ASSESSMENT OF PHYSIO-CHEMICAL PROPERTIES OF HARVESTED RAINWATER IN IKOLE-EKITI AND ITS ENVIRONMENT

BY

ADEDOKUN, TUNDE SOLA

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CERTIFICATION

This is to certify that this project was carried out by **ADEDOKUN, TUNDE SOLA** with matriculation number, **WMA/13/1028**, a student of the Department of Water Resources Management and Agro-Meteorology, Federal University Oye, Oye-Ekiti, Ekiti State, Nigeria.

18-03-2019

Adedokun, T. S

(Project Student)

Date

19/03/19

Mr. J.A. Adeyeye

(Project supervisor)

Date

19/03/2019

Prof. A.A. Olufayo

(Head of Department)

Date

DEDICATION

This project is dedicated to Almighty God, the one who made it possible for me to complete this project despite all odds.

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ABSTRACT

Due to scarcity of potable water, rainwater harvesting from rooftop has been favoured as an alternative source of water supply by most rural communities in Nigeria. This study investigated the physicochemical characteristics of rainwater harvested from four different rooftop sheets in Ikole-Ekiti, Ekiti State. Samples were collected from four different iron sheets at the peak of raining season in the month of August, 2018. Parameters investigated include pH, TDS, Turbidity, Conductivity, Alkalinity, Total Hardness, Ca, Fe, Pb, Zn, Al, Cu, Mg, Na and K. Data obtained were subjected to mean and statistical analysis. The results showed that mean values of harvested rainwater from all sampled rooftops are slightly basic. All measured parameters were high in Aluminum and Coated pans but does not exceed the WHO water quality standards followed by Galvanized zinc rooftop while samples from painted pan had the least. The result shows that the physicochemical parameters ranges from 8.03-9.17 (pH), 0.47-3.17NTU (Turbidity), 56.20-170.43µs/cm (EC), 30.2-50.53mg/L (TDS), 18.56-27.58mg/L (Alkalinity), 19.94-24.08mg/L (Total Hardness), 8.67-14.93mg/L (Sulphate), 4.11-11.67mg/L (Chloride), 0-4.62mg/L (Zn), 7.11-11.13mg/L (Calcium), 0.07-1.56mg/L (Al), 0.01-0.02mg/L (Cu), 9.41-21.33mg/L (Mg), 29.04-40.35mg/L (Na) were all within permissible water quality standard as recommended by World Health Organizations (WHO) except for the presence of particles (Fe) 0.1-0.29mg/L which were found above the permissible limit in Galvanized Zinc pan. Pearson Correlation Matrix of physicochemical properties conducted indicated a strong positive correlation between Zinc and Iron which emphasizes common pathway and origin. The water samples were assessed using Water Quality Index (WQI), the WQI for painted pan, aluminum pan, galvanized zinc pan, and coated pan were 3.296, 1.335, 6.078 (highest) and 2.629

respectively indicating excellent water quality. It can be concluded that harvested rainwater in the area can be used for domestic purpose with minimum treatment.

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CHAPTER ONE

1.0 INTRODUCTION

1.1 Background of Study

Archeological evidence attests to the capture of rain water as far back as 4,000 years ago, and the concept of rainwater harvesting in China may date back 6,000 years. Ruins of cisterns built as early as 2000BC for storing runoff from hillsides for agricultural and domestic purposes are still standing in Israel (Gould and Nisssen-Petersen, 1999). Water is essential for growing food, for household water uses including drinking, cooling, sanitation, as a critical input into industry, for tourism and cultural purposes, and for its role in sustaining the earth's ecosystem Mark et al., (2002). In addition to water is for direct human consumption, it is integrally linked to the provision and quality of ecosystems service. Domestic water is used for drinking, cooking, bathing and cleaning. In most urban areas, population is increasing rapidly and the issue of supplying adequate water to meet societal needs and to ensure equity in access to water is one of the most urgent and significant challenges faced by decision-makers. Among the various alternative technologies to augment freshwater resources, rainwater harvesting and utilization is a decentralized, environmentally sound solution, which can avoid many environmental problems often caused in conventional large-scale projects using centralized approaches.

Quality drinking water is essential for life. Unfortunately, in many countries around the world, including Nigeria, water has become a scarce commodity (IDLO, 2006) as only a small proportion of the populace have access to treated water. Alternative sources of water such as rainwater and ground water have become major sources of drinking water for people living in new settlements and some residents who do not have access to treated water in Nigeria. The need to assess the quality of water from some of these alternative sources has become imperative because they have a direct effect on the health of individuals (WHO, 2011). Water as we know plays a significant role in maintaining the human health and welfare. Clean drinking water is now recognized as a fundamental right of human beings. Around 780 million people do not have access to clean and safe water and around 2.5 billion people do not have proper sanitation, which results to about6–8 million people's death each year due to water related diseases and disasters (UN water, 2013). Therefore, water quality control is a top-priority policy agenda in many parts of the world (WHO, 2011).

Contaminants in the water can affect the water quality and consequently human health. The potential sources of water contamination are geological conditions, industrial and agricultural activities, and water treatment plants. These contaminants are further categorized as microorganisms, inorganics, organics, radionuclides, and disinfectants (Rahmannian*et. al.*, 2015; Jia*et. al.*,2010). The inorganic chemicals hold a greater portion as contaminants in drinking water in comparison to organic chemicals (Azrina *et. al.*,2011). A part of inorganics are in mineral form of heavy metals. Heavy metals tend to accumulate in human organs and nervous system and interfere with their normal functioning of the human system. In recent years, heavy metals such as lead (Pb), arsenic (As), magnesium (Mg), nickel (Ni), copper (Cu), and zinc (Zn) have received significant attention due to related health problems (WHO, 2011). Moreover, the cardiovascular diseases, kidney-related problems, neurocognitive diseases, and cancer are related to the traces of metals such as cadmium (Cd) and chromium (Cr) as reported in epidemiological studies (Rhamannian*et al.*,2015). The Pb is known to delay the physical and mental growth in infants, while As and mercury (Hg) can cause serious poisoning with skin pathology and cancer and further damage to kidney and liver, respectively. Moreover, the presence of toxic and radioactive elements like uranium in the groundwater is another serious concern in many parts of the world such as USA, Canada, Germany, Norway, Greece, and Finland. It has high chemical toxicity and lethal effects on human skeleton and kidney (Katsoyiannis, and Zouboulis, 2013; Tuzen and Soylak, 2006).

1.2 Problem Statement

Rainwater harvesting remained the only source of potable water for rural communities where there are no watery networks (MWI, 2009). Even in some areas where potable water is supplied by networks, harvested rainwater is still a significant supplemental resource for domestic especially during summer season when low quantity of rainwater is supplied. In the past, it was believed that rainwater was pure and could be consumed without pre-treatment. While this may be true in some areas that are relatively unpolluted, rainwater collected in many locations contains impurities. Particularly during the last three decades, "acid rain" has affected the quality of the collected water, to the point where it now usually requires treatment. People due to scarcity of water have engaged in harvesting rainwater for different uses. Rainwater sometimes contain some heavy metals which can cause adverse effect on human beings, animals, plants, and surface water. A great percentage of metals fall through the rain at the place of their production. Roofs are made of variety of materials, and most, with the exception of those made from grass or reed and potentially toxic materials, are suitable as rainwater catchments surfaces. The typical roofing materials that are commonly used in Nigeria today are ceramic tiles, metal sheets, galvanized iron, anodized aluminum and asbestos. All these materials are a potentially source of dissolved ions, alkalinity and trace metals (Ayenimo*et. a.l,* 2006). In Addition, The heavy metals that are emitted in the atmosphere in the form of aerosols, mainly from human activities, are taken away by wet or dry deposition and cause damages to the surface waters and the organisms living there. Also, the metals are absorbed by the plants through the rain, the aerosols; which have a very small falling velocity, are easily transferred by the wind and it is possible to be deposited through the rain at long distances from the point of their emission (Smimioudi *et. al.*,1998). Therefore, it is expected that chemical components in the rainwater (acid components, anions, cations, and heavy metals) damage significantly the environment (surface waters, plants, animals, human beings). Apart from air, and dietary intake, drinking water plays an important role in the bodily intake of trace elements. The concern that trace elements in drinking water presents potential health hazard if they are present in higher than recommended concentrations prompted several regulatory bodies like WHO, to establish maximum allowable concentrations for these elements in drinking water supplies (WHO,1993) and (USEPA, 1991). Rainwater harvesting systems can provide water at or near the point where water is needed or used. The systems can be both owner and utility operated and managed. Rainwater collected using existing structures (i.e., rooftops, parking lots, playgrounds, parks, ponds, flood plains, etc.), has few negative environmental impacts compared to other technologies for water resources development.

1.3 Scope of the Study

The scope of this study will cover the collection, analysis and interpretation of harvested rainfall data from selected areas in Ikole-Ekiti and its environment.

1.4 Justification of the study

Government inability to provide potable water for the growing population in Nigeria has left the citizen to their own fate in term of drinking water quality leading to various cases of water borne diseases in Nigeria. Increasing toll of water-borne diseases such as cholera, typhoid fever and hepatitis some of which has far-reaching effects on the body and can lead to death. The study was embarked upon to ensure the superiority of the quality of rain water from iron and galvanized roofing sheets been consumed in Ikole axis of Ekiti state and their environs state whether it is safe and healthy for drinking. To bridge this information gap, there is an urgent need for the determination of disastrous component associated with rain water in our communities. A good knowledge of the regular physicochemical qualities acceptability of the rain water from both iron and galvanized roofing sheet in the selected homes is necessary so as to guide its suitability for use. This project thus aimed at comparing and evaluating the physicochemical properties of water samples taken thrice within a month in Ikole, Ekiti state.

1.4 OBJECTIVES

1.4.1 General Objectives

i. The general objective of the study is to assess physiochemical properties of harvested rainfall in Ikole-Ekiti and its environs.

1.4.2 Specific Objectives

The specific objectives of this study are to:

1. To assess the physical and chemical characteristics of the harvested rainwater.
2. To ascertain the usability of this harvested rainwater for domestic purpose.

CHAPTER TWO

2.0 LITERATURE REVIEW

2.1 Water

Water is a very essential substance for human existence. Adequate supply of water is important to life and civilization. The provision of water in the past was solely a government affair; however, the inability of the government to meet the daily demands of water for the people has forced some private individuals and communities to seek alternatives and self-help measures of providing water. Private individuals drill their own deep wells (boreholes). In some localities, they dig wells due to its affordability (Ukpong*et.al.* ,2013). These hand dug wells are constructed to serve as a source of water supply. Water meant for food preparation and drinking must be free from contamination (organism) capable of causing diseases and from minerals and organic substances producing adverse physiological effects. In some communities, water from deep wells is sold to the public without reference and conformance to requisite quality standards such as set by the World Health Organization (WHO) (Ukpong*et. al.,*2013).

