is intended to be used as a basis for the development of national standards that, if properly implemented, will ensure the safety of drinking water supplies through the elimination, or reduction to a minimum concentration, of constituents in drinking water that are known to be hazardous to health**,** to be used in the development of risk management strategies which may include national or regional standards in the context of local or national environmental, social, economic and cultural conditions and also as the advantage provided by the use of a risk-benefit approach (qualitative or quantitative) to the establishment of national standards or regulations (Sombo Yamamura *et al.*, 2012).

Besides that, there are also Drinking Water Standards and Health Advisories (2012 Edition) that are created by the Environmental Protection Agency of United States (USEPA). In this standard, the USEPA have using the Maximum Contaminant Level (MCL) and also Maximum Contaminant Level Goal (MCLG), where it shows the highest value of concentration that allowed to be able in the water, especially for drinking water (USEPA, 2007). The Health Advisory (HA) Program, sponsored by the USEPA's Office of Water (OW), publishes concentrations of drinking water contaminants at Drinking Water Specific Risk Level Concentration for cancer (10-4 Cancer Risk) and concentrations of drinking water contaminants at which non cancer adverse health effects are not anticipated to occur over specific exposure durations (EPA, 2012). Table 2.1 shows the value or concentration of each parameter that will be used for this research with the guidelines that provide those limitation.

Table 2.1: The Nutrients and Physical parameters according to standard WHO and USEPA.

Nutrients and Physico-chemical parameters	Level of Concentration based on WHO	Level of concentration based on USEPA
Copper (Cu)	2.0 mg/L	1.0 mg/L
Calcium (Ca)	200 mg/L	-
Magnesium (Mg)	-	150 mg/L
Zinc (Zn)	3.0 mg/L	5.0 mg/L
Fluoride (F-)	1.5 mg/L	2.0 mg/L
Chlorine (Cl)	5 mg/L	4 mg/L
Nickel (Ni)	0.07 mg/L	0.02 mg/L
pH	-	6.5 – 8.5 pH
Turbidity	5 NTU	1 NTU
Total Dissolved Solid (TDS)	1000 mg/L	500 mg/L

(Source: National Primary Drinking Water Regulations USEPA (2009), National Secondary Drinking Water Regulations USEPA (2009), Guidelines for Drinking Water Quality WHO (2006))

2.3 HOUSEHOLD WATER TREATMENT (HWT)

It was reported that 33.0% of households in low- and middle-income countries which is about 1.1 billion people have been using boiling method in order to treat the water for drinking purpose where it is very effective for inactivating waterborne pathogens, including bacteria, viruses and protozoa (Rosa G, 2010). However, there is an important limitation about this boiling method which is that the treated water may be susceptible to recontamination due to unsafe storage and handling after boiling (WHO, 2012). In addition, the usage of certain fuels and stoves for the boiling process has adverse environmental consequences, including contributing to climate change. As with other household water treatment methods, actual use of boiling may be lower than self-reported use and consequently its health impact may be limited in practice (Rosa G, 2010).

Nowadays, the usage of filtration for drinking water becomes more popular in Asia instead of boiling the water. This increasing usage of water filter machine is because the awareness of public about safe drinking water is increasing and this kind of products is getting increase in the market such as in Malaysia, China, Korea and others (WHO, 2016).

In Malaysia, there are various brands of water filter in the market such as e-Spring (Amway), Bio-Pure (Elken), Coway, Cuckoo, Bio-Aura and others. These brands may use several types of filtration components that have been used in the water filter machines which may differ from one another. There are water filters that combine ultraviolet light technology with a patented multi-stage carbon block filter, resulted the filtered water is more than just clean, clear and delicious water as it can reduce more than 140 other potential health-effect contaminants, where in the meantime, all the minerals needed in drinking water such as Ca, Mg and Potassium (K) will be remained after the filtration (Amway, 2012). There are also water filter machines that can eliminates the minerals such as Ca, Mg, K, Sodium (Na), F^-, and Cl in their drinking water after the filtration where its patented system removes virtually all types of contaminants including viruses as small as 0.0001 micron which this type of water filter machine are using the reverse osmosis membrane (RO) as the main component (Elken, 2016). Other than that, there are also water filter machine that can filter the minerals and reduce its concentration in the filtered drinking water.

2.4 TYPE OF DRINKING WATER

There are several types of drinking water that have been popular and people are arguing about which type of water that are the best to be consumed. The companies that produce the water filter system also concern about this type of drinking water as it will give impact to their brand and specification of the water filter.

2.4.1 Reverse Osmosis Water

Reverse Osmosis (RO) water is the water that has been treated by using the RO membrane. The RO membrane technology has been developed for over 40 years ago. The definition of osmosis itself is a process which uses a semipermeable membrane to separate solutions of different concentration. The solvent will flow at a faster rate than the dissolved solids from the side of low concentration to the side with higher concentration. (Greenleea *et al.*, 2009).

There are several methods for filtration of water that involves RO system which are distillation, ion exchange, reverse osmosis, microporous filtration, as well as ultra-filtration and photo oxidation. For the RO process in drinking water filter machine for household, there are five stages usually take place to produce RO water at home; sediment filter, granular activated carbon (GAC) filter, CTO carbon filter, RO membrane and post carbon filter (El-Harbawi, 2010).

Sediment filter is the first stage in RO process. This cartridge pre filters the sediment, dust, coarse material, rust and sand which important in order to protect the RO membrane at the fourth stage. The next stage is GAC filter which it get rid of unpleasant chlorine, taste, odours, cloudiness and colours. It also can remove the organic chemicals by absorbed it into the filter membrane. The third stage is the CTO carbon filter. This type of filter membrane can polishes the water, removes organic chemicals and removes salts up to 5 micron level. It also can self-sterilized which the function able to reduce the residue of chlorine, improve taste, odour and colour, removes insecticide, synthetic detergents and dissolved organic contamination. The fourth stage is RO membrane which remove toxic, metal, germ, chromium and etc. The last stage in this process is the inline filter membrane which functioning on removing any possible residual taste and odours of the water as well as polishing the final water.

Drinking the RO water have some advantages in human. The RO water is able to eliminate all heavy metals that are harmful to human such as arsenic, lead, iron, chromium and others as well as the salinity and being a clean water without any ions in it (Wimalawansa, 2013). However, the consumption of RO water for drinking purpose has an adverse effect to human body. The use of domestic water filter machines that have RO membrane in them will reduce or eliminates the good nutrients that essential for human body such as Ca, Mg, Zn, F^- and others which resulting a recommendation have been done to remineralised the water by adding the mineralised membrane to add up the good nutrients in the drinking water (Janna *et al.*, 2016).

2.4.2 Mineral Water

According to United States of Food and Drug Administration (FDA), mineral water is the water that comes from an underground source and should contains at least 250 parts per million total dissolved solids where the minerals and trace elements in the water must come from the source of the underground water (FDA, 2010). Natural mineral water is water originating in an underground water table, deposit or aquifer, which emerges or is extracted from a source tapped at one or more natural or bore exits where natural mineral water is characterised by its chemical and microbiological composition, which distinguishes it from drinking water, and may not be treated in any way that alters these properties (Burden, 2010).

The consumption of mineral water for drinking purpose is very important for the body in getting enough nutrients. Previous study shows that drinking the mineral water functions like a vehicle that supplies the minerals throughout the body system which gives a lot of benefits to the human health such as increasing in nasal respiratory flow, normalised mucociliary transport, decreased bacterial layer and increased plasma cells in rhinocytogram (Albertini *et al.*, 2007).

2.5 NUTRIENTS AND PHYSICAL PARAMETERS IN DRINKING WATER

It is very essential and important to test the water before it being used for drinking, domestic, agricultural or industrial purpose. The water must be tested with different physical parameters as well as chemical parameters. In this study, the selection of parameters for testing of water is solely depends upon the parameter that always being analysed in the drinking water based on the previous studies and the importance to be present in the drinking water.

2.5.1 Copper (Cu)

Copper is a stable transition metal in its metallic state and forms monovalent (cuprous) and divalent (cupric) cations where dissolved copper can sometimes impart a light blue or blue-green colour and an unpleasant metallic, bitter taste to drinking-water (WHO, 2004). Copper is not only found in surface water, groundwater, seawater and drinking-water, but it is primarily present in complexes or as particulate matter (Mechenich & Andrews, 2004). When high levels of copper are detected in water, a household plumbing system usually is the source where the water can react with copper pipes, fittings and fixtures (a process called corrosion) to release Cu into the water supply (Dozier *et al.*, 2006).

Individuals ingesting large doses of Cu present with gastrointestinal bleeding, haematuria, intravascular haemolysis, methaemoglobinaemia, hepatocellular toxicity, acute renal failure and oliguria (Agarwal SK, 1993). But from the other study, the Cu as an essential nutrients for the human bodies have a lot of function in the human body system including being involved in the gene regulation process, functioning as antioxidant, and also as the functional group for several essential enzymes in the human body such as ferroxidase (Angelova *et al.*, 2011).

Copper can act as both an antioxidant and a pro-oxidant where the free radicals occur naturally in the body and can damage cell walls, interact with genetic material, and contribute to the development of a number of health problems and diseases which as an antioxidant, copper scavenges or neutralize free radicals and may reduce or help prevent some of the damage they cause, and also it promotes free radical damage and may contribute to the development of Alzheimer's disease when the copper acts as pro-oxidants (Osredkar & Sustar, 2011).

2.5.2 Calcium (Ca) and Magnesium (Mg)

Over 99% of total body Ca is found in bones and teeth, where it functions as a key structural element. The remaining body Ca functions in metabolism, serving as a signal for vital physiological processes, including vascular contraction, blood clotting, muscle contraction and nerve transmission. Inadequate intakes of Ca have been associated with increased risks of osteoporosis, nephrolithiasis (kidney stones), colorectal cancer hypertension and stroke, coronary artery disease, insulin resistance and obesity (Atkinson *et al.*, 2009). In the general population, the major portion of Mg intake is via food, and to a lesser extent via drinking water (in Sweden, generally less than 5 percent). However, previous studies support the hypothesis that Mg in drinking water can be critical for the Mg content of the body (Rubenowitz *et al.*, 1996).

Water that contain Ca and Mg resulted from decomposition of Ca and Mg aluminosilicates which at higher concentrations may came from dissolution of limestone, magnesium limestone, magnesite, gypsum and other minerals. Anthropogenic contamination of drinking water sources with Ca and Mg is not common but drinking water may be intentionally supplemented with these elements while treated, as happens with deacidification of underground waters by means of calcium hydroxide or filtration through different compounds counteracting acidity such as $CaCO_3$, $MgCO_3$ and MgO, and possibly also with stabilization of low-mineralized waters by addition of CaO and CO_2 (Kožíšek, 2003).

2.5.3 Zinc (Zn)

Zinc as an essential trace element has indispensable role in human health and diseases where it has been insufficiently recognised by a number of experts as an important public health issue, especially in developing countries (Devi *et al.*, 2014). Zinc is crucial for normal development and function of cells mediating nonspecific immunity such as neutrophils and natural killer cells, other than also functions as an antioxidant and can stabilize membranes and also sufficient Zn is essential in maintaining immune system function (Deshp *et al.*, 2013). Small amount of uptake the Zn is essential to human, but if it is too much, then it may cause death.

Immediate symptoms that can be observed after uptake of toxic amounts of Zn which is high concentration of zinc include abdominal pain, nausea, vomiting, lethargy, anaemia, and dizziness (Porea *et al.*, 2000). Other than that, Zn also can disturb the gastrointestinal system, reduced the concentration of copper when the amount of Zn is high which causing the unbalanced concentration of trace elements or minerals in human body, and may lead to cancer (Plum *et al.*, 2010).

There are many adverse effects of Zn deficiency that have been recognised from the other previous studies. The adverse effect of Zn deficiency on immune system function that have been search are likely to increase the susceptibility of children to infectious diarrhea where it contributes to zinc deficiency and malnutrition, control the disease of malaria, pneumonia, the common cold, wound healing, many complication during pregnancy and other disease such as HIV/AIDS (Das & Das, 2012).

2.5.4 Fluoride (F^-)

Fluoride is a naturally occurring substance and is present in virtually all water, usually at very low levels. Higher concentrations of naturally occurring F^- are often associated with well water, where F^- has dissolved from the rock formations into the groundwater. Community water fluoridation began in 1945, after scientists discovered that higher natural levels of F^- in a community water supply were associated with fewer dental caries (cavities) among the residents (Tiemann, 2013).

In setting national standards or local guidelines for F^- or in evaluating the possible health consequences of exposure to F^-, it is essential to consider the intake of water by the population of interest and the intake of F^- from other sources (e.g., from food and air). But, the consumption of low mineral such as F^- in drinking water will give a lot of effect especially to the children as they need the F^- in order to have a healthy teeth, and the F^- should be within the limit that have been set by the standard for drinking water (Ezrina, 2015).

2.5.5 Chlorine (Cl)

Chlorine can be used for disinfection, control disease-causing microorganisms by killing or inactivating them. By far, the most common method of disinfection in North America is chlorination where chlorine is added to drinking water to destroy pathogenic (disease-causing) organisms (WCC, 2003).

Chlorine was introduced as a disinfectant to the urban water supply at the beginning of the 20th century to improve the hygienic quality by eliminating waterborne bacterial pathogens and the consequent transmission of water borne diseases where it is the most common form of water treatment used worldwide (Achour & Chabbi, 2014). It is also low in cost, easy to use and, most importantly, has been shown to be extremely effective in protecting and preserving the public health by destroying the water-borne pathogens that cause a range of diseases (Arnold & Colford, 2007). In addition to being effective in the primary water treatment facility, only chlorine-based disinfectants provide residual disinfectant levels to help protect treated water as it journeys from the treatment plant to the tap (Whitfield, 2008).

From the previous study, the Cl that have been used for the treatment of water can become chlorate, which is a by-product when the chlorine in the water have being in contact with the food that being consumed by the human, which can become carcinogenic to animals based on the research, and it is possible to become carcinogenic to human as well (CONTAM, 2015). Other than that, the other study shows that the high concentration of Cl in the human body system can become very dangerous to the human health such as being implicated in bladder system and colon cancer in humans, attack the important organs in human such as liver and kidney, and also disturbing the function of the blood circulatory system (Moshtaghie *et al.*, 1996).

2.5.6 Nickel (Ni)

Nickel is one of the heavy metals that most mobile when it released in the water, especially in polluted water as the organic material inside the water will keep the Ni soluble in the water. The reason for Ni present in the drinking water is mostly came from leaching of sanitary fixtures (Khan, 2011). Nickel and Ni compounds have many uses either in industrial or commercial sector such as being used in the production of stainless steel and other nickel alloys that have high resistance to corrosion and temperature, as the main component in the batteries and in nickel-plating, and also as catalysts and pigments (Grandjean, 1984).

The human exposure from Ni comes from a variety of sources and very variable. It can came from the food or water through ingestion, from the air especially near the industrialized area that using nickel as their production as well as from the tobacco smoke either pipe tobacco, cigarettes or other types of tobacco products (Bencko, 1983). Previous study have shown that oral Ni exposure will elicits cutaneous nickel-allergic reactions such as itching, nausea, headache and dizziness especially in individual that sensitive to the present of nickel (Jensen *et al.*, 2003).

