

**EVALUATION OF THE MICROBIOLOGICAL AND PHYSICOCHEMICAL
QUALITY OF BOREHOLE WATER IN THE OFFINSO DISTRICT OF
ASHANTI REGION**

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ABSTRACT

The quality of borehole water from seven administrative town councils namely Asuoso (AS), Akenkaasu (AK), Samproso (SA), Abofour (AB), Offinso (OF), Afrancho (AF) and Bonsua (BO) in the Offinso District of Ashanti region were analysed from January 2007 to June 2007. Water samples were collected from thirty-five boreholes comprising five boreholes in each town council and analysed for temperature, pH, colour, turbidity, conductivity, total dissolved solids, alkalinity, hardness and some selected anions (PO_4^{3-} , NO_2^- , SO_4^{2-}) some heavy metals (Cd, Cu, Zn, Mn and Pb), total and faecal coliforms. From the results, pH of the water was slightly acidic (5.03-6.53) and was unaffected by the seasonal variation. The water was moderately soft to slightly hard (12.8-226.80mg/l CaCO_3). The nutrient loads observed in the water were slightly low and fell within the WHO standards. There were isolated cases of cadmium contamination at Asuoso (AS), Abofour (AB) and Bonsua (BO) recording 0.00198, 0.00124, 0.00158 and 0.00164, respectively. With the exception of pH, all the other parameters analysed were influenced by seasonal variations. There was a general increase in all the parameters during the wet season with turbidity, conductivity and total dissolved solids recording high values. The mean total coliforms ranged between 10 and 20CFU/100ml while all the samples analyzed recorded zero for faecal coliforms. The results suggest that borehole water sources in the Offinso district were of acceptable quality.

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LIST OF ABBREVIATIONS

CSWA.....	Community Water and Sanitation Agency
WHO.....	World Health Organisation
EPA.....	Environmental Protection Agency
AAS.....	Atomic Absorption Spectrophotometer
APHA.....	American Public Health Association
TDS.....	Total dissolved solids
ACS.....	American Chemical Society
CBO.....	Community Based Organisation
NGO.....	Non-governmental Organisation
USEPA.....	United State Environmental Protection Agency
MDG.....	Millennium Development Goals
UNEPA.....	United Nations Environmental Programme
UNO.....	United Nations Organisation
AWWA.....	American Water Works Association
USGS.....	United States Geological Services
IDPH.....	Illinois Department of Public Health
WVI.....	World Vision International
WRI.....	Water Research Institute

CHAPTER ONE

1.0 INTRODUCTION

Water is one of the earth's most precious resources. Although water is essential for human survival, many are denied access to sufficient potable drinking water supply and sufficient water to maintain basic hygiene. Globally, 1.1 billion people rely on unsafe drinking water sources from lakes, rivers and open wells. The majority of these are in Asia (20%) and sub-Saharan Africa (42%). Furthermore, 2.4 billion people lack adequate sanitation worldwide (WHO/UNICEF, 2000).

In developing countries, thousands of children under five years die every day due to drinking contaminated water (WHO, 2004). Thus lack of safe drinking water supply, basic sanitation and hygienic practices is associated with high morbidity and mortality from excreta related diseases.

Water-borne pathogens infect around 250 million people each year resulting in 10 to 20 million deaths world-wide. An estimated 80% of all illness in developing countries is related to water and sanitation and 15% of all child deaths under the age of five years in developing countries result from diarrhoeal diseases (WHO, 2004; Thompson and Khan, 2003).

The lack of safe drinking water and adequate sanitation measures could also lead to a number of diseases such as dysentery, salmonellosis, shigellosis and typhoid, and every year millions of lives are claimed in developing countries.

The evaluation of potable water supplies for coliform bacteria is important in determining the sanitary quality of drinking water. High levels of coliform counts indicate a contaminated source, inadequate treatment or post-treatment deficiencies (Mathew *et al.*, 1984). Many developing countries suffer from either chronic shortages of freshwater or the readily accessible water resources are heavily polluted (Lehloesa and Muyima, 2000).

Microbiological health risks remain associated with many aspects of water use, including drinking water in developing countries (Craun, 1986), irrigation reuse of treated wastewater and recreational water contact (Grabow, 1991). It has been reported that drinking water supplies have a long history of association with a wide spectrum of microbial infections (Grabow, 2000).

The primary goal of water quality management from a health perspective is to ensure that consumers are not exposed to doses of pathogens that are likely to cause diseases. Protection of water sources and treatment of water supplies have greatly reduced the incidence of these diseases in developed countries (Craun, 1986; Grabow, 2000).

In Ghana urban water supply coverage is only 70% of the total water requirements in the urban areas of Ghana. Out of the 70% only 40% can boast of regular water supply. (CWSD, 1999).

One of the goals of the United Nations Millennium Development Goals (MDG's) is to reduce persistent poverty and promote sustainable development worldwide especially in developing countries. Improvement of drinking water supply and sanitation is a

core element of poverty reduction. The MDG target for water is to halve by 2015 the proportion of people without sustainable access to safe drinking water and basic sanitation. The WHO (2004) estimates that if these improvements were to be made in sub-Saharan Africa alone, 434,000 child deaths due to diarrhoea would be averted annually.

This MDG target will at least reduce the above numbers of people without potable water and adequate sanitation. The provision of portable water supply especially in developing countries may not be sufficient because of (a) high population growth, (b) conflict and political instability, and (c) low priority given to water and sanitation programmes.

Boreholes are low-cost technology option for domestic water supply in developing countries and are generally considered as 'safe sources' of drinking water. When properly constructed and maintained, they provide consistent supplies of safe and wholesome water with low microbial load and little need for treatment of the water before drinking.

Water exists in several forms in the environment including sea water, sea-ice, fresh water, and water vapour as clouds and mist. As water moves through the environment it picks up gases and elements, flows to the sea and through ground in an endless process known as the hydrologic cycle.

The hydrological cycle ensures that water available on the earth passes through a cycle of evaporation, condensation and ultimately back to water in what seem endless

and renewable. Groundwater occurs as part of the hydrologic cycle, which is the movement of water between the earth and the atmosphere through evaporation, condensation, transpiration and precipitation. The underground area where groundwater exists is referred to as an aquifer.

Groundwater comes from three major aquifer zones (underground rock or sediment that is permeable and can conduct water) generally situated from 300 to 1,500 feet below land surface. This drinking-water supply (groundwater) is protected from surface contamination by a layer of clay and fine-grained sediments. The level of ground water in the borehole may undergo changes due to the recharge and discharge rate. The rate at which a borehole is recharged may vary due to responses to withdrawal from wells through pumping, as leakage to vertically adjacent aquifers, as natural flow from an aquifer into streams and springs and also through evaporation from the shallow water tables.

1.1 Problem statement

In an effort to provide safe drinking water to the rural and urban dwellers, the government of Ghana in conjunction with development partners, Non Governmental organization (NGO's), Community Based Organisation (CBO's) and some individuals have exploited the groundwater reserves since ground water is believed to be cleaner and therefore do not need further chemical treatment before consumption.

Several practices such as fertilizer application, agrochemicals, abandoned or inactive mine site, septic tanks, landfill etc, if not managed effectively could result in the contamination of groundwater.

Microbiological health risks remain associated with many aspects of water use. Some microorganisms are native or adapted to saturated sediments and rock, and are present in significant numbers in most water supply aquifers and even deep geological formations ([NGWA](#), 1986). Biofilm formation sometimes encourages the growth of bacteria in wells and ground water. The quality of water in boreholes is also affected by the presence of heavy metals such as, Pb, Mn, Cd, Cu, Fe, Zn, K, Ni and Na.

Meteorological events and pollution are a few of the external factors, which affect physicochemical parameters such as temperature, pH, and turbidity of the water. They have a major influence on biochemical reactions that occur within the water. Sudden changes in these parameters may be indicative of changing conditions in the water. Internal factors on the other hand include events which occur between and within bacterial and plankton populations in the water body (Nishiguch, 2000).

The United Nations Organisation (UNO) designated 1981-1990 as the International Drinking Water Supply and Sanitation Decade with the aim of providing safe drinking water and adequate sanitation for all. Close to 11,500 boreholes have been drilled nationwide and about 60,000 hand dug wells have been constructed. This represents a total average increase from 14% in 1984 to about 52% in 1990 of the rural population (WRI, 1992).

The ground water resources of the country has been fairly assessed from some geologic formations in terms of borehole yield, static water levels and water quality in some parts of the country especially in the Volta Region where almost all the springs have been identified and some have been developed and or are being developed (WRI, 1992).

The Offinso District can boost of a number of such boreholes which has been in use for several years. Most of the wells since being constructed have scarcely been maintained, rehabilitated or any major assessment carried out on the quality of water being pumped from it. This study was to determine the quality of water from these boreholes, as to ascertain its safety for consumption in relation to standards set by the World Health Organisation (WHO) for drinking water.

1.3 JUSTIFICATION

The issue of accessibility to clean water is of global magnitude. The global environmental outlook report indicates that about 30% of the world's population lack access to safe drinking water. The consumption of water worldwide increases yearly while most of the world's water resources continue to dwindle due to improper environmental management practices (UNEP, 2000). Globally, more than twenty five thousand people die daily as a result of water related diseases. (WHO, 2002) Ghana has its fair share of problems from the water sector. To achieve the Millennium Development Goals (MDG) targets, for the period 2004 – 2015, data collected by Community Water and Sanitation Agency (CWSA) and Ghana Water Company Limited (GWCL) in 1998, as part of their strategic investment plans estimate that, every year an average of 596,000 people need to gain access to an improved water supply.

1.2 OBJECTIVES

The objective of this research is to determine the quality of water from the boreholes in the Offinso district of Ashanti Region.

The specific objectives were to;

- Determine the levels of these parameters in the borehole water: temperature, pH, Conductivity, total dissolved solids (TDS), colour, turbidity, PO_4^- , SO_4^- , CL^- , NO_2^- Zn, Cd, Pb, Mn and Cu.
- Determine the effect of seasonal variation on the parameters.
- Access the level of Faecal and total coliform in samples.
- Compare the level of the parameters to WHO standards.



CHAPTER TWO

2.0 LITERATURE REVIEW

2.1 How water get into the ground

Whenever it rains, some of the water flows on the land surface into rivers, lakes and streams some evaporates into the atmosphere while a majority seeps into the ground like a glass of water poured on a pile of sand (Clark *et al.*, 1993). The water that eventually get into the soil is utilized by plant and soil organism while the water not used moves deeper into spaces in the ground. This water then moves downwards through cracks in the soil and fractures in rocks until it is intercepted by an impermeable layer of clay or rock. The water then accumulates on this layer filling up all available spaces until saturation. The top of the impermeable layer become the water table while the accumulated water becomes the ground water.

2.2 Aquifers and bore holes

Ground water users would find life easier if the water level in the aquifers that supplied their wells always stayed the same. Seasonal variations in rainfall and occasional drought affect the volume of the ground water. If a well is pumped at a faster rate than the aquifer is recharged, then the level of the groundwater can be lowered (Roger, 1982). The water level in a bore hole can also be lowered if other bore holes near it draw more water than the aquifer is recharged. This makes drawdown fall below the pumps.

Ground water may contain some natural impurities or contaminants, even without human activity or disturbance. Natural contaminants can come from many conditions

in the watershed or in the ground. Water moving through underground rocks and soils may pick up magnesium, calcium and chlorides. Some ground water naturally contains dissolved elements such as arsenic, boron, selenium or radon a gas formed by the natural breakdown of radioactive uranium in soil. These natural contaminants become a health hazard when they are present in high doses. In addition to natural contaminants, ground water is often polluted by human activities such as improper use of fertilizers, animal manure, herbicides, insecticides and pesticides.

Poorly built septic tanks and sewage systems for household wastewater, leaking or abandoned underground storage tanks, piping storm-waters drains that discharge chemicals to ground water and improper disposal or storage of waste chemical spills at local industrial sites all contribute to the pollution of ground water.

2.3 Early days of groundwater development

Groundwater exploitation has been with man way back in the ancient times. Most of the ancient civilizations obtained their water supplies from groundwater as well as surface water. It is reported that in 1183 BC, crusade prisoners in Egypt constructed wells from excavated bedrock which they called the Josephs well to ensure the citadels supply of water (Osiakwan, 2002).

The Holy Bible makes references to groundwater, first in the story of Moses striking a rock with his rod and bringing forth a fountain of water (Exodus 17:6). The drilling instead of the usual digging of wells began in the 12th century with the successful drilling of a well at Artois, France in 1226.

The term artesian usually used for drilled wells comes from the name of this village. An artesian well completed in 1841 at Grenelle near Paris was for many years the

deepest well in the world. Another well known well is the St. Augustine, located in Florida in the United States of America (Osiakwan, 2002).

2.4 History of Borehole construction in Ghana

Groundwater development in Ghana can be traced from the 19th Century where communities solely depended on hand dug wells for their potable source of water supply. The colonial governments from 1920-1945 initiated a national hand dug well program under the patronage of Rural Water Division a wing of the Gold Coast Survey Department (Osiakwan, 2002).

The construction of boreholes in Ghana began in the 1940's. This was to increase the water supply to rural and urban communities. Since then it is believed that thousands of hand-dug wells and boreholes have been constructed both by local and external donors.

The Ghana Water Company Limited by the year 2000 had constructed 25,000 boreholes all over the country. Through the help of the German government, another 3,000 boreholes have been drilled in southern Ghana between 1978 and 1983 (Issah, 2000). The World Vision International (WVI) between 1985 to June 2000 had drilled 1,523 borehole throughout the country (WVI, 2000).

The governments of Ghana through collaboration with bodies like Community Water and Sanitation Agency, Catholic Relief Agency, World Vision International and many other non governmental organizations currently, drill hundreds of boreholes annually throughout the country. This has made boreholes water indispensable in most Ghanaian communities.

2.5 Indicators of ground water quality

The quality of water depends greatly on the levels of some constituent. Some of these Constituents are:

2.5.1 Heavy metals

Heavy metals are natural components of the Earth's crust. They cannot be degraded or destroyed. To a small extent they enter our bodies via food, drinking water and air. Heavy metals (e.g. [copper](#), [selenium](#), [zinc](#)) are essential to maintain the metabolism of the human body. However, at higher concentrations they can lead to poisoning.

Heavy metals are dangerous because they tend to bioaccumulate. Bioaccumulation means an increase in the concentration of a chemical in a biological organism over time, compared to the chemical's concentration in the environment. Compounds accumulate in living things any time they are taken up and stored faster than they are broken down (metabolized) or excreted.

Heavy metals can enter the water supply system through industrial and consumer waste, or even from acid rain breaking down soils and releasing heavy metals into streams, lakes, rivers, and groundwater.

2.5.2 Analysis of metals

Total metals include all metals, inorganic or organically bounded, both dissolved and particulate. Analyses for metals involve digestion of the samples without preliminary filtration. Nitric acids adequately digest many metals. Nitrate is an acceptable matrix

for flame and electro thermal atomic absorption. Some samples may require the addition of perchloric acids for complete digestion (Christian, 1994).

2.5.3 Taste

Generally individuals have a more acute sense of smell than taste. Taste problems in water comes from total dissolved solids (TDS) and the presence of metals such as iron, copper, manganese or zinc. Manganese chloride and magnesium bicarbonate are significant in terms of taste. Fluoride may also cause a significant change in taste.

Taste and odour problems of many different types can be encountered in drinking water. Troublesome compounds may result from biological growth or individual activities. Taste and odour may be produced in the water supply, in the water treatment plant from reactions with treatment chemicals, in the distribution system and or in the plumbing of consumers. Taste and odour can be caused by mineral contaminants in the water, such as salty taste of water when chlorides are 500mg/l or above. Decaying vegetation is probably the most common cause for taste and odour in surface water supplies. In treated water supplies, chlorine can react with organics and cause taste and odour problems.

2.5.4 Iron

Iron is one of the most troublesome elements in water supplies. Making up at least 5 % of the earth's crust. Iron is one of the earth's most plentiful resources. Rainwater as it infiltrates the soil and underlying geological formations dissolves iron causing it to seep into the aquifer that serves as source of ground water for bore holes. Although present in drinking water, iron is seldom found at concentrations greater than 10

milligrams per litre or 10 parts per million. However as little as 0.3mg/l can cause water to turn reddish brown in colour.