The major sources of water include rainfall, snow, sleet, hail, fog and dew from the atmosphere. On the solid part of the earth (lithosphere), there are lakes, rivers, streams, waterfalls, glaciers, oceans and seas; there are also underground waters (Nebel and Wright, 1993; Owuna, 2012). Precipitation and hence water resources are far from evenly distributed on the earth. Some regions are heavily endowed with water such as areas along the equatorial axis while others experience water shortage or scarcity. Also, the major seasons of these zones play a significant role in the distribution of water e.g. winter, summer, autumn and spring all are occasioned by different variation of rainfall, icefall, snowfall, etc. (Raven and Berg, 1998; Owuna, 2012). In Nigeria, however, water is more abundant in the southern part that lies just above the tropical equatorial region while the central and northern parts have variable water supply depending on the season (Filani, 1991). Since water is constantly recycled in the biosphere, it is theoretically a sustainable resource.

2.2 Ground Water Source

Ground water is both an important direct source of water supply, which is tapped by wells, and a- significant indirect source of supply, since a large portion of the flow streams is derived from subsurface water. This is formed as a result of a portion of precipitation (rainfall and snowfall), which sink into the ground. Groundwater movement is generally slow and not as much mixing occurs in an aquifer as with the case of surface waters. Its quality changes as water percolates through natural sediments. These changes are drastic in certain sediments, while negligible in other cases (Deju*et. al.,*1990; Owuna, 2012). During its movement through the surface layers of the earth, it carries some minerals as it passes through porous rocks, since the rocks are subject to mechanical and chemical weathering and leach out (Glenn and William, 1981; Owuna, 2012).

Near the surface of the earth, in the zone of aeration, soil pore spaces contain both air and water. These zones, which may have a zero thickness in swamp lands and several hundred feet thick in mountainous regions, contain three types of moisture. Gravity waters are in transit after a storm through small pore space by capillary action and are available for plant up-take. Hydroscopic moisture is water held in place by molecular forces during all seasons except the driest climatic conditions. Moisture from the zone of aeration cannot be tapped as a water supply source. The zone of saturation offers water in a quantity that is directly available. In this zone, located below the zone of aeration, the pores are filled with water, and this is considered as ground water (Vesilind and Pierce, 1983; Owuna, 2012). Ground water is highly valued because of certain properties that are not possessed by surface water. It is usually characterized by low contents of organic substances and as such usually preferred as a source of drinking water (Goel, 2000).

2.3 Rainwater Source

Rain is liquid water in the form of droplets that have condensed from atmospheric water vapor and then becomes heavy enough to fall under gravity. Rain is a major component of the water cycle and is responsible for depositing most of the fresh water on the Earth. It provides suitable conditions for many types of ecosystems, as well as water for hydroelectric power plants and crop irrigation (*Wikipedia, 2010*). The major cause of rain production is moisture moving along three-dimensional zones of temperature and moisture contrasts known as weather fronts. If enough moisture and upward motion is present, precipitation falls from convective clouds (those with strong upward vertical motion) such as cumulonimbus (thunder clouds) which can organize into narrow rain-bands. In mountainous areas, heavy precipitation is possible where upslope flow is maximized within windward sides of the terrain at elevation which forces moist air to condense and fall out as rainfall along the sides of mountains. On the leeward side of mountains, desert climates can exist due to the dry air caused by down slope flow which causes heating and drying of the air mass. The movement of the monsoon trough, or inter-tropical convergence zone, brings rainy seasons to savannah climes (*Wikipedia, 2010*). Rain is measured in units of length per unit time, typically in millimeters per hour, or in countries where imperial units are more common, inches per hour. The "length", or more accurately, "depth" being measured is the depth of rain water that would accumulate on a flat, horizontal and impermeable surface during a given amount of time, typically an hour. One millimeter of rainfall is the equivalent of one liter of water per square meter.

2.4 Rainwater Harvesting

Rainwater harvesting (RWH) is the ancient practice of capturing rain runoff from roofs and other surfaces and storing it for a later purpose. Issues such as urban growth, limited water supplies, ageing storm water infrastructure and environmental sustainability have prompted a renewed interest in the practice, which has become common in countries such as Nigeria and other African countries. One of the primary areas of concern regarding the use of rainwater, for either non-potable or potable applications, is quality. The quality of water collected in a RWH system is affected by many factors, including:

i. Environmental conditions such as proximity to heavy industry or major roads, the presence of birds or rodents.
ii. Meteorological conditions such as temperature, antecedent dry periods, and rainfall patterns.
iii. Contact with a catchment material and the dirt and debris that are deposited upon it between rainfall events (Simmons *et. al.*, 2001; Van Metre& Mahler 2003).
iv. Treatment by pre-cistern treatment devices such as filtration or first-flush diversion (Martinson & Thomas 2005).
v. Natural treatment processes taking place within the rainwater cistern.
vi. Treatment by post-cistern treatment devices such as particle filtration, ultraviolet disinfection, chlorination, slow sand filtration or hot water systems (Coombes *et. al.*, 2000; Kim *et. al.*, 2005; Ahammed & Meera 2006; Sazakli *et. al.*, 2007).

2.4.1 Effect of Rainwater on Agriculture

Precipitation, especially rain, has a dramatic effect on agriculture. All plants need at least some water to survive; therefore rain (being the most effective means of watering) is important to agriculture. While a regular rain pattern is usually vital to healthy plants, too much or too little rainfall can be harmful, and even devastating to crops. Drought can kill crops and increase erosion, while overly wet weather can cause harmful fungus growth (Robert, 2007). Plants need varying amounts of rainfall to survive. For example, certain cacti require small amounts of water (James, 2006), while tropical plants may need up to hundreds of inches of rain per year to survive. In areas with wet and dry seasons, soil nutrients diminish and erosion increases during the wet season. Animals have adaptation and survival strategies for the wetter regime. The previous dry season leads to food shortages into the wet season, as the crops have yet to mature. Developing countries have noted that their populations show seasonal weight fluctuations due to food shortages seen before the first harvest, which occurs late in the wet season (Marti *et. al.*, 1994). Rain may be harvested through the use of rainwater tanks; treated to potable use or for non-potable use indoors or for irrigation. Excessive rain during short periods of time can cause flash floods (Robert, 2007)

2.5 Water Pollution

Water pollution (surface and ground water) may be considered as a naturally induced change in water quality or conditions induced directly by man's numerous activities which renders it unsuitable for food, human health, industry, agriculture or leisure pursuit (Cifuentes and Rodriguez, 2005). With exploding population and increasing industrialization and urbanization, water pollution by agriculture, municipal and industrial sources has become a major concern for the welfare of mankind. The menace of water borne diseases and epidemics still threatens the well-being of population, particularly in under developed and developing countries. Thus, the quality as well as the quantity of clean water supply is of vital significance for the welfare of mankind.

2.5.1 Types of Water Pollution

Water pollution may be divided into the following five major categories on the basis of sources and storage of water: Groundwater pollution; Surface water pollution; Lake water pollution; River water pollution and Sea water pollution (Owuna, 2012).

2.6 Contaminants in Drinking Water

The Safe Drinking Water Act defines the term "contaminant" as meaning any physical, chemical, biological, or radiological substance or matter in water. Therefore, the law defines "contaminant" very broadly as being anything other than water molecules. Drinking water may reasonably be expected to contain at least small amounts of some contaminants. Some drinking water contaminants may be harmful if consumed at certain levels in drinking water while others may be harmless (EPA, 2003). The presence of contaminants does not necessarily indicate that the water poses a health risk. The categories of drinking water contaminants are:

Physical contaminants: primarily impact the physical appearance or other physical properties of water. Examples of physical contaminants are sediment or organic material suspended in the water of lakes, rivers and streams from soil erosion (Mandal *et. al.,*2012).

Chemical contaminants: are elements or compounds. These contaminants may be naturally occurring or man-made. Examples of chemical contaminants include nitrogen, bleach, salts, pesticides, metals, toxins produced by bacteria, and human or animal drugs (Mandal *et. al.,* 2012).

Biological contaminants: are organisms in water. They are also referred to as microbes or microbiological contaminants. Examples of biological or microbial contaminants include bacteria, viruses, protozoan, and parasites (Mandal *et al.,* 2012).

Water of good quality is of great relevance to human physiology and continued existence. But due to the increase in human population, fertilizer use and industrialization, water is highly polluted with different harmful contaminants. The quest for cheap and readily available potable water has caused the emergence of sachet water (any potable water processed and offered for sale in sealed food grade bottles or other containers for human consumption) (EPA, 2003). The quality of drinking water is a powerful determination of health, assurance of drinking water safety is a foundation for the prevention and control of water-borne diseases. It is of great relevance to break the faecal-oral cycle by preventing faecal matter from entering water sources and by treating water to kill the pathogens (Patil*et al.,*2012).

2.7 Overview of Rainwater Harvesting

Physiochemical parameter study is very important to get exact idea about the quality of water and we can compare results of different physicochemical parameter values with standard values. Chukwuma *et al.*, (2014) investigated the quality of roof harvested rainwater consumed by rural communities in parts of Anambra State Nigeria. The result shows that the physiochemical parameters were all within permissible water quality standard as recommended by National Agency for Food and Drug Administration Control (NAFDAC) except for the presence of particles and for the micro-biological properties which were found quite unsatisfactory. Pearson Correlation Matrix of physicochemical properties conducted indicated a strong positive correlation between Zinc and Iron which emphasizes common pathway and origin. The water samples were assessed using Water Quality Index (WQI), the WQI for the station 1, 2 and 3 were 71.68%, 60.19%, and 77.55% respectively. Low-cost microbial disinfection such as solar disinfection and pre-filtration or otherwise the proper maintenance of the entire Rain Water Harvesting (RWH) system could make the harvested roof rainwater potable for the study area.

Saravanakumar and Ranjith Kumar (2011) presented paper studies about groundwater quality of Ambattur industrial area in Chennai City. They studied parameters such as pH, total alkalinity, total hardness, turbidity, chloride, sulphate, fluoride, total dissolved solids and conductivity. It was observed that there was a slight fluctuation in the physicochemical parameters among the water samples studied. Comparison of the physicochemical parameters of the water sample with WHO (World Health Organization) and ICMR (Indian Council of Medical Research) limits showed that the groundwater is highly contaminated and account for health hazards for human use.

Christopher *et. al.*, (2009) assessed rainwater quality from rainwater harvesting (RWH) systems at seven sites located in a 30 km radius around the City of Guelph in Ontario, Canada. From October 2006 to October 2007, in this research work, a total of 360 samples were collected from two sampling locations the rainwater cistern and at the point of use and analysed for pH, turbidity, colour, total and fecal coliforms, total organic carbon, total nitrogen and UV absorbance (254 nm). Additional parameters, including polycyclic aromatic hydrocarbons, total metals, Campylobacter and Legionella were examined in selected samples. The results of the quality assessment programme were largely consistent with those reported by several other researchers, with the exception of improved microbiological quality during periods of cold weather. Total and fecal coliforms were detected in 31% and 13% of the rainwater samples, respectively, while neither Campylobacter nor Legionella were detected above 1 CFU/100 ml detection limits. The results indicated that, while quality can be expected to vary with environmental conditions, the rainwater from a RWH system can be of consistently high quality through the selection of appropriate catchment and storage materials and the application of post-cistern treatment.