2.5.7 pH

It is noticed that water with low pH is tend to be toxic and with high degree of pH it is turned into bitter taste (Mohsin *et al.*, 2013). Low pH levels can cause tooth decay where the acidic conditions can cause demineralization of the tooth and the dental enamel consists of densely packed mineral crystal mainly hydroxyapatite (HA) and it can become demineralized due to exposure to plaque acid (Adhani *et al.*, 2015).

On the other side, the constant consumption of the alkaline water which is more than pH 7 can create an abnormal digestive condition in a healthy stomach as it will altered the condition of the acid environment in the stomach (Barber, 2008). Extreme pH values can result from accidental spills, treatment breakdowns, and insufficiently cured cement mortar pipe linings (WHO, 2003).

2.5.8 Turbidity

Drinking water turbidity is a measure of the cloudiness of the water where it is commonly being used as a parameters to be measured for the risk of microbial contamination and the effectiveness of the treatment of public drinking water (Schwartza *et al.*, 2000). Turbidity also can be defined as a decreased in transparency of light in a solution due to the presence of suspended particles and also some dissolved substances which make the penetration of light will be scattered or attenuated, and resulting a higher value of turbidity (Ziegler, 2002). By this, the water will become murky and cloudy. The murkier the water, the higher its turbidity. This shows that the higher the suspended solid or dissolve particles in the water, the higher the value of turbidity of the water sample.

The unit for turbidity is using the Nephelometric Turbidity Unit (NTU), indicates the ability of the light intensity being scattered through the water sample (Daphne *et al.*, 2011). Turbidity can shows signal potential contamination problems that happened in the distribution system where high value of turbidity will indicate the breaches to the distribution system integrity, such as backflow, main breaks, cross connections or detachment of biofilm as well as intrusion which may the quality and quantity of microbiological activity in the water distribution system (Kirmeyer, 2000).

2.5.9 Total Dissolve Solid (TDS)

Total dissolve solid is the term that used to describe the content of inorganic salts and the small amounts of organic matter present in solution in water where the usually found in the water are the Ca, Mg, Na, and K cations and carbonate, hydrogencarbonate, chloride, sulphate, and nitrate anions (WHO, 2013). High TDS in drinking water is essential as it indicates a high content of minerals that needed by human body, even though it may affect the pH and also the taste of the water (Verma & Kushwaha, 2014). But, when the TDS level is too high, it may have some adverse effect to human body. High TDS level will give impact in terms of gastro-intestinal irritability, as the high concentration of the dissolved solid may enter the human body orally and interrupt the digestion system and also stomach activities (Archana *et al.*, 2015).

2.6 IMPORTANCE OF EACH PARAMETER IN DRINKING WATER

The nutrients that have been listed for analysis can be divided into two; give benefits to the body and not give any benefits to the body. The nutrients such as Cu, Ca, Mg, F^- and Zn are the essential element that needs by the human body for the development. Each of the element have their own importance which different from each other.

The analysis of Ca and Mg, which is hardness in drinking water is very important. The epidemiological studies about water hardness have been carry out worldwide, especially associated with the cardiovascular disease. One of the study concluded that the low intake of magnesium may increase the risk of developing and dying from the disease such as cardiovascular disease or stroke (Monarca *et al.*, 2006).

Thus, not removing magnesium from drinking water and increasing the magnesium intake from water may be beneficial especially for populations with an insufficient dietary intake of the mineral as there is no proven hypothesis regarding the hardness in the water will causes cardiovascular disease (Calderon & Hunter, 2009).

There were several studies in Malaysia investigated the quality of drinking water in Malaysia. It can be seen that there are many issues in Malaysia that related with the quality of drinking water. One of them is about the drinking water quality of water vending machines where the finding about turbidity of the water is high and exceeding the limitation of the guidelines 0.1 NTU as required by the Malaysian Food Act Regulation (Hashim & Yusop, 2016). But, when the water quality monitoring in Malaysia is still focusing on general parameters, less attention was given to natural organic matter concentration in drinking water sources which this can produce complex mixture of organic compounds that can cause many problems in drinking water quality (Ibrahim & Aziz, 2013)

The USEPA and WHO have put the guidelines level for drinking water standard after being consideration about many aspects, especially about the human health and development. Intake recommendations needed by humans for minerals and other nutrients are provided in the Dietary Reference Intakes (DRIs) which have been developed by the Food and Nutrition Board (FNB) at the Institute of Medicine of the National Academies (formerly National Academy of Sciences). DRI is the general term for a set of reference values used for planning and assessing the nutrient intakes of healthy people which vary by age and gender. The table below shown the Recommended Dietary Allowances and Adequate Intakes for the nutrient (Medicine, 2011):

Table 2.6: The summary of Recommended Dietary Allowances and Adequate Intakes for Copper, Calcium, Magnesium, Fluoride and Zinc

Nutrients	**Intake per day (mg/day)**
Copper	700 – 900
Calcium	1000 – 1300
Magnesium	240 – 420
Fluoride	2 – 4
Zinc	8 – 13

Source : (Institute of Medicine, 1997), (Institute of Medicine, 2000).

These nutrient's intake per day seems higher than the standard in drinking water as the nutrients can be taken in terms of food, not only in drinking water. For Cl and Ni, these two elements did not have any recommended intake been established as the consumption of these elements are likely to pose risk of adverse health effects to almost all individuals in the general population.

The analysis of Ni and Cl also have importance in determining the quality of drinking water. This is because these nutrients may soluble and travel in the water through the pipeline system and goes to the household and premises. Therefore, it is important to measure the concentration of these of both nutrients in the filtered water as it will give indicators either the filter membrane that have been used in the water filter machine is well functioning or not. It is also indicates the quality of the water filter machine as well as to ensure the good things that have been claimed by the promoter of the water filter machine either it is true or not.

One of the research have proved that the contact with nickel compounds either in soluble or insoluble can cause a variety of adverse effects on human health such as dermatitis, lung fibrosis, cardiovascular and kidney diseases, and lung and nasal cancers which make it carcinogens to humans (Duda-Chodak & Blaszczyk, 2008). Chlorine also give adverse impact to human health. Chronic exposure in long-term period to chlorinated drinking water can associated with a moderate increased risk for bladder cancer which is particularly happened among men (Villanueva *et al.*, 2003).

According to USEPA, the elements in drinking water such as Cu, F^-, Zn, pH and TDS have been listed in National Secondary Drinking Water Regulations (NSDWR). The NSDWR is a non-enforceable guidelines regarding the regulating contaminants that may resulting cosmetic effects such as skin or tooth discolouration or even the aesthetic effects such as taste, odour or colour in the drinking water. USEPA have recommended this regulation for water system but it depends on the country or states to choose in order to use them as enforceable standards (USEPA, 2015). Therefore, those elements should not exceeding the limits that have been set up as each parameters have their own significant risk if the concentration is too high.

Each of the parameters that had been chosen in this research give their own impacts in this study. There are previous research that emphasize the advantages and benefit of drinking the alkaline water. One of it showed that a bicarbonate and calcium-rich alkali mineral water decreased bone resorption more than a calcium-rich acidic mineral water, in healthy pre-menopausal subjects on a calcium sufficient balanced diet (Wynn *et al.*, 2009). On the other part, there is a study where patients with functional dyspepsia (indigestion) being tested with alkaline water and it indicate that a regular course of crenotherapy with alkaline water may favour the relief of digestive symptoms where it have a positive influence on gastric functions and release the endogenous gastrin (Bertonia *et al.*, 2002).

CHAPTER 3

MATERIALS AND METHODS

HACH DR 900 Multiparameter Handheld Colorimeter, Hanna Instrument Portable pH/mV Meter - HI8424 and the HACH MP-4 Portable Meter have been used in this study as the USEPA has approved the usage of these equipment for water and wastewater analysis (HACH, 2013b).

3.1 SAMPLE COLLECTION

Water samples have been taken from different brands of water filter machines. In this experiment, five water filter machines from different brands have been selected.

Table 3.1: Summary of Selected Water Filter with Specification

Brand of Water Filter	Number of Filter Cartridge	Stages of Filtration	Specification
A	1	1	- non-woven fabric (remove coarse particle of dirt) - powdered activated carbon (absorb harmful substances)
B	2	2	- CTO Carbon Filter (reduce chlorine, taste, odour) - PP Sediment Filter (remove suspended material)
C	4	6	- sediment and carbon filters (reduce particle, contaminants) - RO membrane - carbon and fine filter membrane (reduce odour and taste) - ceramic filter membrane (prevent microbes)
D	6	6	- 0.9 micron filter pores - removing odour - stabilizing and enriching with minerals - safety (remove radioactive, heavy metals, etc.) - high energy (break smaller water molecule) - alkaline water
E	4	6	- eliminate the impurities - pre-carbon filter cartridge (remove odour, organic substances) - mineral eruption, produce mild alkaline water - eliminate 99% of bacteria and viruses

Water samples have been collected from various houses and premises around Kelantan as the samples be taken from the same source (main piping system of Kelantan by Air Kelantan Sdn Bhd.) and focuses on the area of Kota Bharu only. This is to control the source of water as to reduce the external interference.

The sampling have been done twice. For each water filter machine, six bottles of the water sample (500 ml for each) are being taken; three bottles of the sample is being taken before it enters the water filter machine and another three bottles of the sample is being taken after it has been filtered with the filter machine. Before collecting the samples, the bottles need to be washed with distilled water and rinsed thoroughly with 10% of concentrated nitric acid for preservation (Baharom & Ishak, 2015).

For each sample, the water have been allowed to run for a few minutes before it is collected as samples. The water samples need to be filled into the bottles slowly with a gentle stream to avoid turbulence and air bubbles. Therefore, the total samples for this experiment is 60 samples which encompasses of two times samplings. The nutrients (Cu, Ca, Mg, F^-, Cl, Zn and Ni) and the physical parameters (pH, turbidity, and TDS) analysis had been conducted for all water samples. At the sampling site, the bottles that contain the water samples had been labelled and kept in ice while being transported to the laboratory. The samples was being kept under 4˚C in the chiller at Environmental Science Laboratory for further test.

3.2 SAMPLE ANALYSIS

The nutrients from the water such as Cu, Ca, Mg, Zn, F^-, Cl and Ni and also physico chemical properties such as turbidity are being tested using HACH DR 900

Multiparameter Colorimeter. To test the pH, the Hanna Instrument Portable pH/mV Meter - HI8424 and for TDS, the HACH MP-4 Portable Meter have been used.

3.2.1 Copper

The concentration level of Cu was determined using the Powder Pillow Procedure (Method 8506) for Cu from DR 900 Multiparameter Handheld Colorimeter. This method used the USEPA Bicinchoninate Method which is Method 8506 (CuVer 1) that can test the range of Cu between 0.04 to 5.00 mg/L. For water, wastewater and seawater, USEPA has approved this method for reporting wastewater analysis.

To start this procedure, the program 135 Copper, Bicin in the colorimeter have been chosen. For the preparation of sample, a sample cell was filled with 10 ml of sample. Then, the contents of one CuVer 1 Copper reagent powder pillow have been added. The sample cell should be swirl to mix. After that, the instrument timer have been started for a 2-minute reaction. For the preparation of blank, the second sample cell have been filled with 10 ml of the sample. The blank was cleaned and being inserted into the cell holder. The ZERO button was pushed and the display was shown 0.00 mg/L Cu. After that, the prepared sample was cleaned and being inserted into the cell holder within 30 minutes after the timer expires. READ button was pushed and the results shown in mg/L Cu (HACH, 2013a).

3.2.2 Calcium and Magnesium

The concentration of hardness (magnesium and calcium) in the sample was determined by using the Calmagite Procedure (Method 8030) for Hardness from DR

900 Multiparameter Handheld Colorimeter. This method tested the concentration range of Ca and Mg in between 0.05 to 4.00 mg/L Ca and Mg.

To start this procedure, the program 225 Hardness, Mg in the colorimeter have been chosen. 100 ml of the sample was poured into a 100-ml graduated mixing cylinder. Then, 1.0 ml of Calcium and Magnesium Indicator Solution was added by using the 1.0 ml dropper. The cylinder was closed and being inverted several times to mix. Then, 1.0 ml of Alkali Solution for Calcium and Magnesium Test was added by using a 1.0 ml dropper. The cylinder was closed and being inverted several times to mix. 10 ml of the solution was poured into each of the three sample cells.

For preparation of blank, one drop of 1 M EDTA solution was added to the first sample cell. Then, the cell was swirl to mix. For preparation of magnesium sample, one drop of EGTA solution was added to the second sample cell. The sample cell was swirl to mix. Then, the blank was cleaned and being inserted into the cell holder. ZERO button was pushed and the display shown 0.00 mg/L Mg $CaCO_3$. The prepared magnesium sample cell was cleaned and being inserted into the cell holder. READ button was pushed and the result shown in mg/L magnesium as calcium carbonate. This value is the amount of magnesium in the sample expressed as $CaCO_3$.

The magnesium sample cell was not removed from the instrument. STORE was selected to save the magnesium results before the next step. Then, the program magnesium was exited. Program 220 Hardness, Ca was started. The ZERO button was pushed and the display shown 0.00 mg/L Mg $CaCO_3$. For the calcium sample, the third sample cell was inserted into the cell holder and the READ button was pushed. The results shown in mg/L calcium as calcium carbonate. This value is the amount of calcium in the sample expressed as $CaCO_3$ (HACH, 2013d).

3.2.3 Zinc

The concentration of Zn in this sample have been determined by using the Powder Pillow Procedure (Method 8009) from DR 900 Multiparameter Handheld Colorimeter. This method used the USEPA Zincon Method that can test the range between 0.01 to 3.00 mg/L Zn. It is used for water and wastewater and digestion is required for a total Zn analysis. USEPA has approved this method for the purpose of wastewater analyses 3500 Zn B: Federal Register, 45(105) 36166 (May 29, 1980). This method also have been adapted from Standard Methods for the Examination of Water and Wastewater.

To start this procedure, the program 780 Zinc was selected. A 25-ml graduated mixing cylinder was filled with 20 ml of sample. Then, the contents of one ZincoVer 5 Reagent Powder Pillow was added to the mixing cylinder. The cylinder was closed and being inverted several times to dissolve the powder completely. For the preparation of blank, 10 ml of the solution was poured into a sample cell.

For the preparation of sample, 0.5 ml of cyclohexanone was added into the solution that was still in the mixing cylinder by using a plastic dropper. Then, the instrument timer was started for a 30-second reaction. During the reaction period, the mixing cylinder was closed and vigorously shook the prepared sample. The instrument timer was started for a 3-minute reaction.

During this reaction period, the prepared sampled was poured from the mixing cylinder into a second sample cell. When the timer expires, the blank was cleaned and being inserted into the cell holder. ZERO button was pushed and the display shown 0.00 mg/L Zn. The prepared sample was cleaned and being inserted into the cell holder. READ button was pushed and the results shown in mg/L Zn (HACH, 2013h).

3.2.4 Fluoride

The concentration of F^- in the sample was determined using the SPADNS 2 Reagent Solution Method (Method 10225) from DR 900 Multiparameter Handheld Colorimeter. This method used the USEPA SPADNS Method that can test in range 0.02 to 2.00 mg/L F^-. It is used for water, wastewater and seawater as USEPA accepts it for reporting drinking and wastewater analyses (distillation required).

