HAZARD ASSESSMENT OF SOME HEAVY METALS IN TEMA MUNICIPAL WATER SUPPLY

BY

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CERTIFICATION

I hereby declare that this submission is my own work and the work documented in this thesis has not been submitted to any other university for award of any other degree except where due acknowledgment has been made.

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DEDICATION

This work is totally dedicated to the Almighty God for his tremendous supervision, goodness and mercy during the entire duration of this program. JEHOVAH NISSI, indeed, you have been my provider.

This work is also dedicated to my late mother madam Yohanna Nakotey who taught me the value of education.

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ABSTRACT

The study was undertaken to assess the quality status of drinking water in Tema municipal area. The concentrations of some selected toxic heavy metals (copper, zinc, nickel, cadmium, mercury, chromium, lead, iron, and manganese) were determined using Atomic Absorption Spectrophotometer. Among the nine selected heavy metals nickel and lead show higher concentration than the WHO recommended limits. This is an indication of pollution however their hazard quotients (HQ) of 0.04875 and 0.034938 is far less than 1. Besides, hazard index and incremental lifetime risk were calculated to be 0.0866 and 4.499×10^{9} respectively. Since hazard quotient is far less than 1, and the risk value of 4.499×10^{-9} is also far less than 1×10^{-6} it implies no health risk is associated with the water and therefore their presence had no significant health effect on human life.

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GLOSSARY OF ABBREVIATIONS

AAS:	Atomic Absorption Spectrophotometer
ADD:	Average Daily Dose
AESC:	Architectural and Engineering Services Company
ATL:	Akosombo Textile Limited
CDI:	Chronic Daily Intake
CWSA:	Community Water and Sanitation Agency
CSIR:	Council for Scientific Institute Research
GD:	Million Gallon per Day
GWCL:	Ghana Water Company Limited
HI:	Hazard Index
HQ:	Hazard Quotient
ICP:	Inductively Coupled Plasma
ISO:	International Organisation Standard
MCL:	Maximum Contaminant Level
MGD:	Million Gallon per Day
NGO:	Non-Governmental Organisation
PPAC:	Polyaluminum chloride
RfD:	Reference Dose
SOPC:	Substance of potential concern

UNICEF:	United Nations International Children‟s Emergency Limit
USEPA:	United State Environmental Protection Agency
VREL:	Volta River Estate Limited
WCL:	World Cool Limited
WHO:	World Health Organisation

CHAPTER ONE

INTRODUCTION

1.1 BACKGROUND OF STUDY

One of the most important basic human physiological needs is water. Water ensures the survival of both humans and animals and sustains all life existence on this planet and its importance cannot be overemphasized since life‟s continuous existence depends so much on water accessibility. (Lamikanra, 1999; FAO, 1997)

One of the important areas which cannot be exaggerated when it comes to life on earth is water availability. It is known that, three quarters (3/4) of the earth‟s surface is covered with natural water (Figure 1.1), nevertheless approximately three percent (3%) of this Earth‟s natural water is readily obtainable for human and animal use (Figure 1.2) (www.importanceofwater.org)

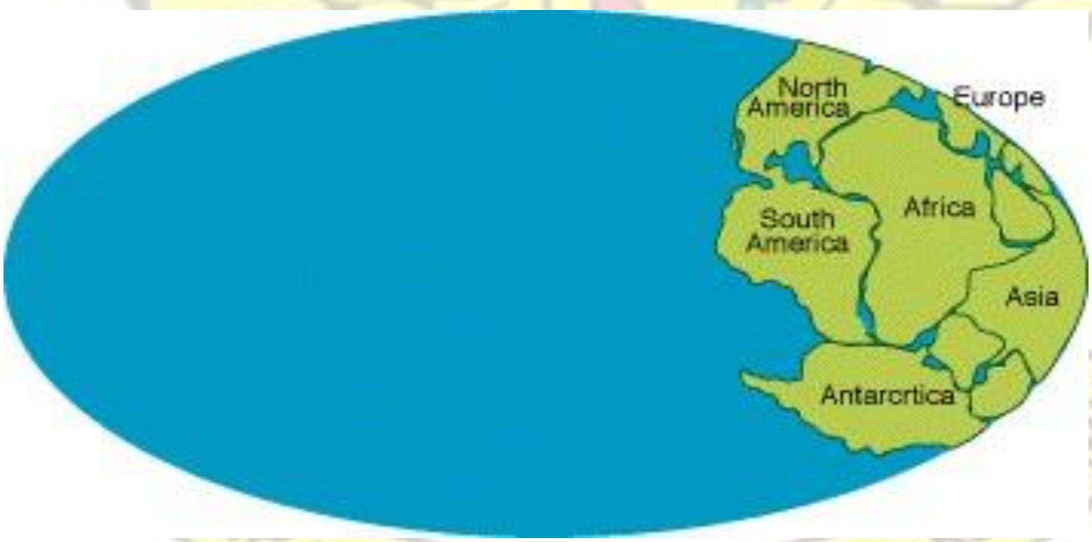


Figure 1.1: Earth composition with all continents put together.

Possibly higher than the importance of water existence, is its safety for consumption. Provision of safe drinking water is essential for the wellbeing of humans for rural and urban inhabitants to prevent health risks (Nikolade and Akastal, 1989; Lemo, 2002).

Portability of water is therefore subject to meet certain physical, chemical and microbiological benchmarks that are designed to ensure the safety of water used for domestic purposes and consumption (Tebutt, 1983).

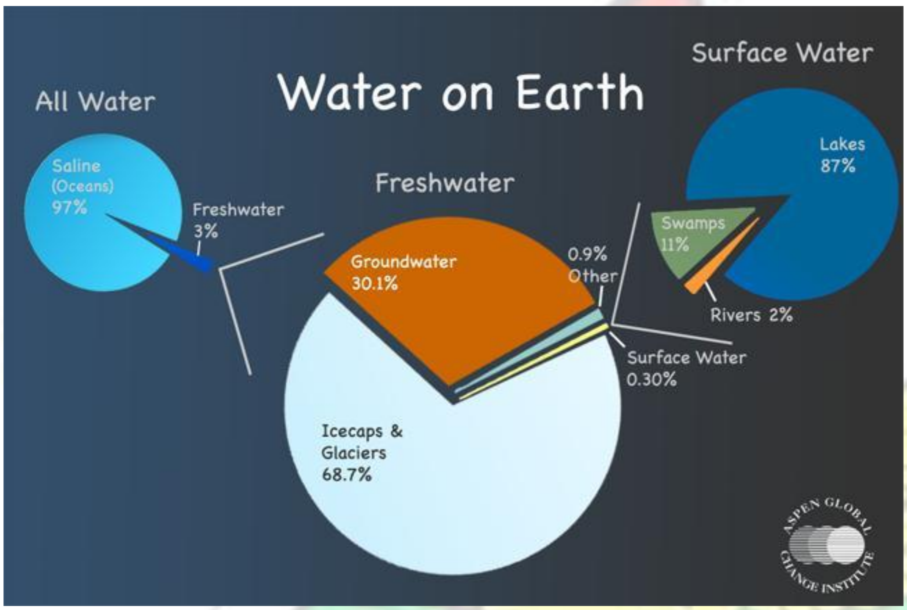


Figure 1.2: composition of water found on the planet earth.

Availability of safe drinking water and healthy sanitation is very essential for the health and safety of communities and homes which totally depend on it and also meaningfully contributes to economic and social wellbeing of humans. (Montgomery **et al., 2009**)

Globally, water, sanitation and hygiene account for nearly 10% of total burden of diseases resulting in the loss of lives in the regions of 3.6 million yearly. (Pruss-Ustun **et al. 2008**).

Access to improved water is a luxury in most developing countries, nonetheless 884 million people in the world still lack access to good drinking water despite the millennium development goal (MDG) target gain. Even though so many progressive works have been done, it has been estimated that by 2016, a total of 672 million people will still not get access to potable water in developing regions globally, especially from sub-Saharan African. (WHO/UNICEF 2010).

In Ghana, 10% of the urban population and 26% of the rural population currently do not access quality drinking water (WHO/UNICEF, 2010).

In the centauries good water purification system was not discovered and therefore much was not known about microorganism and chemical contaminates but rather much prominence was laid on water parameters such as turbidity and salinity (Montgomery, 1985). Importance of quality water became known in the 19th century hence the beginning of public water supply system. (Peavey **et al, 1985**).

Availability of safe water for consumption became critical and immediate for communities and families that depend on public water system.

One of the primary goals of W.H.O is that all people whatever their stage of development, social and economic conditions have the right to have access to adequate supply of safe drinking water.

In various towns and cities, safe water is made available through municipal water treatment plants, concentrating specifically on good production and distribution of drinking water that is fit for consumption (Lamikanra, 1999).

Inadequate treatment processes and poor transmission and distribution system will permit contaminants such as heavy metals, viruses, nitrates and bacteria into the treated water. Also human pollution and industrial discharges can contaminate the water during distribution (Singh and Mosley, 2003).

In the absence of anthropogenic pollution, excess metal and chemical may equally pose a health risk to humans.

The most important heavy metals among the over 20 heavy metals in natural water bodies are copper , mercury, nickel, zinc, manganese, cadmium , iron, lead and chromium.

In the 1920s, public water supply began in cape coast (GWCL, 2008). Currently, there are two public water supply systems in Ghana and these are rural water supply system and urban water supply system. These systems are managed differently and for matter the rural water supply system is manage by community water and sanitation agency (CWSA) while urban system is managed by Ghana water company limited (GWCL).

Today a total of 84 urban water supply system in the country is being operated by Ghana Water Company.

The national target set for urban drinking water supply under the GPRS is 85% coverage by 2015. Available data however shows that Ghana is far from meeting this target. The installed capacity of all the urban water supply systems in the country is about 687,949.61 m^3/day.

Meanwhile 1076526 m3/day has been estimated as current demand of potable water necessary for human consumption. Therefore, the demand gap is 388,576.39.

From the calculation it is observed that 63.90% is the effective urban coverage which is far low as proposed by United Nation‟s Millennium Development Goals and Ghana‟s Own Poverty Reduction Strategy Target (GWSSPR 2010).

KPONG TREATMENT PLANT

Kpong water treatment plant is situated at Kpong near Akosombo in the Eastern region. This plant is one of the treatment plants that serve Tema and part of Accra metropolitan area with a population of 3.5 million people (Binkhoff, 2010). The treatment plant takes it supply from the Volta Lake which is dammed 17km downstream Akosombo Hydro Electric Dam. The plant has three separate treatment units namely; old works, new works and china plant. In 1954 and 1966, old work and new work were respectively commissioned. Both outputs of these treatment plants are 20MGD, 36MGD, and the china plant 40MGD respectively (kpong, 2015). The three treatment plants have separate transmission lines. The new works treatment plant supplies Tema and part of Accra whiles the old works supplies Kpong Township, Manya krobo, Yilo krobo, Adukrom, and Akwapem. Finally, the China treatment plant supplies Adenta, Madina and Legon (AESC, 1975).

1.2 PROBLEM STATEMENT

According to world health organization (2004) 1.1 billion people did not have access to potable water supply in 2002 and 2.3 billion people suffered from diseases caused by contaminated water. Each year 1.8 million of people die from diarrhea diseases and 90%of these deaths are of children under 5 (WHO 2004).

The tremendous increase in the use of heavy metals in past decades has resulted inevitably in an increased flow of metal substances into aquatic environment (Yang and Rose, 2003).

Heavy metals are most important sources of pollution of natural water bodies because of their toxicity and as a matter of fact this has been a critical problem worldwide in recent years.

Most of our natural water bodies are globally contaminated by man –made and natural activities.

The Volta Lake is the main source of water where Ghana Water Company abstracts the raw water for treatment. In recent years increase in human activities such as farming around the catchment area of the lake, sand and stone winning activities around the mountain Yogaga, and weathering of rocks and leaching of soil are the major concerns of pollution of the lake.

Secondly industrial activities such as discharge of effluents from Akosombo Textile Limited (ATL), residues of fertilizers from Volta River Estate Limited (VREL) Banana farm, and World Cool Limited (WCL) are the main contributors to increase of heavy metals in the lake. Although Ghana Water Company is believed to have good quality system of water purification and for that matter most of these heavy metals may be reduced to acceptable limits, it is prudent to assess the quality of the water since the treated water may contain some amount of trace metals.

According to WHO standard, portable water should be free from chemical substances and disease causing microorganisms that are harmful to health (srevastava and Majumder, 2008)

Heavy metals are highly toxic and accumulation in the body for long period of time can be carcinogenic or mutagenic therefore there is the need to investigate the quality of the water.

1.3 OBJECTIVE OF THE STUDY

It is very significant to evaluate the quality and safety of tap water because treated water may contain some amount of trace metals. These metals may be very toxic because they are biodegradable and tend to accumulate in the body, and as a result posing a greater danger to organisms near the top of the food chain. Heavy metal is introduced into tap water through corrosion of plumbing materials, galvanized pipe, leaching of soil due to acid rain, and weak water purification system etc.