Dattatraya *et.al.* (2011) in their study indicates the possible source of contamination in drinking water. A total no of 15 samples of ground water were collected in the month of August-December, and analyzed for physicochemical parameters like, pH, TDS, total alkalinity, total hardness, Dissolved oxygen, turbidity and chloride were analyzed by standard procedure mentioned in IS 10500: 1991. The following result were found, Some ground water samples are show variation of pH, turbidity, hardness, DO and Chlorides this may be due to different soil texture. Some water samples show higher pH and Some Higher hardness. Overall some parts of bore well water needed treatment for drinking purpose due to hardness pH, DO, alkalinity and chlorides are present in desirable limit and some sort little variation.

The study by Moses *et.al.*, (2016) sought to determine the quality of harvested rainwater from some settlements in Uyo, Nigeria, and assess the suitability of the water for domestic household use. In this research work, harvested rainwater samples were collected from selected household tanks at IkotNtuen Oku, Afaha Oku, Ikot Oku, Mbiabong and IfaAtai areas of Uyo. Analyses for physiochemical parameters including pH, electrical conductivity, total dissolved solids, turbidity, total hardness, total alkalinity and acidity, dissolved oxygen, total suspended solids, were done using standard APHA methods. Trace metals were measured using atomic absorption spectrophotometric techniques. The physicochemical parameters measured were below the WHO limits for portability except for dissolved oxygen. Correlation studies showed that Fe was from natural sources while Cr, Mn, Cu, Zn and Cd were from anthropogenic sources. These results indicated expected adverse effects from the consumption of the harvested rainwater with respect to Fe, Cd and Cu. Appropriate treatment of the rainwater to improve quality before use is recommended. This will help improve the water quality and provide portable water for households in the communities.

The study by Ezemonye *et. al.,* (2016) on the physicochemical and bacteriological characteristics of rainwater harvested from rooftops in Esan-West Local Government Area of Edo State investigated the physicochemical and bacteriological characteristics of rainwater harvested from three different rooftop sheets in Esan West Local Government Area, Edo State. Parameters investigated include pH, TSS, TDS, Turbidity, Acidity, Ca^{2+}, Fe, Pb, Cr, TBC, TCC and E-coli. The results showed that mean values of harvested rainwater from all sampled rooftops are acidic especially at the onset of the raining season. TSS and TDS were highest in samples collected from Asbestos rooftop, followed by Aluminum rooftop while samples from galvanized Iron had the least irrespective of the rainfall event. Rainwater samples collected at the onset of rain had higher Ca^{2+} concentration than those collected at the peak of rain for all roof type with galvanized Iron rooftop catchment recording the highest concentration. Samples collected at the onset of the rain for all roof type had Fe^{2+} concentrations above the WHO limit of 0.1mg/l while those collected at the peak of rain had lesser values. Values of Pb, Cr were within WHO permissible limit. Analysis of microbial parameters revealed that samples collected from all rooftop and for both seasons exceeded WHO limit of <100cfu/ml. Rainwater samples collected from corrugated Asbestos rooftop had the highest bacterial load for both onset and peak of rain, followed by samples collected from Aluminum rooftop for the onset on rain. E-coli count was highest in water sample collected from corrugated Asbestos rooftop for onset and peak of rain. The Analysis of variance (ANOVA) shows that quality of rainwater harvested from galvanized Iron, Aluminum and Asbestos rooftop catchments does not significantly differ at 0.05 statistical thresholds among rooftop catchment although samples from asbestos rooftop catchment recorded highest contamination level. In view of the physicochemical and bacteriological results, harvested rainwater can be put to all forms of domestic use except for direct ingestion unless treated.

2.8 Water Quality Assessment

Water quality is the physical, chemical and biological characteristics of water. It is the measure of the condition of water relative to the requirements of one or more biotic species and to any human need or purpose. If fresh and pure, water has no taste, odour, colour or turbidity. But water is never 100% pure as it carries traces of other substances, which bestow physical, chemical and biological characteristics (Nsi, 2007).

2.8.1 pH

pH value is the logarithm of reciprocal of hydrogen ion activity in moles per liter. In water solution, variations in pH value from 7 are mainly due to hydrolysis of salts of strong bases and weak acids or vice versa. Dissolved gases such as carbon dioxide, hydrogen sulphide and ammonia also affect pH value of water. The overall pH value range of natural water is generally between 6 and 8. In case of alkaline thermal spring waters pH value may be more than 9 while for acidic thermal spring waters, the pH may be 4 or even less than 4. pH is most important in determining the corrosive nature of water. The higher the pH value, the higher is the corrosive nature of water. pH is always observed to be positively correlated with electrical conductance and total alkalinity (Guptaa, 2009). The reduced rate of photosynthetic activity, the assimilation of carbon dioxide and bicarbonates is also ultimately responsible for increase in pH, the low oxygen values coincided with high temperature during the summer month. Various factors bring about changes the pH of water. The higher pH values are observed and suggested that carbon dioxide, carbonate-bicarbonate equilibrium is affected more due to change in physicochemical condition (Karanth, 1987).

2.8.2 Electrical conductivity

Electrical conductivity in water (EC_w) is a measure of salinity and the extent to which water is able to conduct an electric current. It is expressed as micro Siemens per centimetre (µS/cm) and, relates to the concentrations of total dissolved solids (TDS) or salts in a specific water body (Ademoroti, 1996). These salts typically include such cations as sodium, calcium, magnesium and potassium, and anions such as chloride, sulphate and bicarbonate. Conductivity is a faster and reliable method of controlling and monitoring water treatment. It gives the idea about ionizable materials in water. It affects all aspects of water treatment and suitability of specific application (Ogundipe, 2015).

2.8.3 Temperature

In an established system the water temperature controls the rate of all chemical reactions, and affects fish growth, reproduction and immunity. Drastic temperature changes can be fatal to fish (Ogundipe, 2015).

2.8.4 Colour

Colour in water may be due to inorganic ions, such as iron & manganese, humus & peat materials, plankton, weeds and industrial wastes. The term true colour is the colour of water from which turbidity has been removed. The term apparent colour includes not only the colour due to substances in solution, but, also that due to suspended matter. Apparent colour is determined on the original sample without filtration or centrifugation (FSSAI, 2015).

2.8.5 Odour

Odour is recognized as a quality factor affecting acceptability of drinking water and food prepared from it, tainting of fish and other aquatic organisms &aesthetes of recreational waters. Most organic and some inorganic chemicals contribute taste or odour. These chemicals may originate from municipal and industrial waste discharges, natural sources, such as decomposition of vegetable matter or from associated microbial activity. Odour of water, though very important, cannot be determined in absolute units. Olfactory sense, which is the most sensitive means of detecting small concentrations of odoriferous substances, lacks precision and mathematical expression nevertheless a qualitative test, is prescribed. In case of doubt as to the intensity or character of odour, a majority opinion of several observers should be recorded (FSSAI, 2015).

2.8.6 Turbidity

The turbidity of sample is the reduction of transparency due to the presence of particulate matter such as clay or slit, finely divided organic matter, plankton or other microscopic organisms. These causes light to be scattered and absorbed rather than transmitted in straight lines through the sample. The values are expressed in nephelolometric turbidity units (NTU). The method is applicable to drinking, surface and saline waters in the range of turbidity 0-40 NTU. Higher values may be obtained by dilution of the sample (Ogundipe, 2015).

2.8.7 Total Dissolved Solids (TDS)

Total Dissolved Solid (TDS) is a measure of the total amount of dissolved substances in the water sample. It is not a direct measure of a specific element or contaminant. An elevated TDS may be associated with an elevated water hardness, chemical deposits, corrosion by-products, staining, or salty bitter tastes (Hach, 2000). If the TDS content of the water is high, the primary recommendation would be to test the water for additional parameters, such as: total hardness, iron, manganese, sodium, chloride, sulphate, alkalinity, and nitrate, to determine the nature of the water quality problem. In natural waters, salts are chemical compounds which comprise of anions such as carbonates, chlorides, sulphates and nitrates (primarily in ground water), and cations such as potassium, magnesium, calcium and sodium. It originates from natural sources, sewage, urban run-off, and industrial waste water. Its concentration in water varies considerably in different geological regions owing to differences in the solubility of minerals. It is measured in milligram per litre (mg/l) (WHO, 2006). The TDS test is an indicator of the potential for water quality problems.

2.8.8 Total Hardness

Water hardness is a traditional measure of the capacity of water to precipitate soap. Hardness of water is not a specific constituent but is a variable and complex mixture of cations and anions (Hach, 2000) caused by dissolved calcium and, to a lesser extent, magnesium salts. The hardness of the water is reported as the equivalent concentration of calcium carbonate ($CaCO_3$) per liter of water, but the actual test measures the calcium, magnesium, manganese, iron, and other multivalent positively charged ions. Individuals typically report aesthetic problems with the water when the total hardness is above 160 mg $CaCO_3$/l, but it is possible that corrosion problems could be associated with water with very low water hardness (Ogundipe, 2015). Depending on pH and alkalinity, hardness above 200 mg/l can result in scale deposition, particularly on heating. It is determined by titration with EDTA (Ethylene diamine tetra-acetic acid) (WHO, 2006). Water with less than 75 mg/l CaCO3 is considered to be soft and above 150 mg/l as hard.

2.8.9 Alkalinity and Acidity

Alkalinity is the presence of ions (primarily of carbonate ($CO_3^{2-)}$ and bicarbonate (HCO_3^-). It refers to the ability of water to neutralize acids. It measures the buffering capacity of water. It is caused by the presence of carbonates, bicarbonates, and hydroxides of calcium, magnesium and sodium metals. It is expressed in terms of $CaCO_3$ (WHO, 2006), Limestone bedrock and thick deposits of glacial till are good sources of carbonate buffering. Lakes within such areas are usually well-buffered. Alkalinity in boiler water essentially results from the presence of hydroxyl and carbonate ions. Hydroxyl alkalinity (causticity) in boiler water is necessary to protect the boiler against corrosion. Too high a causticity causes other operating problems, such as foaming. Excessively high causticity levels can result in a type of caustic attack of the boiler called "embrittlement" (Patil *et. al.,* 2012).

2.8.10 Calcium hardness

Calcium is an element that is found naturally in abundance within the earth's crust. It is also an important and abundant element in the human body. Adequate intake of calcium is essential for normal growth and good health. Calcium is the most important element causing hardness in water. The presence of excess calcium in water causes temporary hardness, but it can be removed easily by boiling (Muhammad, *et. al.,*2015).

2.8.11 Nitrates

Nitrates are found in natural water contaminated with nitrogenous materials, farmyard wastes, faecal matter, plant and animal protein. The use of fertilizers may also add nitrates to both surface and ground water. Nitrates may be biochemically reduced to nitrite by gentrification process usually under anaerobic conditions and it is absorbed through the stomach and it then reacts with the hemoglobin in the blood. Major sources of nitrate or nitrite in drinking water include fertilizers, sewage and feedlots (Ogundipe, 2015). The primary concern for nitrate and nitrite is that infants less than 6 months are susceptible to blue-baby syndrome, which is potentially fatal if not treated. Blue-Baby Disease or methemoglonemia, is an effect in which haemoglobin is oxidized to methemoglobin, resulting in asphyxia. It is a serious condition that can cause brain damage or death. Infants up to three months of age are the most susceptible subpopulation with regard to nitrate. Major sources of nitrate or nitrite in drinking water includes; fertilizer, sewage and feedlots (Patil *et. al.*,2012).