To start this procedure, the program 190 Fluoride have been selected in the colorimeter. For the preparation of sample, 10.0 ml of sample was added into a dry sample cell by using a pipette. For the preparation of blank, 10.0 ml of deionized water was added into a dry sample cell by using a pipette. Then, 2.0 ml of SPADNS 2 reagent was added into each cell by using a pipette. Both sample cell was closed and swirl to mix. The instrument timer was started for a 1-minute reaction. When the timer expires, the blank was cleaned and being inserted into the cell holder. ZERO button was pushed and the display shown 0.00 mg/L F^-. The prepared sample was cleaned and being inserted into the cell holder. READ button was pushed and the results shown in mg/L F^- (HACH, 2013c).

3.2.5 Chlorine

The concentration of Cl in the sample was determined using the Powder Pillow Procedure (Method 8167) from DR 900 Multiparameter Handheld Colorimeter. This method can test the range of Cl between 0.02 to 2.00 mg/L. USEPA has accepted this method for reporting for drinking water analyses.

To start this procedure, the program 80 Chlorine F&T PP was selected. 10 ml of sample was filled in the sample cell. For the preparation of the sample, the contents of one DPD Total Chlorine Reagent Powder Pillow was added into the sample cell.

Then, the sample cell was swirl for 20 seconds to mix. The instrument timer was started for a 3-minute reaction time.

For the preparation of blank, the second sample cell was filled with 10 ml of sample. The blank was cleaned and being inserted into the cell holder. ZERO button was pushed and the display shown 0.00 mg/L Cl_2. The prepared sample was cleaned and within 3 minutes after the timer expires, the sample cell was being inserted into the cell holder. READ button was pushed and the results shown in mg/L Cl_2 (HACH, 2013f).

3.2.6 Nickel

The concentration of Ni in the sample was determined using the Powder Pillow Procedure (Method 8150) from DR 900 Multiparameter Handheld Colorimeter. This method used 1-(2 Pyridylazo)-2-Napthol (PAN) Method which can test the range of Ni between 0.006 to 1.000 mg/L Ni. After pyrophosphate is added to buffer the sample and mask any Fe^{3+}, the nickel reacts with 1-(2-Pyridylazo)-2-Naphthol indicator. The indicator forms complexes with most metals present. After colour development, EDTA is added to destroy all metal-PAN complexes except nickel and cobalt. USEPA has accepted this method for reporting for drinking water analyses.

To start this procedure, the program 340 Nickel, PAN was selected. For the preparation of blank, 10 ml of deionized water was filled into the sample cell. For the preparation of sample, 10 ml of sample was filled into the second sample cell. Then, one Phthalate-Phosphate Reagent Powder Pillow was added into each cell. The sample cell was closed and immediately shook to dissolve the reagent. 0.5 ml of 0.3% PAN Indicator Solution was added into each cell. The sample cells were closed and being inverted several times to mix. The instrument timer was started for a 15-minute reaction time.

When the timer expired, the content of one EDTA Reagent Powder Pillow was added into each cell. The sample cells were closed and being shook to dissolve the reagent powder. The blank was cleaned and being inserted into the cell holder. ZERO was pushed and the display shown 0.00 mg/L Ni. The prepared sample was cleaned and being inserted into the cell holder. READ button was pushed and the results shown in mg/L Ni (HACH, 2013e).

3.2.7 pH

The pH level in the sample was determined using the Portable pH/mV Meter - HI8424. The rod of this pH meter is very sensitive to the slightly changes in pH of the sample that being tested as it made from glass and quiet fragile (Gangurde *et al.*, 2013). Therefore, it is very suitable to be used in this research. To run this analysis, the tip of the rod of this meter needs to be washed with distilled water and it needs to be wiped smoothly and carefully with the tissue paper. After that, the tip of the rod needs to be put into the solution. It needs to be left for about 10 seconds to get the stable reading of pH and the reading needs to be recorded.

3.2.8 Turbidity

The level of turbidity in the sample was determined using the Absorbtometric Method (Method 8237) from DR 900 Multiparameter Handheld Colorimeter was chosen. This method is using the Absorbtometric Method which is adapted from FWPCA Methods for Chemical Analysis of Water and Wastes, 275 in 1969. The scope and application of this method is for water, wastewater and seawater. This instrument have been selected to be used as there is limitation regarding the usage of laboratory instrument.

To start this program, 745 FAU from the colorimeter was selected. For preparation of blank, the sample cell was filled with 10 ml of deionized water. Then, the blank was cleaned and being inserted into the cell holder. ZERO button was pushed and the display shown 0 FAU. For the preparation of sample, the second sample cell was filled with 10 ml of sample. The sample was mixed well before being added into the sample cell. The prepared sample was cleaned and being inserted into the cell holder. READ button was pushed and the results shown in Formazin Attenuation Units (FAU) (HACH, 2013g).

3.2.9 Total Dissolved Solid

The level of TDS in the sample was determined using the HACH MP-4 Portable Meter. The instrument gave more accurate result of the level of TDS in the sample. To carry out this analysis, the conductivity cups was rinsed with the sample three times before put the sample in the cups to be measured. The TDS key was pushed and the value was appeared on the display and the data was being recorded.

CHAPTER 4

RESULTS AND DISCUSSIONS

4.1 RESULTS AND DATA

A total of 60 samples; 30 bottles of samples for the first sampling and 30 bottles of samples for the second sampling, have been analysed for the selected nutrients and physical properties. For each brand of water filter, three bottles of samples have been collected before the water enter the water filter and another three bottles of samples have been collected after the water being filtered by the water filter. Sample for water filter A, B, C, D and E have been collected from the different premises in Kota Bharu area, Kelantan. The first sampling have been done on 16th of July 2016 while the second sampling have been done on 7th of September 2016. The timing of sampling may not statistically related as there are limitations in usage of laboratory instruments.

Concentrations of selected parameters were tabulated in Table 4.1 to Table 4.4. The result was reported for each analysis of triplicate samples. The differences between data for the first sampling and the second sampling can be observed through the tabulated data. More detailed on the result have been discussed in terms of mean for each triplicate samples in Figure 4.1 to Figure 4.19.

Table 4.1: Nutrients value with standard (First Sampling)

	Replication	Nutrient Value													
		Cu (mg/L)		Ca (mg/L)		Mg (mg/L)		Zn (mg/L)		F^- (mg/L)		Cl (mg/L)		Ni (mg/L)	
		Before	After	Before	After	Before	After	Before	After	Before	After	Before	After	Before	After
WHO		2		200		-		3		1.5		5		0.07	
USEPA		1		-		150		5		2		4		0.02	
Water Filter A	1	0.02	0.12	2.86	2.20	0.62	0.68	0.33	0.12	0.22	0.21	0.55	0.03	0.01	0.02
	2	0.04	0.14	2.25	1.16	0.33	1.15	0.56	0.13	0.10	0.23	0.40	0.02	0.03	0.04
	3	0.00	0.03	1.76	2.27	0.43	0.65	0.24	0.19	0.31	0.08	0.40	0.09	0.02	0.01
Water Filter B	1	0.00	0.06	0.91	1.15	0.26	0.24	0.27	0.21	0.05	0.16	0.71	0.02	0.06	0.04
	2	0.05	0.04	1.01	0.33	0.78	0.00	0.18	0.17	0.16	0.09	0.56	0.03	0.00	0.03
	3	0.03	0.25	3.82	1.16	0.94	1.07	0.26	0.19	0.00	0.08	0.89	0.03	0.01	0.00
Water Filter C	1	0.00	0.00	1.79	0.35	0.86	0.90	0.23	0.22	0.00	0.21	1.39	0.04	0.01	0.00
	2	0.04	0.07	2.21	0.43	0.77	1.01	0.19	0.18	0.20	0.00	1.20	0.11	0.05	0.00
	3	0.11	0.00	2.03	0.03	1.28	0.54	0.21	0.26	0.07	0.24	1.04	0.07	0.02	0.00
Water Filter D	1	0.00	0.00	1.37	0.00	0.76	1.17	0.18	0.14	0.00	0.00	0.17	0.03	0.03	0.04
	2	0.11	0.00	0.18	1.57	0.77	0.69	0.20	0.19	0.00	0.10	0.13	0.01	0.02	0.06
	3	0.00	0.00	1.78	0.37	0.00	0.46	0.20	0.17	0.60	0.08	0.15	0.00	0.05	0.03
Water Filter E	1	0.00	0.00	0.00	0.00	1.95	2.11	0.15	0.27	0.14	0.21	1.22	0.01	0.01	0.01
	2	0.01	0.01	0.07	0.07	2.22	1.09	0.22	0.16	0.09	0.00	1.19	0.00	0.01	0.07
	3	0.03	0.00	0.18	0.18	2.35	2.02	0.21	0.18	0.00	0.02	1.29	0.01	0.00	0.02

Table 4.2: Physical properties with standard (First Sampling)

	Replication	Physical Properties					
		pH		Turbidity (NTU)		TDS (ppm)	
		Before	After	Before	After	Before	After
WHO		-		5		1000	
USEPA		6.5 – 8.5		1		500	
Water Filter A	1	8.40	8.12	22	16	734.0	757.9
	2	8.27	8.05	30	14	754.4	779.8
	3	8.19	8.02	29	12	758.4	803.0
Water Filter B	1	7.96	7.90	21	24	803.2	804.3
	2	7.95	7.84	39	25	803.6	804.5
	3	7.97	7.81	43	58	803.5	804.8
Water Filter C	1	7.80	7.84	36	27	803.0	803.5
	2	7.85	7.81	13	14	803.0	803.4
	3	7.88	7.77	30	0	803.0	803.2
Water Filter D	1	6.53	6.50	23	20	802.1	717.0
	2	6.40	6.52	20	33	730.1	716.7
	3	6.67	6.53	22	39	713.6	722.0
Water Filter E	1	6.52	6.54	42	33	734.2	746.4
	2	6.51	6.55	36	16	733.2	747.3
	3	6.55	6.58	32	31	732.5	747.5

Table 4.3: Nutrients value with standard (Second Sampling)

	Replication	Nutrient Value													
		Cu (mg/L)		Ca (mg/L)		Mg (mg/L)		Zn (mg/L)		F^- (mg/L)		Cl (mg/L)		Ni (mg/L)	
		Before	After	Before	After	Before	After	Before	After	Before	After	Before	After	Before	After
WHO		2		200		-		3		1.5		5		0.07	
USEPA		1		-		150		5		2		4		0.02	
Water Filter A	1	0.00	0.00	0.00	0.84	1.04	0.90	0.24	0.16	0.03	0.07	0.25	0.01	0.00	0.01
	2	0.04	0.00	0.50	0.25	1.17	1.31	0.08	0.12	0.08	0.12	0.72	0.01	0.02	0.05
	3	0.02	0.00	0.44	0.27	1.02	1.35	0.14	0.09	0.00	0.14	0.56	0.02	0.01	0.00
Water Filter B	1	0.04	0.05	0.00	0.47	1.27	1.35	0.24	0.18	0.03	0.08	0.67	0.00	0.01	0.05
	2	0.02	0.06	0.94	0.55	0.95	1.21	0.12	0.19	0.12	0.07	0.87	0.02	0.01	0.05
	3	0.00	0.00	1.67	0.49	0.98	1.14	0.21	0.13	0.13	0.13	0.98	0.01	0.00	0.00
Water Filter C	1	0.00	0.05	0.04	0.90	1.23	0.97	0.07	0.10	0.14	0.08	1.13	0.76	0.00	0.02
	2	0.00	0.06	0.85	1.25	0.95	0.83	0.09	0.09	0.00	0.49	1.02	0.50	0.00	0.00
	3	0.02	0.01	0.58	0.85	1.14	1.19	0.13	0.12	0.12	0.03	0.96	0.61	0.01	0.01
Water Filter D	1	0.00	0.00	0.84	0.15	1.11	0.89	0.28	0.14	0.18	0.13	1.08	0.04	0.01	0.00
	2	0.09	0.00	0.75	0.30	1.12	1.20	0.13	0.11	0.04	0.05	1.17	0.03	0.01	0.00
	3	0.00	0.03	0.00	0.32	0.85	1.17	0.14	0.12	0.04	0.17	1.15	0.02	0.00	0.00
Water Filter E	1	0.00	0.00	0.00	0.00	3.17	3.39	0.06	0.11	0.02	0.07	0.18	0.01	0.01	0.00
	2	0.00	0.00	0.00	0.00	2.58	3.09	0.11	0.09	0.18	0.14	0.19	0.02	0.02	0.00
	3	0.05	0.00	0.00	0.00	3.39	3.88	0.06	0.16	0.12	0.00	0.19	0.03	0.01	0.01

Table 4.4: Physical properties with standard (Second Sampling)

	Replication	Physical Parameters					
		pH		Turbidity (NTU)		TDS (ppm)	
		Before	After	Before	After	Before	After
WHO		-		5		1000	
USEPA		6.5 – 8.5		1		500	
Water Filter A	1	6.59	7.07	29	23	667.7	665.6
	2	6.82	7.12	21	16	660.7	663.8
	3	6.95	7.16	24	6	661.3	662.1
Water Filter B	1	7.32	7.27	41	18	670.4	667.6
	2	7.24	7.36	8	29	656.5	662.0
	3	7.28	7.37	16	15	655.0	663.4
Water Filter C	1	7.65	7.39	11	5	660.3	661.9
	2	7.60	7.38	11	7	637.8	654.5
	3	7.60	7.33	0	20	657.4	662.8
Water Filter D	1	7.29	7.31	37	0	656.8	655.0
	2	7.28	7.31	0	13	656.9	658.6
	3	7.29	7.30	20	15	654.8	657.7
Water Filter E	1	7.84	7.26	29	0	662.8	664.0
	2	7.62	7.17	19	0	663.5	663.5
	3	7.48	7.15	18	22	663.2	664.2

4.2 NUTRIENTS CONCENTRATION AND PHYSICAL PROPERTIES IN SAMPLES WITH COMPARATIVE ASSESSMENT ACCORDING DRINKING WATER STANDARD FROM USEPA AND WHO

Based on Figure 4.1, the value of Cu is 0 mg/L after being filtered by water filter D and E. That is the lowest value of Cu in the filtered water. The highest value recorded is 0.12 mg/L in filtered drinking water B. In this first sampling, the water filter A and B shows the increasing in concentration of Cu in their filtered drinking water while the others showed the decreasing of concentration.