The main objective of this study is

To evaluate the quality and safety level of tap water produced by Kpong headworks by determining the levels of heavy metals admissible for potable water according to WHO standards.

The specific objective is

To assess hazard level of some heavy metals (copper, zinc, nickel, cadmium, mercury, chromium, lead, iron, and manganese.) present in Tema municipal water supply.

1.4 SIGNIFICANCE OF STUDY

Since treated water is the main domestic source of water and human lives depend totally on its availability, it very important to evaluate its safety level to ensure that it is safe from chemical contamination and heavy metals.

This research will therefore help to strengthen consumer trust and increase the level of consumption of the water produced at Kpong headworks and any other treated water.

1.5 SCOPE OF THESIS

The scope of this work covers collection and analysis of water produced by Ghana Water Company with specific sampling points around Tema metropolitan area. (Tema Booster Station, community 12, community 9, Tema Newtown, and Tema heavy industrial area). The samples were labeled and sent to CSIR laboratory, stored under ice at about 4^0C prior to the analysis. The metal contents were determined using atomic absorption spectrophotometer (AAS).

1.6 ORGANIZATION OF THESIS

This thesis was structured into five main chapters. Chapter one was basically introductory and background information of the study and objectives. Chapter two was on literature review. Chapter three described the research methodology and material used. Chapter four covered results and discussion. Chapter Five outlined the study conclusion and recommendations.

CHAPTER TWO

LITERATURE REVIEW

2.1 INTRODUCTION

The main sources of water contamination are heavy metals and microorganisms such as bacteria. Since tap water serves as a basic need for human beings and domestic purposes it should be evaluated for it safety. Most analyses conducted on tap water clearly shows that heavy metals really exist in tap water. (G Mebrahtu, **et al** 2011)

Many researches on heavy metal contamination has been done in media such as sea water, rivers, lakes, and dam and had been found out that heavy metal really exist in water but in different concentration levels

2.2 THE STUDY OF HEAVY METALS

Heavy metals are a class of metallic elements which are abundant in the earth‟s crust and their contamination has been a serious concern throughout the world (Romero, **et al**, 2001). Humans may require trace amounts of heavy metals such as copper, and zinc but unfortunately, these metals can be dangerous at high levels. Heavy metal accumulation at higher levels can result even in death. Heavy metal toxins contribute to a variety of adverse health effects (Romero, **et al**, 2001). A total of twenty different known heavy metals were identified that can impact on human health. Accumulation of heavy metals within the body can lead to a decline in the mental, cognitive and physical health of the individual (Aziz **et al**, 2005). Global environmental changes have dramatically increased the overall environmental „load‟ of heavy metals (Lee, **et al**, 2005).

Today heavy metals are abundant in our soil, air and even drinking water. They are present in virtually every area of life (Chen, **et al**, 2008). Heavy metal concentration in drinking water in the

United State is regulated by United States Environmental Protection Agency (U.S.EPA), under the Safe drinking water Act. Several international organizations and national organization like United Nations International Children‟s Emergency Fund (UNICEF), World Health Organization (WHO) World Bank and Non-Government Organization (NGOs) have initiated steps to control heavy metals in drinking water, especially in Asian countries (Hossain, **et al**, 2005). Heavy metals may cause chronic poisoning with some considered to be a human carcinogen. Copper and aluminum have been found in ground water in many parts of the world like India, Bangladesh, Inner Magnolia and Taiwan (Ferguson**, et al** 2007). Higher levels of copper and aluminum were found to cause skin, lung, and bladder cancer (Lee **et al**, 2000).

Heavy meats in ground water tend to be mostly in a reduced state which can be inferred from the lower redox potentials. Geochemical conditions may also lead to naturally occurring higher levels of heavy metals in ground water (Kim **et al**, 2000). The maximum contaminant level (MCL) is referred to as maximum level of heavy metals in water that can cause potential effects on human body.

In most natural water systems, a minute quantity of heavy metal present in drinking water is harmful to humans and other organisms.

Heavy metals are main contaminates in natural water bodies which affect biological treatment of water. In the food chain this hazardous metals concentration creates problems for organisms (including human) near the top of the chain. In aquatic environments, the solubility of heavy metals is extremely high and for that matter heavy metals are easily absorbed by living organism.

Serious health disorders such as cancers and organ damage can occur when metals are ingested beyond the permitted concentration human bodies can accommodate.

On the other hand, biological life depends mostly on these heavy metals. Trace metals such as zinc, copper, and mercury in low concentration are important metabolic agents in the human body.

The major source of water pollution is as result of discharge of effluent from industrial activities and sewage treatment plants. Therefore to meet technology based treatment standards, innovative processes or technologies are used to reduce the toxic level.

2.2.1 COPPER

Copper is one of the most essential transition metals. It is malleable and good conductor of both electricity and heat. The oxidation state of copper is Cu (ll) name cupric. Copper has good corrosive resistance, a ready availability high recyclability and attractive appearance material (P.Saha **et al.**2008)**.** Copper occurs naturally in rock, water, soil, air and sediments. Living organisms including humans, require little amount of copper in their diet to ensure good health. However, too much can cause several and serious health effects. Symptoms such as vomiting, stomach cramps, diarrhea, liver damage, kidney damage and nausea are the effects of high level of copper in the human body.

High level of ingestion of copper can lead to haemolysis, hepatotoxic, nephron toxic effects, renal failure, olgouria and even death. (Ozar **et al** 2007) and (Agarwal, **et al,** 1993)

The toxic effects of copper affect mostly children less than one year because the natural mechanisms developed in adult to maintain the level of cooper will not yet develop in children. Drinking water gets contaminated when copper dissolves from copper pipe in household plumbing. The longer the stagnation of water in pipe the higher copper is likely to be absorbed.

Copper is commonly found in the lungs, kidney, liver, brain (Linder, **et al,** 1996) and its adsorption occurs in the gastrointestinal tract.

Copper is removed from the body through bile, urine and sweat (Luza **et al** 1996, cox 1999) The maximum permissible limit of copper in drinking water proposed by WHO is 2.0mg/l.

2.2.2 ALUMINIUM (Al)

Aluminium is the most abundant metal in the earth‟s crust with atomic number 13 and atomic mass of 26.98amu. It is less dense and forms a thin layer of aluminum oxide on its surface when exposed to air and for matter it has a good corrosion resistance through the phenomenon of passivation. Corrosion can only occur with the presence of oxygen.

It is colorless and typically exists in +3 oxidation state. It is available in oxides and hydroxides along with other metals such as sodium and fluorides. The melting and boiling points are found to be 933K and 2740K respectively.

Aluminum is used in foils, menu trays, and cans for food preservation. Meaning, it provides safe barriers to bacteria and contamination. Besides aluminum is used as an astringent to stop bleedings. Aluminum hydroxide is used to treat kidney failure and stomach ulcers and also increase immune response in vaccines and medicines. It can be found in cosmetic products like deodorant

However, excess aluminum ingested into the human body can create neurotoxic effect, reproduction and possibly bone effects.

Aluminum is widely used in automotive, aircraft construction, electric industries and in alloys. It is also used in water treatment process to reduce the level of microbes, organic matter, color and turbidity. It serves as a coagulant in the water treatment process and it is commonly used in pharmaceutical industries such as in the preparation of antacids. It is also used in antiperspirants and food additives (ATSDR, 1992). The most common source of ingestion of aluminum in humans is by air, food and water.

2.2.3 CADMIUM (Cd)

Cadmium occurs as a minor component in zinc ores and also a byproduct of zinc production. It has atomic number of 48 and standard an atomic weight of 112.414amu. Cadmium is insoluble in water and is mainly use as an anticorrosive, electroplates onto steel. It can also be obtained through erosion of natural deposition, battery and paint waste, sewage and mining, discharge from metal and plastic refineries, photography, insecticides and metallurgy industries, electroplating and deterioration of galvanized plumbing may introduce cadmium in drinking water. Cadmium has no essential benefit to human life but rather numerous health effects are observed at sufficiently high level of exposures. Cadmium gets to the human system through inhalation or ingestion but dermal infection are less significant to consider. Its solubility in water depends largely on increase in acidity (Ros & Slooff, 1987).

Cadmium can cause pulmonary, skeletal, testicular and kidney diseases and has been recognize as a carcinogen. (Rajappa **et al**, 2010). For non-occupational exposures, cadmium inhalation does not burden the human body unless the person is a smoker.

2.2.4 CHROMIUM (Cr)

Chromium is a chemical element with atomic number 24 and standard atomic weight of 51.996amu. It has neither taste nor odor. Chromium exists in water as trivalent chromium (chromium - 3) and hexavalent chromium (chromium-6). Trivalent chromium is a human dietary element (vegetables, fruit, meats, grain, yeast) whiles hexavalent chromium is the toxic form of the mineral and occurs from erosion of natural chromium deposits. Chromium in drinking water only exists as trace metal. Chromium is used in pigment and paints, ceramic and glass industry, leather tanning, catalyst manufacturing, fungicides, photography, metal industries discharges and corrosion prevention. (Hamilton, J. W.; and Wetterhahn, K. E 1988). Chromium is essential in metabolism of fats and carbohydrates, and also functions as insulin-performance enhancer.

Excess chromium in the human body can damage the kidneys, nerves, liver and cause irregular heart rhythm. It also leads to stomach problem and low blood sugar. Chromium has a perfect corrosion resistance property (Geneva, 1990. (ISO 9174:1990).

2.2.5 LEAD (Pb)

Lead is a chemical element with atomic number 85 and standard atomic weight of 207.2 amu. Lead is a ductile material with low melting point, high density, malleable, soft and poor electrical conductivity. It is also a common element and relative inertness against oxygen attack. It is used in building construction, solders, pipes and plumbing materials (Weast, Astle & beyer 1983)

It is poisonous when ingested or inhaled. It is a neurotoxin and can accumulate in bones and tissues to destroy the nervous system. Excessive lead intake can cause blood and brain disorder, kidney damage, cancer, stroke, high blood pressure, miscarriages and subtle abortion, and lower IQ level in children. (Lentech 2006; hanaa et al, 2000; Gregoriaadou et al., 2001)

Lead can enter the human body through food, air and water. Foods such as meats, vegetables, fruit, grain, seafood, soft drinks contain substantial amounts of lead.

When tap water is slightly acidic, corrosion of pipes occur leading to the presences of lead in water. Lead can originate from corrosion of brass fittings on submersible pumps, metal faucets and fixtures.

The maximum amount of lead permitted in drinking water by standards is 0.05 mg/L of water. (Elinder C-G et al.)

2.2.6 ZINC (Zn)

Zinc is a lustrous, diamagnetic metal with atomic number 30 and standard atomic weight of 65.38 amu. At a temperature of 20^0C its electrical resistivity is 59.0 nΩm and thermal conductivity of 116w/ (m-k). Some major applications of zinc are the use of zinc as anticorrosion agent and galvanization, zinc carbonate and zinc gluconate tablets which are sold over – the - counter as dietary supplements to increase immunity and fight colds, zinc sulfide in luminescent paints, zinc chloride in deodorants, zinc methyl or diethyl in laboratory, and in batteries. Zinc has a low affinity for oxides and therefore prefers to bond with sulfides (chalcophile).

The importance of zinc can"t be overemphasized when it comes to healing processes after injury. It is also used to treat diarrhea among children, acrodermatitis enteropathica and gastroenteritis. Furthermore, zinc ions are generally considered as strong antimicrobial agents hence are used in toothpastes and mouthwashes to prevent bad breath.

Deficiency of zinc in the human body can result in impotence and delayed sexual maturation, infertility, poor concentration and memory, hair loss, depressed growth, altered cognition, impaired appetite, chronic renal and liver problems, diabetes and malignancy. (Hambidge, K. M. &KREBS, N.F. 2007)

Zinc can be found in animal- sourced food such as chicken, fish, meat, eggs, and shellfish. Also food plants such as beans, mushroom, cocoa powder, cashew, grains, sunflower seed and nuts are the major sources of zinc.

Although zinc is very important to human health, excessive zinc intake can damage nerve receptors in the nose causing anosmia and can also depress the immune system and impair blood cell formation. (Prasad, A.S 2003).

2.2.7 MERCURY (Hg)

Mercury is a neurotoxin element with atomic number 80 and standard atomic weight of 200.592 amu. It has a density of 13.534 g/cm^3 and a melting point of 234.3210 k. Mercury is normally used in sphygmomanometers, fluorescent lamps, thermometers, relays, liquid mirror telescopes, barometers, valves and manometers. Water soluble mercury such as mercuric chloride or methylmercury is very poisonous when inhale or ingested. Mercury dissolves silver and gold to form amalgams. (Stillman, J. M. 2003)

Improper disposal of devices containing mercury, runoff from farms, households, commercial and medical products, industrial activities, landfills and sediments are some of the major pollution of natural water bodies.

When the concentration of methymercury is accumulated and biomagnified its health effects on adults includes kidney, lung and brain damage, skin rashes and dermatitis.