2.8.12 Chemical Oxygen Demand (COD)

COD is another measure of organic material contamination in water specified in mg/L. COD is the amount of dissolved oxygen required to cause chemical oxidation of the organic *material in water. Both BOD and COD* are key indicators of the environmental health of a surface water supply. They are commonly used in waste water treatment but rarely in general water treatment. (Patil *et. al.*,2012).

2.8.13 Chlorides

Chlorides occur naturally in natural water and they are responsible for the salty taste at high concentrations, they can also be corrosive on various domestic industrial equipment. Other sources of chloride may include industrial effluents such as those from food processing, paperwork, oil wells, human and animal wastes as well as potassium fertilizers and petroleum refineries (FSSAI, 2015).

2.8.14 Calcium

The average abundance of Ca in the earth's crust is 4.9%: in soils it is 0.07 to 1.7 % in streams it is about 15 mg/L; and in groundwater it is from 1 to >500 mg/L. The most common forms of calcium are calcium carbonate (calcite) and calcium-magnesium carbonate (dolomite). Calcium compounds are widely used in pharmaceuticals photography, lime, de-icing salts, pigments, fertilizers, and plasters. Calcium carbonate solubility is controlled by pH and dissolved CO_2. The CO_2, HCO_3^- and CO_3^{2-} equilibrium is the major buffering mechanism in fresh waters. Hardness is based on the concentration of calcium and magnesium salts, and often is used as a measure of potable water quality (Patil*et. al.,*2012).

2.8.15 Magnesium

Magnesium occurs commonly in the minerals magnetite and dolomite. Magnesium is used in alloys, pyrotechnics, flash photography, drying agents, refractories, fertilizers, pharmaceuticals, and foods (WHO, 2006). The common aqueous species is Mg^{2+} The carbonate equilibrium reactions from magnesium are more complicated than for calcium and conditions for direct precipitation of dolomite in natural waters are not common. Important contributors to the hardness of a water, magnesium salts break down when heated, forming scale in boilers. Chemical softening, reverse osmosis, ion exchange reduces magnesium and associated hardness to acceptable levels. Magnesium is an essential element in chlorophyll and in red blood cells. Some salts of magnesium are toxic by ingestion or inhalation. Concentrations greater than 125 mg/L also can have a cathartic and diuretic effect (FSSAI, 2015).

2.8.16 Manganese

Manganese is a widely distributed constituent of ores and rocks. Manganese has no particular toxicological connotations; the objections to manganese - like iron - are aesthetic factor (WHO, 1993). A second effect of the presence of manganese much above the limits is its unacceptable taste problem (WHO, 1993). Generally toxicity is not a factor, as waters with high levels of manganese will be rejected by the consumer long before any danger threshold is reached.

2.8.17 Iron (Fe)

Total iron means the presence of iron in its two prominent oxidation states, Fe^{2+} and Fe^{3+}. At low concentrations, iron is essential to the body as they are components that catalyzes haemoglobin and also very essential for the synthesis of vitamin B (Ward, *et. al.,*1975). As with iron, manganese is found widely in soils and is a constituent of many ground waters. It, too, may be brought into solution in reducing conditions and the excess metal will be later deposited as the water is re-aerated. The general remarks for manganese apply to iron but the staining problems with this metal may be even more severe, hence the stringent limits (Ukpong*et. al.,*2013).

2.8.18 Dissolved Oxygen (DO)

Dissolved oxygen is one of the most important parameter. Its percentage or amount in water body gives direct and indirect information e.g. bacterial activity, photosynthesis, availability of nutrients, stratification etc. (Premlata, 2009). In the progress of summer, dissolved oxygen decreased due to increase in temperature and also due to increased microbial activity (Patil *et. al.,*2012). The high DO in summer is due to increase in temperature and duration of bright sunlight has influence on the percentage of soluble gases (O_2 & CO_2). DO in sample is measured titrimetrically by Winkler's method after 5 days incubation at 293 K. The difference in initial and final DO gives the amount of oxygen consumed by the bacteria during this period. This procedure needs special BOD bottles which seal the inside environment from atmospheric oxygen (Patil *et. al.,*2012).

2.8.19 Chromium

Chromium is used in tanner in textile mills; hence the effluents are potential substances that are toxic waste. The waste originating from tanneries and textile mills can cause toxicity in water sources (Gordan, *et. al.,* 1996).

2.9 Standards for Drinking Water Quality

Presented in tables 2.1 below are a few guidelines by regulatory bodies such as World Health Organization (WHO, 2004) and Nigerian Industrial Standård (NIS, 2007) on the permissible level of the physicochemical properties of drinking water respectively.

Table 2.1: Permissible level of the physicochemical parameters in drinking water by WHO and NIS and their health implications when they exceed the threshold limits.

Parameters	Permissible level (NIS)	Permissible level (WHO)	Health Implications
Appearance	Clear	Clear	None
Colour (TCU)	15	Colourless	None
Odour	Unobjectionable	Unobjectionable	None
Turbidity (NTU)	5	5	None
pH	6.5 – 8.5	7.0 – 8.5	None
Conductivity, µmho/cm	1000	1000	None
TDS, mg/l. $CaCO_3$	500	500	None
Total Alkalinity, mg/l. $CaCO_3$	100	100	None
Total Hardness, mg/l. $CaCO_3$	150	100	None
Calcium Hardness, mg/l. $CaCO_3$	-	200	None
Chloride, mg/l. Cl	250	200	None
Calcium, mg/l. Ca	-	75	
Nitrate, mg/l. N	50	50	Cyanosis, and asphyxia (blue-baby syndrome) in infants under 3 months.
Magnesium, mg/l. Mg	0.20	0.5	Neurological disorder
Manganese, mg/l. Mn	0.2	0.5	Consumer acceptability
Total Iron, mg/l. Fe	0.3	0.3	None
Chromium, mg/l. Cr	0.05	0.05	Cancer
COD	10	10	

Source: World Health Organization (WHO), 2004; Nigeria Industrial Standard (NIS), 2004

CHAPTER THREE

3.0 MATERIAL AND METHODS

3.1 MATERIALS

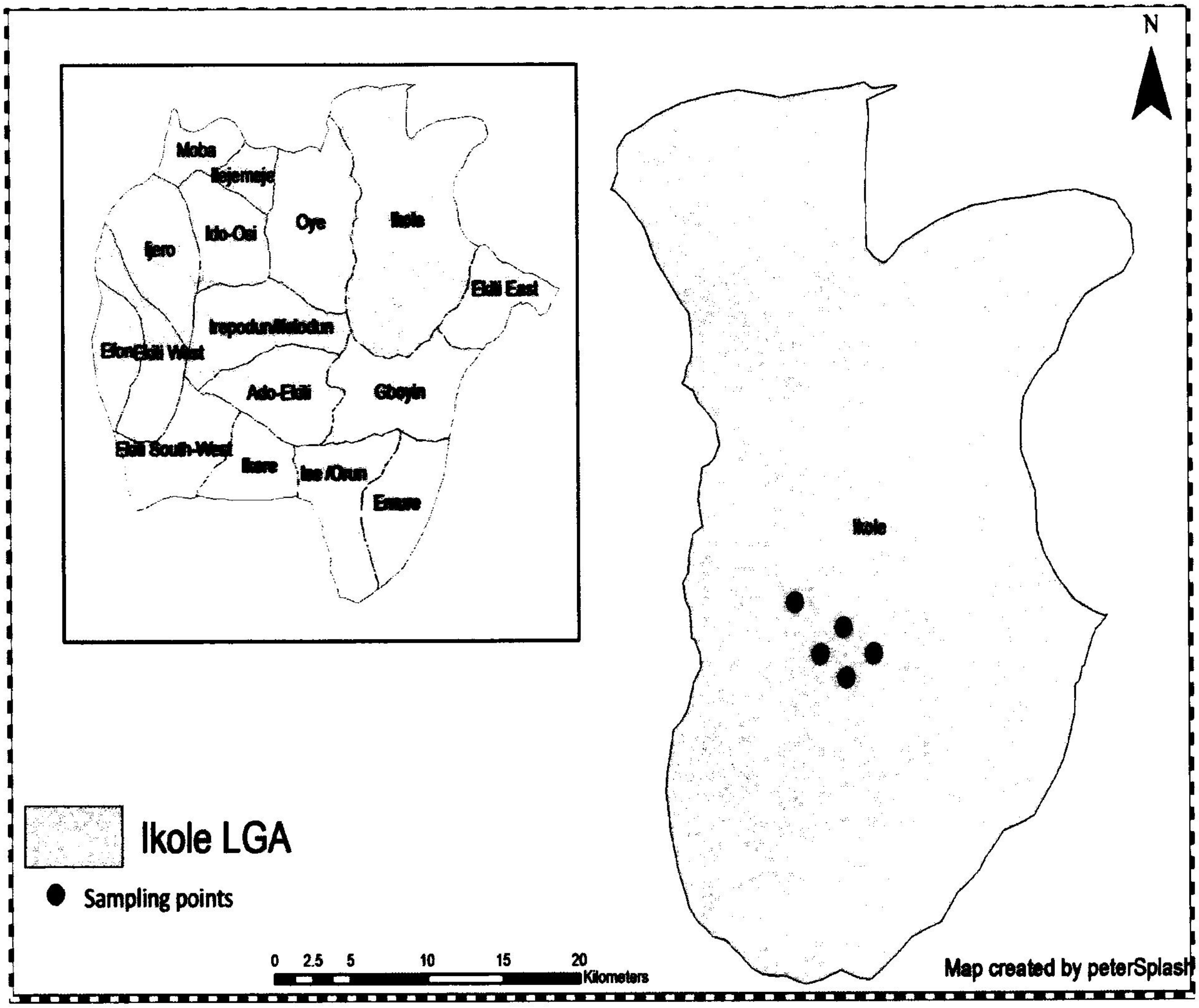
All the reagents used were of analytical grade with some of the reagents purchased from a scientific laboratory outside. All apparatus used are all in good condition. This include Erlenmeyer flasks, Burette, Pipette, Retort stand with clamp, Hot plate, Reagent bottles, Standard flasks, Measuring cylinder, Sample bottle, Weighing balance as well as the equipment used for microbiological analysis.

3.2 METHODS

3.2.1 BACKGROUND OF STUDY SITES

The study area (Ikole) is a local government within Ekiti State in Southwestern Nigeria. Ikole-Ekiti Local Government Area can be accessed through network of roads most especially Oye-Ilupeju, Itapa-Osi-Ikole, Ado-Ijan-Iluomoba-Ijeshaisu-Ikole and Omuo-Ikole roads. Ootunja is one of the twenty-four towns and villages constituting Ikole L.G.A., (Ademola *et. al.*, 2017). The study area is located between 0774916mE; 0862100mN and 0775141mE; 0862297mN. The general geology of Ekiti State is well researched. Examples of such studies include Bayowa et al., 2014; Oyinloye, 2011; Talabi, 2013. Ekiti state is underlain by the Precambrian rocks of the basement complex of southwestern Nigeria which covers about 50% of the land surface of Nigeria. The major lithological units include the granite gneiss, migmatites gneiss and charnockite (Oladapo and Ayeni, 2013). The Basement rocks show great variations in grain size and in mineral composition. The rocks are predominantly quartz gneisses and schists consisting essentially of quartz with small amounts of white micaceous minerals. In grain size and structure, they vary from very coarse grained pegmatite to medium grained gneisses. The study area is shown in Fig. 1 below.