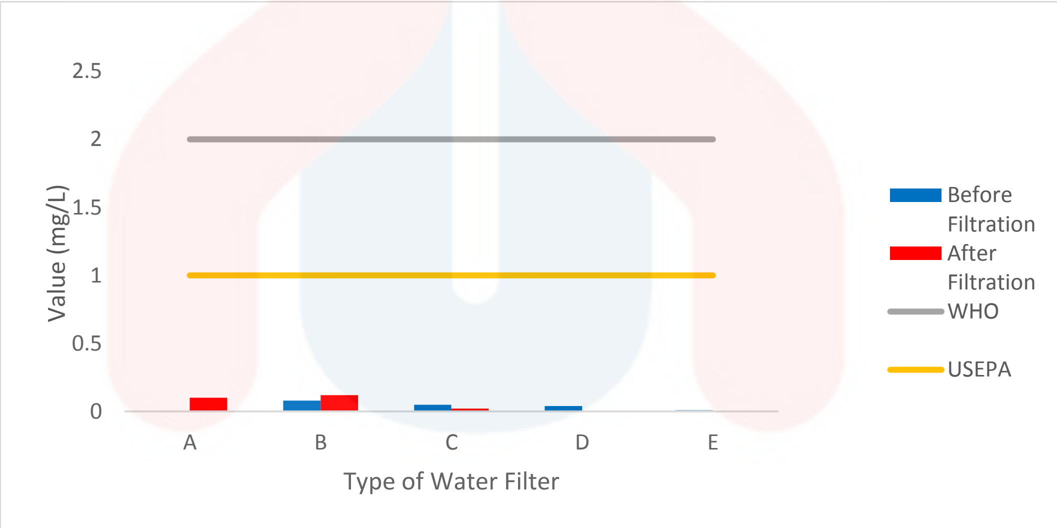

Figure 4.1: Average Value of Copper for First Sampling (mg/L)

In the Figure 4.2, the lowest value of Cu is 0 mg/L in the filtered water Brand A and E while the highest is 0.04 mg/L in filtered drinking water B and C. In this case, the water filter B and C have shown the increasing in concentration of Cu in the filtered drinking water while the other water filter shows less concentration. Therefore, it can be seen that the water filter D and E is consistent in filtering the Cu so that the element did not remain in the water before being consumed.

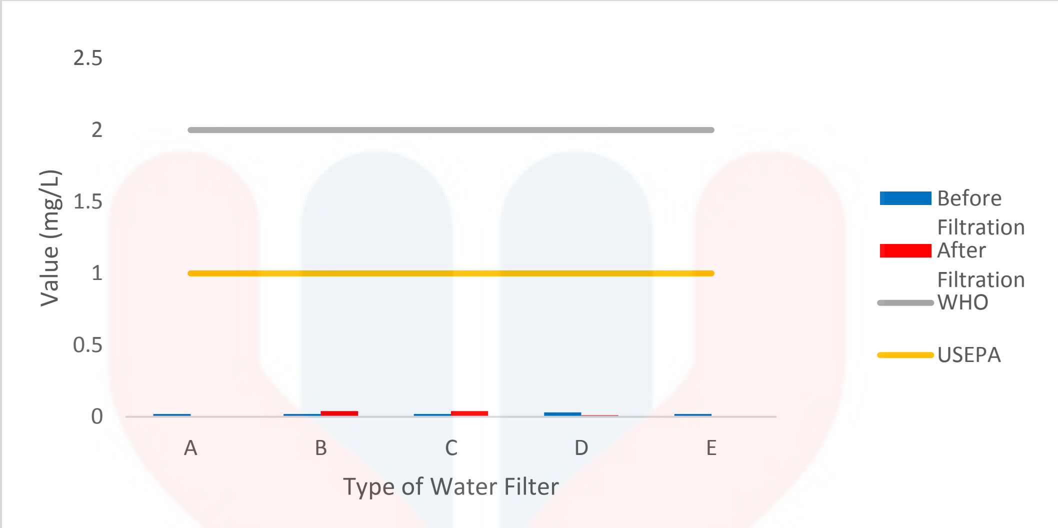

Figure 4.2: Average Value of Copper for Second Sampling (mg/L)

In this study, it is important for the nutrient content in the filtered drinking water is high but did not exceed the standard and guidelines of drinking water that have been established. Based on the results, the concentration of Cu for all samples are below the standard either from WHO or USEPA drinking water standard. The common daily intake for copper is about 2/5 mg, but the proper amount of copper that should be took by an adult person to fulfil the daily body requirement is about 0.9 mg (Angelova *et al.*, 2011). The amount of copper in all selected filtered water in this experiment is much lower than the daily required amount. This is the reason for the both agencies to set much lower limit for this nutrient.

For Ca and Mg, there are water filters that reducing their concentration while the other water filters are increasing their concentration in the water after filtration. Figure 4.3 shows the highest value of Ca in the filtered water is 1.88 mg/L through water filter A and the lowest value of Ca recorded in filtered drinking water E which is 0.08 mg/L. Meanwhile, in the Figure 4.4, the highest value of Mg is 1.74 mg/L in the water that have been filtered by water filter E and the lowest is from the filtered drinking water B which is 0.44 mg/L. The water filter A and D have shown the increasing of Mg concentration in their filtered water while the others shown the decreasing in concentration of those Ca and Mg.

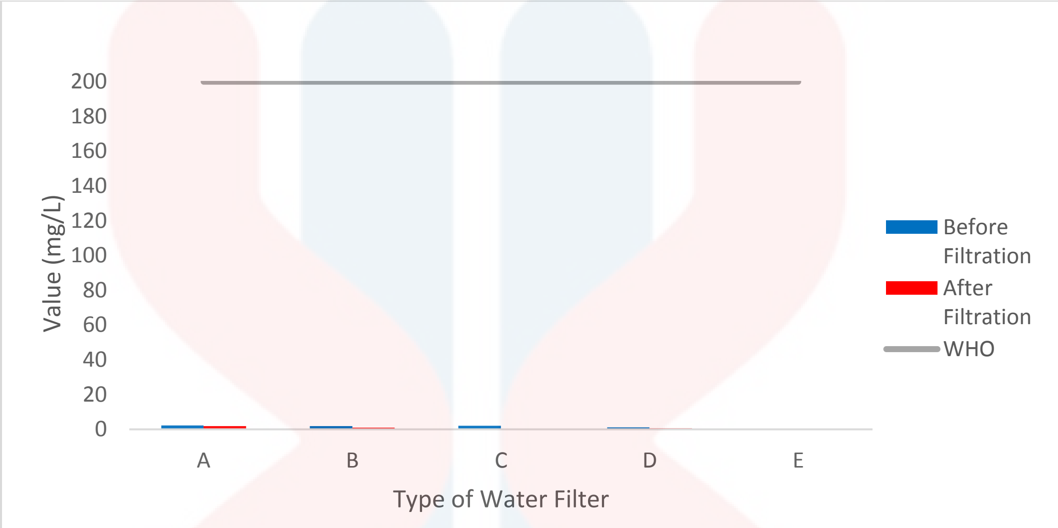

Figure 4.3: Average Value of Calcium for First Sampling (mg/L)

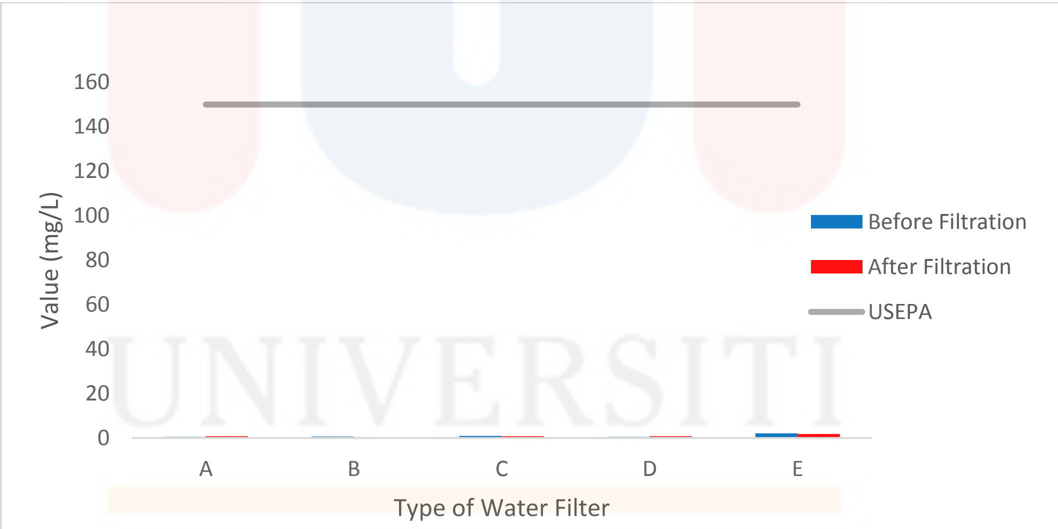

Figure 4.4: Average Value of Magnesium for First Sampling (mg/L)

In the second sampling, the value of Ca is very small which the highest value of Ca is recorded in filtered water C which the concentration is 1.00 mg/L. The lowest value of Ca have been found out in filtered water E which is 0 mg/L. Therefore, the graph of mean for Ca in second sampling did not being displayed. While in Figure 4.5, the highest concentration of Mg have been recorded in filtered water E which the value is 3.45 mg/L while the lowest concentration of Mg is in filtered drinking water C which is 0.00 mg/L. Through the results that have been tabulated, only water filter C function as decreasing the Mg concentration in the filtered water while the other water filter are increasing the concentration of Mg in the filtered water.

Both calcium and magnesium content in these filtered water are not exceeding the standard that have been set by WHO and USEPA. The minimum requirement for the human intake is 700 mg per day for calcium where it significant with the daily dietary intake of 1,000 mg of calcium would potentially result in 800 mg available for tissue nutrient requirements and the remaining 200 mg to maintain serum calcium levels (Beto, 2015). The value of magnesium that should consume regularly is about more than 300 mg per day with 10% of the consumption is taken from drinking (Jahnen-Dechent & Ketteler, 2012). This explained the importance of calcium and magnesium in human body and the high concentration limit for these nutrient based on WHO and USEPA standard.

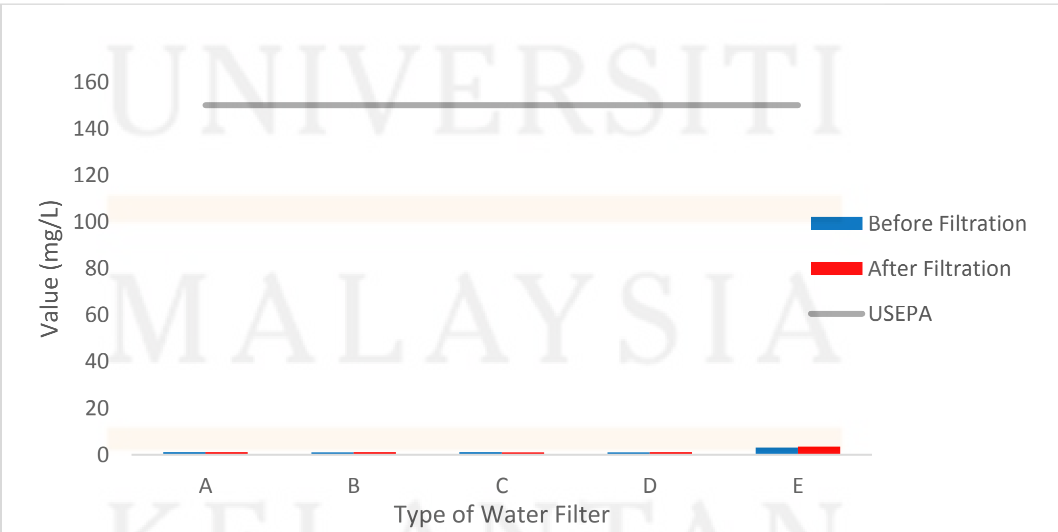

Figure 4.5: Average Value of Magnesium for Second Sampling (mg/L)

For the Zn in the Figure 4.6, the highest concentration can be observed in the filtered water is through the water filter C with the value 0.22 mg/L and the lowest is through the water filter A with the value 0.15 mg/L. The increasing of concentration of Zn in filtered drinking water can be seen through water filter C and E while the other shows decreasing in concentration.

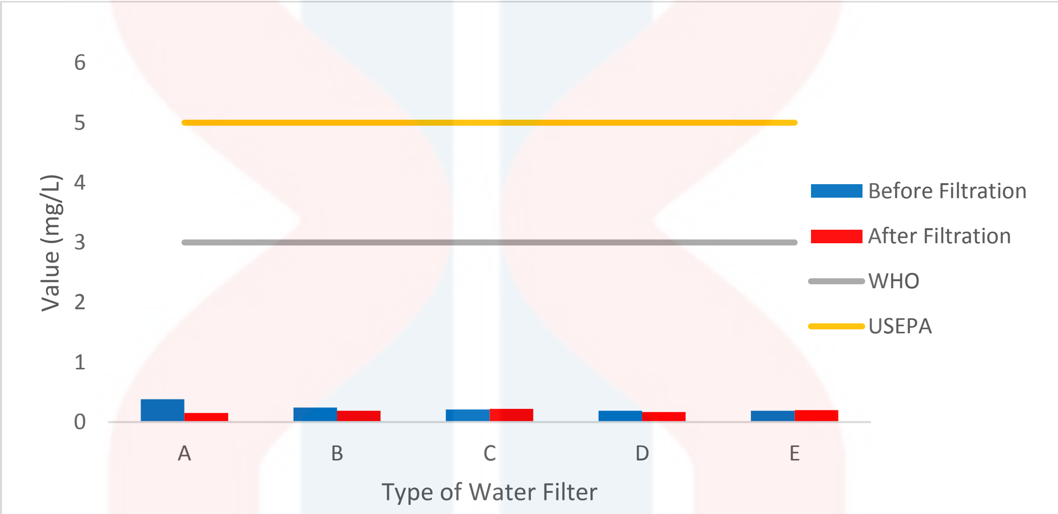

Figure 4.6: Average Value of Zinc for First Sampling (mg/L)

In the Figure 4.7, the highest value of Zn can be seen in filtered drinking water B with the value 0.17 mg/L while the lowest value is in the filtered water C with the value 0.10 mg/L. In this sampling, the water filter C did not have any changes in the filtered water in terms of concentration of Zn. This can be seen as the value of Zn in the water before it being filtered and after being filtered are the same. Water filter E shows increasing in concentration of Zn in the filtered water while the water filter A, B and D shows reduction of Zn concentration. Overall, the value of Zn in the filtered drinking water at the first sampling is higher than the second sampling but did not exceed the limit from USEPA and WHO standard. The daily requirement for zinc is about 0.84 – 4.5 mg per day based on age group and sex and the zinc content in the filtered water is much lower from the daily requirement (Roohani *et al.*, 2013).