Iron is mainly present in water in two forms. Either the soluble ferrous iron or the insoluble ferric iron. Water containing ferrous iron is clear and colourless because the iron is completely dissolved. When exposed to air in the pressure tank or atmosphere the water turns cloudy and a reddish brown substance begins to form. This sediment is the oxidized or ferric form of the iron that will not dissolve in water.

Iron is not hazardous to health but it is considered a secondary or esthetic contaminant. Essential for good health, iron helps transport of oxygen in the blood. Concentrations of iron as low as 0.3mg/l will leave reddish brown stains on fixtures, tableware and laundry that is very hard to remove. When these deposits break loose, from water piping, rusty water will flow through the faucet.

Since iron combines with different naturally occurring organic materials, it may also exist as an organic complex. The combination of naturally occurring organic materials and iron can be found in shallow wells and surface water. This type of iron is usually yellow or brown but may be colourless (IDPH, 1999).

2.5.5 Copper

Copper is an essential substance to human life, but in high doses it can cause anemia, liver and kidney damage and stomach and intestinal irritation. People with Wilson's disease are at greater risk for health effects from over exposure to copper. Copper normally occurs in drinking water from copper pipes, as well as from additives designed to control algal growth.

Copper exhibits some harmful effects and because drinking water may be significant route of exposure to copper, it is important to know how much copper is in drinking water. A metallic taste is usually found in drinking water before copper levels are high enough to create adverse effect. Blue or blue green stains around sinks and plumbing fixtures are also noticed.

On the average, drinking water accounts for less than 5% of our daily copper intake. the United States Environmental Protection Agency (USEPA) has determined that copper levels in drinking water should not exceed 1300 $\mu\text{g/L}$. No adverse health effects would be expected if this level is not exceeded. Measures should be taken to reduce exposure to copper if this level is exceeded. Copper rarely occurs naturally in water. Most copper contamination in drinking water happens in the water delivery system as a result of corrosion of copper pipes or fittings. Copper piping and fittings are widely used in household plumbing.

The physical and chemical characteristics of water vary, the corrosive properties vary as well. Factors causing corrosion include acidity (low pH) high temperature, low total dissolved solids (TDS) content and high amount of dissolved oxygen or carbon dioxide. Generally naturally soft water is more corrosive than hard water because it is more acidic and has low TDS. Observations have shown increased copper levels in water softened with ion exchange water softener. If the water is not corrosive, hard water minerals are deposited on calcium carbonate lining inside pipes and fittings which protects it against copper contamination. However, it may take up to five years for an effective calcium carbonate lining to form and softening hard water with an ion

exchange unit can either prevent or dissolve the calcium carbonate scale reducing or eliminating its protective effect.

The easiest and most effective method for reducing exposure to copper is to avoid drinking or cooking with water that has been in contact with house plumbing works for more than six hours. If an elevated level of copper in drinking water is observed it may be likely that lead levels are also elevated. This is especially true if the plumbing system contains lead solder joints. Since lead and copper enter drinking water under similar conditions, it is advisable to test for lead when testing for copper levels.

2.5.6 Lead

Lead found in fresh water usually indicates contamination from metallurgical waste or from lead-containing industrial poisons. Lead in drinking water is primarily from the corrosion of the lead used to put together the copper piping. Lead in the body can cause serious damage to the brain, kidneys, nervous system and red blood cells.

Except in related cases lead is probably not a major problem in drinking water although they potentially exist in cases where old lead pipes is still used. Lead can be reduced considerably with a water softener activated carbon; filtration can also reduce lead to a certain extent. Reverse osmosis can remove 94 to 98% of the lead in drinking water at the point-of –use (Manahan, 1994).

2.5.7 Effects of Lead on the environment

In humans, exposure to lead can result in a wide range of biological effects depending on the level and duration of exposure. High levels of exposure may result in toxic

biochemical effects in humans which in turn causes problems in the synthesis of haemoglobin, effects on the kidneys, gastrointestinal tract, joints and reproductive system, and acute or chronic damage to the nervous system.

Lead poisoning, which is so severe as to cause evident illness, is now very rare indeed. At intermediate concentrations, however, there is persuasive evidence that lead can have small, subtle, subclinical effects particularly on neuropsychological developments in children. Some studies suggest that there may be a loss of up to 2 IQ points for a rise in blood lead levels from 10 to 20 $\mu\text{g}/\text{dl}$ in young children.

Average daily lead intake for adults in the United Kingdom (UK) is estimated at 1.6 μg from air, 20 μg from drinking water and 28 μg from food. Although most people receive the bulk of their lead intake from food, in specific populations other sources may be more important, such as water in areas with lead piping and plumb solvent in water, air near point of source emissions, soil, dust, paint flakes in old houses or contaminated land. Lead in the air contributes to lead levels in food through deposition of dust and rain containing the metal, on crops and the soil. For the majority of people in the UK however, dietary lead exposure is well below the provisional tolerable weekly intake recommended by the United Nations Food and Agriculture Organisation (UNFAO) and the World Health Organisation (WHO).

Lead in the environment arises from both natural and anthropogenic sources. Exposure can occur through drinking water, food, air, soil and dust from old paint containing lead. In the general non-smoking adult population, the major exposure pathway is from food and water. Food, air, water and dust/soil are the major potential exposure pathways for infants and young children. For infants up to 4 or 5 months of age, air, milk formulae and water are the significant sources.

Lead is among the most recycled non-ferrous metals and its secondary production has therefore grown steadily in spite of declining lead prices. Its physical and chemical properties are applied in the manufacturing, construction and chemical industries. It is easily shaped and is malleable and ductile. There are eight broad categories of use: batteries, petrol additives (no longer allowed in the European Union), rolled and extruded products, alloys, pigments and compounds, cable sheathing, shot and ammunition.

2.5.8 Zinc

Zinc occurs in small amounts in almost all igneous rocks. The principal zinc ores are sulphide such as sphalerite and wurzite. The natural zinc content of soils is estimated to be 1-300mg/kg.

- Organoleptic properties

Zinc imparts an undesirable astringent taste to water. Test indicate that 5% of a population could distinguish between zinc-free water and water containing zinc at a level of 4 mg/l as zinc sulphate (UNEP and WHO, 1996).

- Water

In natural surface water the concentration of zinc is usually below 10ug/l and in groundwater 10-40ug/l. in tap water the zinc concentration can be much higher as a result of the leaching of zinc from piping and fittings. The most corrosive waters are those of low pH. High carbon dioxide content and low mineral salts content. In a Finnish survey of 67% of the public water supply, the median zinc content in the water samples taken upstream and downstream of the waterworks was below 20ug/l much higher concentrations were found in tap water. The highest being 1.1 mg/l. even

higher zinc concentrations up to 24mg/litre were reported in Finnish survey of water from 6000 wells (Lahermo, 1990).

2.5.9 Cadmium

Cadmium is produced as an inevitable by-product of zinc (or occasionally lead) refining, since these metals occur naturally within the raw ore. However, once collected the cadmium is relatively easy to recycle. Cadmium is a natural and usually a minor constituent of surface and ground water. It may exist in water as hydrated ions or as inorganic complexes such as carbonates, hydroxides, chlorides or sulphates or as organic complexes with humic acids

Cadmium may enter aquatic systems through weathering and erosion of soils and bed rock, atmospheric decomposition of direct discharges from industrial operations, leakage from landfills and contaminated sites and the dispersive use of sludge and fertilizers in agriculture. Much of the cadmium entering fresh waters from industrial sources may be rapidly adsorbed by particulate matter and thus sediment may be a significant sink for cadmium emitted to the aquatic environment (WHO, 1992).

Some data shows that recent sediments in lakes and streams range from 0.2 to 0.9 ppm in contrast to the levels of generally less than 0.1 ppm cited above for fresh water partitioning of cadmium between the adsorbed in sediment state and dissolved in water state is therefore an important factor in whether cadmium emitted to water is or is not available to enter the food chain and affect human health.

Rivers containing excess cadmium can contaminate surrounding land, either through irrigation for agricultural purposes, dumping of dredged sediments or flooding. It has

also been demonstrated that rivers can transport cadmium for considerable distance up to 50km from the source (WHO, 1992) Cadmium derives its toxicological properties from its chemical similarity to zinc an essential micronutrient for plants, animals and humans. Cadmium is biopersistent and, once absorbed by an organism, remains resident for many years (over decades for humans) although it is eventually excreted.

In humans, long-term exposure is associated with renal dysfunction. High exposure can lead to obstructive lung disease and has been linked to lung cancer, although data concerning the latter are difficult to interpret due to compounding factors. Cadmium may also produce bone defects (osteomalacia, osteoporosis) in humans and animals. In addition, the metal can be linked to increased blood pressure and effects on the myocardium in animals, although most human data do not support these findings.

The average daily intake for humans is estimated at 0.15 μ g from air and 1 μ g from water. Smoking a packet of 20 cigarettes can lead to the inhalation of around 2-4 μ g of cadmium, but levels may vary widely.

In the general, non-smoking population the major exposure pathway is through food, via the addition of cadmium to agricultural soil from various sources (atmospheric deposition and fertiliser application) and uptake by food and fodder crops. Additional exposure to humans arises through cadmium in ambient air and drinking water.

2.5.10 Effects of Cadmium on the environment

Cadmium is used in metal alloys and pigments for paints, cement, paper, rubber, and other materials. Low-level exposure can irritate the skin and cause ulceration. Long-term exposure can cause kidney and liver damage, and damage to circulatory and

nerve tissue. Cadmium often accumulates in aquatic life, adding to the danger of eating fish that may have been exposed to high levels of Cadmium.

2.5.11 Sodium

Sodium levels in drinking water that are less than 20mg/l are considered safe for most people. In the sea coast area however, elevated levels of sodium and chlorides occur naturally due to the proximity to sea water. Substantially higher levels of sodium and chloride may also be due to contamination by activities of man including the use of road de-icing salts, discharges from water softeners, human or animal waste disposal, Leachate from landfills and many other activities.

At present there are health standards for sodium and chloride in drinking water. A review by EPA in the mid-1980's showed that elevated levels of sodium in drinking water did not cause high blood pressure or heart disease, rather only that sodium should be avoided by those who already had such medical conditions.

It is important to note that sodium is an essential nutrient. The food and nutrition board of National Research Council recommends that healthy adults need to consume at least 500mg of sodium per day and that sodium intake be limited to no more than 2400mg/day. The food and drug administration publication states that most American adults tend to eat between 4000 and 6000 mg of sodium per day (USEPA, 1994).

2.5.12 Potassium

Potassium is alkaline metal closely related to sodium. It is seldom that one sees it analysed separately on a water analysis. Potassium is not a major component in public

or industrial water supplies. Potassium is however essential in a well defined balance diet and can be found in fruits such as bananas (USEPA, 1994).

The potassium content of drinking water varies greatly depending on its source. It tends to be greater in mineral water than ordinary tap water. It however on the average, the daily water consumed by adults supplies less than 0.1 % of their potassium intake but tap water is also used to make beverages like tea, coffee, beer and wines. The average total potassium intake in beverages can supply about 13% of the total daily intake of adults (USEPA, 1994).

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2.6 Some physicochemical parameters which serve as indices of water quality are:

2.6.1 Total dissolved solids (TDS)

TDS is the sum of all the materials dissolved in the water, it has many different mineral sources. Total dissolved solids (TDS) consist of mainly carbonates, bicarbonates, chlorides, sulphates, phosphates, nitrates, calcium, magnesium, sodium, potassium, iron, manganese and a few others. They do not include gases, colloids or sediments. The total dissolved solids can be estimated by measuring the specific conductance of the water.

Dissolved solids in natural water range from less than 10mg/l for rain water to more than 100,000gm/l for brines. Below is an indication of TDS from various sources distilled water=0, deionised water=8, rain and snow=10, brine well-125000 and dead sea-250,000. The TDS of a water sample is determined gravimetrically, a well mixed volume of sample is evaporated in a weighed dish and dried to constant weight in an oven at 103-105°C. The increase in weight over that of the empty dish is the total solid.

The value may not necessary represent the actual suspended and dissolved solids. This is due to interference from highly mineralized water with significant concentrations of calcium, manganese etc. which may be hygroscopic and requires excessive, proper desiccation and rapid weighing. A standard glass fibre filter is used to filter a well mixed sample and the filtrate is evaporated to dryness in a weighed dish to constant weight at 180°C. Total dissolved solids can be determined by using an electric probe which also measures temperature and conductivity (APHA, 1992).

2.6.2 Temperature

Temperature is the measure of how hot or cold water is. This is measured with a thermometer in degree Celsius or Fahrenheit (APHA, 1985). The temperature of water to a large extent determines the extent of microbial activity. Water freezes at 0°C and boils at 100°C.

2.6.3 Hardness

The degree of hardness of water supply is determined by the content of calcium and magnesium salts. Calcium and magnesium combine with bicarbonates, chlorides, sulphates, and nitrates to form these salts. The standard domestic measurement for hardness is grains per gallon (gpg) as CaCO_3 . Water having hardness content less than 0.6 gpg is considered commercially soft. The calcium and magnesium salts which form the hardness are divided into two categories.

Temporal hardness (containing non-carbonates) and permanent hardness containing non-carbonates. Hardness affects the amount of soap that is needed to produce foam or lather. Hard water requires more soap, because the calcium and magnesium ions form complexes with soap preventing the soap from sudsing. Hard water can also

leave a film on the hair, fabrics, and glassware. Hardness of water is very important in industrial uses, because it forms scales in heat exchange equipment, boilers and pipes.

Hardness mitigates metal toxicity because of the presence of Ca^{2+} and Mg^{2+} .

Hardness helps to keep fish from absorbing metals such as lead, arsenic and cadmium into their bloodstream through their gills. The greater the hardness the harder it is for toxic metals to be absorbed through the gills.

2.6.4 Temporary hardness

Calcium Carbonate (CaCO_3) often referred to as limestone, in water supplies causes alkalinity in water. Calcium Bicarbonate forms when water containing CO_2 is released and the calcium bicarbonate reverted to calcium carbonate forming scales.

Magnesium Carbonate (MgCO_3) known as magnetite with properties similar to calcium carbonate.

2.6.5 Permanent Hardness

Calcium sulphate (CaSO_4) known as gypsum used to make pop will precipitate and form scales in boilers when concentrated, calcium chloride (CaCl_2) reacts in a boiler water to produce low pH as follows.



Magnesium Sulphate (MgSO_4) also known as Epsom may have laxative effect if of high quantity in the water. Sodium salts are found in household water supplies but they are considered harmless as long as they do not exist in large quantities (Casidey *et al.*, 1998).

2.6.6 pH

The pH of a solution is the measure of how acidic or basic that solution is or the concentration of hydrogen ions in a solution. Natural water often have a pH of 4-9 and most are slightly basic as a result of bicarbonate and carbonates of the alkali and alkaline earth metals.

The determination of pH involves the activity of hydrogen ions by potentiometric measurement using a standard hydrogen electrode and a reference electrode. The measurement of pH is influenced by temperature in two ways. Mechanical effects caused by changes in the properties of the electrode and chemical effects caused by equilibrium changes.

In the former, the nerstian slope increases with increasing temperature and takes a lot of time to attain thermal stability. This can cause a long term drift in the pH. Due to the effect of chemical equilibrium on pH; standard pH buffers have a specific pH at specified temperatures (APHA, 1985).

2.6.7 Conductivity

Conductivity is defined as the ability of a solution to carry electric current. This is normally dependant on the presence of mobile ions. Their concentration, mobility, valency, relative concentration and temperature of measurement.

Compounds which dissociates easily in solution are good conductors whiles those which do not dissociate easily are poor conductors. Inorganic, bases, and salts are good conductors whiles organic compounds are poor conductors. In a laboratory determination, conductivity is measured as resistance measured in ohms. The

conductivity of fresh distilled water is in the range of 0.5-2.0 micro-ohms/cm. the conductivity of portable water is in the range of 50-10000µmhos/cm.