Fig. 1: The Geographical Map Ikole LGA showing Sampling Points (ArcMap 9.2)



3.2.2 Sample collection

The sample was collected around Ikole town and its environment, from four different types of roofing sheets. Direct sources from the atmosphere was also collected which serve as control for analysis. The samples were collected using 5L plastic buckets. The new plastic buckets used for this analysis were purchased from a nearby market and were thoroughly washed and rinsed with distilled water before it was used to collect the samples. The four different types of roofing sheets on which the rainwater was harvested from are listed below;

1) Pan (galvanized zinc) roofing sheets
2) Coated pan
3) Painted pan
4) Aluminum

During collection of rainwater, samples bucket was placed around each roofing sheet types, another bucket was used to collect water directly from the sky. Rainwater was randomly collected from 5 sampling sites which was replicated (3 coated pans, 3 aluminum, 3 painted pans, 3 pans and 3 controls) within Ikole and its environment. The samples were collected at the peak of rainfall in the month of August,2018 and the samples were immediately analysed for pH, Temp, EC, and TDS after each collection. Containers for collecting the rainwater samples were 5 buckets, which had been thoroughly washed and rinsed with distilled water to avoid any physical or chemical contamination of samples. The samples were collected in 750ml capacity poly propylene containers, which had been previously soaked for 24 hours in 1% $HN0_3$. Few drops of concentrated nitric acid (analytical grade) were then added to the samples and refrigerated pending the analysis to ensure metals remained in solution.

3.2.3 Sample preservation

All collected rainwater samples were preserved, each with 1ml of concentrated nitric acid-hydrogen trioxonitrate (v).

3.2.4 Digestion of Samples

10% HCL was used to rinse apparatus after washing and drying. 100ml of water sample was measured into a clean 250ml conical flask and 10ml of the concentrated nitric acid was added. This solution was allowed to boil for few minutes (to about 25ml) on a hot plate placed in the fume cupboard. The remaining volume of solution after heating was measured. The blank was taken on the reagents through the complete procedure except that the sample was omitted; thence it was sent for analysis. The concentrations (mg/L) of three metals Zn, Pb and Cr were determined in the samples and the blanks with a computerized Buck Scientific model 210 VGP atomic absorption spectrophotometer.

3.2.5 Laboratory Analysis

The laboratory analyses were carried out in the Department of Chemistry (Analytical Laboratory), Federal Polytechnic Ado-Ekiti. Total dissolve solid, total hardness, carbonate and chloride were done according to APHA, (1998) standards for water analysis. Total alkalinity, calcium (in form of mg $CaCO_3$/L and Ca^{2+}) and bicarbonate were done according to Standard Analytical Procedures for Water Analysis, 1999 by FSSAI, (2015). Sodium was analysed using Flame Photometer. Other metal parameters were analyzed using AAS (Atomic Absorption Spectrophotometer, Buck Scientific, 210VGP). Turbidity was measured using the Nephelometric method of analysis and Electric conductivity was determined using conductivity meter.

3.2.5.1 Determination of pH (APHA, 1998)

The pH was measured using a handheld pH meter (Techmel and Techmel USA, S20). The electrode was washed thoroughly first with distilled water and then with the sample. The pH meter was standardized using buffer 4, 7, 10, solution. The pH of the samples was measured and the readings were recorded on site.

3.2.5.2 Electrical conductivity (EC)

Electrical conductivity (EC) is a measure of the ability of ions in a solution to carry electric current. This ability depends on the presence of ions, their total concentration and temperature. The conductivity was determined with a conductivity meter which was calibrated using conductivity solution at 25^0C using a Babtech digital conductivity meter. The electrical conductivity meter was switched on and its probe dipped into the sample contained in a beaker. The electrical conductivity was read directly and recorded in μScm^{-1}.

3.2.5.3 Total Dissolved Solids (TDS)

Total dissolved solids were determined as the residues left after evaporation of the filtered sample. As reported for TDS, an evaporating dish of 100 ml capacity was ignited at 550 ± 50 C in muffle furnace for half an hour, cooled in desiccators and weighed. 100 ml of filtered sample was added to it and evaporated in a pre-weighed evaporating dish on the hot plate at 98 C. The residues collected were heated at 103-105 C in an oven for one hour and final weight was taken after cooling the evaporating dish in a desiccators. TDS was calculated as,

$$TDS\ (mg/L) = \frac{(\mathrm{A} - \mathrm{B}) \times 1000}{\mathrm{V}}$$

Where, A = Final weight of the dish (g)

B = Initial weight of the dish (g)

V = Volume of sample taken (mL)

3.2.5.4 Total Hardness

For the estimation of total hardness, in 100 ml. of sample, 2 ml of buffer solution and 3 drops of Eriochrome Black-T (used as an indicator) were added. After the appearance of wine red colour, the mixture was titrated against 0.02M EDTA stirring continuously till end point change of wine red to blue is achieved (APHA, 1998). The total hardness was calculated using formula below:

$$Total\ Hardness\ (mg\ CaCO3/L) = \frac{\mathrm{A} \times N \times 1000}{\mathrm{V}}$$

Where A = ml of titrant (EDTA) used.

N = Normality of EDTA.

V = Volume of sample

3.2.5.5 Turbidity Measurement

The turbidity of the water samples was measured using a standardized turbidity meter. The samples were poured into the measuring bottles and were inserted into the turbidity meter and the reading was obtained.

3.2.5.6 Chlorides (Cl^-)

To 100 ml. of sample, 1 ml. of K_2CrO_4 indicator was added and was titrated against 0.02M $AgNO_3$ till brick red precipitates were formed (APHA, 1998). The formula used to calculate mg. of Cl^-/L is as follows:

$$Chloride\ (mg\ Cl/L) = \frac{\mathrm{A} \times N \times 35.45 \times 1000}{\mathrm{V}}$$

Where, A = Burette reading (Amount of titrant used).

N = Normality of Silver Nitrate.

35.45 = Equivalent weight of Chloride.

V = volume of sample

3.2.5.7 Total Alkalinity

2 to 3 drops of bromocresol green indicator was added to 100ml of the sample and titrated with 0.02M H_2SO_4 until color changes from blue to yellow (pH 4.6 ± 3) was observed (Standard Analytical Procedure, 1999). The total volume of acid used for the titration was recorded and the total alkalinity was calculated as below:

$$Total\ alkalinity\ (mg\ CaCO3/L) = \frac{\mathrm{A} \times N \times 50{,}000}{\mathrm{V}}$$

Where, A = Amount of acid used to reach pH 4.5 (ml)

N = Normality of acid

V = volume of sample

3.2.5.8 Estimation of Na, Cu, Mn, Al,Pb, Ca, and Fe

Few of the digested water samples were analyzed, the sample and the blank were analyzed for sodium, copper, lead, aluminium, calcium, manganese and iron using Atomic Absorption Spectrophotometer (AAS) Buck Scientific 210 VGP.

3.2.6 Water Quality Index

Accurate information on the quality of water is inevitable to form a public policy and to implement the water quality improvement programmes. Water quality index (WQI) provides information about water quality in a single value. WQI is commonly used for the detection and evaluation of water pollution and may be defined as a reflection of composite influence of different quality parameters on the overall quality of water (Horton, 1965). WQI indices are broadly classified into two types, they are physico-chemical and biological indices. The physico-chemical indices are based on the values of various physico-chemical parameters in a water sample, while biological indices are derived from the biological information. Here attempt has been made to calculate the water quality index of the study area based on some selected physico-chemical data such as pH, turbidity, electrical conductivity, total dissolved solids, total alkalinity, total hardness, Calcium, Magnesium, and chloride.

3.2.6.1 WQI Calculation

Calculation of WQI was carried out in this work by Horton's method. The WQI is calculated by using the expression given in Equation (1) below. (Qureshimatva *et. al.,*2015).

$$\mathbf{WQI} = \frac{\Sigma \mathbf{Qn\ Wn}}{\Sigma \mathbf{Wn}} \quad \text{...}(1)$$

Where, q_n= Quality rating of n^{th} water quality parameter.

W_n = Unit weight of n^{th} water quality parameter.

Quality Rating (q_n)

The quality rating (qn) is calculated using the expression given in Equation (2).

$$q_n = \frac{[\mathrm{Vn} - \mathrm{V10}]}{[\mathrm{Sn} - \mathrm{V10}]} \times 100 \quad \text{...}(2)$$

Where, V_n = Estimated value of n^{th} water quality parameter at a given sample location.

V_{10}= Ideal value for n^{th} parameter in pure water. (V_{id} for pH = 7 and 0 for all other parameters and 14.6 mg/L for Dissolved Oxygen)

S_n = Standard permissible value of n^{th} water quality parameter.

Unit Weight (W_n)

The unit weight (Wn) is calculated using the expression given in Equation (3).

$$\mathbf{Wn} = \frac{\mathrm{K}}{\mathrm{Sn}} \quad \text{...}(3)$$

Where, Sn = Standard permissible value of n^{th} water quality parameter.

k = Constant of proportionality and it is calculated by using theexpression given in Equation (4).

$$\mathbf{K} = \mathbf{1}/(\sum_{Sn=1,2,,\ldots n}^{n} \binom{n}{Sn} \frac{1}{\mathrm{Sn}}) \quad \ldots\ldots(4)$$

3.3 Statistical Analysis

All the experiments were conducted in triplicates and the data were presented as mean values ± standard deviation of the triplicate determinations using Microsoft Excel, 2016. The data obtained were subjected to Pearson Correlation Matrix (2 - tailed) using IBM SPSS statistical tool 20.