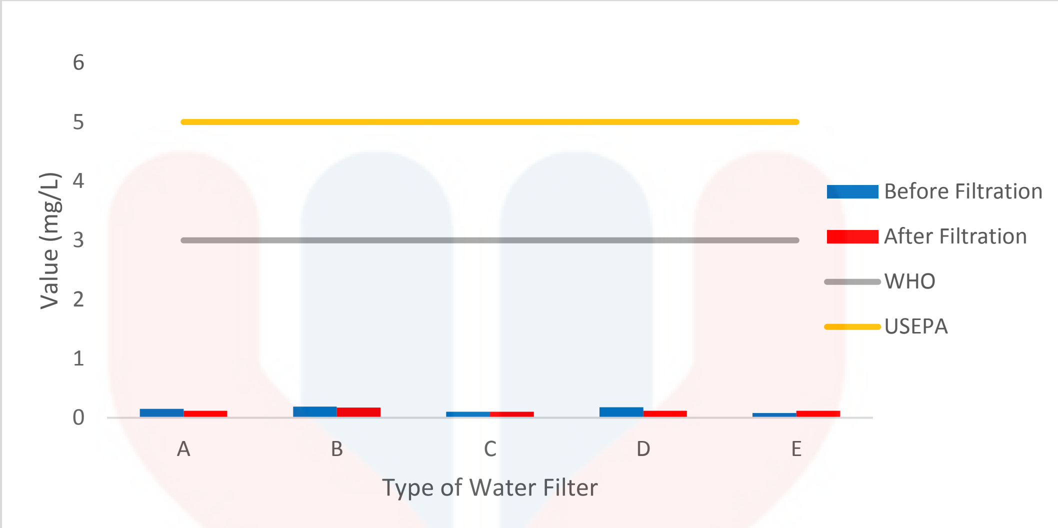

Figure 4.7: Average Value of Zinc for Second Sampling (mg/L)

For the concentration of F^- in the filtered drinking water as shown in the Figure 4.8, the highest value in the first sampling is 0.17 mg/L which is through water filter A and the lowest value is 0.06 mg/L which can be observed in the filtered water D. Water that pass through the filter E did not have any reduction or addition in concentration of F- as the value 0.08 mg/L is remain unchanged. The water that being filtered by water filter B and C are increasing in terms of concentration of F- while being decreasing when pass through water filter A and D.

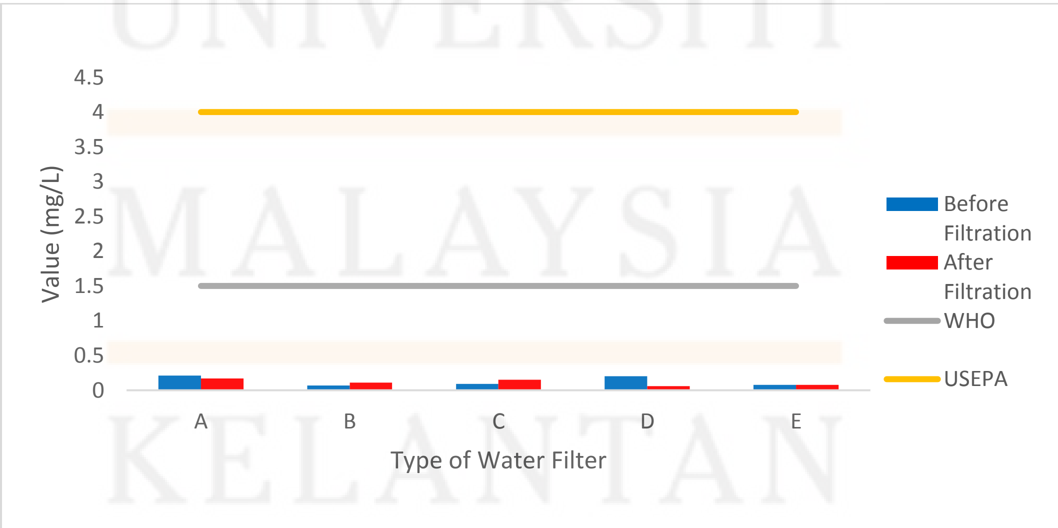

Figure 4.8: Average Value of Fluoride for First Sampling (mg/L)

As shown in the Figure 4.9, the highest value of F^- can be observed in the filtered water C which is 0.20 mg/L while the lowest concentration have been recorded in the filtered water E which is 0.07 mg/L. At this time, the water filter B have shown no changes happen in the filtered water in terms of concentration of F^- where the value is remain the same at 0.09 mg/L. The water filter A, C and D have shown the increasing of concentration of F^- in the filtered water while the water filter E shows the reduction of concentration of F^- in the filtered drinking water. The content of F^- in these filtered water did not exceed the limit from USEPA and WHO. The daily recommended intake of F^- is about 0.7 – 4 mg per day and the value of this nutrient in the filtered drinking water is much lower for recommended value as well as the limit of standard.

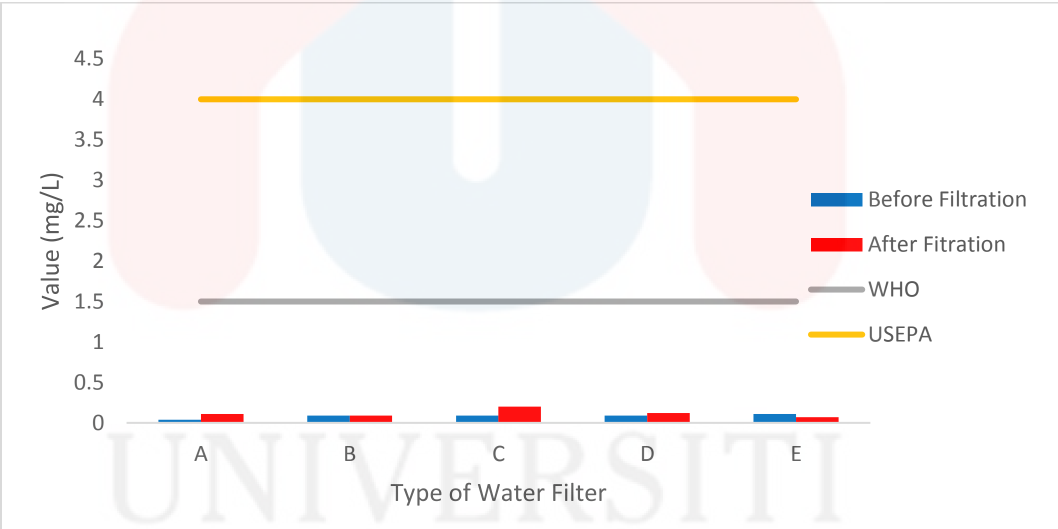

Figure 4.9: Average Value of Fluoride for Second Sampling (mg/L)

In the first sampling as shown in Figure 4.10, the highest value of Cl that can be observed in the filtered drinking water is through water filter C which is 0.07 mg/L while the lowest concentration of Cl that can be seen is in the filtered water D and E which is the value is 0.01 mg/L for both water filter. Overall, all the water filter can reduced the concentration of Cl in the water until they achieve below 0.10 mg/L.

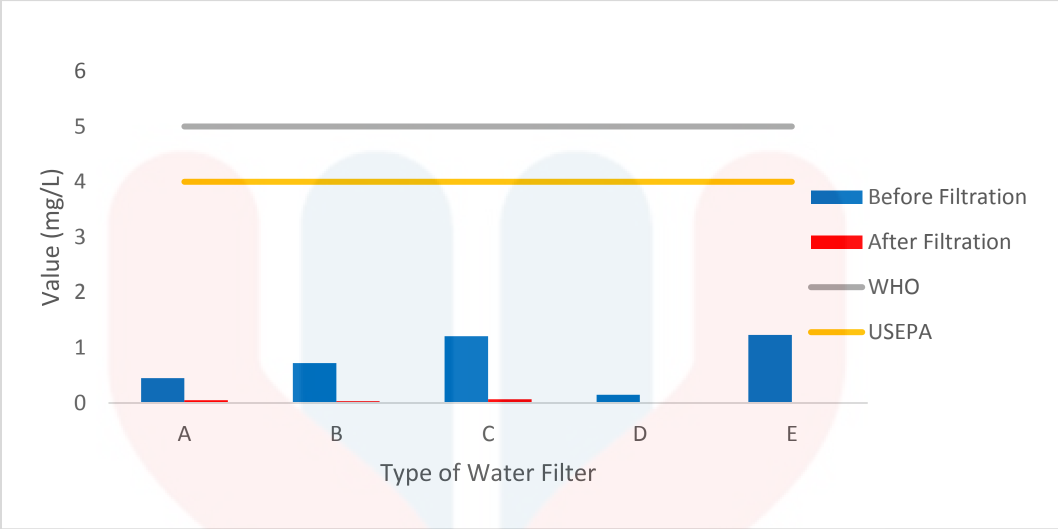

Figure 4.10: Average Value of Chlorine for First Sampling (mg/L)

Based on Figure 4.11, the highest value of the concentration of Cl can be observed in the filtered water C which is achieve 0.62 mg/L, too high compared to the other filtered water from other filter machine. The lowest value of Cl in this sampling can be seen in filtered water from water filter A and B which is the value is 0.01 mg/L for both filter machine. It can be seen that all of the water filter in this study can reduced the concentration of Cl in the water effectively.

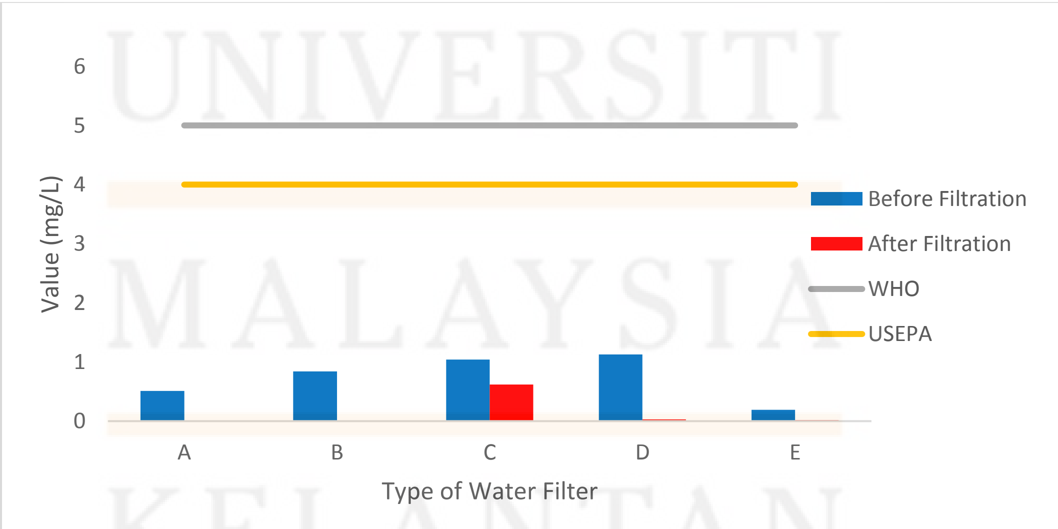

Figure 4.11: Average Value of Chlorine for Second Sampling (mg/L)

Cl is very well-known as the disinfectant for the treatment of wastewater as well as groundwater which it have been used widely throughout the world. The water treatment system used this element to kill the bacteria inside the water effectively. Therefore, this element is essential to be checked in order to know the concentration of it in the water when it comes to the houses through the tap. The value of concentration of Cl in the filtered drinking water for all samples are below the limit of guidelines either from USEPA or WHO.

For the value of Ni that present in the filtered water for the first sampling, Figure 4.12 shows that it seems the highest value have been recorded through water filter D which the concentration is 0.043 µg/L. For the lowest value of Ni, it can be observed in the filtered water C which the concentration is 0.002 µg/L. In this sampling, the water filter A, D and E shows the increasing of Ni concentration in their filtered water while opposite with the water filter C that shows the reduction of the concentration of Ni. The water filter B shows no changes in the concentration of Ni in the filtered water when the value remain constant at 0.020 µg/L.

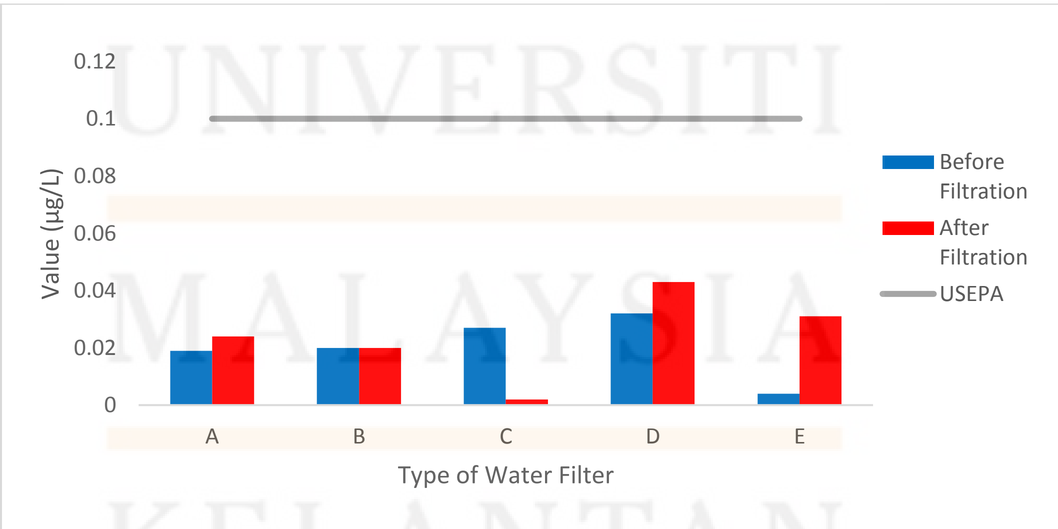

Figure 4.12: Average Value of Nickel for First Sampling (µg/L)

In contrast to the second sampling, Figure 4.13 shows the highest value of Ni can be observed in the filtered water B with the concentration is 0.033 µg/L while the lowest value of Ni can be detected in the filtered water D which the concentration is 0.001 µg/L. Water filter A and B shows the increasing of Ni concentration in their filtered water while water filter D and E shows the decreasing in concentration of Ni in the filtered water. For water filter C, it can be seen that the concentration of Ni in the water before and after it being filtered does not change in concentration 0.010 µg/L.

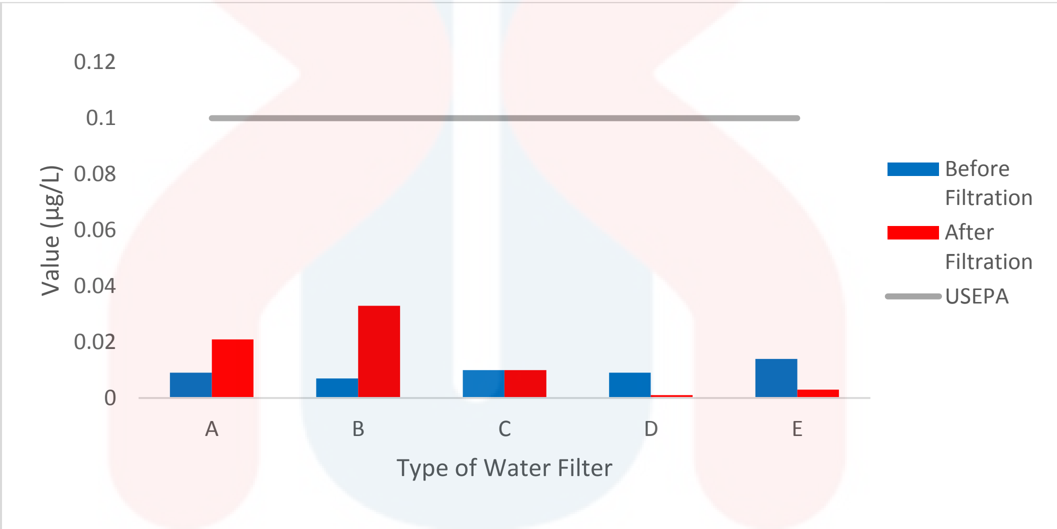

Figure 4.13: Average Value of Nickel for Second Sampling (µg/L)

The Ni is an element that widely used in the plating and it may have present in the groundwater or even in the tap water as there are maybe some leaching in the piping system. This maximum concentration can be increased when the pipes are assembled with tinned copper and gunmetal fittings (WHO, 2005). The drinking water standard from USEPA have put the guidelines level for Ni is 0.1 mg/L, which is very low because the adverse effect on health causes by this element. In this study, the value of concentration of Ni that present in the filtered drinking water is below the standard from USEPA and WHO that have been set by both agencies.