Laboratory conductivity measurements are used to:

- Establish degree of mineralization, to assess the effect of the total concentration of ions on chemical equilibria, physiological effects on living things and the rate of corrosion
- To assess the degree of mineralization of distilled water and deionised water.
- To check the result of a chemical analysis and estimate the sample size to be used for simple chemical determinations.
- Determine the amount of ionic reagents in the precipitation and neutralization reactions. The end point of such reactions is determined by plotting a graph of conductivity verses burette readings.
- When conductivity is multiplied by a factor, total dissolved solids of water can be determined. This factor may vary from 0.055 to 0.9 depending on the soluble component of the water and on the temperature of measurement.

2.6.8 Alkalinity

Alkalinity is defined as the ability of water to neutralize an acid, and is determined by titration against a known standard acid (usually 0.02N sulfuric acid). Alkalinity has traditionally been reported in terms of mg/L as calcium carbonate. This is somewhat a confusing nomenclature since the chemical species responsible for virtually all the alkalinity of natural waters is the bicarbonate ion. The optimal amount of alkalinity for a given water is a function of several factors including pH, hardness and the concentration of dissolved oxygen and carbon dioxide that may be present.

As a general rule 30 to 100 mg/l calcium carbonate is desirable although up to 500 mg/L may be acceptable. Alkalinity is apparently unrelated to public health but is very important in pH control. Alum, gaseous chlorine and other chemicals are occasionally used in water treatment to acts as acids and therefore tend to depress pH. Many waters are deficient in natural alkalinity and must be supplemented with lime (CaO) or some other chemicals to maintain the pH in the desirable range to usually 6.5 to 8.5. Alkalinity values can change significantly from groundwater between samples taken at the wellhead and samples taken from other spots. (USEPA, 1994).

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2.6.9 Colour

Basically water is colourless so to a greater extent, colour in water is always due to the presence of foreign material. Suspended and decaying organic and inorganic materials usually extracted from decaying vegetation, add colour and odour to the water. Colour is common in surface water supplies.

While it is virtually non-existent in spring and deep wells due to material screening. colour in water supplies may also be the result of natural metallic ions (iron and manganese) a yellow tint to the water indicates that humic acids are present, referred to as 'tannins' a reddish colour would indicate the presence of precipitated iron. Stains on bathroom fixtures and on laundry are often associated with colour also reddish – brown is ferric hydroxide (iron) will precipitate when the water is exposed to air. Dark brown to black stains are created by manganese. Excess copper can create blue stains.

The observed colour of water is the result of light back scattered upwards from the water after it has passed through various depths and undergone selective absorption.

Colour and turbidity determines the depth to which light penetrates in water systems. In water, light intensity or irradiance at a particular depth (I_z) is a function of the intensity at the surface (I_0) to the exponent of the negative extinction coefficient at the depth distance z which is called the beer-lambert law $I_z = I_0 e^{-kz}$ (Freifelder, 1985).

The visible colour in a water sample is the light that is refracted, reflected, emitted or re-emitted by substances in water because it has not been absorbed to produce heat or chemical reactions. True colour is due to minerals such as ferric hydroxide and dissolved organic substances such as humic or fulvic acids. Colour measured in water containing suspended matter is defined as apparent colour (APHA, 1992).

The colour of water measured by colometric methods is based on the calibration or absorbance of the water sample at a variety of single wavelengths, usually against the Pt-Co Standard measurement. Comparisons can be made with sealed containers. Natural water range from $<5\text{m/L Pt}$ in very clear water to 1200mg/L in dark peaty waters (Keysre, 1997).

2.6.10 Turbidity

Turbidity is the term given to anything that is suspended in a water supply. It is most common in surface waters and usually non-existent in ground water except in shallow wells and springs after heavy rains. Turbidity gives the water a cloudy appearance or shows as dirty sediments. Undissolved materials such as sand, clay, silt or suspended irons contribute to turbidity.

Turbidity can cause the staining of sinks and fixtures as well as the discolouring of fabrics. Usually turbidity is measured in NTU (nephelometric turbidity units) typical

drinking water have turbidity level of 0 to 1 NTU. Turbidity can also be measured in ppm (parts per million) and its size is measured in microns. Turbidity can be particles in the water consisting of finely divided solids larger than molecules, but visible to the naked eye, ranging from 0.001 to 0.150mm (1 to 150 microns).

Typically turbidity can be reduced to 75 microns with a cyclone separator then reduced down to 20 microns with standard back washable filter, however flow rates of 5gpm/sq. ft are recommended maximum. Turbidity can be reduced to 10 microns with a multimedia filter while providing flow rate of 15 gpm/sq. ft cartridge filter of various sizes are also available down into the submicron range (USEPA, 1994).

Turbidity is caused by suspended matter such as clay, silts, finely divided organic and inorganic matter, soluble coloured organic compounds and plankton and other microscopic organisms. Turbidity expresses the optical property that causes light to be scattered and absorbed rather than transmitted in a straight line through the sample. Correlation of turbidity with weight concentration of suspended matter is difficult because the size, shape and refractive index of the particle also affect the light scattering properties of the suspension.

2.7.0 Nutrient contaminants

2.7.1 Chlorides

Chlorides (Cl^-) is one of the major anions found in water and is generally combined with calcium, magnesium or sodium. Since almost all chloride salts are highly soluble in water, the chloride content ranges from 10 to 100 mg/l. Sea water contains over 30,000mg/L as NaCl. Chloride is associated with the corrosion of piping systems. The

corrosion rate and the iron dissolved into the water from piping increases as the NaCl content of the water is increased. The suggested maximum contaminant level (SMCL) for chloride is 250mg/l which is due strictly to the objectionable salty taste produced in drinking water (USEPA, 1994).

2.7.2 Sulphates

Sulphates (SO_4) occur in almost all natural waters. Most sulphate compounds originate from the oxidation of sulphate ores, the presence of the shale and the existence of industrial waste. Sulphate is one of the major nutrients dissolved in rain. As water moves through the soil and rock formations that contain sulphate minerals, some of the sulphate dissolves in the water into the groundwater.

Minerals that contain sulphate include magnesium sulphate (Epsom salt) sodium sulphate and calcium sulphate (gypsum). A high concentration of sulphate in drinking water causes a laxative effect when combined with calcium and magnesium, the two most common components of water hardness. Bacteria which attack and reduce sulphates cause hydrogen sulphide gas to form. Sulphate has a suggested level of 250mg/L in the secondary drinking water standards published by the (USEPA, 1994)

Sulphate (SO_4) ion is precipitated in an acetic acid medium with barium chloride to form barium sulphate. Light absorbance of barium sulphate suspension by a UV-visible spectrophotometer at 420nm is used to determine the sulphate concentration. This is done by comparison with the calibration curve (APHA, 1985).

2.7.3 Phosphates

Phosphorus is one of the key elements necessary for the growth of plants and animals. Phosphorus in elemental form is very toxic and is subjected to bioaccumulation. Phosphates PO_4^{-3} is formed from this settlement. Phosphates exist in three forms Orthophosphate, metaphosphates (polyphosphates) and organically bounded phosphate. Each compound contains phosphorus in a different chemical formula. Ortho forms are produced by natural processes and are found in sewage. Poly forms are used for treating boilers and in detergents. In water, they change into ortho form. Organic phosphates are important in nature. Their occurrence may result from the breakdown of organic pesticides which contains phosphates. They exist in solution as particles, loose fragments or in the bodies of aquatic organisms. Rainfall can cause varying amounts of phosphates to wash from farm soils into nearby waterways. Phosphate stimulates the growth of plankton and aquatic plants which provides food for fishes. Phosphate also leeches into groundwater. It may not be toxic to people or animals unless they are present in very high levels. Digestive problems could occur from extremely high levels of phosphates (USGS, 1970).

2.7.4 Nitrites

Nitrites are not usually found in drinking water supplies at concentrations above 1 or 2 mg/L (ppm). Nitrates are reduced to nitrites in the saliva of the mouth and upper gastro intestinal tract, this occur to much greater degree in infants than in adults because of the higher alkaline conditions in their gastrointestinal tract. The nitrite then oxidizes haemoglobin in the blood stream to methemoglobin, thus limiting the ability of the blood to carry oxygen throughout the body leading to Anoxia and death

can occur. The USEPA has established the MCL (Maximum contaminant level) for nitrites is 1mg/ L (Alloway and Ayres, 1997).

Nitrite ion in a suitable medium is diazotized with sulphanilamide resulting in diazo compound. This in turn is coupled with N (1-naphtyl) ethylene-diamine to form a highly coloured azo dye (APHA, 1985).

2.7.5 Nitrates

Nitrate (NO_3) comes into water supplies through the nitrogen cycle rather than via dissolved minerals. It is one of the major ions in natural water. Most nitrates that occur in drinking water are as a result of contamination of ground water by septic systems. Feed lots and agricultural fertilizers. Nitrates is reduced to nitrite in the body Reverse osmosis will remove 92-95%of the nitrates. Anion exchange resin will also remove both as will distillation (Alloway and Ayres, 1997).

2.8 Chemical composition of ground water

The major sources of ground water are rain and snow and they contain certain very little dissolved materials. This is because the atmosphere acts as a giant sieve that removes impurities from the system. Human activities such as burning of fossil fuels or wood and geological events such as volcanic gases emit compounds into the atmosphere that later are dissolved in falling rain.

Generally rainwater contains 10 to 20 mg of dissolved substances per liter of solution. By the time precipitation has percolated through soil sediments and rocks to replenish the groundwater, it has accumulated many hundreds of times those amounts of dissolved substances.

Most of the minerals in rocks are soluble in water and each mineral has a different solubility in pure water. The solubility varies with the acidity of the water and the amount of oxygen dissolved in it. Groundwater readily dissolves the most soluble minerals in rocks. With increasing depth, the amount and types of materials dissolved in the ground water vary with deeper waters generally having higher concentrations of salt and less oxygen. As soon as rain water infiltrates the soil and becomes ground water, its composition begins to change. With increasing depth, groundwater is depleted of oxygen.

Nitrogen generated from soil forming processes dissolve in water to form nitrogen compounds (NO_2 and NO_3). Nitrogen is essential for plant growth and its present in large quantities in manure and artificial fertilizers which farmers often use in their farms often use in their production. This has led to an unprecedented increase in the level of nitrate in water in recent decades.

As water moves through soil rich in organic matter much CO_2 gas is dissolved and the reaction of the CO_2 and H_2O forms a weak acid of pH 5 to 7 which in turn dissolves rocks in the form of CaCO_3 .

Magnesium and potassium are also common in groundwater from the dissolution of rocks Sulphide ions released in the weathering while sulphide minerals are also present in minute quantities.

Calcium and magnesium ions contribute to water hardness. Hard water contains 50 to 100mg or more of dissolved calcium and magnesium ions per litre of water. This ion crystallizes to form deposits that leave rings in bathtubs and scaly deposits in water

pipes. There is continuous dissolution of solids as water moves deep into the subsurface. The total amount of dissolved solids rises but there is much exchange of ions between water and mineral surfaces.

Clay minerals found in rocks and sediments are generally associated with large amounts of sodium during deposition in offshore marine environments. Cation exchange occurs between calcium and magnesium from the water rich in sodium bicarbonate. Clay particles have a large surface area because of their small size. This makes clay exposed to a lot of exchangeable sodium ions. The age of ground water increases with depth. Studies of carbon in groundwater using radiometric dating have shown that its age can be as long as 10,000 and 40,000 years in the deeper part of some aquifers.

The trend of groundwater evolution with depth and age is a transformation from bicarbonate-rich water to sulphate (SO_4) rich water then finally to brine, a water solution rich in sodium chloride. The circulation of water at great depths is usually much more restricted at shallow levels. Sodium chlorides which is a very soluble in water is not flushed out from ground water. Many hydrologist in the earliest times thought the brine pumped from deep wells were ancient marine water taped in sediments as they were laid down. It is now clear that groundwater can evolve to become more saline with depth and age (Merritis *et al.*, 1998).

2.9 Contaminants of Ground water

There are a number of important factors that determine whether a chemical is likely to reach and become groundwater contaminants. These major factors are:

- Properties of the chemical
- Properties of the soil
- Existing conditions at the site
- Human actions or properties

2.9.1 Properties of the chemical

Each chemical that comes into contact with soil moisture has the characteristics of solubility, absorption, volatility and degradation.

Solubility is a measure of how readily a chemical dissolves in water. Water moving down through soil carries water-soluble chemicals with it. This leaching occurs continuously as water moves from the surface down to the ground water aquifers.

Absorption is the ability of a chemical to be held on the surface of the soil particles or soil organic matter. A chemical that is held tightly by soil is less likely to be carried downwards by leaching

Volatility determines the ability of a chemical to be lost to the atmosphere. A highly volatile chemical may escape to the atmosphere before it becomes dissolved in water. This may not be true of chemicals that are also highly water-soluble.

Degradation is the chemical breakdown of a substance in the soil microorganisms and other chemical and physical properties. A chemical that degrades slowly is more likely to be moved downwards by leaching.

A type of contaminant that is especially troublesome is the group of chemicals known as dense non-aqueous phase liquids or DNAPLs. These include chemicals used in dry cleaning, wood preservation, asphaltting, machining and in the production and repair of automobile, aviation equipments ammunition and electrical equipments. These substances are heavier than water and they sink quickly into the ground. This makes spills of DNAPLs more difficult to handle than spills of petroleum products. Except in large cities, drinking water is rarely tested for these contaminants (Vandre, 1995).

2.9.2 Properties of the soil

The important characteristics of soil which helps determine groundwater contamination are texture, permeability and organic matter content. Soil texture is the relative proportions of sand and clay, coarse, sandy soils allow more water movement by percolation and have less capability to absorb chemicals than clay. The coarser the texture of the soil, the greater the chance of a chemical reaching the groundwater.

Soil permeability is a measure of how fast water moves downwards through a soil. Highly permeable soils have a greater capability to lose chemicals to leaching. Applying pesticides or fertilizers to highly permeable soils should be done in such a way that leaching is kept to a minimum.

Soil organic matter influences soil capability to hold water and to adsorb chemicals. The incorporation of organic matter into a soil will increase the capability and decrease the downward movement of chemicals by leaching (Vandre, 1995).

2.9.3 Existing conditions at the site

The depth to groundwater at a specific location is important because the soil between the surface and groundwater acts as a filter less soil means more leaching, less adsorption and less degradation. When groundwater is close to the surface, care must be taken whenever pesticides or fertilizers are applied or incorporated. Smaller applications, spilt applications or no application may be less the best alternative. The geologic conditions of a site should be determined to assess groundwater vulnerability. Layers of gravel above the groundwater area do not offer much. Protection against percolation or leaching. A layer of clay does create an effective filter for many chemicals. A steeper slope increases the potential for surface runoff and the subsequent movement of chemicals to other vulnerable areas.

Climate is another consideration at every location. Excessive rainfall increases percolation and leaching. Cold soils slow the rate of degradation and increases the time the chemical is available for leaching (Vandre, 1995).

2.9.4 Human actions or practices

The application of pesticides, fertilizer or any other chemical is regulated by the landowner or applicator. Application methods and dosage can influence the leaching of the chemical. Soil incorporation or injection of a pesticide poses a greater groundwater hazard than foliage or surface application. Decreasing the amount of the pesticide applied through the use of effective alternatives will also protect groundwater resources. This can be accomplished by using pesticides which are less susceptible to leaching and surface runoff.

The timing of pesticide application can be important in minimizing groundwater risk. Application prior to heavy rains or irrigation may result in leaching rather than effective use (Vandre, 1995).

2.10 Sources of ground water pollution

Pesticides, fertilizers, herbicides and animal waste are agricultural sources of ground water contamination. The means of agricultural contamination are varied and numerous. But some examples are spillage of fertilizers and pesticides during handling runoff from the loading and washing of pesticides sprayers or other application equipment using chemicals uphill from within a few hundred feet of well.

Agricultural land that lacks sufficient drainage is considered by many farmers to be lost income land. So they may install drain tiles or drainage wells to make the land more productive. The drainage well then serves as a direct conduct to groundwater for agricultural waste which is washed down with the runoff, storage of agricultural chemicals near conducts to ground water. Such as open and abandoned wells, sink holes or surface depressions where water is likely to accumulate. Contamination may also occur when chemicals are stored in uncovered areas. Unprotected from wind and rain or are stored in locations where the ground water flows from the direction of the chemical storage.