CHAPTER FOUR

4.0 RESULTS AND DISCUSSION

4.1 RESULTS

The result of the physicochemical analysis of rain water sample from painted pan, aluminum pan, galvanized zinc pan, coated pan and control are represented in Table 4.1 and the result of water quality index calculation for the four samples is shown in Table 4.2. The result of the person's correlation coefficient between paired samples is shown in Table **A.**

Table 4.1: Result of the Physicochemical Analysis of Rain Water Samples

PARAMETERS	PAINTED PAN	ALUMINUM PAN	GALVANIZED ZINC PAN	COATED.PAN	CONTROL
Colour	Colurless	Colurless	Colurless	Colurless	Colurless
Odour	Odourless	Odourless	Odourless	Odourless	Odourless
Ph	8.03 ± 0.058	9.17 ± 0.115	8.67 ± 0.058	8.87 ± 0.153	8.57 ± 0.058
Turbidity (NTU)	0.47 ± 0.058	0.57 ± 0.058	3.17 ± 4.532	0.53 ± 0.058	0.47 ± 0.058
Conductivity (µs/cm)	87.30 ± 0.265	100.07 ± 1.901	56.20 ± 0.361	170.43 ± 0.577	76.40 ± 0.693
Total Dissolved Solids (ppm)	33.77 ± 1.115	36.40 ± 0.436	30.20 ± 1.044	50.53 ± 0.503	33.07 ± 1.021
Alkalinity (mg/L)	21.30 ± 1.584	26.34 ± 1.451	21.54 ± 1.977	27.58 ± 5.499	18.56 ± 2.073
Total Hardness (mg/L)	22.39 ± 0.318	21.88 ± 5.811	22.15 ± 5.583	24.08 ± 5.972	19.94 ± 0.050
Zn (ppm)	2.40 ± 0.082	1.41 ± 0.017	4.62 ± 0.075	2.83 ± 0.023	0.00 ± 0.000
Fe (ppm)	0.29 ± 0.026	0.10 ± 0.000	0.64 ± 0.021	0.22 ± 0.015	0.10 ± 0.000
Ca (ppm)	9.90 ± 0.115	11.13 ± 0.106	9.71 ± 0.023	10.33 ± 0.006	7.11 ± 0.006

Pb (ppm)	0.00 ± 0.000	0.00 ± 0.000	0.00 ± 0.000	0.00 ± 0.000	0.00 ± 0.000
Al (ppm)	0.93 ± 0.044	1.56 ± 0.527	1.52 ± 0.074	0.63 ± 0.032	0.07 ± 0.029
Cu (ppm)	0.02 ± 0.000	0.02 ± 0.000	0.02 ± 0.000	0.02 ± 0.000	0.01 ± 0.001
Mg (ppm)	11.92 ±0.606	10.69 ± 1.369	21.33 ± 0.017	11.89 ± 0.006	9.41 ± 0.612
Na (ppm)	40.35 ± 1.172	39.97 ± 1.026	34.66 ± 1.565	31.07 ± 0.793	29.04 ± 0.968
Chloride (ppm)	9.56 ± 0.958	5.62 ± 0.905	11.67 ± 0.000	9.01 ± 0.000	4.11 ± 2.682
Carbonate (ppm)	3.23 ± 0.732	3.46 ± 0.450	3.60 ± 1.062	3.94 ± 0.363	2.45 ± 0.381
Bi-carbonate (ppm)	18.25 ±2.581	22.81 ± 1.311	17.98 ±2.365	23.09 ± 5. 842	15.72 ± 1.930
Sulphate (ppm)	12.33 ± 1.928	13.90 ± 1.928	11.41 ±0.686	14.93 ± 1.663	8.67 ± 1.765

***Data are represented as mean ± standard deviation of three determinations.**

Table 4.2: Calculation of Water Quality Index For Water Samples (PAINTED PAN)

S/N	PARAMETRS	OBSERVED VALUS (Vn)	STANDARD VALUES (Sn)	IDEAL VALUE (V10)	K Value	UNIT WEIGHT (Wn)	QUALITY RATING (Qn)	WnQn
1.	pH	8.03	8.50	7.00	0.00953	0.0011	68.67	0.0770
2.	Turbidity	0.47	5.00	0.00	0.00953	0.0019	9.40	0.0179
3.	Electrical Conductivity	87.30	300.00	0.00	0.00953	3.18×10^{-5}	29.10	0.0009
4.	Total Dissolved Solids	33.77	500.00	0.00	0.00953	1.9×10^{-5}	6.75	0.0001
5.	Alkalinity	21.30	100.00	0.00	0.00953	9.53×10^{-5}	21.30	0.0020
6.	Total Hardness	22.39	100.00	0.00	0.00953	9.53×10^{-5}	22.39	0.0021
7.	Calcium	9.90	75.00	0.00	0.00953	0.0001	13.20	0.0017
8.	Magnesium	11.92	30.00	0.00	0.00953	0.0003	39.73	0.0126
9.	Chloride	9.56	250.00	0.00	0.00953	3.81×10^{-5}	3.82	0.0001
10.	Sulphate	12.33	200.00	0.00	0.00953	4.76×10^{-5}	6.17	0.0003
11.	Zinc	2.40	5.00	0.00	0.00953	0.0019	48.00	0.0915
12.	Iron	0.29	0.30	0.00	0.00953	0.0318	96.67	3.0708
13.	Lead	0.00	0.01	0.00	0.00953	0.9530	0.00	0.0770
14.	Copper	0.02	1.00	0.00	0.00953	0.0095	2.00	0.0179
						$\Sigma Wn = 1$		**$\Sigma WnQn = 3.296$**

WQI = 3.296

Table 4.2: Calculation of Water Quality Index For Water Samples (GALVANIZED ZINC PAN)

S/N	PARAMETRS	OBSERVED VALUS (Vn)	STANDARD VALUES (Sn)	IDEAL VALUE (V10)	K Value	UNIT WEIGHT (Wn)	QUALITY RATING (Qn)	WnQn
1.	pH	8.67	8.50	7.00	0.00953	0.0011	111.33	0.1248
2.	Turbidity	3.17	5.00	0.00	0.00953	0.0019	63.40	0.1208
3.	Electrical Conductivity	56.20	300.00	0.00	0.00953	3.18×10^{-5}	18.73	0.0006
4.	Total Dissolved Solids	30.20	500.00	0.00	0.00953	1.9×10^{-5}	6.04	0.0001
5.	Alkalinity	21.54	100.00	0.00	0.00953	9.53×10^{-5}	21.54	0.0021
6.	Total Hardness	22.15	100.00	0.00	0.00953	9.53×10^{-5}	22.15	0.0021
7.	Calcium	9.71	75.00	0.00	0.00953	0.0001	12.95	0.0016
8.	Magnesium	21.33	30.00	0.00	0.00953	0.0003	71.10	0.0226
9.	Chloride	11.67	250.00	0.00	0.00953	3.81×10^{-5}	4.67	0.0002
10.	Sulphate	11.41	200.00	0.00	0.00953	4.76×10^{-5}	5.71	0.2749
11.	Zinc	4.62	5.00	0.00	0.00953	0.0019	92.40	0.4251
12.	Iron	0.64	0.30	0.00	0.00953	0.0318	213.33	0.7293
13.	Lead	0.00	0.01	0.00	0.00953	0.9530	0.00	1.4580
14.	Copper	0.02	1.00	0.00	0.00953	0.0095	2.00	2.9159
						$\Sigma Wn = 1$		**$\Sigma WnQn = 6.078$**

WQI = 6.078

Table 4.2: Calculation of Water Quality Index For Water Samples (COATED PAN)

S/N	PARAMETRS	OBSERVED VALUS (Vn)	STANDARD VALUES (Sn)	IDEAL VALUE (V10)	K Value	UNIT WEIGHT (Wn)	QUALITY RATING (Qn)	WnQn
1.	pH	8.87	8.50	7.00	0.00953	0.0011	124.67	0.1398
2.	Turbidity	0.53	5.00	0.00	0.00953	0.0019	10.60	0.0202
3.	Electrical Conductivity	170.43	300.00	0.00	0.00953	3.18×10^{-5}	56.81	0.0018
4.	Total Dissolved Solids	50.53	500.00	0.00	0.00953	1.9×10^{-5}	10.11	0.0002
5.	Alkalinity	27.58	100.00	0.00	0.00953	9.53×10^{-5}	27.58	0.0026
6.	Total Hardness	24.08	100.00	0.00	0.00953	9.53×10^{-5}	24.08	0.0023
7.	Calcium	10.33	75.00	0.00	0.00953	0.0001	13.77	0.0018
8.	Magnesium	11.89	30.00	0.00	0.00953	0.0003	39.63	0.0126
9.	Chloride	9.01	250.00	0.00	0.00953	3.81×10^{-5}	3.60	0.0001
10.	Sulphate	14.93	200.00	0.00	0.00953	4.76×10^{-5}	7.47	0.0004
11.	Zinc	2.83	5.00	0.00	0.00953	0.0019	56.60	0.1079
12.	Iron	0.22	0.30	0.00	0.00953	0.0318	73.33	2.3296
13.	Lead	0.00	0.01	0.00	0.00953	0.9530	0.00	0.0000
14.	Copper	0.01	1.00	0.00	0.00953	0.0095	1.00	0.0095
						ΣWn = 1		**ΣWnQn = 2.629**

WQI = 2.629

Table 4.2: Calculation of Water Quality Index For Water Samples (CONTROL)

S/N	PARAMETRS	OBSERVED VALUS (Vn)	STANDARD VALUES (Sn)	IDEAL VALUE (V10)	K Value	UNIT WEIGHT (Wn)	QUALITY RATING (Qn)	WnQn
1.	Ph	8.57	8.50	7.00	0.00953	0.0011	104.67	0.1173
2.	Turbidity	0.47	5.00	0.00	0.00953	0.0019	9.40	0.0179
3.	Electrical Conductivity	76.4	300.00	0.00	0.00953	3.18×10^{-5}	25.47	0.0008
4.	Total Dissolved Solids	33.07	500.00	0.00	0.00953	1.9×10^{-5}	6.61	0.0001
5.	Alkalinity	18.56	100.00	0.00	0.00953	9.53×10^{-5}	18.56	0.0018
6.	Total Hardness	19.94	100.00	0.00	0.00953	9.53×10^{-5}	19.94	0.0019
7.	Calcium	7.11	75.00	0.00	0.00953	0.0001	9.48	0.0012
8.	Magnesium	9.41	30.00	0.00	0.00953	0.0003	31.37	0.0100
9.	Chloride	4.11	250.00	0.00	0.00953	3.81×10^{-5}	1.64	0.0001
10.	Sulphate	8.67	200.00	0.00	0.00953	4.76×10^{-5}	4.34	0.0002
11.	Zinc	0.00	5.00	0.00	0.00953	0.0019	0.00	0.0000
12.	Iron	0.10	0.30	0.00	0.00953	0.0318	33.33	1.0589
13.	Lead	0.00	0.01	0.00	0.00953	0.9530	0.00	0.0000
14.	Copper	0.01	1.00	0.00	0.00953	0.0095	1.00	0.0095
						$\Sigma Wn = 1$		$\Sigma WnQn = 1.220$

WQI = 1.220

4.2 DISCUSSION

4.2.1 Physicochemical Parameters

The results of the laboratory analysis of physicochemical characteristics of rainwater samples harvested at the peak of raining season (August) for different rooftop sheets are presented in Table 4.1. It was observed that all harvested rainwater samples were odourless and colourless. This was due to the absence of little physical contamination. The odour and taste of all samples were satisfactory.

The pH (Figure Ai) of all harvested water sample ranged from 8.03 – 9.17 with mean of 8.7 and permissible limit ranging from 6.5-8.5. Only samples from painted pan (8.03± 0.058) fall below the standard while other samples fall above it. This shows that roof harvested rainwater samples from this study area is slightly basic. This could probably be as a result of anthropogenic activities such as indiscriminate refuse burning and old practice of bush burning by few hunters and farmers in the study area. This result was however similar to values obtained from Anambra (Chukwuma et al., 2014).

Turbidity values ranged from 0.47 – 3.17NTU with the mean of 1.2. This mean value was low compared to the WHO limit of 5.0 NTU (Figure Aii). High turbidity reflects the presence of particulate matter in the atmospheric air that is highly influenced by anthropogenic activities such as mining. Low turbidity values recorded in this study might be due to the fact that the harvested water were sampled from rural communities with no or low mining or other major particulate producing anthropogenic activities.

The conductivities of the harvested rainwater were generally low with values ranging from 56.20 – 170.43µs/cm with the mean of 103.5µs/cm. This value was low compared with permissible level of 1000µs/cm. Low electrical conductivities of the study area shows minimum atmospheric contamination with particulate matter as explained for turbidity above. The results generally indicate good atmospheric condition of the areas sampled.