The physical properties that have been selected in this study are the Turbidity (FTU), TDS (ppm) and pH. For the pH value in the filtered water at the first sampling, Figure 4.14 shows the highest value have been recorded through water filter D which is the value is pH 6.52 while the lowest value of pH can be seen from water filter A which the value is pH 8.06. It can be seen that the water that pass through water filter E have increasing in terms of pH level. This not happened to the other water filter A, B, C and D where the pH value when pass through them are decreasing in pH. The filtered water A is alkaline water as the pH is more than pH 8. The filtered water B and C are slightly alkaline as the pH value is more than pH 7. This is different with water filter D and E where their filtered water is slightly acidic as the pH is under 7.

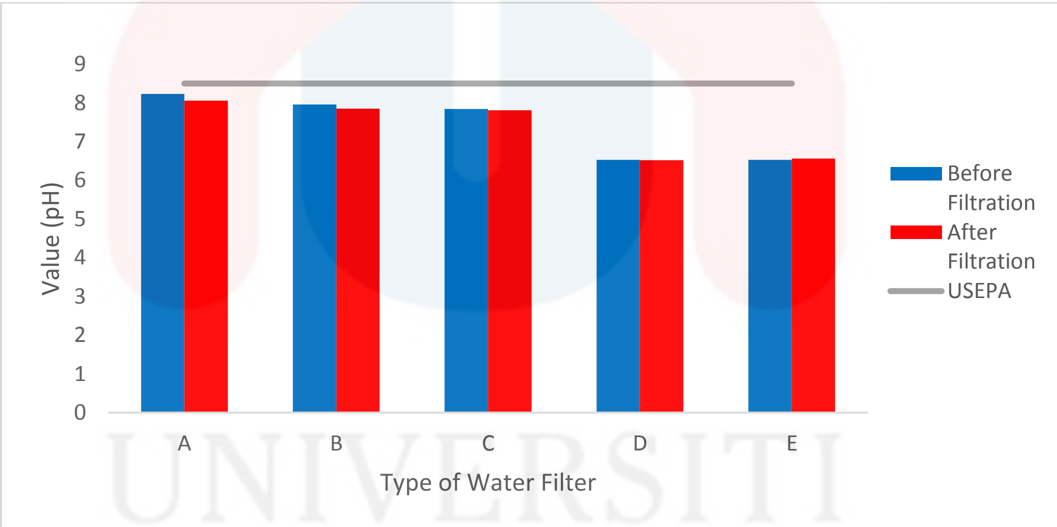

Figure 4.14: Average Value of pH for First Sampling (pH)

In Figure 4.15, the highest value of pH that have been recorded is pH 7.37 in filtered water C while the lowest value of pH is in filtered water A which the value is pH 7.12. The water that being filtered by water filter A, B and D are being increasing in pH value. Meanwhile for water filter C and E, the value of pH in the filtered water is decreasing from the raw water before it being filtered. In this sampling, all the filtered water is at pH 7 and above but below pH 7.5, where it can be said that overall the water that being filtered is neutral.

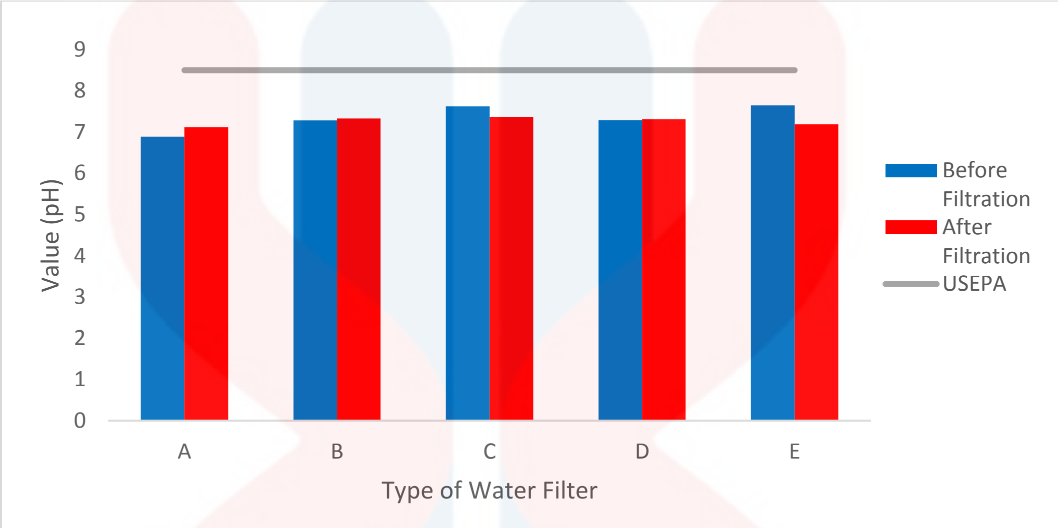

Figure 4.15: Average Value of pH for Second Sampling (pH)

Overall, the pH value for all samples are within the standard that have been stated by the USEPA. For WHO, It is not considered to be necessary to propose a health-based guideline value for pH as any effect on health is likely to be indirect to the human. The pH is an important parameter for the drinking water. In Malaysia, many water filter companies as well as the company that produce the mineral water claimed that their product have high pH level which is alkali.

For the turbidity in the first sampling, in the Figure 4.16 shows the lowest value has been recorded in the filtered water C that is 13.67 FAU while the highest value of turbidity can be seen in filtered water B which is 35.67 FAU. The value of turbidity seems to be higher in the filtered water through water filter A, C and E even it have been filtered while the value of turbidity seems decreasing in the filtered water B and D.

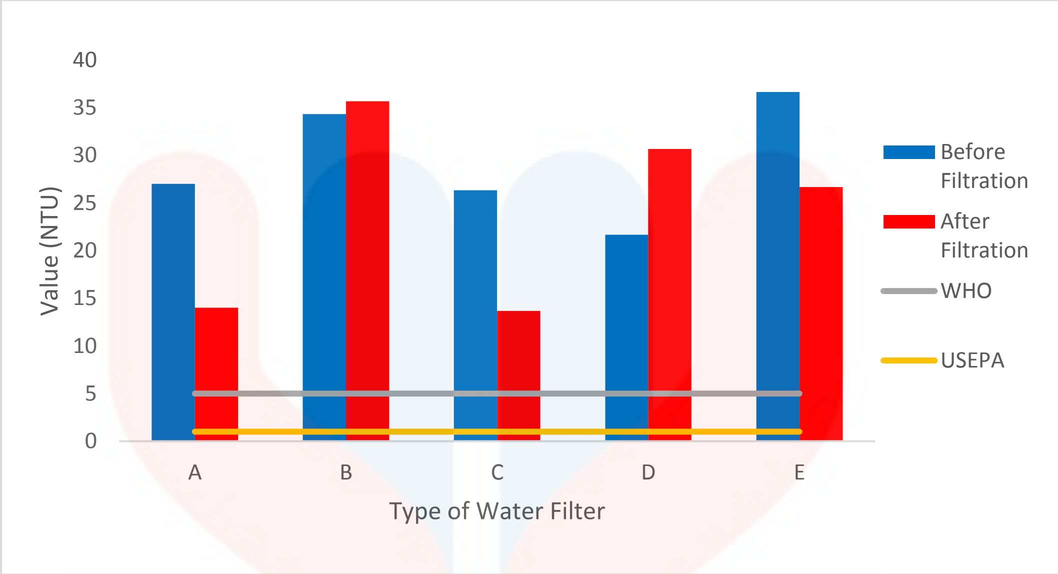

Figure 4.16: Average Value of Turbidity for First Sampling (NTU)

While in the second sampling, Figure 4.17 shows the value of turbidity 20.67 NTU is the highest value that have been recorded which owned by the filtered water B. On the other side, the lowest value of turbidity have been recorded in filtered water D which is 7.33 NTU. In this sampling, it can be observed that the value of turbidity is increasing in the filtered water through the water filter C while the other water filter such as A, B, D and E have shown reduction of turbidity value in the filtered water.

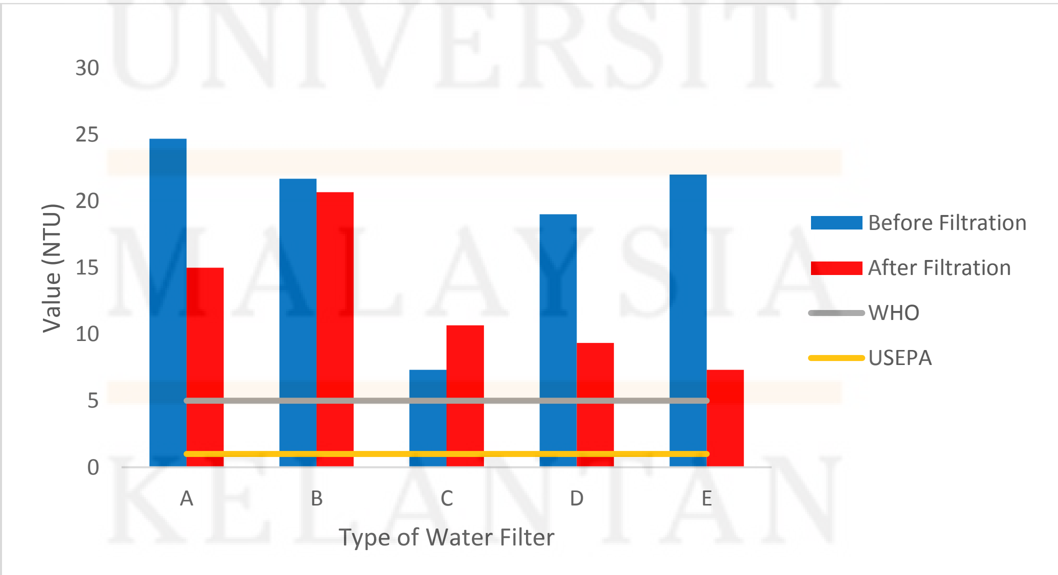

Figure 4.17: Average Value of Turbidity for Second Sampling (NTU)

In this study, the value of turbidity for all filtered water are exceeding the limitation that have been set by USEPA (1 NTU) and WHO (5 NTU). The turbidity level for all filtered water have been observed in between 5 NTU to 40 NTU. The usage of colorimeter for analyse the turbidity gives the value in FAU unit while the standard have been set up in unit NTU. The turbidity units NTU, FNU, FTU, and FAU are all based on calibrations using the same Formazin primary standards. Therefore when a Formazin standard is measured, the value for each of these units will be the same, however the value on samples may differ significantly (FRWC, 2011) The high value of turbidity that have been recorded may due to some errors that happened during carry out the procedure. They may be the moisture or condensation occur on the wall of the sample cell and it did not wipe to dry enough. The bubbles resulting from shaking the sampling bottle with the sample inside in order to mix the particles in the water perfectly may present in the sample cell and did not being removed thoroughly before put it in the instrument for analysed.

For the value of TDS in the first sampling, Figure 4.18 shows the highest value have been recorded in the filtered water B which the value is 804.53 ppm. Meanwhile the lowest value of TDS can be observed in filtered water D that is 718.57 ppm. It can be seen that the value of turbidity in the water have reduce after being filtered with water filter D while the other four which are water filter A, B, C and E have shown the increasing in their TDS value in the filtered water.

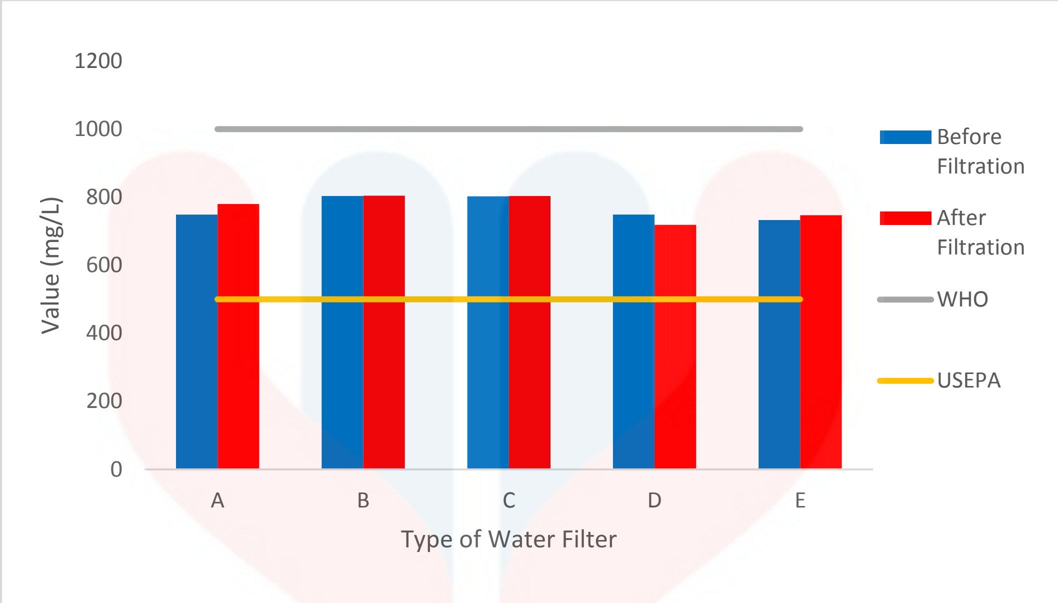

Figure 4.18: Average Value of TDS for First Sampling (mg/L)

In the Figure 4.19, the highest value of TDS can be observed in filtered water B which the value is 664.33ppm. The lowest value of TDS can be seen in the filtered water D which the value is 657.10 ppm. In contrast with other parameters, the value of TDS shows increasing in the filtered water through all five water filter that being used in this study.