Mixing and distributing pesticides and fertilizer with irrigation water can cause ground water contamination if chemicals such as fertilizers, herbicides and insecticides and fungicides are over applied in the crop field could also introduce these contaminants into the ground water. Organic compounds, cadmium, chlorides,

mercury and selenium which occur naturally in the soil and also contaminate ground water. Feedlots are potential contaminant sources. Animal waste is often collected in impoundments from which the waste may infiltrate the ground water. Runoff could also enter an aquifer through a poorly sealed well casing. Livestock waste is a source of nitrate coliform bacteria, total dissolved solids and sulphates. Within the garage or farm equipments shed, chemicals that are improperly stored or disposed off that could potentially contaminate ground water include paint containing lead and barium, gasoline and oils containing volatile organic compounds.

Many sources of ground water contamination can originate in the house or other forms such as trailers or dormitories, leaks from under ground storage tanks, oil spills, overloading or poor maintenance of septic systems can result in the following contaminants entering ground water. Coliform bacteria, nitrate, total chloride, sodium, sulphates, detergents and chromium.

Both aboveground and underground storage tanks (USTs) are at risk of leaking and releasing gasoline which contains benzene.

Abandoned wells that have not been plugged or dismantled provide a potential pathway (direct route) for water to flow directly from the surface into the ground water. Open wells can become contaminated by the working fluids such as grease and oils from the pump or from contaminants from the surface if the well cap is not tightly closed or incase the lining of the well is cracked or corroded. In addition, many older farm wells were merely shallow holes dug into the ground. These wells can easily be contaminated and are also a safety hazard to children and animals (USEPA, 1997).

2.10.1 Industrial sources of groundwater contamination

Modern economic activity requires transportation and storage of materials used in manufacturing, processing and construction. Along the way, some of this material can be lost through spillage, leakage or improper handling. Even the cleanup of spills may pose a threat to ground water when the spills are flushed with water rather than cleaned up with absorbent substances.

The disposals of waste associated with the above activities contribute other sources of ground water contamination. Some businesses usually without access to sewer systems rely on shallow underground disposal. They use cesspool or dry holes, or send the wastewater into septic tanks. Any of these forms of disposal can lead to contamination of underground sources of drinking water. Dry holes and cesspools introduce waste directly into the ground. Septic systems cannot treat industrial waste. Wastewater disposal practices of certain types of business, such as automobile service stations, dry cleaners, electrical component or machines manufacturer, photo processors and metal platters or fabricators are of particular concern because the waste they generate is likely to contain toxic chemicals.

Other industrial sources of contamination include cleaning off holding tanks or spraying equipment on the open ground. Disposal of waste in septic systems or dry wells and storing hazardous materials in uncovered areas or in areas that do not have pads with drains or catchments basins.

Although business may run a 'clean shops' small amounts of waste fluids can end up on the shops floors and be washed down floor drains. These drains may be connected to shallow injection well systems, which are not designed to handle the industrial

chemical typically used by businesses such as those listed above. Even low concentrations of certain contaminants can accumulate through time.

Underground and above ground tanks holding petroleum products, acids, solvents and chemicals can develop leaks from corrosion, defects, improper installation or mechanical failure of the pipes and fittings. Mining of fuel and non-fuel minerals can create many opportunities for ground water contaminations. The problems stem from the mining process itself disposal of wastes and processing of the ores and the waste it creates (USEPA, 1997).

2.10.2 Domestic sources of ground water contamination

A major cause of ground water contamination is effluent (outflow) from septic tanks and cesspools. Misuse of these systems for disposal of anything other than domestic or sanitary waste can pose a substantial threat to ground water. Residential wastewater systems can be a source of many categories of contaminants including bacteria, viruses and nitrates from human waste and organic compounds.

Injection wells used for domestic wastewater disposal (septic systems, cesspool drainage wells for storm water runoff, ground water recharge wells) are of particular concern to ground water quality if located close to and up gradient of drinking water wells. Improper storing or disposal of household chemicals such as paints, synthetic detergents, solvents, oils, medicines, disinfectants, pool chemicals, pesticides, batteries, gasoline and diesel fuel can lead to ground water contamination. When stored in garages or basements with floor drains, spills and flooding may introduce such contaminants into the ground water because community landfills are not

equipped to handle hazardous materials. Similarly, waste dumped or buried in the ground can contaminate the soil and leach into the ground water.

As urban areas grow, there is an increase in rain water runoff caused by the additions of paved surfaces. Some municipalities use storm water drainage wells to dispose off this additional runoff particularly if the area is not served by storm sewers nor has a limited sewer system. These low-cost low-tech wells and landscaped areas. Storm water drainage wells that communities use to control water during storm events pose a threat to ground water particularly in kart area or areas with a high water table. Fertilizers, herbicides, insecticides, fungicides and pesticides applied to the lawn and garden contain hazardous chemicals that can travel through the soil and contaminate the ground water.

In the garage, items that are improperly used, stored or disposed off may potentially contaminate ground water especially if there is a drain to the ground in the floor of the garage. Sources include batteries that contain lead, cadmium or mercury. Paints containing lead and barium, gasoline and oils containing compounds, barium from diesel fuel combustion.

Water used in the home and entering a septic system or sewer system may contain detergents from dishwashing and laundry, organic compounds from garbage, disposal bacteria, nitrates, and sulphates from sewage, greases and oils. Cleaning agents, aerosol sprays coolants and solvents which all contain carbon tetrachloride household pesticides.

Water percolating through landfills is known as Leachate. From landfills that contain household and other waste may pick up dissolved solids and volatile organic compounds. Lawns with over applied or misapplied fertilizers, herbicides and fungicides might introduce these contaminants tetrachloride and heavy metals such as manganese into ground. (USEPA, 1997).

2.10.3 Natural sources of groundwater contamination

Ground water contains some impurities even if it is unaffected by human activities. The types and concentrations of natural impurities depends on the nature of the geological materials through which the groundwater moves and the quality of the recharge water.

Ground water moving through sedimentary rocks and soils may pick up a wide range of compounds such as magnesium, calcium and chlorides. Some aquifers have high natural concentration of dissolved constituents such as arsenic, boron and selenium. The effect of these natural sources of contamination on ground water quality depends on the type of contaminants and its concentration.

Some of the contaminants that occur naturally are:

Aluminum, arsenic, barium, chloride, chromium, coliform bacteria, copper, fluoride, hardness, iron, lead. Manganese, mercury, nitrate, selenium, silver, sodium, sulfate, zinc (USEPA, 1997).

2.11 Speciation of metals

Legislation governing the maximum permissible levels of a polluting element in environmental samples such as surface or ground water refers to total concentrations

rather than the chemical form of the element. This total concentration however provides no information concerning the fate of the elements in terms of its interactions with sediments its ability to cross biological membranes (bioactivity) or its resultant toxicity.

Changes may dramatically affect the toxicity of metal for example mercury species are generally unable to cross biological membranes and this has low toxicity. Methylmercury species are lipids soluble and hence extremely toxic to aquatic organisms. It is therefore imperative to have information concerning the chemical form of an element (speciation) in order to assess its environmental impact (Fifield, 1997).

2.12 Potential microbial accumulation in boreholes and wells

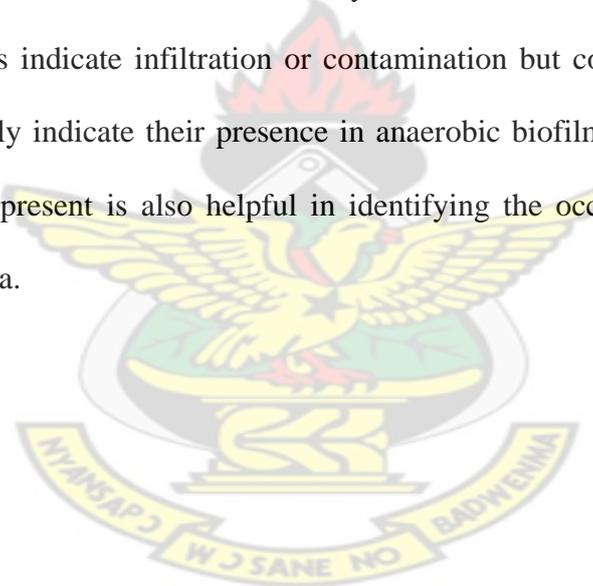
Bacteria and their associated colonies account for 80% of the fouling problems found in well systems. All bacteria produce slime or polysaccharide exo-polymers often referred to as biofilm. These bacteria are often spoken of as the slime former which fouls screens, gravels pack and aquifer formations. They often lead to general fouling of the well because they not only block the flow of water with their heavy slimy growth but encourages the deposit of mineral in this slime matrix. Anaerobic and sulphur bacteria live in anaerobic environments which is typically found in the lower extensions of the well and boreholes Areas of low flow and clay lenses can also harbour anaerobic bacteria. Sulphur reducing bacteria (SRB) reduces sulfur and produce the characteristic 'rotten egg' odour of hydrogen sulphide gas. This gas is acidic and therefore it changes the pH of the surrounding areas to an acid condition which can lead to the corrosion of metal present. The other anaerobes whiles not

producing hydrogen sulphide will produce other compounds which produce acidic conditions and leads to odour and taste problems.

2.13 Coliform bacteria and borehole contamination

These are really members of the slime former group but because they are the organisms that come to our attention from a regulatory point of view, we have listed them separately. Coliforms are aerobic or facultative anaerobic which means they can live in both environments (with or without oxygen) the industry monitors for them because of their tendency to indicate contamination. Knowledge of their habits will help you to deal with them as and when they are detected.

Excessive levels indicate infiltration or contamination but counts below 16 per 100 millilitres usually indicate their presence in anaerobic biofilm Specific identification of the bacteria present is also helpful in identifying the occurrence and sources of coliform bacteria.



2.14 The ground water quality in Ghana

Groundwater needs to be assessed globally since it does not respect national boundaries. It has to be started on local, national, regional and finally International levels. Generally groundwater in Ghana can be said to be of good quality for all purpose use. The average pH lies in the range of 3.5-6.0 with high levels of fluoride, manganese and iron in certain localities. There is also high mineralisation resulting in TDS in the range of 1458-2000m/L in some coastal aquifers especially in the greater Accra Region. Groundwater with low pH is normally found in the forest regions of the southern belt of the country. About 30% of the boreholes in Ghana have a problem with its iron content. 1-64mg/L of iron is present in almost all geological formation.

The high iron content originates from the corrosion of borehole pumps with water and partly from the aquifers. The exact contribution from the aquifers is however not known (MOWH, 1998). According to a work done by Issah on the quality of ground water in some borehole wells sampled from the Upper East and the Northern regions of Ghana. He discovered high levels of NO_4^- , PO_4^- , Mn, Pb, Fe and F in some of the wells sampled. These values were compared to WHO and GWSC guidelines (Issah, 2002). In the Ashanti region, The World Vision and Community Water and Sanitation Agency (CWSA) have been involved in the construction of boreholes and analysis of it's water.

The CSWA's work in the Sekyere East, Ahafo-Ano North and South and Bosomtwi-Atwima-Kwanwoma districts in the Ashanti region revealed that the levels of NO_2^- Level was high in parts of Sekyere-East District. The levels of the determined parameters for the Amansie West were all below the WHO guidelines (CWSD, 1999).

CHAPTER THREE

3.0 MATERIALS AND METHODS

3.1 Study Area

The Offinso District is one of the 18 Administrative Districts of the Ashanti region which was recently split into two (Offinso North and South). It shares boundaries with Atwima, Ahafo-Ano South, Kwabre, Afigya-sekyere and Ejura-Sekyere Dumase districts in the Ashanti and Tano South, Sunyani, Techiman and Nkoranza districts of Brong Ahafo.

3.2 Location

Offinso is located in the North-western portion of the region and lies within longitude $1^{\circ}65' W$ and $1^{\circ}45' W$ and latitudes $7^{\circ}25' N$ and $6^{\circ}55' N$.

The district covers an area of 1,225Km² and is divided into 48 electoral areas (Fig 3.2).

3.3 Geology

Offinso is one of the largest Districts in the region. The district has a very interesting geological formation beneath it. The southern part of the district is characterized by granite and Birmanian rock formations while the northern part is mainly characterized by granitic rock formations (Fig 3.1).