Total dissolved solids (TDS) concentrations ranged from 30.2 – 50.53 mg/L having the mean as 37.7. These values are very low compared to the value (500mg/L) recommended by WHO for drinking water. This indicates that the harvested water sample is good and can be used as potable water. Dissolved solids can precipitate following storage and deposit at the bottom of storage containers thereby reducing the levels of dissolved solids in the water.

Alkalinity and total hardness had respective values which ranged from 18.56 – 27.58mg/L and 19.94 – 24.08mg/L with the mean of 24.19mg/L and 21.80mg/L. Alkalinity and total hardness of the water sample were below the WHO permissible limit of 100mg/L for drinkable water. According to reviewed literatures, alkalinity of water results from the presence of HCO_3^-, CO_3^{2-} and OH^-. The results show low availability of ions in the water. Hardness of water results from the effects of calcium carbonate and magnesium carbonate on water according to literature and hardness of water has been linked to heart diseases. However, since the harvested water were soft, there were no expected adverse effect of the water for domestic use.

The concentrations of sulphate ranges from (8.67 – 14.93mg/L) with the mean of 13.4 and concentration of chloride ranges from (4.11 – 11.67mg/L) with the mean of 8.9mg/L nutrients in the harvested water samples was however, lower than the WHO permissible limit of 200 and 250mg/L respectively. Since the concentrations of these nutrients were below the recommended limit for potable water, this indicates that their levels will not pose threat to human health from consumption of the harvested rainwater.

The levels of heavy metals in harvested rainwater are also shown in Table 4.1. The concentration ranged from 0 – 4.62mg/L (Zn) with the mean of 2.82mg/L, 0.1 – 0.29mg/L (Fe) with the mean of 0.05mg/L, 7.11 – 11.13mg/L (Ca) with the mean of 10.27mg/L, lead (not detected), 0.07 – 1.56mg/L (Al) with the mean of 1.16mg/L, 0.01 – 0.02mg/L (Cu) with the mean of 0.015mg/L, 9.41 – 21.33mg/L (Mg) with the mean of 13.96mg/L and 29.04 – 40.35mg/L (Na) with the mean of 36.5mg/L are however lower compared to the WHO recommended limits for potable water with limits set at 5mg/L, 0.3mg/L, 75mg/L, 0.01mg/L, 3mg/L, 1mg/L, 30mg/L and 75mg/L respectively. Lead was not detected in the water sample and copper at a very minimal level which would not in any way pose threats to human health if such water is consumed. Zinc is an essential element although, it gives and undesirable astringent taste to water at levels above the standard limit. The level of concentration of zinc in this study indicated that the harvested water were palatable for drinking. The low level of the analyzed metals is probably due to the zero industrial and motor vehicular activities in the study area.

4.2.2 Water Quality Index

Water quality index is commonly used for the detection and evaluation of water pollution and it may be defined as the reflection of composite influence of different quality parameters on the overall quality of water. The WQI of the study area for painted pan, aluminum pan, galvanized zinc, coated and control harvested rainwater samples with values of 3.296, 1.335, 6.078, 2.629 and 1.220 respectively indicates that the rainwater harvested in the study area are of excellent quality and can be consumed domestically without causing any threat to human health according to the WQI level by Chaterjee and Raziuddin, 2002 and Thakor et al., 2011.

Table 4.3: Water Quality Index (WQI) and Its Status According to Chaterjee and Raziuddin, 2002 and Thakor et al., 2011

Water Quality Index	Water Quality Status
0 – 25	Excellent Water Quality
26 – 50	Good Water Quality
51 – 75	Poor Water Quality
76 – 100	Very Poor Water Quality
>100	Unsuitable for Drinking

4.2.3 Correlation Studies

Pearson's correlation matrixes for pairs of measured variables are shown in Table A below. Low to negative correlations existed for pH and trace metals, indicating different sources to their inputs other than particulate matter. Similarly, low to negative correlations existed between pH and the measured anions, showing different sources of their contamination and interactions in the water. Correlations for Pb were not calculated as the values were all about 0.01mg/L indicating the absence of lead in the study area which may probably be due to the absence of industry and very few mechanic workshops in the area which could bring about lead particle. Sulphates correlated significantly with Zn, Cu and Fe, indicating possible similar sources or strong interactions among the measured species. Correlation between the trace metals is significant at $p>0.05$ indicating that the trace metals are possibly influenced by the same anthropogenic sources that contributed to their atmospheric concentrations or there are strong interaction between them in water. Correlations between TDS and Conductivity, Mg and Turbidity, Mg and Fe, Chloride and Zinc, and Bicarbonate and Alkalinity are significant at 0.001 level.

CHAPTER FIVE

5.0 CONCLUSION AND RECOMMENDATION

5.1 CONCLUSION

In this study, the physicochemical parameters measured were below the WHO standard limits for portability indicating their suitability for domestic use and would not pose any adverse effect since they are within acceptable limits (WHO, 2004). The computed WQI indicates that the harvested rainwater quality is excellent having fall within the 0 – 25 range for WQI standard and it is safe for human consumption with extremely low level of pollutant which would hold no adverse effect to human health.

5.2 RECOMMENDATION

It is however recommended that the harvested rainwater be further treated appropriately before drinking. This will help complement or improve the water quality thereby providing portable water for households in the communities. Future studies would seek to identify the atmospheric contributions of the parameters measured in the harvested rainwater as well as their bacteriological profile.

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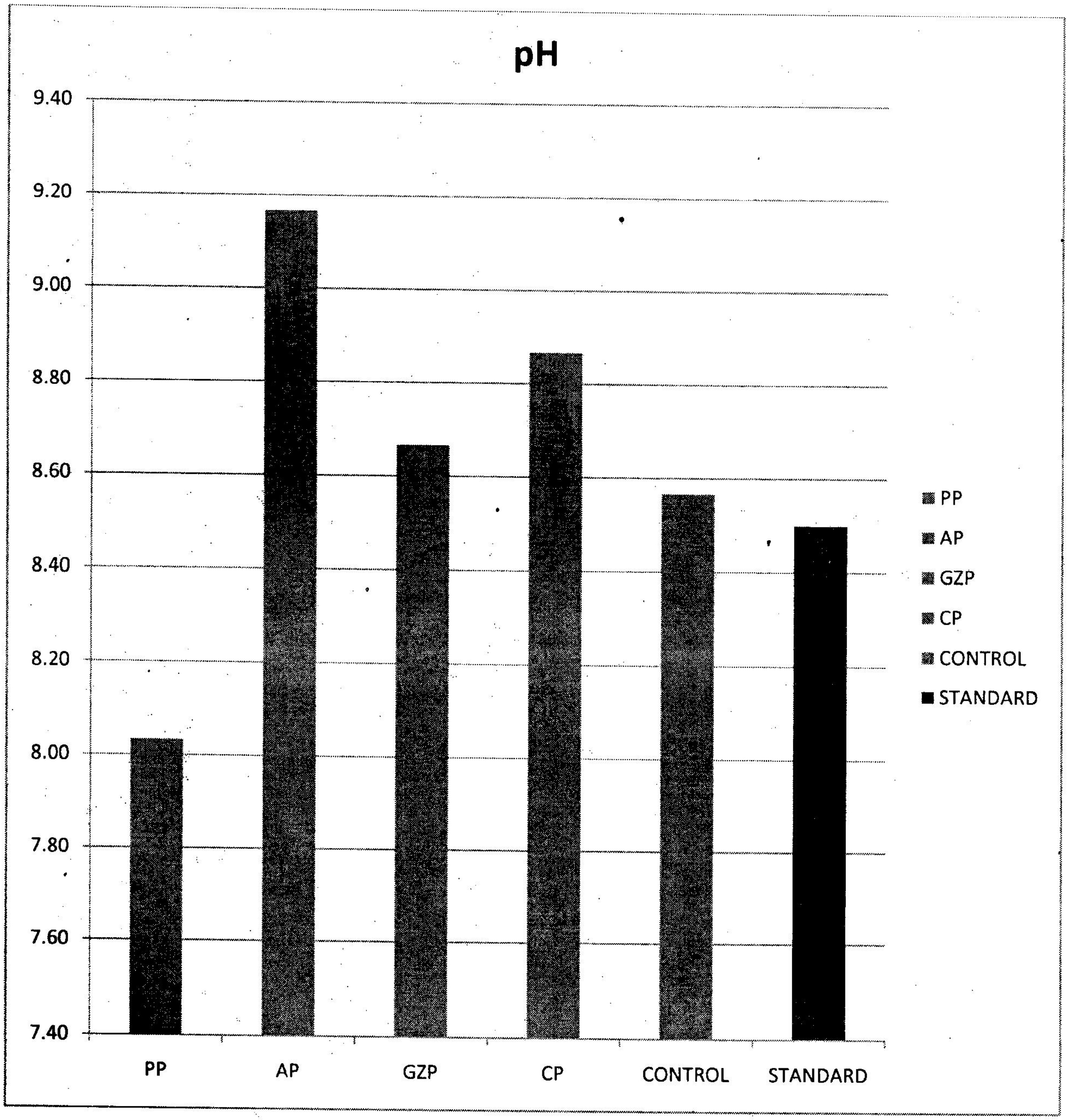
FIGURE A

(CHARTS SHOWING COMPARISON OF MEASURED PARAMETERS WITH WHO STANDARD VALUES)