During mercury poisoning sensory impairment (hearing, vision, speech), and lack of coordination are observed. Also emotional changes (excessive shyness, excitability, irritability, nervousness, mood swings), neuromuscular changes, poor performance on tests of mental function and insomnia are some of the symptoms of occupational exposures of adults to mercury.(Stockinger 1981)

Moreover, infants and children who are exposed to methylmercury whiles are in the worm will experience cognitive thinking problems, memory, fine motor skills, language, and visual spatial skill problem when they are born. (Clarkson,TW, Magos L, Myers GJ)

Mercury can only be removed from treated water by the use of reverse osmosis, the use of cartridges and carbon filters.

2.2.8 NICKEL (Ni)

Nickel is a hard, ductile and malleable metallic element with atomic number 28 and standard atomic mass of 58.71 $gmol^{-1}$. It‟s specific gravity at 20^0 C is 8.9 gcm^{-3} . Similar like iron, it dissolves in dilute acids and turns passive when treated with nitric acid.

Nickel has the ability to resist corrosion at a high temperature hence it is used to manufacture gas turbine, desalination plants, and rocket engines. (Derek G. E. Kerfoot 2005)

Human exposure to nickel is through inhalation (breathing air, smoking cigarette), oral (drinking water, foods), and dermal routes. Foods such as chocolate, fats and vegetables contain substantial amount of nickel and therefore excess intake can be carcinogenic and toxic.

Consequences such as lung cancer, prostate cancer, nose cancer, respiratory failure, heart disorder, asthma and chronic bronchitis are serious issues that affect human health. The presence of nickel in drinking water may be due to leaching from metals in contact with drinking water such as pipes and fittings. (World health organization, 2004).

2.2.9 IRON (Fe)

The second most abundant metal in the earth‟s crust is iron. It is found in nature as the irons Fe^{2+} and Fe^{3+} combine with oxygen and sulfur-containing compounds to form oxides, hydroxides, carbonates, and sulfides. (Ghulman **et al.,** 2008). High level of iron in drinking water makes the water taste metallic. The water may appear brownish, discolored, and may contain sediment. It leaves red, orange rust stains in sink, bathtub, shower, and toilet. It discolors ceramic dishes, water heaters, laundry equipment and cause stains on clothing. Iron is very important to human being because it used in cellular metabolism and form hemoglobin which transports oxygen to all cell of the body.

High level of iron in drinking water has no adverse effect but chronically consuming large amount s of iron can lead to a condition known as iron overload. Iron overload is caused by the disease hemochromatosis. It is a genetic disease caused by a change (mutation) in a gene that is important in limiting the absorption of iron from the intestine. If this is not treated iron overload can lead to hemochromatosis, and many diseases that can destroy the body‟s organs.

Symptoms such as fatigue, joint pain, and weight loss are first observed but if hemochromatosis is not treated, it can lead to heart disease, liver problems and diabetes. (Elinder C – G Iron. In: Friberg L, Nordberg GF, Vouk VB, eds)

2.2.10 MANGANESE (Mn)

Manganese is a mineral that is present in water, soils, sediments and rock. It is an important minerals found commonly in vegetable and grains but generally regarded as unhealthy in water for humans in concentrations of as little as 0.5ppm. Manganese can cause black and brown staining. Manganese can exist in 11 oxidative states and the most environmentally and biologically important manganese compounds are those that contain Mn^{2+}, Mn^{4+}, Mn^{7+}. Manganese is essential for prevention of sterility, for glucose utilization, cholesterol metabolism, pancreatic function and development, lipid synthesis and lipid metabolism, and normal skeletal growth and development.

Excess manganese interferes with the absorption of dietary iron and may result in iron-deficiency anemia. Excess manganese can cause increase in bacteria growth in water. Manganese causes hypertension in patients older than 40years, severe hepatitis and posthepatic cirrhosis, in dialysis patient and in patents suffering heart attacks. (Weast, Robert 1984)

The maximum contaminated level (MCL) standards for heavy metals (Babel and Kurniawam, 2003) are shown in table 2.1

Table 2.1: maximum contaminated level (MCL) for hazardous heavy metals

Heavy Metal	Major sources	Effects on human health	Toxicities MCL(mg/L)
Lead	Mining Paint, pesticides, burning of coal smoking, automobile emission.	Reduced intelligent quotient (IQ), increased antisocial behavior, reduced educational attainment, renal impairment, developmental delay, congenital paralysis, hypertension, immunotoxicity, anaemia	0.006
Copper	Metal piping, mining, pesticides, chemical industry.	Cardiovascular toxicity, diarrhea, abdominal pain, dizziness, jaundice, stomach pain, coma, heart problems.	0.25
Chromium	Incineration facilities, cement dust, land field, textile manufacturing,	Lung cancer, kidney and liver damage, irregular heart rhythm, skin rashes, ulcers, weakened immune system,	0.05

		upset stomach, respiratory problems. Fatigue, vomiting.	
Nickel	Acid rain, sandstone, volcanic eruption, steel production, burning of residual and fuel oil	Dermatitis, nausea, chronic asthma, coughing, respiratory failure, cancer, vomiting, abdominal pain, diarrhea, neurological effects, lung embolism,	0.20
Arsenic	Fungicides, pesticides, metal smelters.	Dermatitis, bronchitis, poisons.	0.2
Cadmium	Phosphate fertilizers, pesticides, plasttics, Cd and Ni batteries, Electroplating.	Psychological disorders, damage to the immune system, possible DNA damage, cancer development, reproductive failure (infertility problems), damage central nervous system, pulmonary edema, pneumonitis, diarrhea.	0.01
Mercury	Coal plant, cement kilns Pesticides, batteries, gold mining.	Contact dermatitis, nervous damage, digestive disorder, loss of memory, excessive shyness, vomiting, tremors	0.00003
Zinc	Plumbing, Refineries, brass manufacture,	Skin irritation, stomach cramps, Oral ulceration, stomatitis eczema,	0.80

	metal plating.	Depression, nervous membrane.	
Iron	Natural deposits, industrial waste. Refining of iron ores, corrosion of iron containing metals	Heart problems, liver problem, Anemia, developmental delay, cognitive impairment, adverse pregnancy and diabetes	0.03
Manganese	Weathering of manganese bearing mineral and rocks. Industrial effluent, acid-mine drainage, sewage and landfill leachate may also contribute manganese	Infertility, metal confusion, impaired memory, loss of appetite, neurological problems, psychiatric illnesses,	0.4

In summary, the following adverse health effects of heavy metals are recognized: cancer, endocrine, gastrointestinal, cardiovascular of blood, musculoskeletal, reproductive, neurotoxicity, immunotoxicity, lever, kidney, skin sensitivity and respiratory toxicity.

2.3 METHODS OF REMOVING HEAVY METALS FROM WATER

There are several methods in which heavy metals can be removed from water. Some of these methods are:

Physico-chemical method

- Mechanical screening
- Gravity concentration
- Magnetic separation
- Electrostatic separation
- Membrane filtration.

Conventional chemical precipitation methods

- Coagulation
- Flocculation
- Adsorption
- Ion exchange
- Electrochemical deposition
- Electrodialysis

Biological methods

- Biosorption
- By bacteria and microorganism
- Biofilters
- Anaerobic digestion

Water quality actually fines the physical, chemical and microbiological characteristic of water. The most essential requirement is that water must be safe to drink and must be fit for other use. Water for domestic use in terms of appearance, odour and taste must be aesthetically pleasing and chemically stable thus must not cause corrosion or form deposits in pipes or fixtures.

To achieve an excellent maintenance and distribution systems, chemical stability of water must be considered in other to determine whether the water will be chemically stable, aggressive – corrosive or scale forming.

2.3.1 MECHANICAL SCREENING

Screening is the initial step in water treatment plant. The main objective of mechanical screening is to remove heavy metals, rags, plastics and debris that might clog and damage piping and downstream equipment. There are two main types of screen. These are coarse screens and fine screen. Coarse screen are employed to remove debris and large solids from waste water while fine screens are used to remove materials that can create operation and maintenance problems in downstream processes.

2.3.2 GRAVITY CONCENTRATION

This is a technique used to separate two or more substances with different specific gravity in relation to gravitational force. Since heavy metals have high atomic weight and density at least 5 times greater than water, this method is used to remove heavy metals from water.

2.3.3 MAGNETIC SEPARATION

Mineral magnetite, or iron ferrite ($FeO.Fe^2O^3$) that is synthetically prepared is used to separate heavy metals from waste water. The ferromagnetic property of ferrite solids makes magnetic separation of solids from solution more readily (Boyd **et al**. 1988).

2.3.4 ELECTROSTATIC SEPARATION

This process operates on the principle of electrostatic charges to separate crushed particles of material. It is based on corona discharges. The separation of particulates in fluid is accomplished by electrical forces on an insulating fluid so that an electric field can be superimposed across it.

2.3.5 MEMBRANE FILTRATION

Membranes are porous and thin sheets of material that separate contaminants from water when a high force is applied across the membrane. This technology is employed in drinking water for desalination, removal of bacteria and other microorganisms, micropollutants and natural organic material, which can impart taste, odor, and colour. Example of membrane filtration methods are reverse osmosis, microfiltration, ultrafiltration and nanofiltration.

Reverse osmosis

This is a water purification technology that uses semipermeable membrane to remove pollutants and microorganism from potable water. The principle of operation is moving solvent from high potential (low concentration) to low potential (high concentration) for chemical potential equilibrium. For effective reverse osmosis system ultraviolent light or ozone are used to prevent microbiological contamination.

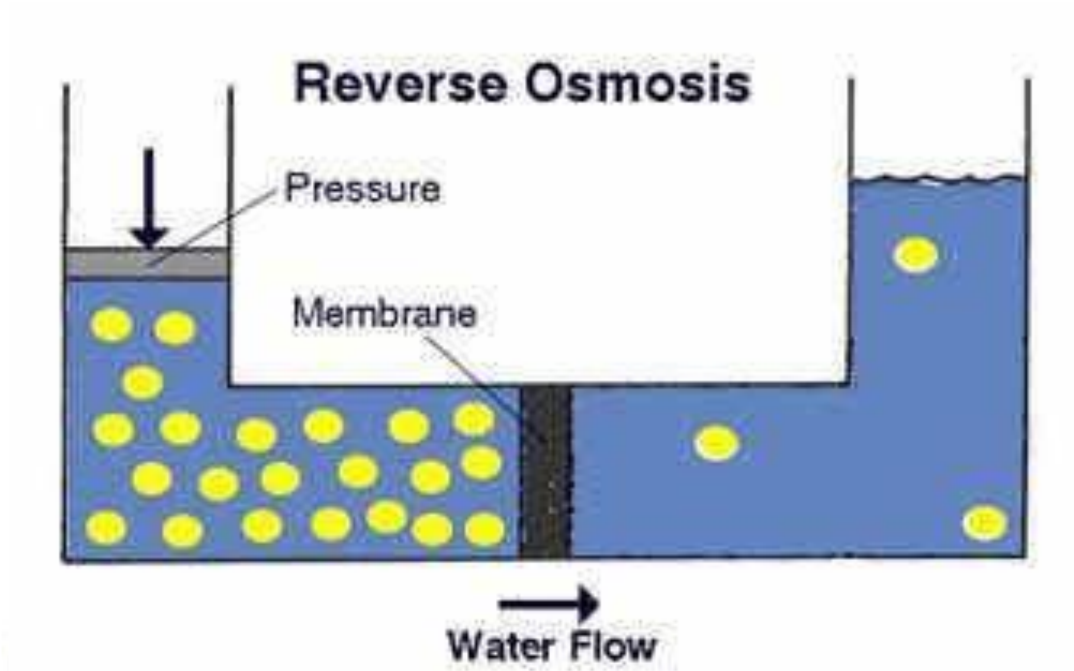


Figure 2.1: principle behind reverse osmosis operations (www.cnmeditech.com)

In reverse osmosis, the flow of water can be reversed with an opposing pressure that exceeds osmotic pressure. With reverse osmosis, water is forced out of a concentrated solution, leaving the impurities behind.

2.3.6 COAGULATION

Coagulation is a water treatment method by which colloidal particles in water are destabilized so as to form flocs through the process of flocculation that can be readily separated from water. For effective results destabilization is achieved by adding coagulants to water. There are different types of coagulants, these are:

- Aluminium sulphate (Alum) $Al_2(SO_4)_3.18H_2O$

When alum is added to waste water containing calcium and magnesium bicarbonate alkalinity, a precipitate of aluminum hydroxide will form

$$3Ca(HCO_3)^2 + Al_2(SO_4)_3 + 18H_2O = 2Al(OH)_3 + 3CaSO_4 + 6CO_2 + 18H_2O$$

Insoluble

The insoluble aluminum hydroxide is a gelatinous floc that settles slowly through the wastewater, sweeping out suspended material and producing other charges.