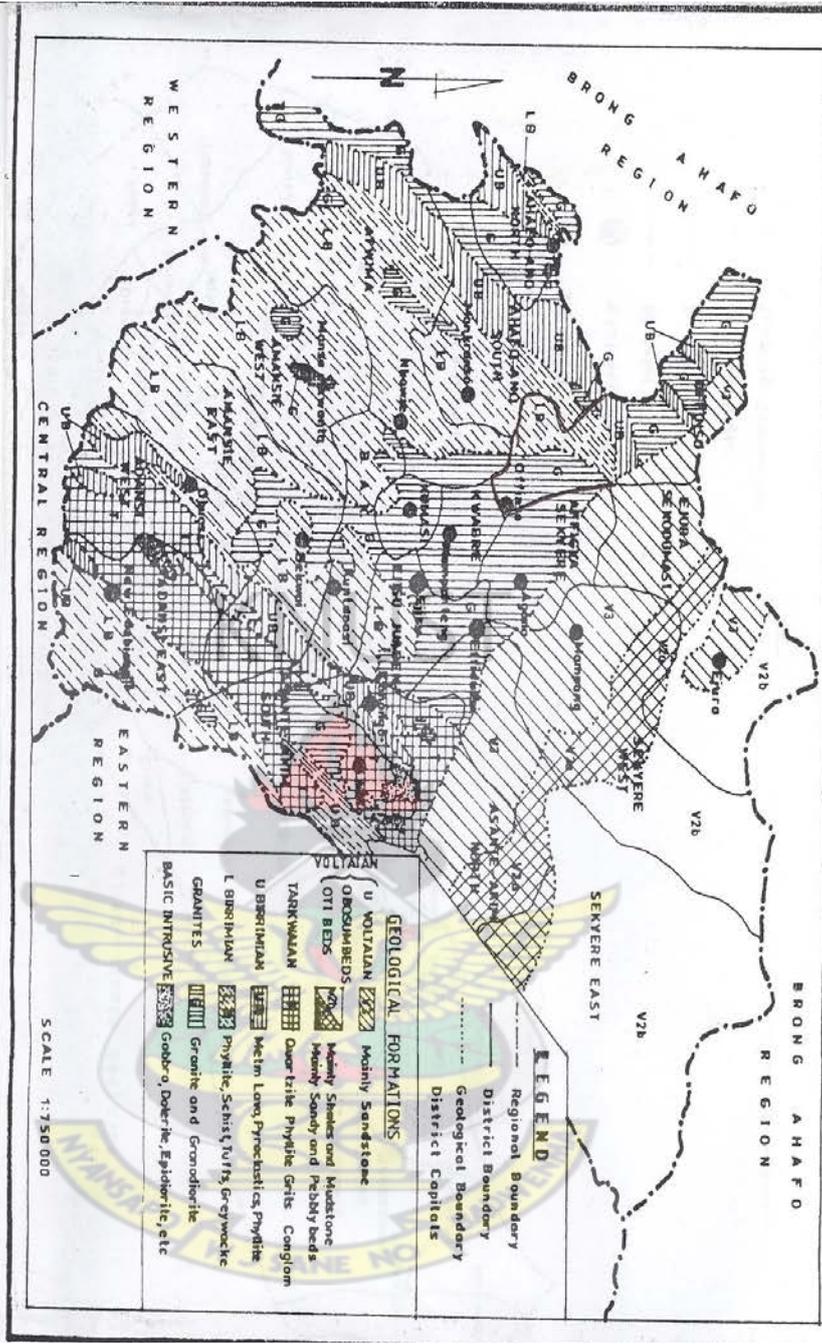


Fig 3.1 The geological map of the Ashanti Region of Ghana

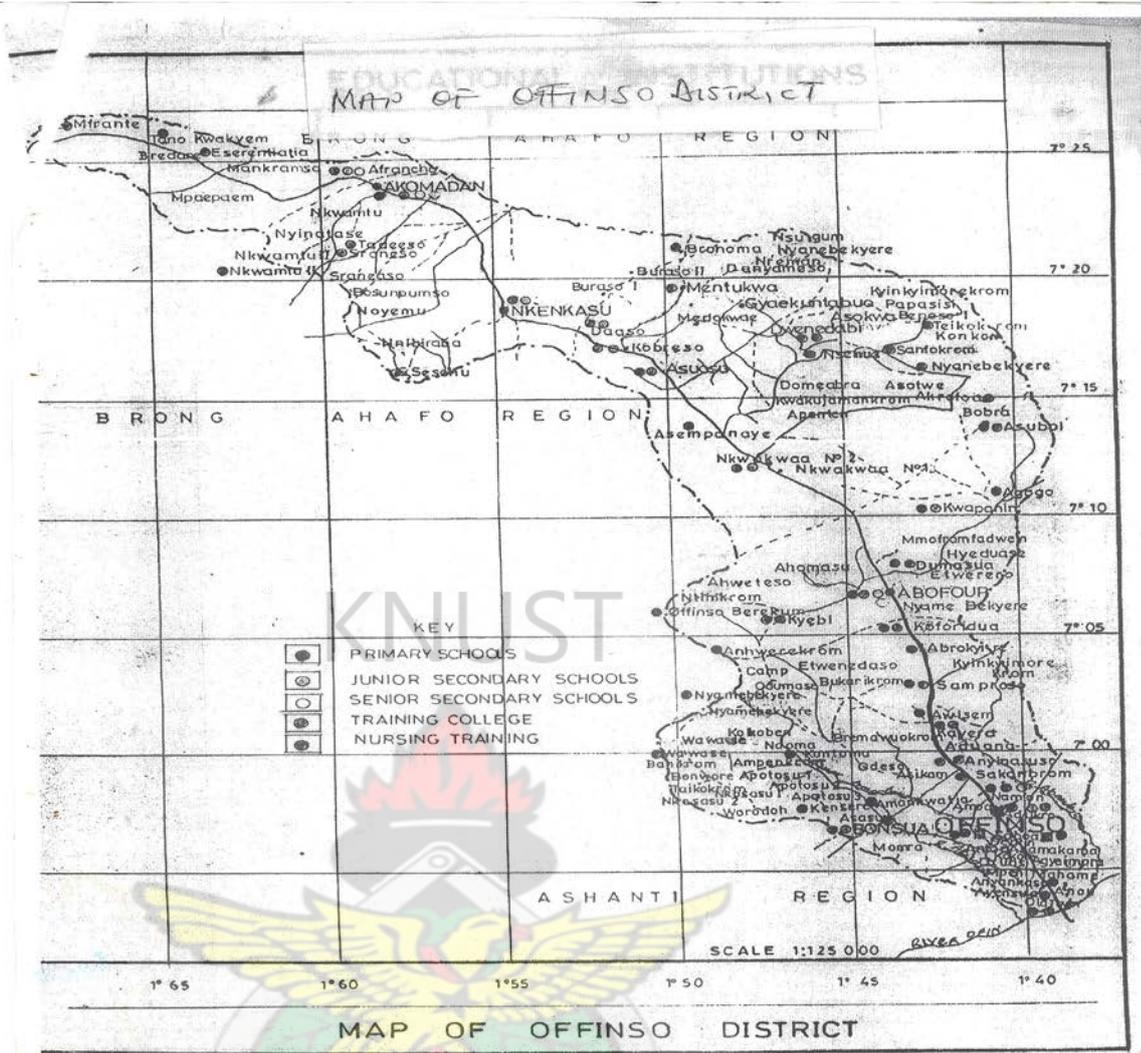


Fig. 3.2: Map of Offinso district

3.4 Climate

The District falls in the moist semi-deciduous forest zone of Ghana and therefore experiences an annual rainfall average of 1200mm. The district is characterized by two rainfall patterns with different intensities (Dickson and Benneh, 1980). The major rainy season extends from April to July and the minor between September and November. The annual temperature is about 27°C with March being the hottest and August being the coldest Month.

3.5 Description of sampling sites

This research was conducted in the Offinso North and South districts of Ashanti region. The district is one of the biggest in the Ashanti region and therefore the region is administered by the district assembly through nine major (9) town councils.

The research was conducted in seven (7) out of the nine (9) town councils. Five villages were randomly selected from each of the seven town councils. Samples were taken over a six month period beginning January, 2007 to June, 2007. Samples were collected in the early hours of the morning. This was to ensure that the water had not been disturbed much through pumping which can affect the temperature and total dissolved solids (TDS) content.

A total of thirty five (35) boreholes were sampled. Thorough chemical and biological analysis was carried out on all the samples for the entire duration. The parameters analysed from the samples are the temperature, colour, TDS, pH, turbidity, conductivity, alkalinity and hardness.

The presence of trace metals such as Pb, Cd, Cu, Fe, and Zinc were also analysed. The nutrient levels were also analysed to determine the presence and levels of phosphate, nitrates and chloride in the samples. The topographic conditions as well as kind and type of human activities in the immediate environs (50 meters) of the boreholes were taken into consideration at the time of sampling since they have a high tendency of contributing to the level and nature of contaminants.

In general most of the areas around the taps about 5m were all cemented into a platform. Sixty percent of the boreholes sampled were all located in the main township whilst forty percent of the total were mostly at the outskirts of the townships. Two of the taps precisely Akenkansu Disabled School and Bobra village were located at the down side of the public place of convenience giving a high tendency for contamination.



Table 3.1 Nature of sampling sites

Community (Town council)	Sample name	Activities within 50m of catchments	Topography	Depth of borehole
Asuoso town council				
Asuoso	A1	Road side and settlement.	Level ground	65
Asemaneye	A2	Within settlements.	In gentile slope towards bore hole	„
Kobreso	A3	Surrounded by farm lands.	In gentile slope towards bore hole	„
Darso	A4			
Mantukwa	A5	Located at road side	In gentile slope towards bore hole	„
Ankenkaasu town council				
Ankenkaasu	NK1	Within settlement	Level ground	65
Seseko	NK2	Outskirt of township	In gentile slope towards bore hole	„
Bobra	NK3	Within settlement	In gentile slope towards bore hole	„
Nibriba	NK4	Within settlement	Level	„
Asotwe	NK5	Outskirt of town surrounded by farmlands	In gentile slope towards bore hole	„
Samproso town council				
Samproso	SA1	Within ettlements	In gentile slope towards bore hole	40
Anyinasuso	SA2	Beside the main road	Level ground	„
Aduana	SA3	Beside the main road	In slope toward borehole	42
Kayera	SA4	Within settlement	Level ground	„
Sakamkrom	SA5	Outskirt of township	Level ground	„
Abofour town council				
Afransua	AB1	Within settlement	Level ground	-
Ahwetieso	AB2	Beside the main road	Level ground	40
Adukofikrom	AB3	Beside the main road	Level ground	„
Brekum	AB4	Within settlement	Level ground	„
Kyebi	AB5	Outskirt of town surrounded by farmlands	Level ground	„

Offinso town council

Kokote	OF1	Beside the main road	In gentle slope towards bore hole	40
Maase	OF2	Outskirt of town surrounded by farmlands	In gentle slope towards bore hole	„
Obuase	OF3	Within settlement	In gentle slope towards bore hole	„
Mpehin	OF4	Within settlement	In gentle slope towards bore hole	„
Ayankasu	OF5	Outskirt of township	In gentle slope towards bore hole	„

Afrancho town council

Tanokwaem	AF1	Within settlement	Level ground	50
Sretiatia	AF2	Within settlement	Level ground	40
Nkubesa	AF3	Outskirt of town surrounded by farmlands	Level ground	„
Mfante	AF4	Beside the main road	Level ground	„
Attakrom	AF5	Beside the main road	Level ground	„

Bonsua town council

Bonsua	BO1	Outskirt of town surrounded by farmlands	Level ground	„
Anaite	BO2	Within settlement	Level ground	„
Apotosu	BO 3	At school grounds	Level ground	„
Gambia	BO 4	Outskirt of town surrounded by farmlands	Level ground	„
Amankwatia	BO 5	Beside the main road	Level ground	

Microbiological analysis was also carried out on all the samples to determine the presence of faecal and total coliforms.

3.6 Experimental methods.

Water samples were collected using 500ml plastic bottles. The containers were cleaned with warm water and soap and rinsed with double distilled water. The glass containers were washed by soaking in aqua regia (3 parts con. HCL and 1 part (HNO₃) and rinsed with tap water and finally distilled water.

3.7 Sample storage

Some parameters, pH and temperature were analyzed in-situ. Water samples were transported to the laboratory in cool box with ice and analyzed within 6 hours. Samples meant for metal analysis were stored in a refrigerator at 4°C.

3.8 Sampling

Water was pumped out of the boreholes at a very fast rate to cool the metal pipe in order to eliminate the influence of the water temperature with that of the metal pipe. The pumping was sustained for at least five minutes. The sample container was rinsed with some of the water and then completely filled to capacity leaving no air space and immediately covered. The cover of the container was then sealed with masking tap. The environmental sanitation condition around the borehole was taken into consideration. The human activity around the borehole as well as the underlying topography was noted.

Concentrated nitric acid was added to the samples meant for heavy metal analysis making the pH <2.0.

3.10 pH determination

The pH meter was calibrated with 4.0, 7.0 and 10.0 pH buffers and ensured that a plot of mV verses pH followed the nerstian relation. A 100ml aliquot of each sample was measured into a beaker and the pH determined using a pH meter. This was done in-situ and at the time of the analysis in the laboratory.

3.11 Conductivity determination

The conductivity meter was standardized with 0.01N KCL solution. The conductivity of this solution was found to be 1413 $\mu\text{mhos/cm}$ at 25 °C with a cell constant of 1. 100ml sample of water was measured into a beaker and its conductivity determined with the WTW conductivity meter within two hours of sampling. The determinations were made after refrigerated samples had been allowed to attain room temperature.

3.12 Total dissolved solids (TDS) determination

A 50ml well-mixed sample was measured into a beaker.

The WTW TDS/ Conductivity meter probe was immersed in the sample and its conductivity recorded.

3.13 Temperature determination

This was determined on site at the time of analysis. An aliquot of 50 ml of sample was measured into a 100ml beaker and a 0-60°C thermometer immersed in the solution.

The reading on the thermometer was then recorded.

3.14 Sulphate determination

Solutions of concentration $1\mu\text{g/ml}$ were prepared. To each of these was added 10ml of conditioning reagent and 0.3g of barium chloride. The standards were allowed to stand for 45 minutes. The respective absorbance of the solution at 420nm was determined. From this data a graph of absorbance verses concentration was plotted.

A 10ml volume of conditioning reagent was added to 25ml of sample. It was followed by the addition of 0.3g of BaCl_2 the mixture was then diluted to 100ml with double distilled water. Prepared samples were allowed to stand for 45 minutes. The concentrations were determined using the UV-Visible spectrophotometer at 420nm. A blank without BaCl_2 was prepared and run at the same wavelength.

3.15 Phosphate determination

Ascorbic acid Method (orthophosphate-Phosphorus)

Standard solutions of 1, 2, 3 and $4\mu\text{g/ml}$ were prepared. To these were added 2 ml of combined reagent. The absorbance of the solutions after 10 minutes was taken at 655nm against a blank solution. A curve of absorbance verses concentration was plotted. To 50ml of the sample was added 2ml of combined reagent. The mixture was allowed to stand for 10 minutes after which the absorbance of the sample was taken with calibrated curve. A blank analysis was performed with all the reagents without sample for all the analysis.

3.16 Colour determination

Colour was determined within 2 hours of sampling. This was done after samples had been allowed to rest on a bench to attain room temperature. An aliquot of 50ml of

sample was measured into a special test tube used for colour analysis. The colour disc was rotated until a standard colour match was found for the samples.

3.17 Nitrate determination

Aliquots of 0.1, 0.2, 0.3 and 0.4ml of the stock solution were measured into different 100ml volumetric flasks. To these 2ml of 0.1M NaOH was added followed by the addition of 1, 2, 3 and 4 ml of colour developing reagent respectively. The mixtures were diluted to 100ml mark forming 0.25 μ g/ml 0.50 μ g/ml 0.75 μ g/ml and 1.00 μ g/ml respectively

A straight line graph of absorbance at 543nm versus concentration passing through the origin was obtained for the prepared standard solutions. An aliquot of 2ml of 0.1M NaOH solution and 1ml of colour developing reagent was added to a 50ml sample. The mixture was allowed to stand for 15 to 20 minutes. The nitrite concentration was determined at wavelength 543nm of absorbance. A blank analysis was performed with all the reagents without samples for all the analysis.

3.18 Turbidity determination

A 30ml aliquot of each sample was measured into the cuvette of Nephela-EU turbidimeter and the respective reading taken. This was done three times and the mean value taken.

3.19 Total Metal determination using Atomic Absorption Spectrophotometer (AAS).

The concentrations in mg/L of five metals were determined in all the samples namely, Cu, Zn, Cd, Pb and Fe with the Atomic Absorption Spectrophotometer. The flame used for the analysis was air-acetylene mixture. A 100ml stock solution of multi – element solution was obtained from the laboratory of the Environmental Protection Agency, Accra. Standard solutions ranging from 0.2 to 5.0mg/l were prepared for calibration curves of the various metals.

A blank analysis was performed with distilled water treated to the sample treatment.

The following concentrations of metal solutions were prepared to determine the baseline absorbance value at 4.0

Pb: 9.4mg/L, Zn: 1.2mg/L, Cu: 3.7mg, Cd: 3.0mg/L, Fe: 5.5 mg/l.

The metal concentrations were determined one after the other using their respective hollow cathode lamps (HCL) and calibration curves. Air-acetylene wave flame was used for all the analysis. The respective wavelengths employed for the metal determinations were Fe at 248.7nm, Pb at 217.0nm, Zn at 213.9nm, Cu at 324.8 and Cd at 228.8nm

3.20 Digestion of samples for Zn, Pb, Cd, and Cu

An aliquot of 5ml of concentrated nitric acid was added to 50ml of sample of water in a 100ml beaker. This mixture was heated on a hotplate to boil until the colour of the solution became pale and clear. The solution was heated on a hot plate to boil until its volume got to about 20ml. Another 5ml of concentrated nitric acid was added and the beaker was covered with a watch glass and the heating continued for about 10 more minutes. A final 5ml acid was used to rinse the slides of the beaker. The solution was

poured into a 50ml volumetric flask and topped with distilled water to the mark. A blank solution was similarly prepared. The absorbance of the blank was taken before all the analysis.

3.21 Total Hardness Determination

A 500ml sample was measured into a conical flask. To this was added 1ml portion of ammonium chloride buffer solution and was then followed by the addition of 30mg erichrome black T indicator crystal. The resulting solution was titrated with 0.01M EDTA solution with continuous stirring until the end point was reached. The end point is when the last reddish tinge disappears.

Calculations: (total hardness) mg/L $\text{CaCO}_3 = \frac{A \times B \times 1000}{I \text{ ml sample}}$

Where A=ml of titrant and B=mg CaCO_3 equivalent to 1 ml EDTA titrant.

3.22 Alkalinity Determination

A 50 ml sample was measured into a conical flask. Two drops of methyl orange indicator was added and the resulting mixture titrated against the standard 0.1M HCL solution to the first permanent pink colour at pH 4.5

The following equation was used in the calculation

Alkalinity mg (CaCO_3)/L = $\frac{A \times N \times 50,000}{1 \text{ ml sample}}$

Where A=ml of acid used.

N= Normality of standard acid used

Chloride Determination by argentometric titration

An aliquot of 50ml of sample was measured into a conical flask. The pH was then adjusted to a range of 7-10 with H_2SO_4 for high pH samples and NaOH for low pH samples. Two drops of K_2CrO_4 indicator was added.

Standard $AgNO_3$ solution of 0.01M was titrated against the resulting mixture above to a pink yellow end point.

Blank titration with only the reagents and no water sample was also performed

Chloride (mg chloride per litre) = $\frac{X \times N \times 1000 \times 35.5}{1 \text{ ml of sample}}$

X=end point volume.

N=Normality of $AgNO_3$.

3.23 Preparation of reagents

- **Ammonium chloride buffer.**

The buffer solution was prepared by dissolving 16.9 g of ammonium chloride (NH_4Cl) in 143 ml of concentrated ammonium hydroxide solution (NH_4OH). This was dilute to 25ml with distilled water

- 0.01M Sodium salt of EDTA.