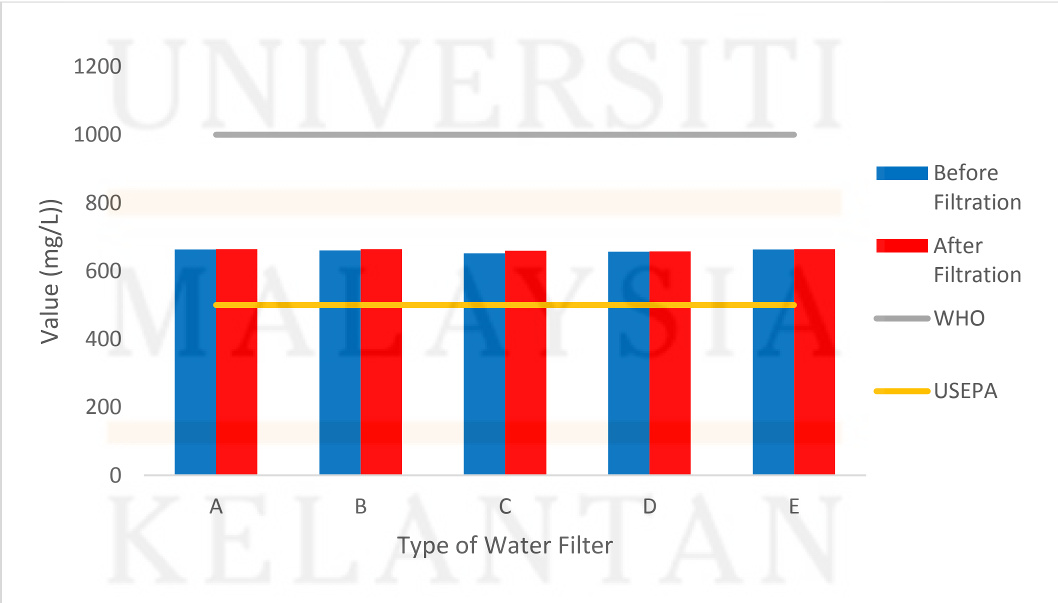

Figure 4.19: Average Value of TDS for Second Sampling (mg/L)

The average value of TDS for all samples are being exceeded the standard level of drinking water by USEPA but not exceed the standard from WHO. The results shows that a high TDS level have been recorded. The limitation that have been set by WHO is at 500 ppm. Overall, the turbidity level for all filtered water are higher than 500 ppm but did not exceed 1000 ppm The WHO have stated that the high level of TDS in the drinking water will give some effect to the consumer especially in terms of organoleptic properties. Organoleptic properties is the characteristic of the food, water or other substances which a person will be experiences it via the senses such as taste, sight, smell, and touch. It did not include any usage of chemicals for the testing. In this case, the range of the TDS is between 600 to 900 mg/L for all the samples which is in fair level of organoleptic properties.

4.3 SPECIFICATION AND PERFORMANCE OF EACH WATER FILTER

Water filter A is a compact and stylish design water filter that using non-woven fabric and powdered activated carbon as the component for cartridge filter. The non-woven fabric provides the exceptional filtration which functioning in removing the coarse particles of dirt. At the same time, the activated carbon, which has an outstanding self-cleansing effect, absorbs harmful substances such as red dust and moulds which contaminated the water. These two features work together to provide clean water as they helps to remove the colouring, odour and taste in the drinking water. But, it have been told by the specifications of the water filter that there are unremovable matters such as iron compounds and heavy metals (silver, copper, lead) that dissolved in the water, salt (sea salt) and others. It also have the specification on removing chlorine for 95% and turbidity about 90% in the drinking water.

In this research, the water filter A is constantly reducing the concentration of Ca, Zn, Cl and turbidity but constantly increasing the concentration of Mg, Ni and TDS. Copper have done inconsistent filtration as the concentration is increased in first sampling but decreased in second sampling. It is the same as for F- and pH where the concentration is decreasing in first sampling but increasing in second sampling. This shows that the ability of the cartridge filter in water filter A is removing chlorine and turbidity, not about mineralization of the water and removing the heavy metals in the drinking water.

Water filter B can be categorized as dual-stage water filtration system that being installed at the countertop. This type of water filter have two cartridge for filtration which are the CTO Carbon Filter and PP Sediment Filter. The CTO itself is stand for chlorine, taste and odour, which this carbon filter is made up by the coconut shell based carbon that creates the drinking water with sweeter taste. The unique structure of this 5 micron carbon filters is well suited for chemical adsorption, including VOCs, while reducing chlorine and chemicals that contribute to taste and odour. This filter also have dirt-holding capacity and may remove or reduce contents of all chemicals, PCBs from plastic pipes, dirt, sediment, rust and algae in the water. While for PP sediment filter, the propylene type of cartridge can removes suspended material in the water such as sand, silt, loose scale, clay, or inorganic material which can cause high turbidity or cloudiness in the water (Dvorak & Skipton, 2014).

Based on this research, the elements that constantly can be reduced from the water filter B are calcium, zinc and chlorine. These elements are included in the list of elements that can affect the taste and odour of drinking water (Ojo *et al.*, 2012). The other elements shown the fluctuation in the reading which is decreasing in first sampling but increasing in second sampling and vice versa. The copper and TDS for the water filter B is increasing for both sampling. This is due to the specification of the cartridge filter which designated focusing on reducing the chlorine content in drinking water. The increasing and decreasing of turbidity in both sampling may due to the capacity of the filter cartridge which have been used for a long period without being serviced or change for the new cartridge. From the observation, the colour of the cartridge filter itself is rusty and dark brown, which indicates a lot of sediments have been coated outside the filter membrane that can reduces its efficiency. The poor condition of the filtration system can be seen from the outside as the container is transparent and easy to be seen.

Water filter C is a countertop type of water filter that consist of four filter membrane inside it. This four filter membrane carry out six stages of water filtration before it can be used by the consumer. The Stages 1 and 2 are using the filter membrane for sediment and carbon filters which can reduces particles and soluble contaminants, making it free from chlorine, volatile organic compounds (VOCs) and others. Stage 3 for this water filter consist of RO membrane filter which have the ability to removes water contaminants such as heavy metals, waterborne microorganisms and harmful organic chemicals. Stage 4 & 5 consist of carbon and fine filter membrane which can reduces odours and improves the taste of water. For the last stage that is stage 6, it consist of ceramic filter membrane which can prevents growth of microorganisms inside the water tank.

From this research, it can be seen that the concentration of element chlorine, pH and turbidity is constantly decreasing while it is increasing for TDS. The reducing of chlorine in the water is fulfilling the specification of the filter system where it can it can reduce and make the water free from chlorine. Even with that, the pH level drop from almost pH 8 to become more neutral water near the pH 7. For other parameters in this analysis for this filter system, it can be seen that the result is fluctuating either it is decreasing for the first sampling and increasing in second sampling or vice versa. The ability to remove heavy metals that have been claimed by this company also did not clearly justified as there is no list of heavy metals that can be remove by the filter system being issued by the company. Even when the water being tested for the nutrients, it shows that it still present in the water, which make the ability of the RO membrane filtration cartridge can be disputed as the water should not contain any of the nutrients at all.

Water filter D is a water filter that have six types of filter cartridge inside the body kit. Filter cartridge A have ability for cleaning where it can filters 99.999% contaminants such as rust, dirt, bacteria and sand silt with its 0.9 micron filter pores. Filter cartridge B has the ability to remove odour, colour, tastes, detergents and any contaminants which may cause bacteria growth. Filter cartridge C is for stabilizing and enriching with minerals where it utilizes NSF standards conformed activated carbon block and KDF metal ion to filter heavy metals, chlorine as well as stabilizes water, eliminates bacteria and algae. Besides, the resin softens water molecules and enriches water with minerals. Filter cartridge D is for safety where it meets international safety standards. Water molecules can be absorbed easily while heavy metals, radioactive substances, chemicals and pesticides been removed vastly. Filter cartridge E is for high energy where the energy conversion technology breaks water into smaller water molecules effectively for easy absorption by human body. Besides, it enriches the oxygen content in water to supply body with more oxygen. Filter cartridge F is for alkaline where it utilizes high-tech energy stabilizer with Nano technology to stabilize energy in small water molecule clusters. Besides, it regulates pH value of water effectively to provide a slightly alkaline drinking water for body to promote cellular metabolism, activate immune system and enhance detoxification.

From the analysis that have been done towards the samples, the nutrients such as copper, calcium, zinc and chlorine are reducing constantly in both sampling. From the characteristic of the filter system itself, it can remove or reduce chlorine as well as other heavy metals and keep the water stabilize. For the pH of water, it is slightly alkaline in the first sampling which is comply with the specification of filter cartridge from the company, but become acidic in second sampling. It happens to the other parameter as well when the concentration may increase in the first sampling but decrease in second sampling and vice versa. This fluctuation data may came from the long period of usage of the water filter system that may reduce the efficiency of filtration as well as no services provided for the maintenance of the water filter as being mention by the regular consumer at the sampling place.

Water filter E have six stages of filtration system with four filter types of filter. The sediment filter cartridge carry out the stage 1 of filtration has the ability to eliminate the impurities in the water such as rust, deposits, particles and others. For pre-carbon filter cartridge in stage 2, it has the ability for primary absorption which can removes odours, organic substances and others. Stage 3 to stage 5 occur in the natural filter cartridge which patented for secondary absorption and mineral eruption as well as produce a mild alkaline water with average 7.5 pH to promote a healthy pH balance for the body. In this filtration also have abundant hydrogen. Nano positive filter cartridge has been patented to eliminate 99% of bacteria and viruses as well as to remove the harmful substances in the water, especially heavy metals, algae, fungi and other while preserving the good minerals. It is also containing the electric collector of positive charge which can absorb harmful substances with negative charge.

Based on the result of this research, this water filter is constantly reducing the concentration of copper, calcium, chlorine and turbidity in the water for both sampling. While for TDS, the concentration increasing for both sampling. The higher value of TDS may cause by the minerals that present in the water as being issued by the company of the water filter itself. For the pH value, it is increasing in first sampling and decreasing in second sampling, which indicates that the water filter E try to achieve neutral pH in their drinking water, contradicted with the specification of the product which aim to get a mild alkaline water with average 7.5 pH.

CHAPTER 5

CONCLUSION AND RECOMMENDATION

5.1 CONCLUSION

As the conclusion, the level of nutrients (Cu, Ca, Mg, Zn, F^-, Cl and Ni) and physical properties (pH, TDS and turbidity) in filtered drinking water by various brand of water filter are able to be determined. Overall, it is shown that the value for all elements in the filtered drinking water is still under the guidelines that have been set from both WHO and USEPA agencies, except for the turbidity level and TDS concentration. Other than that, all the water filters are able to reduce or remove the chlorine content in the water which is corresponding with the specification of each water filter.

The turbidity of all filtered water are exceeding the limitation from USEPA and WHO while the TDS concentration are exceeding the USEPA guidelines for drinking water. It can be concluded that all the water filter did not manage to reduce the turbidity and TDS level until comply with standard which contradict with the specification of each water filter that provide the ability to reduce the turbidity. Therefore, all the water filters in this research are failed to comply with the standard of drinking water for turbidity.

Each brand of water filter gives different specification for their ability of filter membrane. Therefore, there is no the best water filter that can provide the best drinking water for the consumer. But, it is good for human to consume mineral water instead of RO water. Before making a choice for installing the water filter at the premise, some research should be done about the specification of the water filter and the ability to provide clean and healthy drinking water which is suitable with the usage.

5.2 RECOMMENDATION

For the improvement of this research, this study should be furthered in terms of adding more parameters to be analysed such as testing the microbial activity (Coliforms, faecal coliforms and *E. coli*) and replenish the heavy metals (As, Pb, etc.) to be analysed as well as the inorganic elements. Many more other brand of water filter should be include in the study in order to make the research become more comprehensive.

Other than that, the usage of advanced laboratory instruments are very helpful in this research. The high technology instruments for testing the water sample may resulting a precise result for each parameters. These kind of instruments also can minimize the errors that may happen during carry out the analysis of the sample due to human mistake. Example of these type of instrument such as using the Atomic absorption spectroscopy (AAS), Inductively Coupled Plasma Mass Spectrometry (ICP-MS) and other type of instrument may give a good result for this experiment.

Besides that, the periodic sampling should be done in order to see the pattern of changes for each parameters that have been used in this research. This experiment should be carry out for three times of sampling, but due to some limitations from the instrument and time management itself, this experiment only get to be done for two times. A good time management for the sampling process and carry out the test as well as being alert with the availability of the instrument in the laboratory may improve the way for conducting this experiment.

REFERENCES

Achour, S., & Chabbi, F. (2014). Disinfection Of Drinking Water Constraint And Optimization Perspectives in Algeria. *Larhyss Journal*, *19*, 193 - 212

Adhani, R., Widodo, Sukmana, B. I., & Suhartono, E. (2015). Effect pH on Demineralization Dental Erosion. *International Journal of Chemical Engineering and Applications*, *6*(2), 138-141.

Agarwal SK, T. S., Dash SC. (1993). Spectrum of Poisoning Requiring Hemodialysis in A Tertiary Care Hospital in India. *International Journal of Artificial Organs, 16*(1), 20-22

Aini, M. S., Fakhrul-Razi, A., Mumtazah, O., & Chen, J. C. M. (2007). Malaysian Households' Drinking Water Practices: A case study. *International Journal of Sustainable Development & World Ecology*, *14*(5), 503-510.

Albertini, M. C., Dachà, M., Teodori, L., & Conti, M. E. (2007). Drinking Mineral Waters: Biochemical Effects and Health Implications – The State-Of-The-Art *International Journal Environmental Health*, *1*(1), 154-169.

Amway. (2012). Kehidupan Bermula dari e-Spring *Singapore*. Malaysia: AMWAY (B) Sdn Bhd

Angelova, M., Asenova, S., Nedkova, V., & Koleva-Kolarova, R. (2011). Copper in The Human Organism. *Trakia Journal of Sciences*, *9*(1), 88-98.

Archana, D. A., Kaur, D. P., Kanodia, D. S., Seema, D., Priyanka, G., Khuntia, P., . . . Kumar, S. (2015). Evaluating Microbial & Chemical Quality of Delhi-NCR Drinking Water, Enhancing its Standard & Spreading Mass Awareness. *DU Journal of Undergraduate Research and Innovation, 1*(1), 14-35.

Arnold, B. F., & Colford, J. M. (2007). Treating Water with Chlorine at Point-Of-Use to Improve Water Quality and Reduce Child Diarrhea in Developing Countries: A Systematic Review and Meta-Analysis. *The American Journal of Tropical Medicine and Hygiene*, *76*(2), 354-364.

Atkinson, S. A., Costello, R., & Donohue, J. M. (2009). Overview of Global Dietary Calcium and Magnesium Intakes and Allowances *Calcium and Magnesium in Drinking-Water: Public Health Significance*. Geneva, Switzerland: World Health Organization.

Azrina, A., Khoo, H. E., Idris, M. A., Amin, I., & Razman, M. R. (2011). Major Inorganic Elements in Tap Water Samples Peninsular Malaysia. *Malaysian Journal of Nutrition*, *17*(2), 271 - 276.

Baharom, Z. S., & Ishak, M. Y. (2015). Determination of Heavy Metal Accumulation in Fish Species in Galas River, Kelantan and Beranang Mining Pool, Selangor. *Procedia Environmental Sciences, 30*, 320-325.

Barber, J. (2008). *Drinking Water Scams: Rip-offs, Deceptions, & Outright Lies!* Florida.

Bencko, V. (1983). Nickel: A Review of Its Occupational and Environmental Toxicology. *Journal of Hygiene Epidemiol Microbiol Immunol, 27*(2), 237-247.

Bertonia, M., Oliveria, F., Manghettia, M., Boccolinia, E., Bellominia, M. G., Blandizzib, C., . . . Taccab, M. D. (2002). Effects of A Bicarbonate-Alkaline Mineral Water on Gastric Functions and Functional Dyspepsia: A Preclinical and Clinical Study. *Pharmacological Research, 46*(6), 525-531.

Beto, J. A. (2015). The Role of Calcium in Human Aging. *Clinical Nutrition Research, 4*, 1-8.

Binnie, C., Kimber, M., & Smethurst, G. (2002). *Basic Water Treatment*: Thomas Telford.