- Ferric Chloride, $FeCl_3$

$$2FeCl_3 + 3Ca(HCO_3)2 \leftrightarrow 2Fe(OH)_3 + 3CaCl_2 + 6CO_2$$

Ferric chloride and lime

$$2FeCl_3 + 3Ca(OH)_2 \leftrightarrow 2Fe(OH)_3 + 3CaSO_4$$

Ferric sulfate and lime

$$Fe(SO_4)_3 + 3Ca(OH)_2 \leftrightarrow 2Fe(OH)_3 + 3CaSO_4$$

- Hydrated Lime, $CaCO_3$

When lime alone is added as a precipitant, the principles of clarification are explained by the following reactions for the carbonic acid and the alkalinity.

$$Ca(HCO_3)_2 + Ca(OH)_2 = 2CaCO_3 + 2H_2O$$

$$H_2CO_3 + Ca(OH)_2 \leftrightarrow CaCO_3 + 2H_2O$$

Slightly soluble

- Polymeric coagulants
- Polyelectrolytes
- Aluminium polymers
- Activated silica

2.3.7 FLOCCULATION

Flocculation is the process that causes aggregation destabilized colloidal particles to form rapidsetting flocs. The flocs which form can be removed by sedimentation, sand filtration or flotation. Flocculation is similar to coagulation and in flocculation process the velocity of water is reduced to much lower value to enable large and strong aggregates to form. If the of water velocity is high aggregates may break up and therefor flocs will not form properly.

2.3.8 ADSORPTION

Adsorption is the adhesion of atoms, ions, or molecules from water to a surface. Is a phenomenon of accumulation of large number of molecular species at the surface of liquid in comparison to the bulk.

Adsorption is a surface phenomenon and a consequence of surface energy. Adsorption is similar to surface tension. Adsorption is used in industrial application such as activated carbon in water treatment process to adsorbed odour and residual chlorine in potable water. Adsorbents are classified as:

Oxygen containing compounds (e.g. silica gel and zeolites).

Carbon based compounds (e.g. activated carbon and graphite)

Polymer based compound

2.3.9 ION EXCHANGE

Ion exchange is a water purification method where one or more undesirable contaminants are removed from water by exchange with another non-objectionable or less objectionable substance. It is an exchange between electrolytes or electrolytes solution and a complex. Ion exchange is used for water purification, separation and decontamination water and solutions with polymeric or mineralic ion exchangers. Ion exchange is a purification process used to separate and purify metals. It is also used to demineralized or soften where calcium and magnesium are to be removed from water.

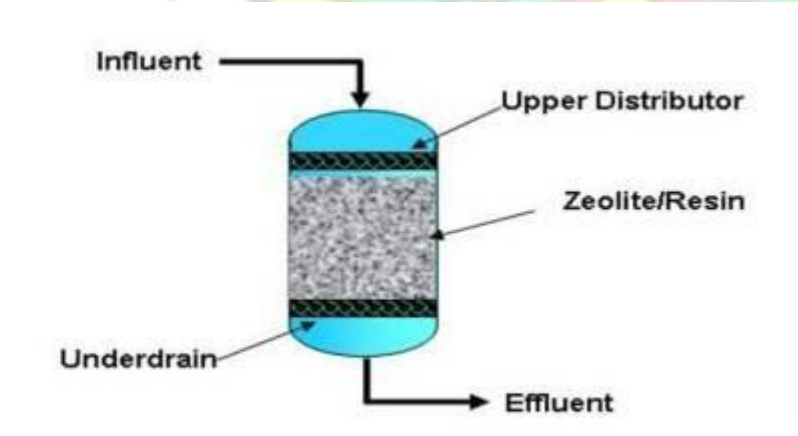


Figure 2.2 ion exchange diagram.

2.3. 10 ELECTRODIALYSIS

Electrodialysis is a water purification process where ions are transmitted through semi permeable membrane, under the influence of an electric potential. Electrodialysis is employed in pharmaceutical application, stabilization of wine and desalination of salt water.

2.3.11 BIOSORPTION

Biosorption is a property of certain types of inactive, dead, microbial biomass to bind and concentrate heavy metals from even very dilute aqueous solutions.

In biosorption treatment process microorganisms are used to break down organic material with aeration and agitation for solids to settle out. Biosorption is a metabolically passive process, it does not require energy.

2.4 THE TREATMENT PROCESS AT KPONG HEADWORKS

Water is a unique substance and one of its unique characteristics is that it is a good solvent. As water goes through its hydrological cycle, comprising of runoff, impounding, rainfall, infiltration and evaporation, it dissolves all suspended matters to make the water impure. The main objective of water treatment is to make water fit for domestic use reliable and consistent.

Water treatment is very important particularly from source such as rivers, lakes and ponds. Human beings consume water daily by bathing, drinking, and preparing food with it.

In water treatment, systematic procedures are used to achieve the water quality. Flocculation process which combines small particles into large particles is the first procedure then the water passes through a filtering system to remove all undesirable particles. After that, water undergoes ion exchange process to remove any inorganic contaminants.

The process continues by adsorption which removes all organic contaminates, unwanted coloring, taste and odor, and then chlorination process is carried out to disinfect the water.

With all this treatment process some consumers still do not trust the safety of tap water.

Tap water being the main source of domestic and animal use may be contaminated with heavy metals. In water treatment, they are found as trace metals and are 5 times denser then the specific gravity of water.

Nonetheless, in a long period of time these constituents are very toxic and tend to accumulate in the human body.

The figure 2.3 is the flow diagram of the treated process used at Kpong headworks.

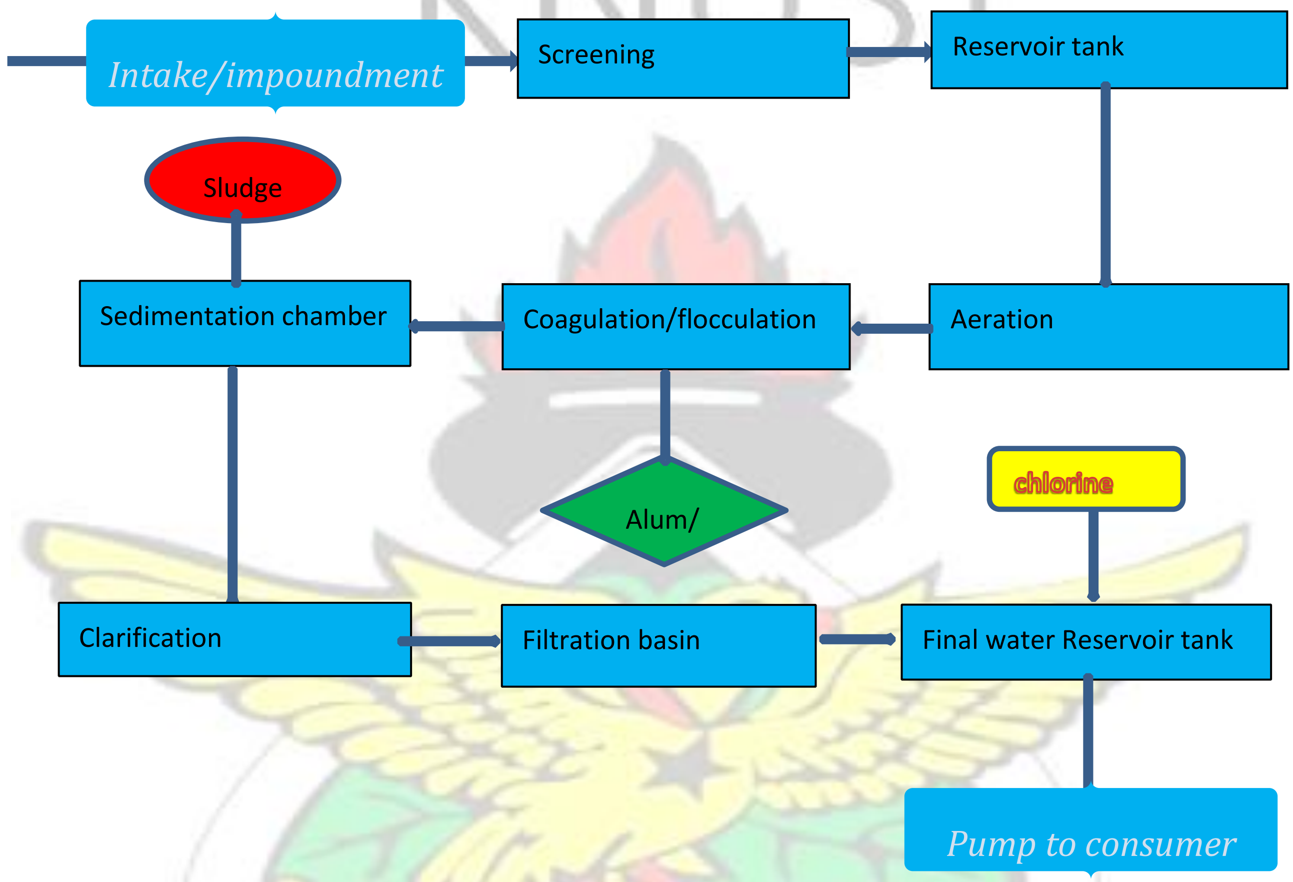


Figure: 2.3 schematic diagram of treatment process at Kpong.

2.4.1 INTAKE

The water treatment plant at Kpong headworks have a raw water intake, pumping and conveyance system and flow measurement. The raw water is taken from the volta lake over a predetermined range of the water level.

Centrifugal pumps with a capacity of 830 m^3/h are submerged in the lake to lift raw water at a flow rate of 0.2 m^3/s to the treatment plant.

Flow measurement devices such as venturi meters and flow nozzles are installed in the raw water line and distribution main to monitor the flow of raw water.

2.4.2 SCREENING

In the intake gate or in the sump, both micro strainers (fine screen) and coarse screen are used to prevent all debris, suspended particles, algae, stones and sand from entering the pumps and the pipe lines. This is done in other to protect the process equipment, reduce overall treatment process reliability and effectiveness or contaminate waterways.

2.4.3 RESERVOIR TANKS

Reservoir tank is a storage facility used to store fluids. The term reservoir can also be used for artificial lake or ponds.

2.4.4 AERATION

Aeration is the addition of air or oxygen to water or wastewater usually by mechanical means to increase dissolved oxygen level and maintain aerobic condition or to allow aerobic biodegradation of the pollutant components. During aeration odour, dissolved gases (carbon dioxide), oxidizes dissolved metals (iron, hydrogen sulfide) and volatile organic chemicals are removed. When air enters the water, it promotes microbial growth in the wastewater and this microbes feed on the organic material to form flocs. Some common aeration systems are gravity aerator, spray aerator, mechanical aerators and diffuser.

2.4.5 COAGULATION AND FLOCCULATION

Coagulation and flocculation are used interchangeably. Coagulation is the process of destabilizing colloidal particles so that particle growth can occur as a result of particle collision. Coagulation can be achieved when coagulants such as alum with a positive charge neutralize the negative charges on the particle. This formation causes the particles to stick together to form large particles as flocs.

Flocculation is used to describe the process whereby the size of particles increases as a result of particle collision. It causes aggregation of destabilized colloidal particles to form rapid settling flocs.

2.4.6 SEDIMENTATION CHAMBER

Sedimentation is the term applied to the separation of suspended particles that are heavier than water by gravitational setting. During sedimentation aggregates that form during coagulation and flocculation settle out from the water. When water is pumped from the low lift, it comes straight to distribution chamber. The water first enters mixing basin one with capacity of 500m^3 formed below through a metal pipe. In the sedimentation chamber sludge that is form is occasionally removed and discharged to the downstream of the lake.

2.4.7 CLARIFICATION

Clarification is the technique of removing suspended matters in raw water. It allows the formation of large flocs to sink to the bottom of a tank or basin. The sediments are allowed to settle and the clarified water collected from the top of the basin while the sediments are removed from the bottom with the crapper mechanism. Each clarifier at Kpong headwork has a volume of 5650m3.

2.4.8 FILTRATION

Filtration is the process of removing particulate suspended material in a liquid by passing the liquid through a filter bed comprised of a granular or compressible filter medium. It is noted that flocculation, flotation, coagulation and sedimentation are extremely important in water treatment process. However without filtration the quality standard of potable water will not be achieved.

Filtration is considered as the polishing step of the treatment process starting with chemical dosing.

The sand filter bed at Kpong headworks is shown in figure 2.4

Figure 2.4 Kpong headworks filter bed

The clear water from the clarifier is directed to the filter bed. The filter bed is made up of several uniformly sized grains. The media is made up of gravel and grit. The filter flow is made up of filter nozzles with equal spaces. When the filter media is dirty, backwashing is carried out by applying bubble air through the bed (air scour process). In case the pH is higher, lime may be added to water in the filter bed to correct the pH.

2.4.9 DISINFECTION

It is essential to disinfect water after clarification since bacteria and other micro-organisms may possibly remain in water to cause diseases. This can be achieved by adding an amount of chemical agent to water to destroy all pathogens present in the water. Physical method of disinfection of water includes irradiation with ultra-violet light and boiling.

Other disinfectants includes chlorine gas (Cl2), chlorine dioxide (ClO_2), ozone, calcium hypochlorite ($Ca(OCl))_2$, sodium hypochlorite (NaOCl) also known as bleach and monochloramine (NH_2Cl).