A 0.01m Solution of disodium salt of EDTA (Analar grade) was prepared to dissolving 3.7224g of the salt in distilled water and diluting to 1000ml. To this 780mg of magnesium sulphate heptahydrate was added

- 0.1M HCL.

A 2.1ml solution of 12M concentrated HCL was added to 200ml of distilled water to 1000ml mark

- 0.05N Na₂CO₃ Solution.

A litre of the carbonate solution was prepared by dissolving a 4.5g of dried Na₂CO₃ in double distilled water and transferred into a 1l volumetric flask. The solution was made to the mark with double distilled water

- Standard HCL.

The approximate 0.1M HCL prepared was titrated against 40ml of 0.05N Na₂CO₃ diluted with 60ml of water. The acid was added until a pH of 5 was reached. The solution was boiled for 5 minutes and cooled in desiccators at room temperature. The solution was boiled for 5 minutes and cooled in desiccators at room temperature. The titration was then continued to the pH inflection point

$$N = \frac{AXB}{53XC}$$

$$53XC$$

A=weight in grams of sodium carbonate, B=ml of sodium carbonate solution taken for titration.

C=ml of acid used

- 5% K₂CrO₄

This was prepared by weighing 5g of K₂CrO₄ powder. It was dissolved in a beaker of double distilled water and poured into a 100ml volumetric flask. The mixture was then diluted to the mark with double distilled water

- 0.101M AgNO₃.

A one litre solution of silver nitrate was prepared by weighing 1.699g of solid silver nitrate. It was then dissolved with double distilled water in a beaker and then transferred into 1000ml volumetric flask. It was then diluted with double distilled water to the mark

- Stock sulphate solution.

A 1.479g of anhydrous sodium sulphate salt was dissolved in double distilled water and diluted to 1000ml. This stock solution contains 1000 μ g/ml of sulphate.

- Conditioning reagent.

A 50ml aliquot of glycerol was mixed with a solution containing 30ml of concentrated HCL, 30ml of distilled water. 100ml 95% ethanol and 7.5g of NaCL

- Stock Orthophosphate solution (phosphorus solution)

Potassium dihydrogen orthophosphate was dried at 110°C. A 0.4393 g of the salt was weighed and dissolved in 1l of double distilled water. The stock was preserved with 5ml of chloroform and stored in a stopper flask. The strength of this stock solution is 100 μ orthophosphate-phosphorus per litre.

- 2.5m Concentrated H₂SO₄.

An aliquote of 70ml of analar grade concentrated H₂SO₄ was slowly added to 30ml of double distilled water in 500ml volumetric flask. The flask was cooled under running tap and the solution made to the mark with distilled water.

- Ammonium molybdate solution (4%).
- A weighed 40g of analar grade ammonium molybdate was dissolved in 5000ml of distilled water in a 600ml beaker. After cooling the solution was transferred into a 1l volumetric flask and made to the mark with double distilled water. The solution was kept in a plastic bottle and stored in a refrigerator.

- Ascorbic acid (0.01M).
- A 1.8g of analar grade ascorbic acid was dissolved in 100ml of distilled water. This solution was prepared freshly before use. However it could be stored in a refrigerator for one work.
- Single combined reagent.

This was prepared by pouring 50ml of 2.5M H_2SO_4 , 5ml potassium tartrate, 15ml ammonium molybdate and 30ml ascorbic acid solution.

- Standard sodium nitrate solution.

A mass of 1.232g of sodium nitrate was weighed from a previously dried amount at $100^\circ C$ for 2hours, dissolved in double distilled water and diluted to the 1000ml mark.

The concentration of the standard prepared is $250\mu g/l$ as nitrate

- 0.1M NaOH.

An amount of 4g of sodium hydroxide pellets was weighed. It was dissolved in a small volume of distilled water before transferring to 100ml volumetric flask where it was diluted to mark.

- Colour Developing reagent.

A 300ml distilled water. 50 ml concentrated phosphorous acid and 7.5g of sulphanilamide and 0.375g of naphthyl-1-amide were mixed together and diluted to 500ml.

3.24 Microbiological Analysis

3.24.1 Preparation of serial dilution

The 10^{-1} or 1/10 dilution

The sample was thoroughly mixed by inverting sample bottles several times and preparing serial dilutions as follows

Using an automatic pipette and sterile 1ml pipette tip a 1ml aliquot from an inch below the surface was added drawn to 9ml of sterile ringers in a test tube. This is the 10^{-1} dilution.

For a 10^{-2} or 1/100 dilution, a fresh sterile pipette was used to mix the 10^{-1} dilution by drawing the suspension up and down ten times. 1ml of the 10^{-1} was drawn and placed into another tube containing 9ml of the sterile ringer's solution.

This is the 10^{-2} dilution.

3.24.2 Total viable count

Using a fresh sterile pipette tip for each dilution aseptically add 1ml of each the dilution of water samples was placed into universal bottles containing molten plate count agar at 40°C . The sample and agar was mixed by rotating the bottle between the palms taking care not to form bubbles. The mixture was then poured into a sterile Petri dish and incubated at 37°C for 48 hours. After which the colony counter was used to count the number of microorganisms on countable plates.

3.25 Total coliforms

Using a fresh sterile pipette tip for each aseptically and add 1ml of each of the dilution of water sample to 5ml of MacConkey broth provided. 1ml of water sample to 3 tubes of MacConkey broth and 1ml of the 10^{-1} dilution to 3 tubes of MacConkey broth. 1ml of the 10^{-2} dilution to 3 tubes of MacConkey and continued to the 10^{-6} .

The bottle and tubes containing the Durham tubes for the collection of gas ensured that there is no gas in the inverted tubes before they were incubated. The samples were labeled and incubated at 37°C for 48 hours. Tubes with gas in the inverted durham tubes and Change in colour from pink to yellow is positive .tubes with no change in colour and or collection of gas is negative. The colonies were counted using the colony counter and the result read from the most probable number (MPN) tables.

3.26 Statistical Analysis

Analysis of variance (ANOVA) was used to examine the apparent differences in observed data between the different sampling location in the stream and the wastewater. Significant difference was tested at 95% confidence level. The result of the ANOVA is found in the results and discussion section.

CHAPTER FOUR

4.1 RESULTS

4.2 Physicochemical parameters for borehole water in the dry and wet seasons

The mean pH for the entire dry season ranged from 4.64-6.26 with the highest of 6.26 recorded at Asuoso and the lowest of 4.64 at the Offinso township site (Table 4.1). In the wet season, mean pH also ranged from 4.64 to 6.09 (Table 4.2). The highest pH of 6.09 was recorded at Samporosos and the lowest of 4.64 at the Offinso township. pH for all the samples in both the dry and wet seasons were mildly acidic. There was no statistically significant differences ($p=0.727$) in pH between the wet and dry seasons.

Turbidity of the borehole water samples during the dry season varied from 0.74 to 2.15NTU with the lowest recorded at Samproso and the highest at Akenkaasu. Contrastingly, turbidity of the borehole water samples were higher during the wet season and varied from 1.39 to 3.93 NTU (Table 4.2). However, these values fell within the WHO recommended acceptable limits 0.00-5.0 NTU.

Mean total dissolved solids concentrations ranged from 66.06 to 240.64 mg/l in the dry season and 81.86 to 292.13 mg/l in the wet season with the highest values recorded at Afrancho and the lowest at Abofour (Table 4.1 and 4.2). The total dissolved solids were within the WHO acceptable limits of 1000mg/l (Table 4.1 and 4.2). There were no statistically significant differences ($p=0.512$) between the mean concentration for the wet and dry seasons respectively.

Average hardness for the borehole water samples ranged from 92.80-290.60 in the dry season and 98.6 to 312.20 mg/l in the wet season (Table 4.1 and 4.2). The highest values were recorded at the Offinso township and the lowest at Asuoso. The hardness values were low which indicates that the water samples were all soft and within the WHO permissible limit of 500mg/l.

Alkalinity ranged from 71.00-107.40 in the dry season and 73.40-107.40 in the wet season with the highest values recorded at Afrancho and the lowest at Asuoso for the dry season and Abofour in the wet season. These values were within the WHO limit of 200mg/l (Table 4.1 and 4.2).

Similarly, colour ranged from 2.00 to 7.78 HU in the dry season and 2.30 to 7.78 HU wet season with the highest at Bonsua and the lowest at Samproso. All the samples were within the WHO limit of 15 HU (Table 4.1 and 4.2).

Mean conductivity of water samples from the town councils increased considerably in the wet season (Table 4.1 and 4.2). The highest conductivity value of 179.97 μ mhos/cm was recorded at Samproso in the wet season and the lowest of 82.25 μ mhos/cm at Offinso in the dry season. There were no statistically significant difference ($p=0.603$) between the mean concentration for the wet and dry seasons respectively.

Table 4.1 Range and mean values of physicochemical parameters analysed for borehole water in the Offinso District from January-March 2007

Sample ID	Temp °C	pH	TDS mg/l	Conductivity µmhos/cm	Colour HU	Turbidity NTU	Alkalinity mg/l	Hardness mg/l
WHO LIMIT		6.50-8.50	1000.00	1500.00	15.00	5.00	200.00	500.00
Asuoso	29.70-29.40	6.50-4.92	90.24-43.19	186.21-102.86	8.00-5.00	3.45-0.89	125.00-25.00	115-60
	29.58	6.26	90.24	146.49	5.80	1.95	71.00	87.00
Nkenkaasu	29.70-29.41	6.30-4.39	111.25-50.25	154.64-78.21	20.00-0.00	3.41-0.40	184.00-29.00	198.00-75.00
	29.52	5.81	78.36	122.61	7.40	2.15	81.20	153.00
Samporoso	29.70-28.00	6.90-5.59	111.25-73.21	158.65-105.41	5.00-0.00	2.45-0.10	143.00-34.00	522.00-43.00
	28.96	6.09	90.99	134.51	2.00	0.74	83.8	222.00
Abofour	29.70-28.60	6.80-5.25	80.21-47.41	142.68-97.82	15.50-0.00	3.95-0.02	113.00-21.00	221.00-51.00
	29.36	6.25	66.06	115.37	6.10	1.79	73.40	100.80
Offinso	29.80-29.40	4.04-5.32	310.45-32.04	168.21-16.50	18.50-0.00	4.30-0.42	231.00-43.00	512-98
	29.64	4.64	145.29	82.25	6.80	2.07	106.80	262.25
Afrancho	29.70-29.50	6.42-5.45	498.23-151.14	101.24-81.20	9.50-5.00	2.95-0.50	267.00-23.00	212.00-62.00
	29.58	5.99	240.64	91.82	6.10	1.71	107.40	162.00
Bonsua	29.70-29.50	6.32-5.24	232.13-135.21	161.36-60.14	22.10-0.00	4.02-0.28	123.00-23.00	268.00-26.00
	29.54	5.83	180.16	98.79	7.78	1.95	99.60	100.20

Table 4.2 Range and mean values of physicochemical parameters analysed for borehole water in the Offinso District from April-June 2007

Sample ID	Temp °C	pH	TDS	Conductivity µmhos/cm	Colour HU	Turbidity NTU	Alkalinity mg/l	Hardness mg/l
WHO LIMIT		6.50-8.50	1000.00	1500.00	15.00	5.00	200.00	500.00
Asuoso	29.80-29.40	6.21-4.12	199.90-48.51	115.00-60.00	8.00-5.00	4.75-3.21	125.00-35.00	125-70.00
	29.58	5.53	115.88	87.00	5.8	3.93	73.6	98.6
Nkenkaasu	29.70-29.41	6.30-4.39	105.04-68.48	127.77-87.19	20.00-0.00	4.63-0.80	184.00-29.00	234.00-70.00
	29.52	5.81	86.53	112.42	7.4	2.94	81.2	167.6
Samporoso	29.70-28.00	6.90-5.59	113.15-94.58	251.56-135.59	6.50-0.00	3.75-0.10	143-34	540.00-55.00
	28.96	6.09	100.57	179.97	2.3	1.39	83.8	231.6
Abofour	29.70-28.60	6.80-5.25	96.10-69.39	195.37-118.58	15.50-0.00	4.07-0.02	113.00-21.00	241.00-53.00
	29.36	6.25	81.86	148.55	6.1	2.23	73.4	112.8
Offinso	29.80-29.40	5.32-4.04	399.57-37.98	216.19-18.10	18.50-0.00	4.70-0.80	231.00-43.00	616.00-126.00
	29.64	4.64	178.14	102.63	7.1	2.41	106.8	312.2
Afrancho	29.70-29.50	6.42-5.24	623.79-168.18	160.20-84.2	9.5-5.00	4.65-0.25	267-23	256-24.00
	29.58	5.99	292.13	117.54	6.1	2.2	107.4	148.8
Bonsua	29.70-29.40	6.32-5.24	276.81-156.23	136.76-16.36	22.10-0.00	5.20-0.77	123-62	324.00-38.00
	29.54	5.83	219.66	83.72	7.78	3.76	99.6	118.6

Table 4.3 Range and mean values of physicochemical parameters analysed for borehole

Turbidity NTU

water in the Offinso District from January-June 2007

Sample ID	Temp °C	pH	TDS mg/l	Conductivity µmhos/cm	Colour HU		Alkalinity mg/l	Hardness mg/l
WHO LIMIT		6.50-8.50	1000.00	1500.00	15.00	5.00	200.00	500.00
Asuoso	29.80-29.40	6.42-4.52	191.10-45.85	380.20-141.50	8.00-5.00	4.10-2.05	125.00-30.00	120.00-65.00
	29.58	5.89	103.07	208.98	5.8	2.94	72.6	92.8
Nkenkaasu	29.70-29.41	6.60-4.39	98.80-59.5	125.80-98.80	20.00-0.00	4.02-0.60	4.02-0.06	205.00-91.00
	29.52	5.95	78.9	117.94	7.4	2.53	2.53	164
Samporoso	29.70-28.00	7.02-5.91	112.20-84.80	203.10-120.50	6.50-0.00	3.10-0.10	143.00-34.00	531.00-49.00
	28.96	6.362	95.78	157.24	2.3	1.06	79	226.8
Abofour	29.70-28.60	6.96-5.78	87.2.-58.40	150.67-108.20	15.5- 0.00	4.01-0.02	113.00-21.00	231.00-52.00
	29.36	6.53	73.96	131.96	6.1	2.01	73.4	106.8
Offinso	29.80-29.40	5.51-4.58	192.217.30	355.01-35.01	18.50-0.00	192.20-17.30	231.00-43.00	564.00-112.00
	29.64	5.03	92.44	164.51	6.8	2.26	106.8	290.6
Afrancho	29.70-29.50	6.96-5.78	128.8-82.70	561.01-159.86	9.50-5.00	3.80.68-0.06	267.00-23.00	234.00-23.00
	29.58	6.24	105.14	266.39	6.1	2.26	107.4	141.4
Bonsua	29.70-29.50	6.59-5.97	123.80-68.60	251.01-150.11	22.10-0.00	4.61-0.50	123.00-62.00	296.00-32.00
	29.54	6.27	98.24	199.91	7.78	1.96	99.6	109.4

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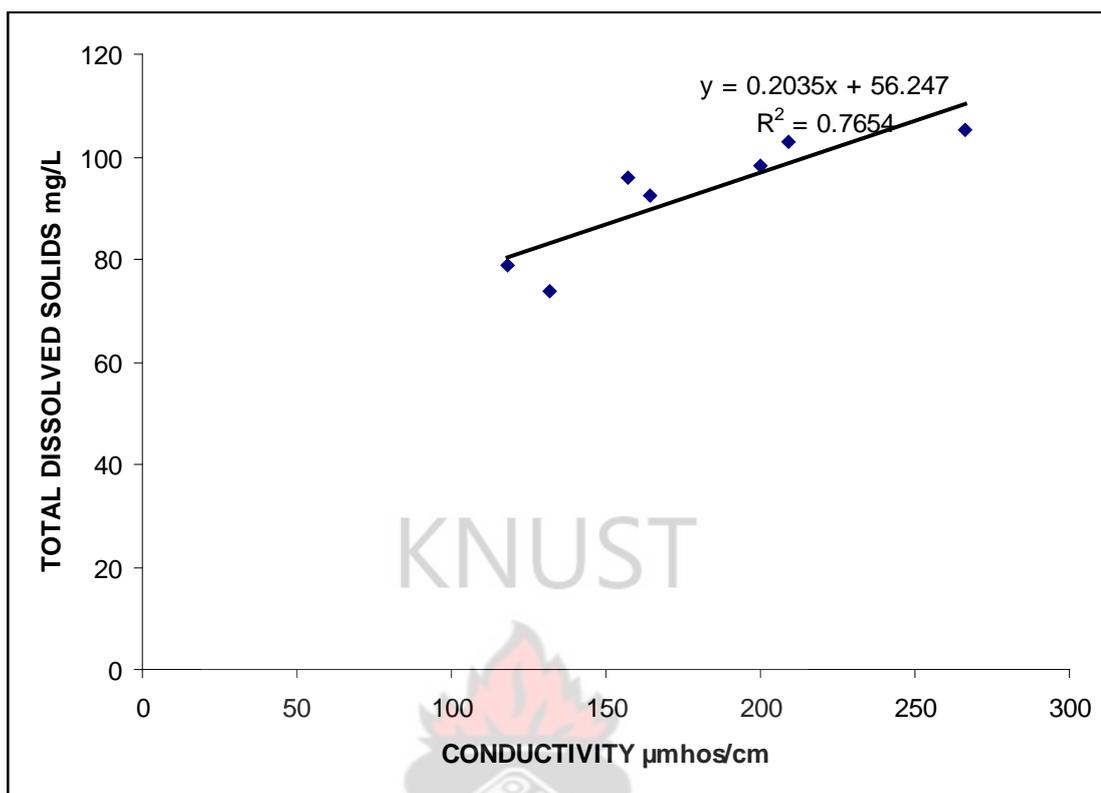


Fig 4.1 Relationship between conductivity and total dissolved solids (TDS)

The linear curve gave correlation of $R^2 = 0.7654$ as shown in Figure 4.1. It is an indication that TDS increases in direct proportion with conductivity. Therefore the conductivity of a sample can be worked mathematically using the equation above when the TDS is known.