Burden, R. (2010). *The Natural Mineral Water, Spring Water and Bottled Drinking Water (England) Regulations 2007 (As Amended)*. England Food Standard Agency

Cabral, J. P. S. (2010). Water Microbiology. Bacterial Pathogens and Water. *International Journal of Environmental Research and Public Health, 7*, 3657-3703.

Calderon, R., & Hunter, P. (2009). Epidemiological Studies and The Association of Cardiovascular Disease Risks with Water Hardness *Calcium and Magnesium in Drinking-Water : Public Health Significance*. Geneva: World Health Organization.

CONTAM. (2015). *Risks for Public Health Related to The Presence of Chlorate in Food* (Vol. 13). Parma, Italy: European Food Safety Authority (EFSA).

Cutler, D., & Miller, G. (2004). *The Role of Public Health Improvements in Health Advances: The 20th Century United States* National Bureau of Economic Research. Cambridge.

Daphne, L. H. X., Utomo, H. D., & Kenneth, L. Z. H. (2011). Correlation between Turbidity and Total Suspended Solids in Singapore Rivers. *Journal of Water Sustainability, 1*(3), 313–322.

Darby, J. L., & Tchobanoglous, G. (2000). Providing Reliable Supply of Safe Drinking Water Poses Challenges. *California Agriculture, 54*(5), 69-77.

Das, M., & Das, R. (2012). Need of Education and Awareness Towards Zinc Supplementation: A Review. *International Journal of Nutrition and Metabolism*, *4*(3), 45-50.

Deepali, & Joshi, N. (2014). Problems of Ground Water Contamination with Focus on Water Borne Diseases, Causes and Prevention. *Applied Science Reports, 5*.

Deshp, J. D., Joshi, M. M., & Giri, P. A. (2013). Zinc: The trace element of major importance in human nutrition and health. *Int J Med Sci Public Health, 2*(1), 1-6.

Devi, C. B., Nandakishore, T., N., S., Basar, G., Devi, N. O., Jamir, S., & Singh, M. A. (2014). Zinc in Human Health. *IOSR Journal of Dental and Medical Sciences (IOSR-JDMS), 13*(7), 18–23

Dozier, M. C., McFarland, M., & Lesikar, B. J. (2006). Drinking Water Problems: Copper. Texas: Texas Water Resources Institute of Texas Cooperative Extension

Duda-Chodak, A., & Blaszczyk, U. (2008). The Impact of Nickel on Human Health. *Journal Elementol, 13*(4), 685-696.

Dvorak, B. I., & Skipton, S. O. (2014). *Drinking Water Treatment: Sediment Filtration*. Retrieved from USA:

El-Harbawi, M. (2010). Design of A Portable Dual Purposes Water Filter System. *Journal of Engineering Science and Technology, 5*(2), 165 - 175.

Elken. (2016). Purefection in a Klass of its Own: Bio Pure K-Series In E. S. Bhd (Ed.), (pp. 30). Malaysia.

EPA. (2000). The History of Drinking Water Treatment. *25 Years of the Safe Drinking Water Act: History and Trends*.

EPA. (2006). *Point-of-Use or Point-of Entry Treatment Options for Small Drinking Water Systems*. Arlington, Virginia United States Environmental Protection Agency

EPA. (2012). 2012 Edition of the Drinking Water Standards and Health Advisories. Washington, DC: Environmental Protection Agency

EPU. (2013). Laporan Kesejahteraan Rakyat Malaysia 2013. from Unit Perancang Ekonomi Jabatan Perdana Menteri Putrajaya

Ezrina, A. (2015). Penapis Air dan Kesannya Kepada Kesihatan Mulut. *Dental/Pergigian and Health Education.*

FDA. (2010). *Bottled Water Everywhere: Keeping it Safe* (U. S. F. a. D. Administration Ed.). Maryland: US Food Drug Administration.

Fonyuy, B. E. (2014). Prevalence of Water Borne Diseases within Households in the Bamendankwe Municipality-North West Cameroon. *Journal of Biosafety Health Education, 2*(122).

FRWC. (2011). *Section Five: The Water Quality Tests*. Retrieved from Michigan:

Gangurde, A. V., Pagar, S. S., Kadam, A. V., & Ghodke, R. S. (2013). Micro Controller Based ph Meter using Magnetic Stirrer. *IOSR Journal of Computer Engineering, 10*(5), 45-49.

Grandjean, P. (1984). Human Exposure to Nickel. *IARC Scientific Publication*(53), 469-485.

Greenleea, L. F., Lawlerb, D. F., Freemana, B. D., Marrotc, B., & Moulin, P. (2009). Reverse Osmosis Desalination: Water Sources, Technology, and Today's Challenges. *Water Research Journal, 43*(9), 2317–2348.

HACH. (2013a). Copper: Method 8506 (CuVer 1) and Method 8026 (CuVer 2) (8 ed., Vol. 4). USA: Hach Company/Hach Lange GmbH.

HACH. (2013b). DR 900 Spectrophotometer *Procedures Manual* (8 ed., Vol. 4). Germany: Hach Company.

HACH. (2013c). Fluoride: Method 10225 (8 ed., Vol. 4). USA: Hach Company/Hach Lange GmbH.

HACH. (2013d). Hardness, Calcium and Magnesium: Method 8030 (8 ed., Vol. 4). USA: Hach Company/Hach Lange GmbH.

HACH. (2013e). Nickel: Method 8150 (8 ed., Vol. 4). USA: Hach Company/Hach Lange GmbH.

HACH. (2013f). Total Chlorine: Method 8167 (8 ed., Vol. 4). USA: Hach Company/Hach Lange GmbH.

HACH. (2013g). Turbidity: Method 8237 (8 ed., Vol. 4). USA: Hach Company/Hach Lange GmbH.

HACH. (2013h). Zind: Method 8009 (8 ed., Vol. 4). USA: Hach Company/Hach Lange GmbH.

Hashim, N. H., & Yusop, H. M. (2016). *Drinking Water Quality of Water Vending Machines in Parit Raja, Batu Pahat, Johor*. Paper presented at the Soft Soil Engineering International Conference 2015 (SEIC2015), Langkawi, Malaysia.

Ibrahim, N., & Aziz, H. A. (2013). Trends on Natural Organic Matter in Drinking Water Sources and its Treatment. *International Journal of Scientific Research in Environmental Sciences,, 2*(3), 94-106.

Institute of Medicine, F. a. N. B. (1997). *Dietary Reference Intakes for Calcium, Phosphorus, Magnesium, Vitamin D, and Fluoride*. Washington, DC: National Academy of Sciences.

Institute of Medicine, F. a. N. B. (2000). *Dietary Reference Intakes for Vitamin A, Vitamin K, Arsenic, Boron, Chromium, Copper, Iodine, Iron, Manganese, Molybdenum, Nickel, Silicon, Vanadium, and Zinc*. Washington, DC: National Academy of Sciences.

Jahnen-Dechent, W., & Ketteler, M. (2012). Magnesium Basics. *Clinical Kidney Journal, 5*(1), i3-i14.

Janna, H., Abbas, M. D., & Mojid, M. H. (2016). Demineralized Drinking Water in Local Reverse Osmosis Water Treatment Stations and the Potential Effect on Human Health. *Journal of Geoscience and Environment Protection, 4*, 104-110.

Jensen, C. S., Menne, T., Lisby, S., Kristiansen, J., & Veien, N. K. (2003). Experimental Systemic Contact Dermatitis from Nickel: A Dose-Response Study. *Contact Dermatitis, 49*(3), 124-132.

Khan, T. A. (2011). Trace Elements in the Drinking Water and Their Possible Health Effects in Aligarh City, India. *Journal of Water Resource and Protection, 3*, 522-530.

Kirmeyer, G. J. (2000). *Guidance Manual for Maintaining Distribution System Water Quality*: AWWA Research Foundation and American Water Works Association.

Kožíšek, F. (2003). *Health Significance of Drinking Water Calcium and Magnesium* (TrinkwV Ed.): National Institute of Public Health.

Mechenich, C., & Andrews, E. (2004). Home Water Safety: Interpreting Drinking Water Test Results. Wisconsin: Board of Regents of the University of Wisconsin System.

Medicine, I. o. (2011). In A. C. Ross, C. L. Taylor, A. L. Yaktine, & H. B. Del Valle (Eds.), *Dietary Reference Intakes for Calcium and Vitamin D*. Washington (DC): National Academies Press

Miller, G. T. J. (1997). Environmental Science: Working with the Earth (6th Ed ed.). California: Wadsworth Publishing Company.

Mohsin, M., Safdar, S., Asghar, F., & Jamal, F. (2013). Assessment of Drinking Water Quality and its Impact on Residents Health in Bahawalpur City. *International Journal of Humanities and Social Science, 3*(15), 114-128.

Monarca, S., Donato, F., Zerbini, I., Calderon, R. L., & Craun, G. F. (2006). Review of Epidemiological Studies on Drinking Water Hardness and Cardiovascular Diseases. *European Journal of Cardiovascular Prevention and Rehabilitation, 13*(4), 495–506.

Moshtaghie, A. A., Pourmoghadas, H., & Aghdamizadeh, B. (1996). Study of The Effect of Residual Chlorine on Serum Iron and Related Parameters *Medical Journal of the Islamic Republic ofIran, 10*(3), 237-240.

Nouri, D. A., Abdulkarim, B. A., Arzoo, S., & Bakeet, Z. A. N. (2014). Quality Characteristics of Commonly Consumed Drinking Water in Riyadh and Effect of Domestic Treatments on Its Chemical Constituents. *Journal of Food and Nutrition Research, 2*(1), 25-33.

Ojo, O. I., Otieno, F. A. O., & Ochieng, G. M. (2012). Groundwater: Characteristics, Qualities, Pollutions and Treatments: An Overview *International Journal of Water Resources and Environmental Engineering, 4*(6), 162-170.

Osredkar, J., & Sustar, N. (2011). Copper and Zinc, Biological Role and Significance of Copper/Zinc Imbalance. *Clinical Toxicology Journal, 3*(1).

Plum, L. M., Rink, L., & Haase, H. (2010). The Essential Toxin: Impact of Zinc on Human Health. *International Journal of Environmental Research and Public Health, 7*(4), 1342-1365.

Porea, T. J., Belmont, J. W., & Mahoney, D. H., Jr. (2000). Zinc-induced anemia and neutropenia in an adolescent. *J Pediatr, 136*(5), 688-690.

Roohani, N., Hurrell, R., Kelishadi, R., & Schulin, R. (2013). Zinc and Its Importance for Human Health: An Integrative Review. *Journal of Research in Medical Sciences : The Official Journal of Isfahan University of Medical Sciences, 18*(2), 144-157.

Rosa G, C. T. (2010). Estimating the scope of household water treatment in low- and medium-income countries. *Am J Trop Med Hyg*(82), 289–300.

Rubenowitz, E., Axelsson, G., & Rylander, R. (1996). Magnesium in Drinking Water and Death from Acute Myocardial Infarction. *American Journal of Epidemiology, 143*(5), 456-462.

Schwalfenberg, G. K., & Genuis, S. J. (2015). Vitamin D, Essential Minerals, and Toxic Elements: Exploring Interactions between Nutrients and Toxicants in Clinical Medicine. *The Scientific World Journal, 2015*, 8.

Schwartza, J., Levin, R., & Goldsteinc, R. (2000). Drinking Water Turbidity and Gastrointestinal Illness in The Elderly of Philadelphia. *Epidemiol Community Health Journal, 54*, 45-51.

Sievers, E. (2005). Nutrient Minerals in Drinking Water: Implications for the Nutrition of Infants and Young Children *Water, Sanitation, and Health* (pp. 164 - 179). Geneva World Health Organization.

Sobsey, M. D., Handzel, T., & Venczel, L. (2003). Chlorination and Safe Storage of Household Drinking Water in Developing Countries to Reduce Waterborne Disease. *Water Science and Technology, 47*(3), 221-228.

Soetan, K. O., Olaiya, C. O., & Oyewole, O. E. (2010). The Importance of Mineral Elements for Humans, Domestic Animals and Plants: A Review. *African Journal of Food Science, 4*(5), 200-222.

Sombo Yamamura, Jamie Bartram, Mihaly Csanady, Hend Galal Gorchev, & Redekopp., A. (2012). Chapter 5: Drinking Water Guidelines and Standards (Draft) (Vol. 30 pp. 50). Geneva, Switzerland: World Health Organization.

SYABAS. (2016). What Standard Does Malaysia Drinking Water Quality Conform To? *Frequently Asked Questions (FAQs).*

Tiemann, M. (2013). *Fluoride in Drinking Water: A Review of Fluoridation and Regulation Issues* (C. R. Service Ed.): CRS Report for Congress.

USEPA. (2007). Drinking Water Standards and Health Advisories Table. San Francisco: United States Environmental Protection Agency.

USEPA. (2015). National Secondary Drinking Water Regulations (NSDWRs). *Drinking Water Regulations and Contaminants.*

Verma, C. K. C., & Kushwaha, L. C. A. S. (2014). Demineralization of Drinking Water: Is It Prudent? *Medical Journal Armed Forced India, 70* 377-379

Villanueva, C. M., Fernández, F., Malats, N., Grimalt, J. O., & Kogevinas, M. (2003). Meta-analysis of studies on individual consumption of chlorinated drinking water and bladder cancer. *Journal of Epidemiology and Community Health, 57*(3), 166-173.

WCC. (2003). *Drinking Water Chlorination: A Review of Disinfection Practices and Issues*. Canada: World Chlorine Council

WECAM. (2010). *Memorandum Mengenai Informasi dan Iklan yang Mengelirukan oleh Syarikat-Syarikat Produk Penapis Air*. Selangor Water and Energy Consumer Association of Malaysia.

Whitfield, A. (2008). *The Benefits of Chlorine Chemistry in Water Treatment*. Chlorine Chemistry Division of the American Chemistry Council

WHO. (2003). Guidelines for Drinking-water Quality *pH in Drinking-water*. Geneva: World Health Organization.

WHO. (2004). WHO Guidelines for Drinking-water Quality *Copper in Drinking-water* Geneva, Switzerland: World Health Organization.

WHO. (2012). *Technical Brief: Boil Water*. Geneva, Switzerland World Health Organization

WHO. (2013). *Total dissolved solids in Drinking-water*. Geneva: World Health Organization.

WHO. (2016). Results of Round I of the WHO International Scheme to Evaluate Household Water Treatment Technologies. In W. H. Organization (Ed.). Geneva 27, Switzerland: WHO Press.

Wimalawansa, S. J. (2013). Purification of Contaminated Water with Reverse Osmosis: Effective Solution of Providing Clean Water for Human Needs in Developing Countries. *International Journal of Emerging Technology and Advanced Engineering, 3*(12), 75-89.

WQA. (2016). *Improve Your Water: Water Treatment Basics*: Water Quality Association

Wynn, E., Krieg, M. A., Aeschlimann, J. M., & Burckhardt, P. (2009). Alkaline Mineral Water Lowers Bone Resorption Even in Calcium Sufficiency: Alkaline Mineral Water and Bone Metabolism. *Bone, 44*, 120-124.

Ziegler, A. C. (2002). *Issues Related to Use of Turbidity Measurements as a Surrogate for Suspended Sediment*. Retrieved from Reno, Nevada