Chlorine is an oxidizing agent and therefore has ability to oxidize micro-organisms making them inactive and finally destroys them. Factors that significantly determine the effectiveness of disinfection by means of chlorine are the chlorine contact time and chlorine concentration. The accepted free chlorine residual in water must be less than 0.5 mg/l after 30 minutes contact time. An effective disinfection can only occur when the turbidity of water is very low because colloidal particle can shield microorganisms from the action of the disinfectant.

Excess chlorine in water can be reduced by the use of dechlorination reducing agents such as sulfur dioxide, sodium metabisulfite or by adsorption on activated carbon.

2.5 STABILISATION OF WATER

Stabilization of water entails addition of chemicals to water to adjust its chemical properties in order to prevent corrosion or scale formation in pipes and fixtures. It also involves the addition of chemicals to the water to produce water with calcium carbonate precipitation potential of about 4 mg/l. Water should always have a low super-saturation value of calcium carbonate since water with supersaturated calcium carbonate may cause excessive scale to form in pipes and household fixtures.

In summary, conventional water treatment methods include coagulation of small colloidal particles, flocculation of small particles to form larger flocs or aggregates, followed by sedimentation and finally sand filtration.

2.6 AAS PRINCIPLE OF OPERATION

AAS is one of the most valuable techniques for determining the level of heavy metals in water. AAS is very simple to use, reliable, and cost effective.

The technique makes use of absorption spectrometry to assess the concentration of an analyte in a sample. It requires standards with known analyte content to establish the relation between the measured absorbance and the analyte concentration and relies therefore on the Beer –Lambert Law. (Robert Bunsen and Gustav Kirchhoff)

$$C = K.\ A$$

The factor k is dependent on length of the optical cell, wavelength of the light and properties of atoms absorbing this light. The absorbance A is defined by the following equation:

$$A = \log \frac{I_0}{I}$$

Where: I_0 – intensity of the light before absorption I – intensity of light after absorption.

AAS involves the absorption of radiant energy produced by a special radiation source (lamp), by atoms in their electronic ground state. The lamp emits the atomic spectrum of the analyte elements, i.e., just the energy that can be absorbed in a resonance manner. The analyte elements are transformed in atoms in an atomizer. When light passes through the atom cloud, the atoms absorb ultraviolet or visible light and make transitions to higher electronic energy levels. A monochromator is used for selecting only one of the characteristic wavelengths of the element being determined, and a detector, generally a photomultiplier tube, measures the amount of absorption. The amount of light absorbed indicates the amount of analyte initially present.

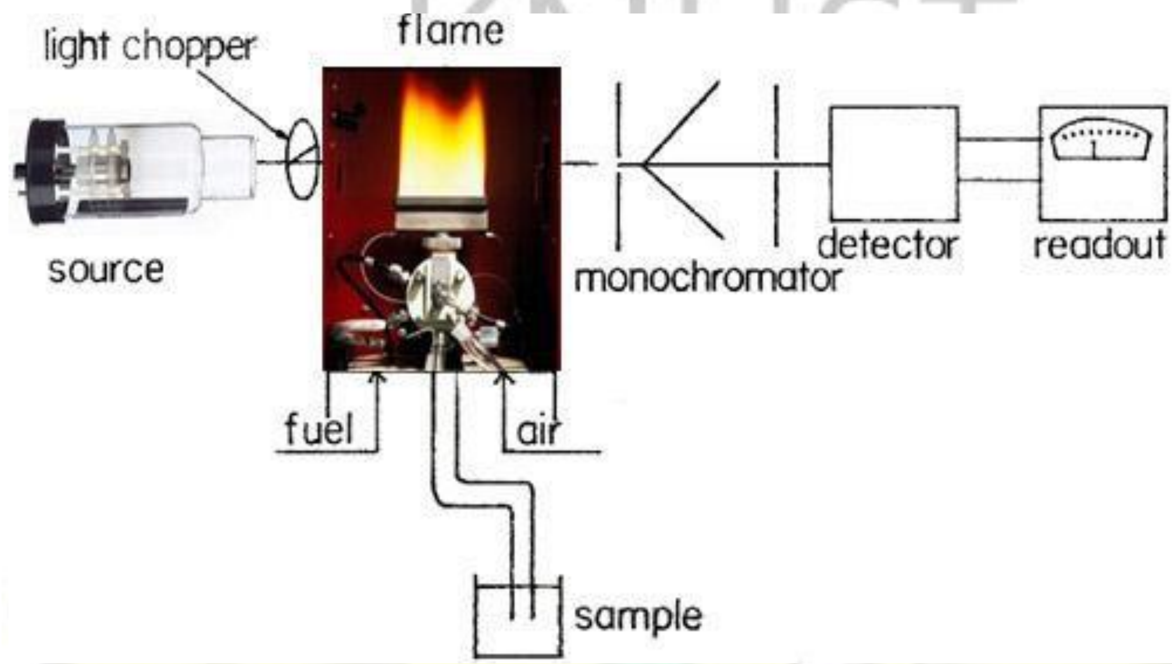


Figure 2.5 Schematic diagram of ASS

INTERFERENCE

Interference from background absorption may be eliminated by the use of deuterium background correction lamp.

Matrix effects may be controlled by making standards and test solution with same acid concentration as the samples. This is done to obtain a uniform matrix for both standard and sample. (J. Arc Broekaert 1998).

CHAPTER THREE

MATERIALS AND METHODOLOGY

3.1 SAMPLE COLLECTION

The potable water was sampled in 1.5 L polyethylene bottles from five sampling points. These points were designated as KW 1- KW 5. The sampling bottles were cleaned by washing them in non- ionic detergent, then further rinsed with tap water and later soaked in 10% HNO_3 for 24 hours and finally rinsed with de-ionized water before usage. During sampling the sample bottles were rinsed with the sample water for three consecutive times before finally filled to the brim.

3.2 SAMPLE TRANSPORTATION AND PRETREATMENT

At each sampling point samples were labeled according to sampling point identification name, sampling time and date of sampling before transporting it to the laboratory. In order to maintain the integrity of the samples, the sample were preserved or stored under ice at 4^0 C. Heavy metal content was then determined using the Atomic Absorption Spectrophotometer (AAS) Unicam 969 Atomic Absorption Spectrophotometer (AAS) with 50mm burner.

3.3 CALIBRATION OF METHODS

- Optimization

  The instrument was set up as shown in figure 3.1. Align burner head and hollow cathode lamp position in order to obtain the highest signal to noise ration. ➢ Sensitivity check

Immediately after optimization, a verification standard (e.g. 5.5 mg/l Fe solution) was aspirated to an absorbance of 0.4A

- The highest standard of aspiration was set at absorbance between 0.1 and 0.8A to

Auto zero the instrument and aspirate the calibration standards. Measure and store the absorbance readings. These were used for generation of the calibration curve.

CALCULATION

All results were recorded to two decimal places.

The concentration of the analyte (e.g. Fe) in water samples digested was calculated as follows:

Fe conc. mg/l = (A*B)/C

Where A= conc. Of metal in digested sample mg/l

B= volume of digested solution in ml

C= sample vol. in ml

(U.S.EPA 1983 Manual)

3.4 ATOMIC ABSORPTION SPECTROPHOTOMETER (AAS)

The AAS was used to determine level of heavy metal (copper, zinc, nickel, cadmium, mercury, chromium, iron manganese, lead) in the tap water.

A blank sample was prepared from de- mineralized water as well as reference standard solution for the individual parameters and used to calibrate the instrument.

The instrument was adjusted to achieve the acceptable calibration parameters as shown in table 3.1. Once that was done the sample was run to determine the metal level in it.

Figure 3.1 THE AAS OPERATING CONDITIONS

Table: 3.1 AAS operation conditions

Parameters	Cu	Zn	Ni	Cd	Hg	Cr	Pb
Wavelength(nm)	324.7	213.9	232.0	228.9	253.7	357.9	283.2
Slit width(nm)	0.5	1.0	0.2	0.5	0.5	0.2	1.0
Sensitivity (ppm)	0.03	0.009	0.066	0.011	0.05	0.055	0.11
Detection limit (ppm)	0.01	0.002	0.008	0.0006	0.003	0.005	0.02
Op. working range	0.5	1.0-4.0	3.0-12	0.5-2.0	0.5-10.0	2.0-8.0	5.0-20

CHAPTER FOUR

RESULTS AND DISCUSSION

4.1 CONCENTRATION OF HEAVY METALS

The analysis was carried out at five different locations at Tema municipal assembly to determine the level of heavy metal in tap water. Table 4.1 shows the various results of heavy metals concentration of the selected sampling points of the study.

Table 4.1: Concentration of Heavy Metals

Sample ID	Iron (mg/l)	Nickel (mg/l)	Manganese (mg/l)	Zinc (mg/l)	Copper (mg/l)	Lead (mg/l)	Cadmium (mg/l)	Chromium (mg/l)	Mercury (mg/)
Kw1	0.041	0.012	0.012	0.207	0.033	0.025	<0.002	<0.010	<0.001
Kw2	0.037	0.039	<0.005	0.011	0.029	<0.005	<0.002	<0.010	<0.001
Kw3	0.048	0.034	<0.005	0.017	0.035	<0.005	<0.002	<0.010	<0.001
Kw4	0.010	<0.010	0.017	0.023	<0.020	<0.005	<0.002	<0.010	<0.001
Kw5	0.028	0.025	<0.005	0.011	<0.020	0.046	<0.002	<0.010	<0.001
WHO guideline	0.3	0.02	0.4	2.0	2.0	0.01	0.003	0.01	0.001

Where kw1 = Tema community 12. kw2 = Tema booster station, kw3 = Tema new town, kw4 = Tema community 9, kw5 = Tema heavy industrial area.

In Table 4.2, the study shows the concentration levels of the treatment plant, showing the various heavy metals concentrations.

Table 4.2: Treatment Plant Analysis Results

Sample mg/l	iron	nickel	Manganese	zinc	Copper	Lead	Cadmium	chromium	Mercury
Conc.	<0.1	<0.001	<0.0005	0.01	<0.020	<0.0005	< 0.002	< 0.010	< 0.001

WHO guidlin	0.3	0.02	0.4	2.0	2.0	0.01	0.003	0.01	0.001

4.2.1 Concentration of Iron at Sampling Points

The concentration of iron in the samples for the five locations is shown in Figure 4.1. The level of iron content in the sample was highest in the sample kw3 and lowest in the sample kw4.

The concentrations of iron in all samples are below WHO standard which is 0.3mg/l. The important of iron in human life cannot be overemphasized since the shortage of iron can cause the disease called anemia. It involved in the transport of oxygen and the regulation cell grow and differentiation and also provide hemoglobin. Insufficient iron in human body leads to fatigue, decreased immunity or iron- deficiency anemia. However, excess iron in the body can be dangerous and since the body has a limited capacity to excrete iron, the excess iron can build up in the liver, pancreas and heart organ leading to the disease called hearmosiderosis. (Rajappa **et al., 2010**; Bhaskar **et al., 2010**) It also dangerous because iron is a potent oxidizer and can damage the body tissues leading to serious health issues such as liver cancer, cardiac arrhythmias, diabetes, bacterial and viral infections, and cirrhosis.

Besides high iron concentration will stain whatever it is used to wash, including laundry, bathroom fixtures, sink, toilet, and silverware and can also cause water to become discolored and appear brownish and taste metallic

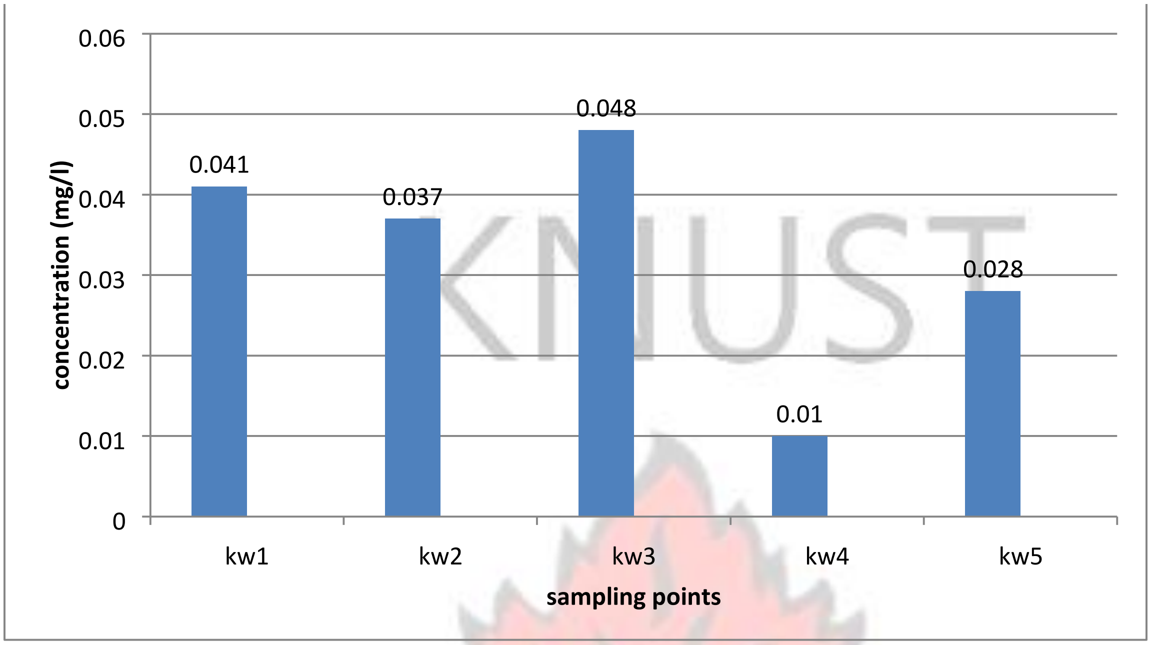


Figure 4.1 concentration of iron in water samples at sampling points.