The mean hardness of the borehole water samples ranged from 92.80-290.60 during the dry season with the highest value recorded at Samproso and the lowest at Asuoso (Table 4.3). However, during the wet season, there was a general increase in water hardness (Table 4.1 and Table 4.2). The United States Public Health Service recommends a maximum of 500mg/l hardness in drinking water. However, a maximum limit is not set by the WHO. There were no statistically significant

differences ($p= 0.709$) between the mean concentration for the wet and dry seasons respectively.

Turbidity of samples analysed from the boreholes varied from 0.74 to 2.15NTU. The lowest was recorded at Samproso and the highest recorded at Akenkaasu. The values were rather very low and fell within the acceptable limit 0.00-5.0 NTU prescribed by WHO.

Table 4.4 Range and mean values of nutrients in the Offinso district Borehole water samples from January-March 2007

Sample ID	Chloride mg/l	Sulphate $\mu\text{g/ml}$	Phosphate mg/l	Nitrate $\mu\text{g/l}$
WHO LIMIT	250.00	250.00		50.00
Asuoso	5.54-1.50	1.02-0.03	1.52-0.54	10.50-0.10
	3.11	0.44	1.1	2.33
Nkenkaasu	11.23-0.24	0.98-0.01	0.16-0.10	1.50-0.75
	4.35	0.38	0.12	1.13
Samporoso	13.10-1.86	2.14-0.61	0.16-0.01	1.67-0.01
	6.74	1.22	0.1	0.72
Abofour	12.79-4.30	3.94-0.40	0.28-0.01	1.12-0.31
	9.22	1.68	0.12	0.59
Offinso	11.54-2.34	3.01-0.62	0.81-0.03	0.63-0.24
	7.25	1.55	0.3	0.63
Afrancho	15.80-7.85	1.23-0.09	0.98-0.03	1.41-0.24
	11.34	0.43	0.27	0.84
Bonsua	9.98-4.22	20.2-0.01	0.3-0.01	1.51-0.42
	7.62	4.29	0.18	0.83

4.3 Nutrients in Offinso district borehole water samples in the dry and wet seasons

Mean chloride levels during the dry and wet seasons ranged from 3.11 to 11.34mg/l with the highest value of 11.34mg/l recorded at Afrancho in the wet season whilst

Asuoso recorded the lowest value of 3.11 mg/l in the dry season (Table 4.4 and 4.5). There were no statistically significant differences ($p= 0.999$) between the two seasons. The chloride values for all samples analysed were within the WHO permissible level of 250.00 mg/l. 34 mg/l.

Mean phosphate concentration in the samples varied between 0.10 and 1.24 mg/l (Table 4.4 – 4.6).

The highest value was recorded at Asuoso in the wet season and the lowest at Samporoso in the dry season (Table 4.4 and 4.5). The wet season samples however showed slight increases in the level of phosphates. There were no statistically significant differences ($p=0.994$) in the mean of phosphate between the two seasons. Phosphate concentrations in the samples were within the WHO permissible limit.

The mean level of sulphate in the samples analysed for the entire period ranged from 0.372 to 5.33 $\mu\text{g/l}$ (Table 4.4 – 4.6). The highest value of 4.29 mg/l was recorded at Bonsua in the wet season and Asuoso recorded the lowest value of 3.11 mg/l in the dry season whilst Nkenkaasu recorded the lowest in the wet season (Table 4.4 and 4.5). These seasonal variations were not statistically significant ($p= 0.998$). The values were however within the WHO permissible limit of 250 $\mu\text{g/ml}$.

From Table 4.4 to 4.6, nitrate concentration in the borehole water samples for both seasons ranged from 0.13 to 2.23. Samples from Asuoso had the highest level of nitrate recording 2.33 $\mu\text{g/l}$ in the dry season and the lowest of 0.72 $\mu\text{g/l}$ at Samporoso also in the dry season. These seasonal variations were not statistically significant ($p= 0.996$). These values were within the acceptable limit of 50.0 $\mu\text{g/l}$ prescribed by the WHO.

Table 4.5 Range and mean values of nutrients in the Offinso district borehole water samples from April to June, 2007

Sample ID	Chloride mg/l	Sulphate µg/ml	Phosphate mg/l	Nitrate µg/l
WHO LIMIT	250.00	250.00		50.00
Asuoso	5.54-1.50	1.02-0.03	1.52-0.54	10.5-0.10
	3.11	0.44	1.10	2.33
Nkenkaasu	11.23-0.24	0.98-0.01	0.16-0.10	1.5-0.75
	4.35	0.38	0.12	1.13
Samporososo	13.1-1.86	2.14-0.61	0.16-0.01	1.67-0.01
	6.74	1.22	0.10	0.72
Abofour	12.79-4.30	3.94-0.40	0.28-0.01	1.12-0.31
	9.22	1.68	0.12	0.59
Offinso	11.54-2.34	3.01-0.62	0.81-0.03	0.632-0.24
	7.25	1.55	0.30	0.63
Afrancho	15.8-7.85	1.23-0.09	0.98-0.03	1.41-0.24
	11.34	0.43	0.27	0.84
Bonsua	9.98-4.22	20.2-0.01	0.3-0.01	1.51-0.42
	7.61	4.28	0.17	0.82

Table 4.6 Range and mean values of nutrients in the Offinso district borehole water samples from January-June 2007

Sample ID	Chloride mg/l	Sulphate µg/ml	Phosphate mg/l	Nitrate µg/l
WHO LIMIT	250.00	250.00		50.00
AS	6.08-1.780	1.05-0.11	1.62-0.84	1.62-0.84
	3.488	0.49	1.24	1.24
NK	12.01-0.55	1.05-0.02	0.22-0.18	1.52-0.86
	4.68	0.37	0.20	1.15
SA	15.60-1.98	2.92-0.51	0.23-0.12	0.23-0.12
	7.55	1.41	0.16	0.16
AB	14.2-5.4	4.03-0.52	0.34-0.14	0.34-0.14
	9.95	1.75	0.21	0.21
OF	15.23-2.723	3.12-0.52	0.95-0.02	0.95-0.02
	8.79	1.58	0.40	0.40
AF	16.12-8.51	1.51-0.113	1.03-0.02	1.03-0.02
	11.35	0.54	0.33	0.33
BO	14.1-5.01	25-0.01	0.22-0.02	0.22-0.02
	9.43	5.33	0.14	0.13

Table 4.7 Range and mean values of heavy metals in the Offinso district

borehole water samples from January-June 2007

Sample ID	Zinc (Zn) mg/l	Lead (Pb) mg/l	Copper (Cu) mg/l	Manganese (Mn) mg/l	Cadmium (Cd) mg/l
WHO LIMIT	3.000	0.010	2.000	30.0000	0.0030
Asuoso	0.7400-0.0400	*	0.7000-0.2400	0.5100-0.0020	0.0025-0.0014
	0.2500	*	0.5320	0.2530	0.0020
Nkenkaasu	0.6000-0.1500	*	0.4800-0.0100	0.6000-0.0100	0.0021-0.0001
	0.4960	*	0.3380	0.2980	0.0005
Samporoso	0.1400-0.0500	*	0.7000-0.0100	2.4-0.02	0.0025-0.0001
	0.1020	*	0.3880	1.1180	0.0012
Abofour	0.8900-0.0600	*	0.700-0.0100	0.56-0.002	0.0025-0.0001
	0.5140	*	0.3820	0.2020	0.0010
Offinso	0.7400-0.0600	*	0.5100-0.0100	1.020.03	0.0021-0.0001
	0.3100	*	0.1560	0.3840	0.0008
Afrancho	0.8900-0.0500	*	0.7000-0.0100	1.2000-0.2000	0.0025-0.0001
	0.5560	*	0.4860	0.5640	0.0016
Bonsua	0.7800-0.0800	*	0.7000-0.2400	2.7000-0.1500	0.0025-0.0001
	0.4460	*	0.4340	0.8660	0.0016

*= parameter not detected.

4.4 Heavy metal content of samples analysed in the dry and wet season

Copper concentration in water samples varied from 0.156mg/l to 0.5320mg/l (Table 4.7 and 4.8). Copper levels were highest at Asuoso and the lowest recorded at Abofour all in the dry season. These seasonal variations between the wet and dry seasons were significant ($p= 0.029$). The values were within the acceptable limit of 2.0 mg/l prescribed by WHO.

The mean level of zinc in the water samples analysed for the entire period ranged from 0.102 to 0.566 (Table 4.7 to 4.9). The highest value of 0.556 mg/l was recorded at Afrancho in the dry season and Samporosu recorded the lowest value of 0.102mg/l also in the dry season (Table 4.7). There were no statistically significant differences ($p= 0.373$) between the seasons. The values were within the acceptable limit of 3.00 mg/l prescribed by WHO.

The mean level of manganese in the water samples for the entire period ranged from 0.020 to 1.118 mg/l (Table 4.7). The highest value of 1.118 mg/l was recorded at Samporosu and Nkenkaasu recorded the lowest value of 0.208 mg/l also in the dry season with no statistically significant differences ($p= 0.387$) between the seasons. These values were within the acceptable limit of 30 mg/l prescribed by WHO.

The mean level of cadmium in the water samples for the entire period ranged from 0.0008 to 0.0020 (Table 4.7 and 4.8). The highest value of 0.0020 mg/l was recorded at Asuoso and Offinso recorded the lowest value of 0.0008 (Table 4.7). These seasonal variations were not significant ($p= 0.5198$). These values were within the acceptable limit of 2.0 mg/l prescribed by WHO.

Table 4.8 Range and mean values of heavy metals in the Offinso district borehole water samples from January-March 2007

Sample ID	Zinc(Zn) mg/l	Lead (Pb) mg/l	Copper (Cu) mg/l	Manganese (Mn) mg/l	Cadmium (Cd) mg/l
WHO LIMIT	3.000	0.010	2.000	30	0.003
Asuoso	0.7400-0.0400	*	0.7000-0.2400	0.5100-0.0020	0.0025-0.0014
	0.2500	*	0.5320	0.2530	0.0020
Nkenkaasu	0.6000-0.1500	*	0.4800-0.0100	0.6000-0.0100	0.0021-0.0001
	0.4960	*	0.3380	0.2980	0.0005
Samporoso	0.1400-0.0500	*	0.7000-0.0100	2.4000-0.2000	0.0025-0.0001
	0.1020	*	0.3880	1.1180	0.0012
Abofour	0.8900-0.0600	*	0.7000-0.0100	0.5600-0.0020	0.0025-0.0001
	0.5140	*	0.3820	0.2020	0.0010
Offinso	0.7400-0.0600	*	0.5100-0.0100	1.0200-0.0300	0.0021-0.0001
	0.3100	*	0.1560	0.3840	0.0008
Afrancho	0.8900-0.0500	*	0.7000-0.0100	1.2000-0.2000	0.0025-0.0001
	0.5560	*	0.4860	0.5640	0.0016
Bonsua	0.7800-0.0800	*	0.7000-0.2400	2.7000-0.1500	0.0025-0.0001
	0.4460	*	0.4340	0.8660	0.0016

*= parameter not detected

Table 4.9 Range and mean values of heavy metals in the Offinso district borehole water samples from April – June 2007

Sample ID	Zinc (Zn) mg/l	Lead (Pb) mg/l	Copper (Cu) mg/l	Manganese (Mn) mg/l	Cadmium (Cd) mg/l
WHO LIMIT	3.0000	0.0100	2.0000	30.0000	0.0030
Asuoso	1.1500-0.0800	*	1.0000-0.0100	1.2000-0.2300	0.0025-0.0001
	0.3160	*	0.5220	0.6780	0.00124
Nkenkaasu	1.1250-0.1300	*	0.1800-0.0100	0.5000-0.0100	0.0025-0.0001
	0.7340	*	0.5100	0.2080	0.00124
Samporoso	0.6400-0.0400	*	0.9000-0.0100	2.7000-0.6000	0.0025-0.0001
	0.2000	*	0.4880	1.1100	0.0025
Abofour	1.3800-0.1500	*	0.9400-0.0100	1.0900-0.1300	0.0025-0.0001
	0.8640	*	0.5220	0.4340	0.00124
Offinso	0.9800-0.0500	*	0.8800-0.0100	1.8000-0.0400	0.0025-0.0001
	0.4460	*	0.4860	0.6660	0.00124
Afrancho	0.8600-0.0800	*	0.8900-0.0100	3.600-0.0100	0.0025-0.0001
	0.3800	*	0.4760	0.9020	0.00124
Bonsua	0.8900-0.0800	*	0.9900-0.0100	1.8700-0.0200	0.0025-0.0001
	0.4378	*	0.5200	0.7680	0.00124

*= parameter not detected

Table 4.10 Range and mean values of coliforms in the Offinso district borehole water samples from April – June 2007

Sample ID	Total Coliforms CFU/100ml	Feacal Coliforms CFU/100ml
WHO LIMITS	400.00	0.00
Asuoso	ND	ND
Nkenkaasu	20	ND
Samporoso	10	ND
Abofour	ND	ND
Offinso	10	ND
Afrancho	5	ND
Bonsua	ND	ND

ND=parameter not detected in sample analysed.

4.5 Microbiological analysis

All the water samples analysed from the boreholes in the dry season did not contain any coliform but samples obtained in the wet season showed the presence of coliform (Table 4.10). The Highest counts of total coliform was 20 CFU/100ml and was recorded at Nkenkaasu whilst the lowest counts of 5 cfu/100ml was recorded at Afrancho. Feacal and total coliform were however not detected in samples from Asuoso, Abofour and Bonsua.

CHAPTER FIVE

5.0 DISCUSSION

5.1 Analysis of physicochemical parameters

5.1.1 Temperature

In this study, the temperature ranged from 28.0 to 29.5°C (Table 4.1). The relatively low sampling temperature could be attributed to the fact that most of the samples were collected very early in the morning. Temperature of drinking water is often not a major concern to consumers especially in terms of drinking water quality. The quality of water with respect to temperature is usually left to the individual taste and preference and there are no set guidelines for drinking water temperature.

5.1.2 pH

pH of the Offinso district borehole water samples ranged from 5.03 to 6.54 which makes it slightly acidic. However samples from Offinso, Asuoso and Nkenkaasu rather showed very low pH values of 5.03, 5.89 and 5.95, respectively. These pH values were very low compared to the WHO standard for drinking water (6.5-8.5). Most of the values however fell within 6.0 – 7.0, few were slightly below 6.0. The mean pH of samples analysed did not vary much between the two main seasons (Fig 4.1 and 4.2)

5.1.3 Turbidity

Mean turbidity values ranged from 1.06 to 2.94 NTU. All the samples analysed were clear with turbidity values below the WHO standard limit of 5.0 NTU. Even though all

the samples were within acceptable limits, samples from Asuoso and Nkenkaasu however, showed significant turbidity values recording 2.94 and 2.53 NTU respectively. Turbidity values over the two seasons showed some remarkable differences. Turbidity directly influences the colour of water and there is a general increase in colour with increasing turbidity values. The turbidity values recorded in the dry season for all the town councils almost doubled in the raining season. This can be attributed to increased infiltration (percolation) into the aquifers during the raining season leading to increased dissolution of substances that made the ground water turbid. However in the dry season when there is virtually no infiltration into the aquifers, most of the dissolved substances settle down leading to a reduction in the overall turbidity of the water.

Turbidity in water causes problems with water purification processes such as flocculation and filtration which normally increases the cost of water treatment (DWAF,1989). High turbidity values may also increase the possibility of microbiological contamination (DWAF, 1998).

5.1.4 Colour

Colour standard is set for reasons of appearance and requires that water be virtually colourless. According to WHO standards for drinking water, the colour limit should be 15 HU or 20 mg/l Pt/Co. All the water samples were within the WHO limit and ranged between 7.78-2.30 HU (Table 4.3). Colour in natural water usually results from the leaching of organic materials and is primarily the result of dissolved and colloidal humic substances, primarily humic acid and flavic acid. Colour is also strongly influenced by

the presence of iron and other metals. However the overall colour content of the samples analysed do not pose any health threat to those that use the water.

5.1.5 Total Dissolved solids (TDS)

Suspended solids and total dissolved solids (TDS) are indicators of polluted water. The value for TDS ranged from 73.96 to 105.14 mg/l. These values were within the WHO standard value of 1000.00. McCutcheon *et al.*, (1983) stated that the palatability of water with TDS level less than 600 Mg-' is generally considered to be good whereas water with TDS greater than 1200 mg/l becomes increasingly unpalatable.

5.1.6 Conductivity

Electrical conductivity gives an account of all, the dissolved ions in solution. Electrical conductivity values varied from 117.94 to 266.39 $\mu\text{mhos/cm}$ with Afrancho recording the highest conductivity of 266.39 and Nkenkaasu the lowest, 117.94. The acceptable limit of conductivity is 1500 $\mu\text{mhos/cm}$ (WHO, 1992). Generally, conductivity of clean water is lower but as it moves down the earth it leaches and dissolves ions from the soil and also picks up organic from biota and detritus (Ferrari, 1989). Generally the conductivity values recorded for communities sampled from the district does not pose any potential health risk for consumers. They were all within the acceptable limit prescribed by WHO limits.

5.1.7 Hardness

Hardness of water may not have any health implications but may affect the taste of water as well as influence its lathering ability when used for washing. Mean hardness of the

water samples ranged from 92.80 to 290.60 mg/l. The United States Public Health Service recommends a maximum of 500mg/l hardness in drinking water. A maximum limit is not set by the WHO.

5.2 Analysis of nutrient loads in the samples

5.2.1 Chloride

The chloride content of the water samples ranged from 3.488 to 9.948 mg/l. The WHO standard for chloride in drinking water is 250 mg/l and the samples were all within the acceptable limits prescribed by WHO and GWCL. Chlorine is an active chemical which has disinfecting capabilities. The sources of chlorine in natural water may be from mine drainage waste and from dissolving rocks. The closeness of the water source to the sea can also influence the chloride content since the sea is characteristically saline. Chloride in water may react with sodium to form sodium chloride. Since sodium chloride has the salty taste, it can be deduced that Chloride in water impacts a salty taste in the water. However the salty taste may be absent in water containing as high as 1000 mg/l chlorine when the predominant cations are calcium and magnesium. That is to say that too much of chlorine in water makes the water esthetically undesirable for drinking purposes.

5.2.2 Phosphate

The phosphate content of the samples ranged from 0.138 – 1.24 mg/l with all the being within the WHO acceptable limit. The concentration of phosphate encountered in the natural water environment is normally not enough to causes any detrimental health effect on humans or animals. Phosphate like any other nutrient is harmless in lower

concentrations but become harmful only in higher doses. Higher doses of Phosphate are known to interfere with digestion in both humans and animals.

5.2.3 Sulphate

The sulphate levels of the water samples ranged from 0.372 to 5.331 mg/l and were within the WHO limit of 250 mg/l and the GWCL limit of 400 mg/l. Sulphate gets into ground water through the dissolution of rocks containing sulphur and mine drainage waste. Water with sulphate levels above 500 mg/l can have a laxative effect until an adjustment to the water is made. The effect of sulphate depends largely on the body mass of an animal - the smaller the animal, the greater the effect. Increased sulphate levels can cause deficiencies in trace minerals which can contribute to a depressed growth rate and infertility in herd. The most serious is thiamine deficiency. The major physiological effect resulting from the ingestion of large quantities of sulphate leads to catharsis, dehydration, and gastrointestinal irritation. Water containing magnesium sulphate at levels above 600 mg/l acts as a purgative in humans. The presence of sulphate in drinking water can also result in a noticeable taste, the lowest taste threshold concentration for sulphate.

5.2.4 Nitrate

Nitrate concentrations ranged from 0.13 to 1.24 and were within the acceptable limit prescribed by WHO and GWC limit of 50.0. Nitrogen is present in soils which are normally fixed by nitrogen fixing bacteria. Nitrogen may exist as nitrates and nitrites.

Nitrogen like any other nutrient is harmless in lower concentrations but become harmful only in higher interconvertible organic nitrogen.

5.3 Analysis of heavy metals in the samples

Heavy metals are often referred to as common pollutants which are widely distributed in the environment with sources mainly from the weathering of minerals and soils (Marian, 1991; O'Neil, 1993). However the level of these metals in the environment has increased as a result of increase in human activities (Prater, 1975; Marian, 1991). With the exception of lead, all the other heavy metals analysed (Zn, Cd, Fe, Mn) were detected in all the samples. However, their levels were within the acceptable limits prescribed by the WHO. Samples from Samproso and Afrancho however recorded higher levels of manganese recording 1.100 and 0.902, respectively.

Manganese is also a naturally occurring element in rocks and is released into the soil through weathering of the rocks. It can therefore be deduced that the high levels of manganese contamination is as a result of the underlying geological formation (rocks). Manganese like other trace metals is essential to the sustenance of life. Manganese, molybdenum, selenium and zinc are needed at low levels as catalyst for enzyme activities. However, drinking water containing high levels of these essential metals or elements may be hazardous to human health (Jennings *et al.*, 1996). Its contact to groundwater is however through leaching. Excess manganese in a person's diet may inhibit the use of iron in the regeneration of blood haemoglobin. A high dose of manganese causes apathy, headaches, insomnia and weakness of legs. Symptoms of

excessive manganese include impulsive acts, absent-mindedness, hallucinations, aggressiveness and unaccountable laughter. Under extreme case, nervous system disorders such as Parkinson's disease may develop (Jennings *et al.*, 1996). Lead was however not detected in any of the samples analysed.

Copper ranged from 0.47 to 0.522 mg/l. Water containing amounts higher than 1.00mg/L is likely to supply too much of this metal. One milligram per litre is also a taste threshold for an average individual. Copper deficiency causes anemia, loss of hair pigment, growth inhibition and loss of arterial elasticity. Higher doses of copper can however be very dangerous and toxic to people especially infants resulting in metabolic disorders. High levels of vitamin C however inhibit good copper absorption. Zinc, silver, cadmium and sulphates in the diet can also affect the uptake of copper. Copper deficiency causes complications in the blood circulatory system.

Zinc in the samples ranged from 0.2 to 0.864 mg/l and were within the WHO acceptable limit of 3.0. This notwithstanding, Abofour, Nkenkaasu and Offinso recorded appreciably high levels of the heavy metal recording 0.864, 0.734 and 0.446 mg/l, respectively. The seasonal variation in the level of the metal was however very minimal.

5.4 Microbiological quality of the borehole water analysed

The result obtained for the microbial analysis indicated that all the water samples were free from faecal coliforms (faecal contamination). Samples collected from Nkenkaasu, Samporoso, Offinso and Afrancho during the wet season showed some total coliforms.

The mean total coliforms ranged between 05.00 and 20.00 with the samples collected in the dry season having neither total nor faecal coliforms. The contamination even though small can be attributed to increased infiltration during the wet season. The results suggest that the general sanitary conditions around the boreholes were very good.

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CHAPTER SIX

6.0 CONCLUSION AND RECOMMENDATION

Water is an indispensable resource in our fast growing industrialised world including Ghana. The pollution of water bodies has become a major global concern because apart from the high cost incurred in water treatment, most water bodies are drying up because of excessive pollution. Since borehole water is central in the daily water consumption needs of persons living in the Offinso district, this study brings to the fore the need for increased water quality.

This work was carried out to determine the quality of borehole water from the Offinso district. Regardless of the very low pH values of less than 5.03 recorded for Asuoso as well as isolated cases of high trace metal levels, colour, turbidity and alkalinity in some of the communities, the status of water in the Offinso district of Ashanti region using microbiological, chemical and physicochemical parameters as indicators can be said to be of acceptable limit for human consumption.

The results indicated that the pH were all within their natural background levels of 6.5–8.5 and 5.0–7.0, respectively. The turbidity, TDS, and conductivity values observed during the analysis were all within the WHO permissible limit.

The levels of trace metals investigated (Cu, Zn, Pb, Cd) were all below the WHO guideline levels. Hence the trace metal concentration does not pose any health hazard to consumers. The microbiological quality of all the water samples were very good since

fecal contamination was absent and the level of total coliforms very low to cause any health problems.

6.2 Recommendation

Based on the outcome of the study the following is recommended;

1. It is recommended that water quality analysis be carried out on all the boreholes in the district at least once every two years. This will ensure that incidences of contamination are noticed earlier for remedial action to be taken.
2. The communities should be educated on the need to keep their surroundings clean most especially around the boreholes.
3. The communities should be educated on the dangers associated with sighting boreholes down slope and public places of convenience uphill as was in a case at “Akenkensu disable”.

6.3 Suggestions for further research

The research has shown that the quality of water pumped from the boreholes is of good quality. It is suspected that contamination could occur through the varying water carrying receptacles. Further research can therefore be carried out on quality of water stored by people in the district for consumption.

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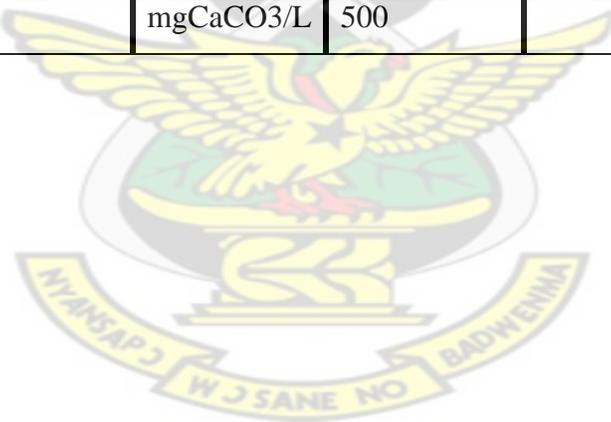
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APPENDIX 1

GHANA WATER COMPANY LIMITED(GWCL) GUIDELINES FOR DRINKING WATER			
PARAMETER	UNIT	VALUE	PERMISSIBLE LEVEL
Turbidity	NYU	0-5	
Colour	HZ	0-15	50
Ph	pH Units	6.5-8.5	>5
Electrical conductivity	μS/cm	N/A	
Total dissolved solids	mg/L	1000	
Total suspended solids	mg/L	0	
Total solid	mg/L	1000	
Sodium	mg/L	200	
Potassium	mg/L	NHRG	
Calcium	mg/L	NHRG	
Magnesium	mg/L	NHRG	
Iron	mg/L	0-10	
Copper	mg/L	1	
Zinc	mg/L	5	
Arsenic	mg/L	0.01	
Cadmium	mg/L	0.005	
Selenium	mg/L		
Uranium	mg/L		
Lead	mg/L	0.01	
Chromium	mg/L	-	
Mercury	mg/L	-	
Barium	mg/L	-	
Nickel	mg/L	-	
Boron	mg/L	-	

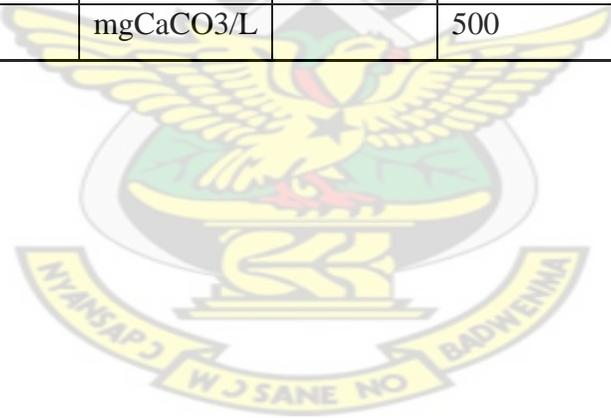
Antimony	mg/L	-	
Aluminium	mg/L		
Manganese	mg/L	0-0.1	0.5
Silica	mg/L	-	
Hydrocarbons	mg/L	-	
Total cynideAmmonia-N	mg/L	0-5	
Chloride	mg/L	250	600
Iodine	mg/L	NAD	
Flouride	mg/L	1.5	
Sulphate	mg/L	400	
Nitrate-N	mg/L	0-10	50
Nitrate-N	mg/L	0-3.0	
Phosphate	mg/L	-	
Alkalinity	mgCaCO3/L	0	
Total Hardness	mgCaCO3/L	500	



APPENDIX 2

OTHER GUIDELINES FOR DRINKING WATER QUALITY				
PARAMETER	UNIT	UNIT	EU NOV 1998	USA 199
Turbidity	UNIT			5
Colour	NYU	NHRG	15	15
Ph	HZ	>6.5-<9.5	6.5-9.5	6.5-8.5
Electrical conductivity	pH Units	2500		1500
Total dissolved solids	µS/cm	2500		2
Total suspended solids	mg/L		500	1000
Total solid	mg/L			1000
Sodium	mg/L	200		200
Potassium	mg/L	NHRG	NHRG	
Calcium	mg/L	NHRG	NHRG	75
Magnesium	mg/L	NHRG	NHRG	30
Iron	mg/L	0.2	0.3	1
copper	mg/L	2	1	2
Zinc	mg/L		5	3
arsenic	mg/L	0.01	0.05	0.01
Cadmium	mg/L	0.005	0.005	0.003
Selenium	mg/L	0.01	0.05	0.01
Uranuim	mg/L			NAD
Lead	mg/L	0.01		0.01
Chromium	mg/L	0.05	0.1	0.05
mercury	mg/L	0.001	0.002	0.001
barium	mg/L		2	0.7
nickel	mg/L	0.02	0.1	0.02
boron	mg/L	0.001		0.3
Beryllium	mg/L		0.004	NAD
Antimony	mg/L	0.005	0.006	0.005

Aluminium	mg/L	0.2	0.2	0.2
manganese	mg/L	0.05	0.05	0.5
silica	mg/L			30
hydrocarbons	mg/L			0.01-0.03
total cynide	mg/L			0.07
Ammonia-N	mg/L			1.5
Chloride	mg/L	0.05	0.2	250
Iodine	mg/L			NAD
Flouride	mg/L	250	4	1.5
Sulphate	mg/L		250	250
Nitrate-N	mg/L	1.5	10	50
Nitrate-N	mg/L	250	1	3
Phosphate	mg/L	50		
Alkalinity	mgCaCO3/L	0.5	500	200
Total Hardness	mgCaCO3/L		500	300



APPENDIX III



PEOPLE FECTHING WATER FROM BOREHOLE AT AFRANCHO IN THE OFFINSO DISTRICT OF ASHANTI REGION.