4.2.2 Concentration of Nickel

The analysis shows that nickel is present in the sample and the concentration of Nickel in samples 2, 3, and 5 were significantly above the recommended value of WHO standard which is 0.02 mg/l. However, the content was significantly lower in sample 4 (Figure 4.2).

Nickel is predominantly used in its metallic form united with other metals and nonmetals as alloys. It is estimated that 8% of nickel is used for household appliance (IPCS, 1991). Leaching from metals such as pipes, valves, fittings in contact with drinking water is the main source of nickel in the water. However, dissolution from nickel ore- bearing rocks present in fresh water bodies can increase the level of nickel in drinking water. The increase of nickel in the samples 2, 3 and 5 may be attributed to leaching of nickel ions from the surface of pipes and fittings but not corrosion. Also due to industrial activities and pollution caused by the highly populated area around Tema Newtown may have resulted in significant increase of nickel in the water.

Allergic contact dermatitis is the most prevalent effect of nickel in human and excessive injection of nickel chronically results in vomiting, giddiness, headache, nausea, diarrhea, lassitude, and shortness of breath.

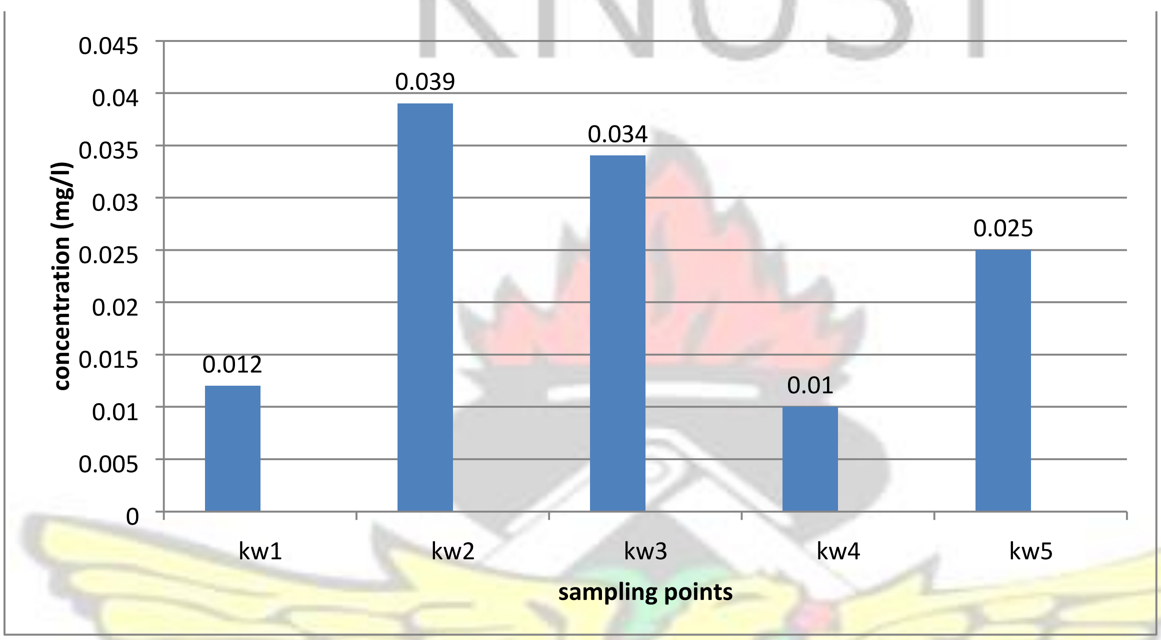


Figure 4.2: concentration of nickel in water samples at sampling points.

4.2.3 Concentration of Manganese

Although manganese is not a health concern in drinking water its presence can cause water hardness. Because of its bitter metallic taste property it makes water undesirable and unpleasant to drink and use in the home. Manganese causes a dense black stain, stain plumbing fixtures and Laundry and can form coatings on water pipes that with time slough off as black precipitate. For these reasons, WHO recommended that manganese level in drinking water should not be more than

0.4 mg/l. From the results it was observed that although the concentration of manganese is higher in sample 4 and lower in samples 2, 3 and 5 all the five samples were within the required standard (Figure 4.3).

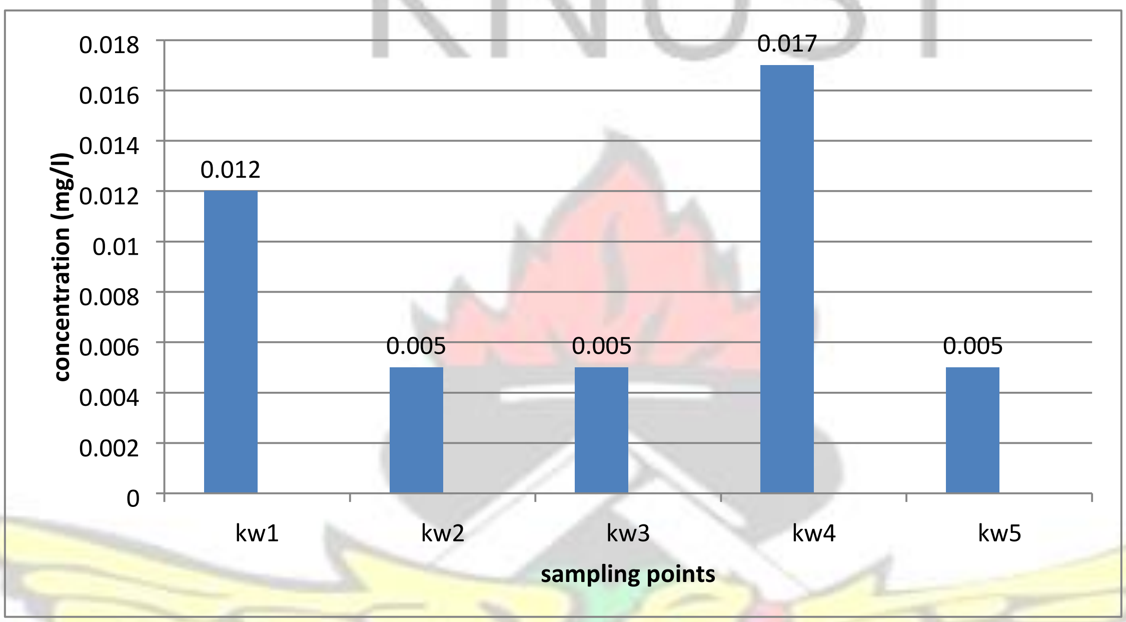


Figure 4.3: concentration of manganese in water samples at sampling points.

4.2.4 Concentration of Zinc

The level of zinc is extremely high in sample 1 and lower in sample 2 and 3. However the concentrations of all samples are below the acceptable limits proposed by WHO which is 2.0 mg/l. High carbon dioxide content, low pH and low mineral salts content are the typical characteristics of corrosive water and therefore zinc concentration can be high as a result of the leaching of zinc from fittings and piping. Also older galvanized metal pipes and well cribbing were coated with zinc may be dissolved by soft, acidic waters.

Zinc is a very important nutrient for body growth and development. However Consumption of more than 500 mg of zinc sulfate leads to acute toxicity, vomiting, pulmonary distress, chills, fever, gastroenteritis, diarrhea, and nausea, sometimes accompanied by bleeding and abdominal cramps. Also corrosion of pipes, bad tasting water, cloudy water, stomach problem, and possible cognitive issues are some of the causes of high level of zinc in our body. On the other hand low concentration of zinc can cause slow wound healing decreased sense of taste and smell, skin sores, damage in immune system and loss of appetite. (Fosmire G.J February, 1990).

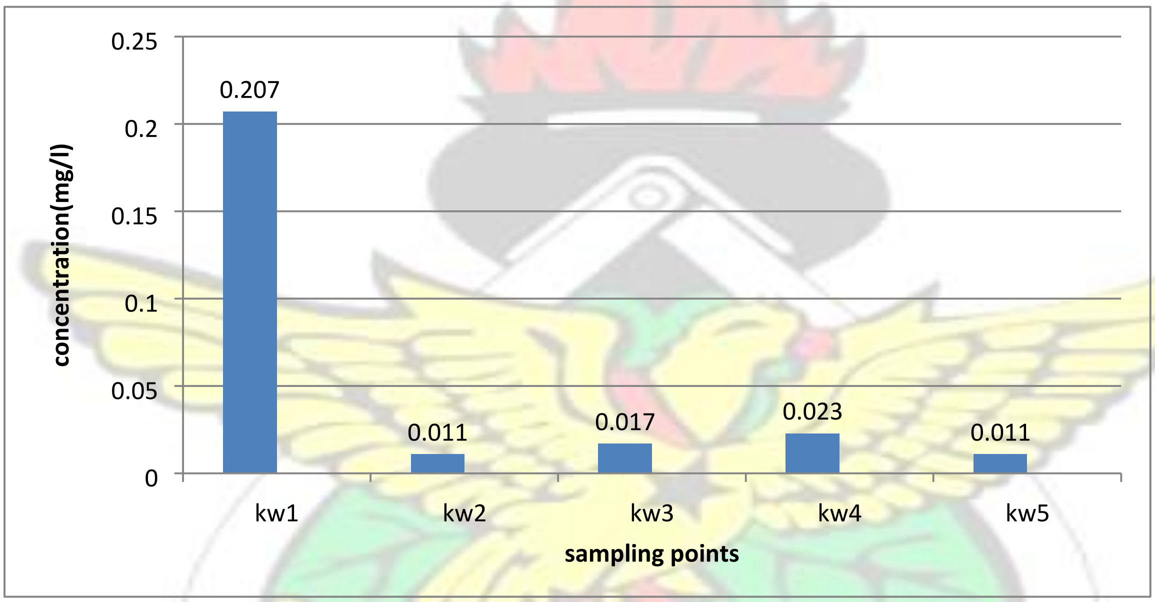


Figure 4.4 concentration of zinc in water samples at sampling points.

4.2.5 Concentration of Copper

From Figure 4.5, the concentration of copper is highest in the sample 3 and lowest in samples 4 and 5. However all the five samples were within the WHO required standard. WHO recommends that the concentration of copper in drinking water should not exceeds 2.0 mg/l. The concentration of copper in potable water varies as a result of variations in the characteristic of water such as hardness, pH, and copper availability in the distribution system.

The concentration can also increase during distribution, mainly in a system with an acid pH or high carbonated waters with an alkaline pH. Copper is essential for proper functioning of enzymes such as superoxide dismutase, ceruloplasmin, cytochrome-c oxidase, tyrosinase and monoamine oxidase its contact can cause headache, diarrhea, vomiting and vomiting at low dose.
Moreover, heamolysis, nephron toxic effect and hepatotoxic, convulsions, cramps, vomiting and even death are the results of extensive intake of copper.

Increase doses of copper can result in chronic anemia, gastrointestinal bleeding, hepatocellular toxicity, renal failure and oligouria. (Acharya **et al., 2008**)

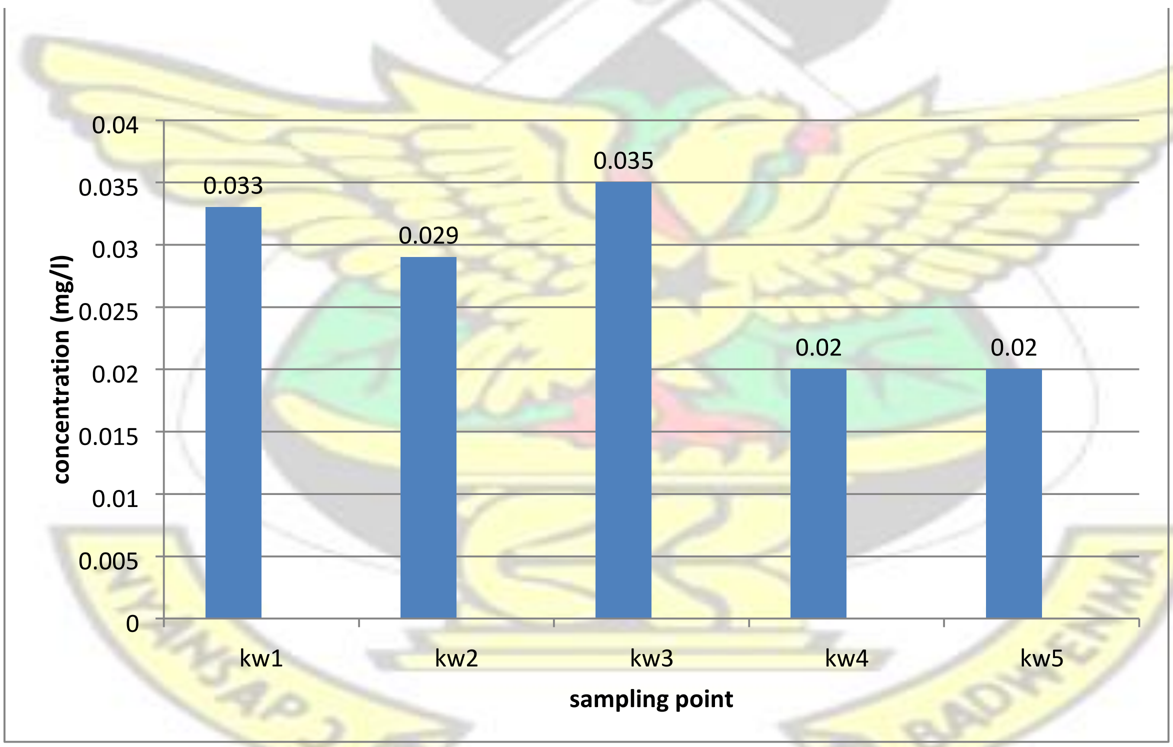


Figure 4.5: concentration of copper in water samples at sampling points.

4.2.6 Concentration of Lead

The most significant of all the heavy metals is lead because of its toxicity. Is very harmful and even small amount can lead to death. (Gregoriaadou **et al., 2001**). Lead is a toxic heavy metal found in water from the corrosion of plumbing materials, automobile exhaust, mining waters, incinerators, paint, lead pipes and solder. In all the five samples, lead content is highest in sample 5, followed by sample 1 and lowest in the remaining three samples. The concentration of lead in sample 5 and 1 are 0.046 and 0.025, respectively. These values are higher than the recommended lead content standard for drinking water given by WHO. Usually lead contamination generates mostly during water transportation from the processing plant through the distribution system right down to consumer household faucet and plumbing systems in the apartment. This contamination may originate from lead solder, lead lined pipes, and brass plumbing fixtures inside the apartment.

Lead can be inhaled in dust from lead paints, or waste gases from leaded gasoline.

The delay in mental and physical development in infant and children are mainly cause by lead. Also brain damage and nervous system, kidneys, cancer, hypertension and hyperactivity are caused by excessive lead intake. (Hanaa **et al., 2000**)

Besides excessive intake of lead can lead to the disruption of the biosynthesis of hemoglobin and anemia, kidney damage, high blood pressure, miscarriage (subtle abortion) and brain damage.

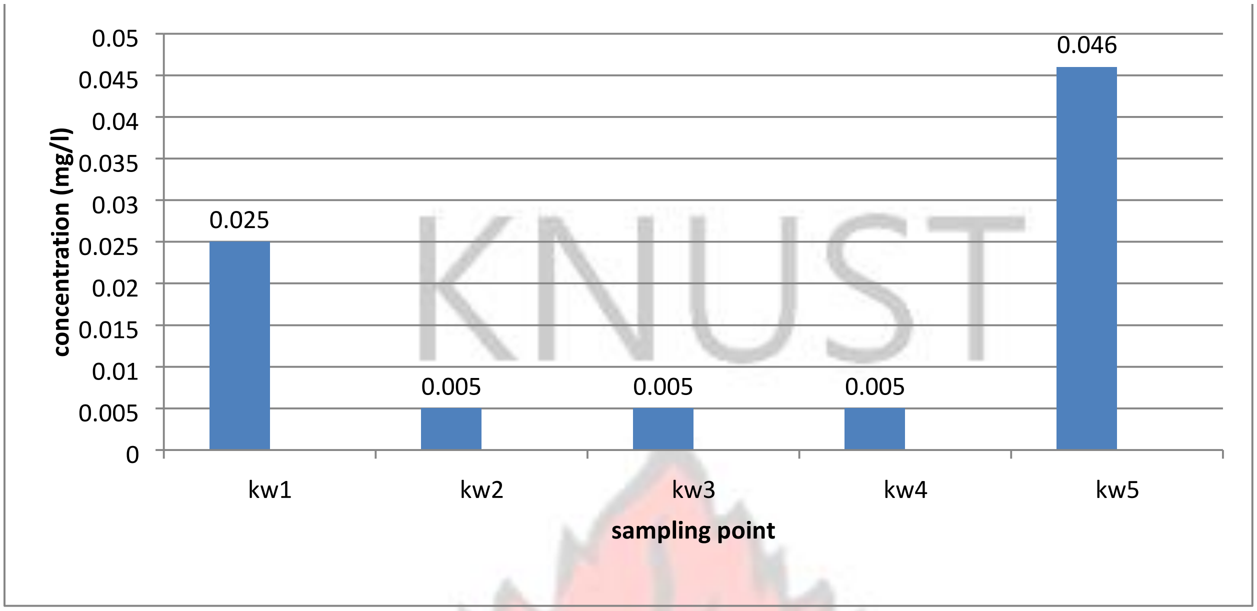


Figure 4.6: concentration of lead in water samples at sampling points.

4.2.7 Concentration of Cadmium

The presence of cadmium in drinking water is due to corrosion of zinc coated or galvanized pipes and fittings. (Danamark. Com 2008). It occurs in association with zinc and at maximum concentrations it is known to have a toxic potential. From the analysis it was concluded that the level of cadmium in all the five samples were lower than the recommended WHO requirement which is 0.003 mg/l. The levels of cadmium were all less than 0.002 mg/l which is less than the 0.003 mg/l recommended value. Cadmium can be generated from industrial activities such as electroplating, stabilizers, battery industries, plastics, pigments, water near industrial areas and hazardous waste sites. (Nassef **et al., 2006**)

From the analysis the concentration of cadmium is lower and therefore the water is potable and free from health effect such as nausea, diarrhea, salivation, convulsions, vomiting, muscle cramps, sensory disturbances, shock and renal failure and liver injury. Small quantities of cadmium cause adverse changes in the arteries of human kidney. It replaces zinc biochemically and causes high blood pressures and kidney damage. (Idris, 2008)

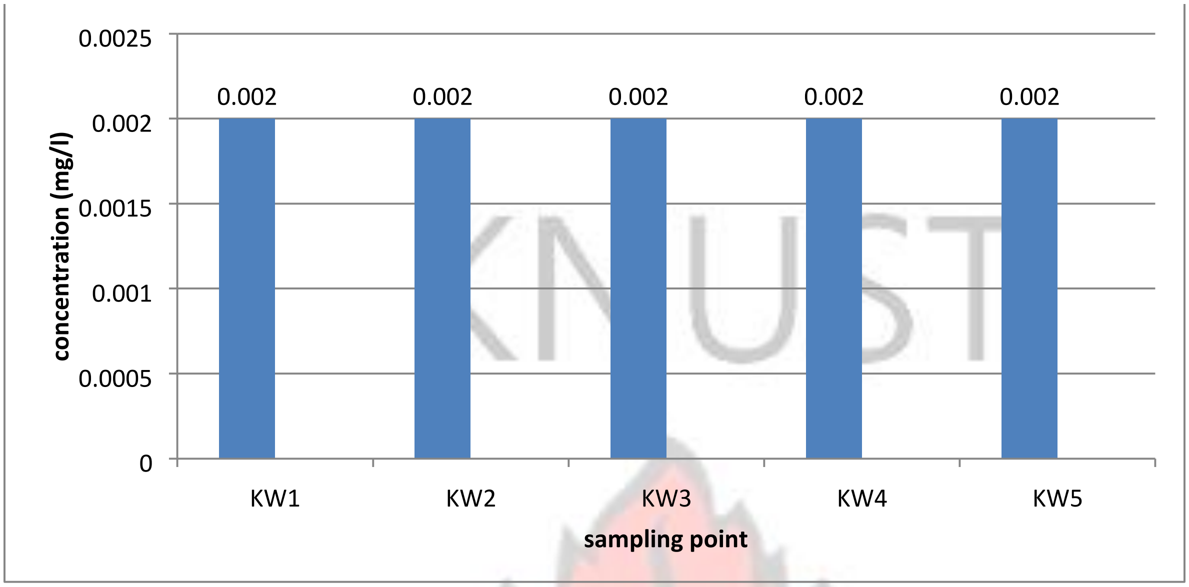
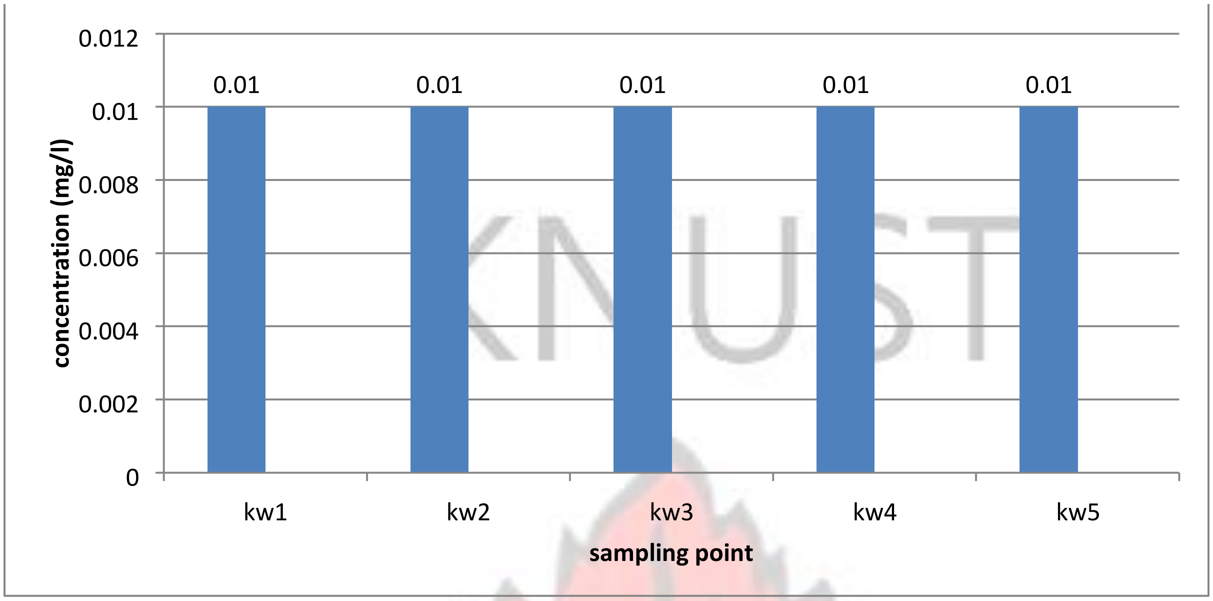


Figure 4.7 concentration of cadmium in water samples at sampling points.

4.2.8 Concentration of Chromium

The importance of chromium cannot be overemphasized since is a micronutrient for plants and animals. Generally the natural content of chromium in potable water is low except regions with substantial chromium deposits. From the analysis it was realized that the concentration of chromium in all the five samples (figure 4.8) were below the required standard proposed by WHO. WHO recommends that the maximum acceptable level of chromium in drinking water is 0.01mg/l but the total chromium metal content detected from the analysis was less than 0.01mg/l. Because sodium dichromate solution is used to prevent corrosion in piping the level of chromium in potable water is always low. Excess chromium can be toxic especially in the hexavalent form and subsequent exposure to chromic acid can cause dermatitis and ulceration of the skin, liver, kidney, and nerve tissue damages. (Hanaa **et al**, 2000; pandey **et al** 2010; Idris, 2008). Apparently, chromium is commonly used as a coating for the protection of alloys and metals, owing to its high resistance to corrosive agents



Finger 4.8 concentration of chromium in water samples at sampling points.

4.2.9 Concentration of Mercury

From figure 4.11 all the five samples had their concentrations less than the WHO maximum admissible limit of mercury in drinking water which is 0.001 mg/l.

The presence of Mercury in water was from the leaching of soil due to acid rain, residential and mining waste, coal burning, and landfills cropland and run off. There are various forms of mercury. Methyl mercury is one of the most common highly toxic mercury. It is found in shellfish, fish and animals that consume fish.

An excessive intake of mercury can lead to kidney damage, poor vision, lungs damage, brain and heart problem, disturbances in sensations (pins and needles feelings), impairment of speech, lack of coordination, walking and muscle weakness, emotional changes, headaches and performance deficits on tests of cognitive function. (Stockinger 1981). Finally, in the bloodstream of unborn babies and young children methyl mercury may prevent development of the nervous system, making the child less able to think and learn.

Like many environmental contaminants, mercury undergoes bioaccumulation.

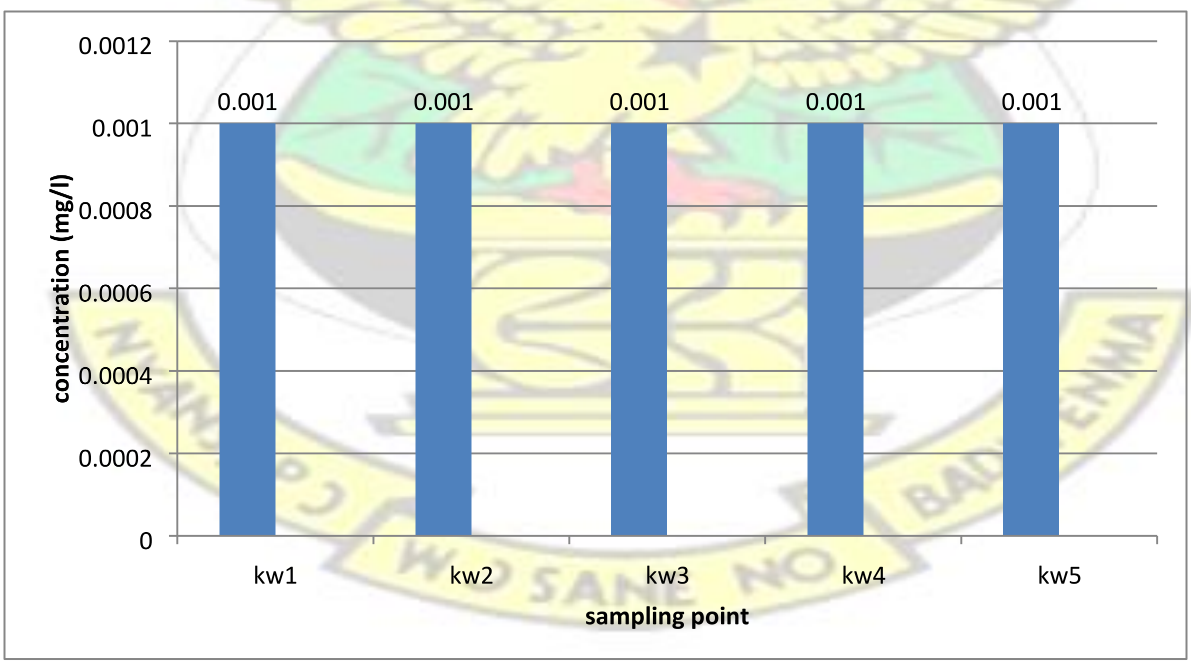


Figure 4.11 concentration of mercury in water samples at sampling points.

4.3 HEALTH RISK ASSESSMENT OF HEAVY METAL

In order to assess the concentration of the nonconforming metals (table 4.3) lead and Nickel for a possible risk assessment, the average concentration of the metals were estimated to represent a probable concentration of Nickel and Lead. Though the value obtained was deterministic it does present a probable estimate due to the challenge that, the available data was not enough to fit a probabilistic distribution to quantify it.

Table 4.3 Table of nonconformance parameters

Sample ID	**Nickel**	**Lead**
KW 1	0.012	0.025
KW 2	0.039	<0.005
KW 3	0.034	<0.005
KW 4	<0.010	<0.005
KW 5	0.025	0.046
WHO GUIDELINE	0.020	0.010

Therefore, average concentration was estimated as follows at the various sampling points

$$\text{Average value of nickel} = \frac{kw\ 1+kw\ 2+kw\ 3+kw\ 4+ kw\ 5}{5}$$

$$\text{Average value of nickel} = \frac{0.012+0.039+0.034+0.010+0.025}{5}$$

$$= \frac{0.12}{5}$$

$$= 0.024 \text{ mg/l}$$

$$\text{Average value of lead} = \frac{0.025+0.005+0.0050.005+0.046}{5}$$

$$\frac{0.086}{5}$$

$$= 0.0172 \text{ mg/l}$$

Furthermore, for a chemical risk assessment, the reference dose is needed in order to compare the results and thus model the risk to exposure due to drinking. The reference dose for both lead and nickel is as shown in Table 4.4. It should be noted that, oral slope factor for nickel compound is not available.

Table 4.4: Toxicity reference values selected for human risk assessment

SOPC	RfD(mg/kg/day)	Pf	Oral TRV	Source
Nickel	0.02	N/A	Decreased and body organ weight	USEPA 1996
Lead	0.02	0.009	Kidney damage	USEPA 2006

An oral slope factor is not available for any nickel compound.

4.3.1 NON- CANCER RISK ASSESSMENT

AVERAGE DAILY DOSE (ADD)

Average daily dose which is the assumed maintenance dose per day is calculated as

$$ADD = \frac{CW \times DI}{BW}$$

Where CW = Contaminant concentration in water

DI = average daily intake

BW = average body weight

Therefore ADD for nickel = 0.024mg/l x 2.6 L per day

$$\frac{}{64kg}$$

$= 9.75 \times 10^{-4}$mg/kg day

ADD for lead = $\frac{0.0172mg/l \times 2.6 \text{ L per day}}{64kg}$

$= 6.9875 \times 10^{-4}$mg/kg day

The average daily consumption of contaminated water contains 9.75×10^{-4}mg/kg day of nickel and 6.9875×10^{-4}mg/kg day of lead. This enables us to calculate the exposure rate for ingestion of water.

4.3.1.1 HAZARD QUOTIENT OF THE METALS

Some chemicals do not demonstrate a threshold response. Lead and ozone are two examples of chemicals with non-cancer effects that do not have a threshold below which no adverse effects are observed. In addition, non-cancer estimate only identifies the exposure level below which adverse effects are unlikely.

$$\text{Hazard Quotient} = \frac{\text{Average Daily Dose (ADD)}}{\text{Reference Dose (RfD)}}$$

$$\text{Hazard quotient of nickel (HQ)} = \frac{9.75 \times 10\text{-}4 \text{ mg/kg day}}{0.02\text{mg/kg day}}$$

$= 0.04875$

$$\text{Hazard quotient of lead (HQ)} = \frac{6.9875 \times 10^{-4} \text{ mg/kg day}}{0.02\text{mg/kg day}}$$

= 0.034938

Average Daily Dose is divided by RfD to get the Hazard Quotient (HQ). The HQ has been defined so that if it is less than 1.0, 1the should be no significant risk or systemic toxicity.

However ratios above 1.0 could represent a potential risk. The hazard quotient of nickel and lead are far less than 1, this implies no potential risks to consumers.

4.3.1.2. HAZARD INDEX OF THE 2 NONCONFORMANCE PARAMETERS

Non-cancer estimate only identifies the exposure level below which adverse effects are unlikely.

Hazard index (HI) = Σ HQ

= HQ (nickel) + HQ (lead)

HI = 0.04875+0.034938

= 0.0856

When exposure involves more than one chemical the sum of the individual hazard quotients for each chemical is used as a measure of the potential for harm and since the hazard index is less than 1, it implies the water is safe.

4.3.2 CANCER RISK ASSESSMENT

To assess the health risk of these metals, we first have to look at the exposure assessment which involves measuring or estimating the intensity, frequency and the duration of exposure to the default exposure parameters (heavy metals).

4.3.2.1 CHRONIC DAILY INTAKE (CDI)

Exposure expressed as mass of a substance contacted per unit body weight per unit time averaged over a long period of time usually 70 years.

$$CDI = \frac{CW \times IR \times EF \times ED}{BW} \times \frac{1}{AT}$$

$$CDI = \frac{CW \times CR \times EFD}{BW} \times \frac{1}{AT}$$

Where CDI is chronic daily intake by injection (mg/kg day)

CW = concentration in water (mg/L)

IR (CR) = ingestion rate or contact rate (L/day)

EF = exposure frequency (days/year)

ED = exposure duration (years)

BW = average body weight (64kg)

AT = averaging time (70 years)

Chronic daily intake of iron (CDI)

CDI = $\underline{CW \times CR \times EFD}$ X $\underline{1}$

BW AT

For convenience, conservative default exposure parameters as suggested by USEPA (1997) are used for exposure quantification

Assuming a period of 5years CDI exposure rate for ingestion of water is calculated as below.

Chronic daily intake of nickel (CDI)

$$CDI = \frac{0.024mg/L \times 2.6L/day \times 365days/year \times 5years}{64\ kg \times 70years \times 365\ days/\ years}$$

$$=6.964 \times 10^{-5}\ mg/kg\ day$$

Chronic daily intake of lead (CDI)

$$CDI = \frac{0.0172mg/L \times 2.6L/day \times 365day/years \times 5years}{64kg \times 70years \times 365\ days/years}$$

$$= 4.991 \times 10^{-5}\ mg/kg\ day$$

The probability of getting cancer (not the probability of dying of cancer) and the associated dose for a period of 70 years, the exposure concentration of contaminated water intake or ingested was calculated as 6.964×10^{-5} mg/kg day (nickel) and 4.991×10^{-5} mg/kg day (lead).

4.3.2.2 INCREMENTAL LIFETIME RISK OF CANCER

Risk estimate represents the incremental probability that an individual will develop cancer over a lifetime as a result of specific exposure to a carcinogenic chemical.

RISK = (CDI) (Potency factor)

Incremental life time risk of lead = (4.991×10^{-5} mg/kg day) x 0.009

$$= 4.499 \times 10^{-7} \text{ (lead)}$$

The results indicates that, for a 5 year period there is approximately 5 out of 10,000,000 people exposed to the level of lead is likely to suffer from cancer related diseases.

CHAPTER FIVE

CONCLUSION, SUMMARY OF FINDINGS AND RECOMMENDATIONS

5.1 CONCLUSION

This study was carried out to assess the quality status of municipal water supply with special emphasis on heavy metal.

Nine metals were detected in five samples collected in Tema metropolitan area. All the nine metals (iron, nickel, manganese, zinc, copper, lead, cadmium, chromium and mercury) were analysed using Atomic Absorption Spectrophotometer. From the analysis, it was found out that only the concentration of nickel and lead were higher than the WHO admissible limit. Therefore it was necessary to calculate the hazard quotient of both nickel and lead and also incremental lifetime risk for lead Since Lead is both a non-carcinogen, and potential carcinogen to quantify the impact on human health.

It is stated that, if hazard quotient (HQ) is greater than 1, the exposed population is assumed to be at risk, else not.

Also risks values exceeding 1×10^{-4} are regarded as intolerable, risks less than

1×10^{-6} are not regarded to cause significant health effects and risks lying between 1×10^{-4} and 1×10^{-6} are regarded generally as satisfactory range.

Although the level of nickel and lead were slightly higher than the WHO permissible limit their hazard index and incremental lifetime risk were calculated to be 0.0866 and 4.499×10^{-9} respectively.

Since hazard quotient is far less than 1, and the risk value of 4.499×10^{-9} is also far less than 1×10^{-6} it implies no health risk is associated with the water and therefore no danger from its consumption or simply it effect on human health is insignificant and therefore the water is potable.

5.2 SUMMARY OF FINDINGS

1. The significant increase or change in parameter may be due to the transportation of the potable water from the processing station (source) to consumer premises (storage).

2. Dead ends where dirt accumulates may lead to stagnation and also when there is burst on the pipeline contaminants are leached from the soil into the water to record high toxic level.

3. During transportation especially at low pH or in acidic medium the content of the distribution pipelines is corroded and leached into the water thereby increasing concentration of the various metals.

4. Secondly many water quality problems are directly associated with water retention storage facilities.

5. The indication of nickel pollution could be due to leaching from metals such as pipes, valves, fittings in contact with drinking water or probably dissolution from nickel ore- bearing rocks present in fresh water bodies can increase the level of nickel in drinking water.

6. Usually lead contamination generates mostly during water transportation from the processing plant through the distribution system right down to consumer household faucet and plumbing systems in the apartment. This contamination may originate from lead solder, lead lined pipes, and brass plumbing fixtures inside the apartment.

5.3 RECOMMENDATION

The flow pressure, and volume of water in storage are major contributing factors that influence water quality.

By integrating the concept with volume and pressure requirement many future water quality problems can be avoided.

This thesis recommends

1. Ghana Water Company authorities should ensure the following:

   - Generally use lined ductile iron, concrete pressure and polyvinyl chloride pipes for the distribution of tap water since they are the most favourable materials for maintaining water quality.
   - Most water quality problems in the distribution systems can be controlled by effectively addressing the issues of water retention storage facilities.

   - They must maintain positive pressure and control the direction and velocity of bulk water.

2. Also consumers must minimize bulk water retention time (control water age)

3. Waste disposal into fresh water bodies must stop immediately.

4. The thesis also recommends further study to be conducted which are of chemical, biological and physical parameters on important public health concern.

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APPENDIX

Appendix 1: Mixing basins at kpong headworks

Appendix 2: Kpong filter house

Appendix 3: Master Control Room

Appendix 4: The view of Volta LAKE

Appendix 5: sampling point

Appendix 6: Spiral wound membrane element