i



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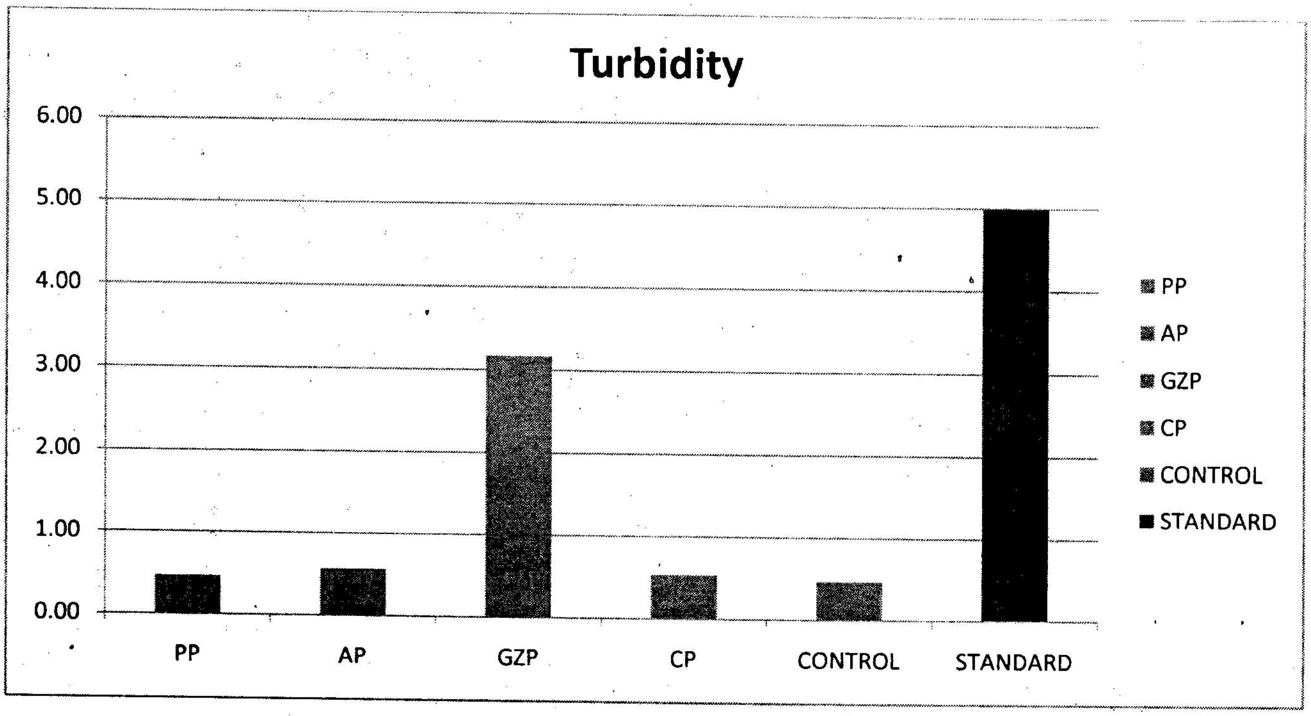
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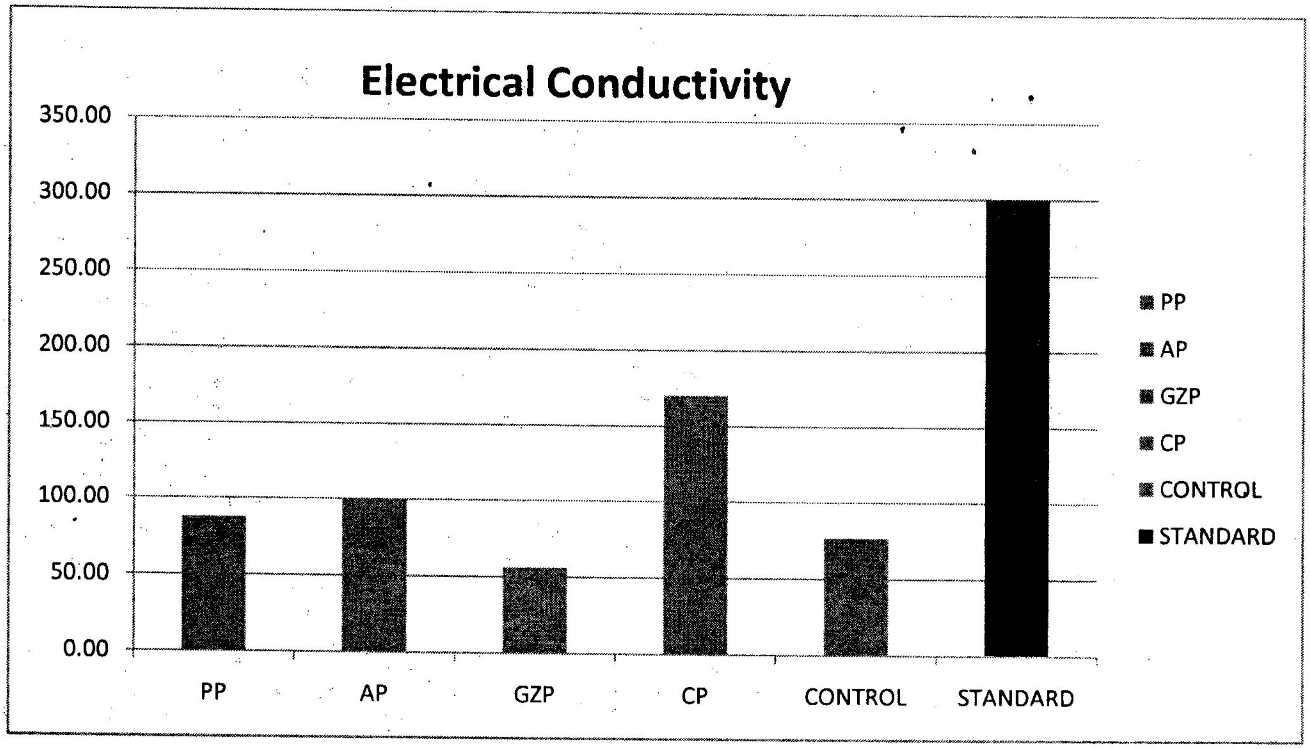
AP
GZP
CP
CONTROL
STANDARD
PP
AP
GZP
CP
CONTROL
STANDARD

iii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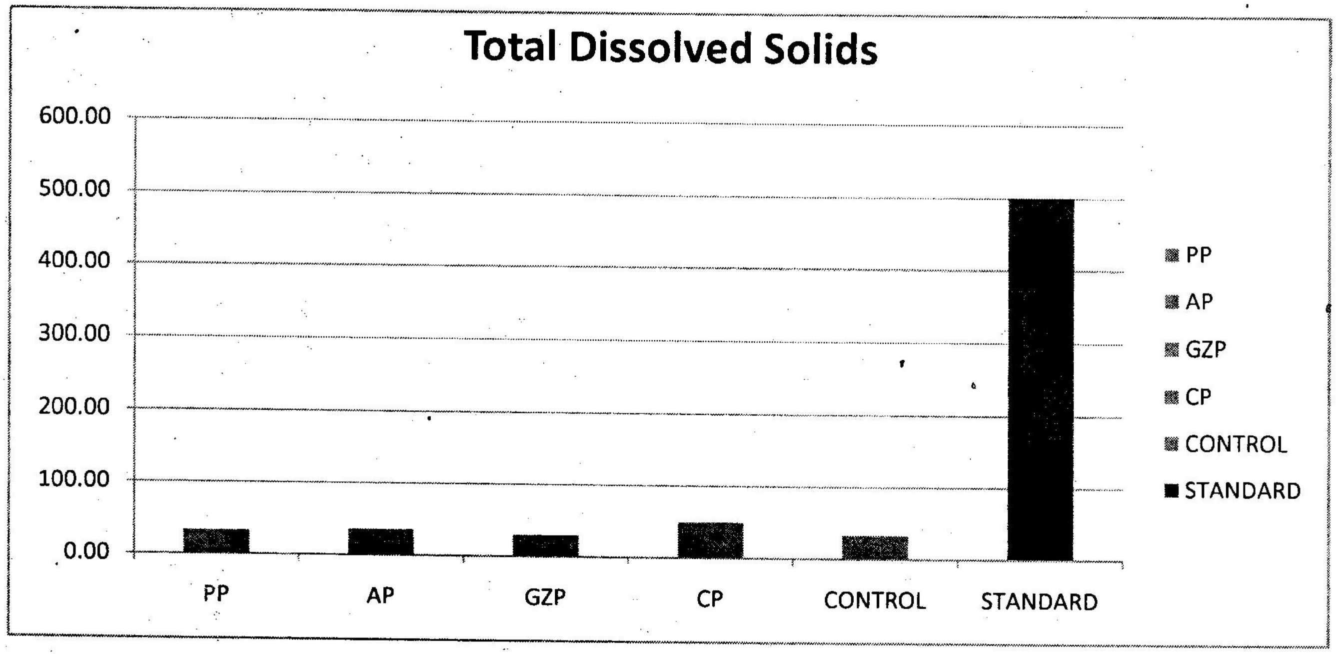
AP
GZP
CP
CONTROL
STANDARD
PP
AP
GZP
CP
CONTROL
STANDARD

iv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200.00
100.00
0.00
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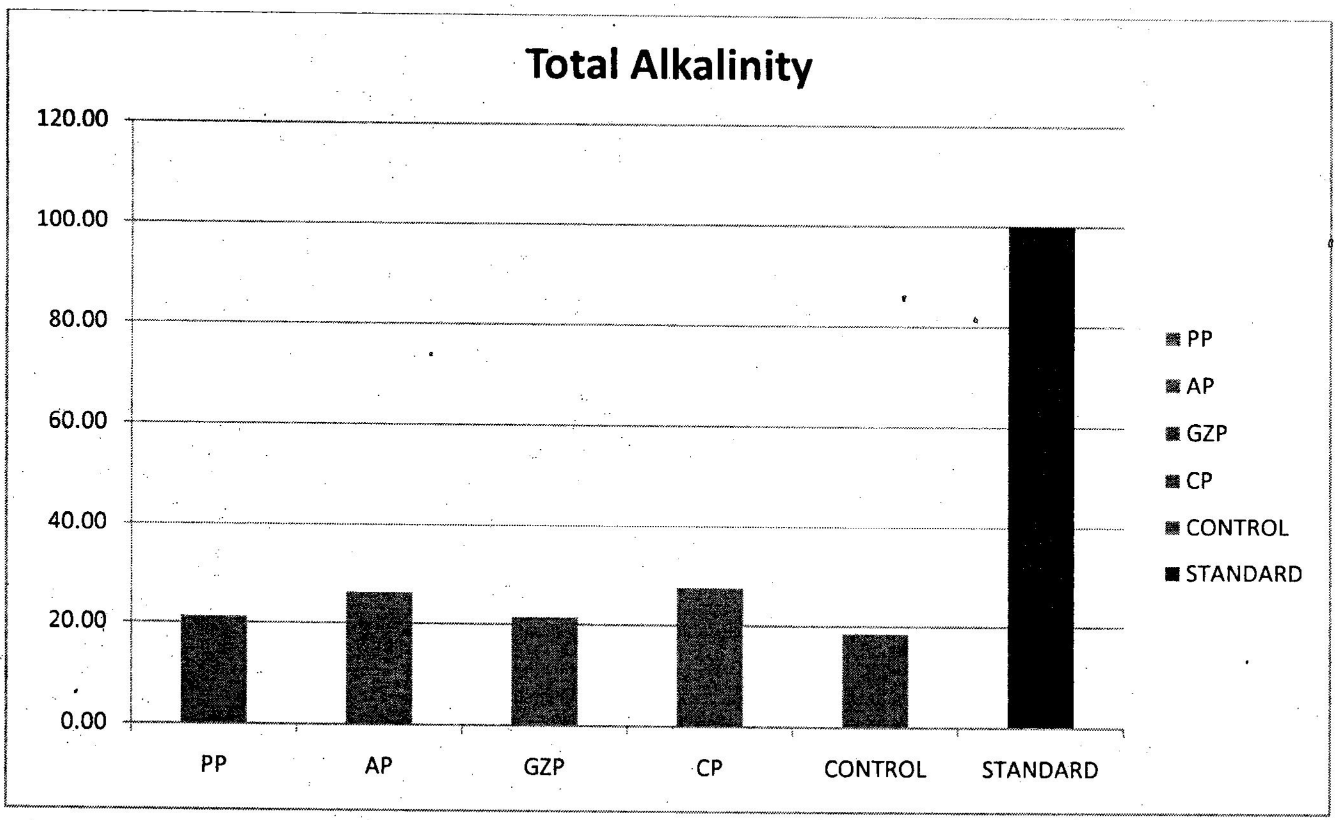
AP
GZP
CP
CONTROL
STANDARD
▨ PP
▨ AP
▨ GZP
▨ CP
▨ CONTROL
■ STANDARD

v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0.00
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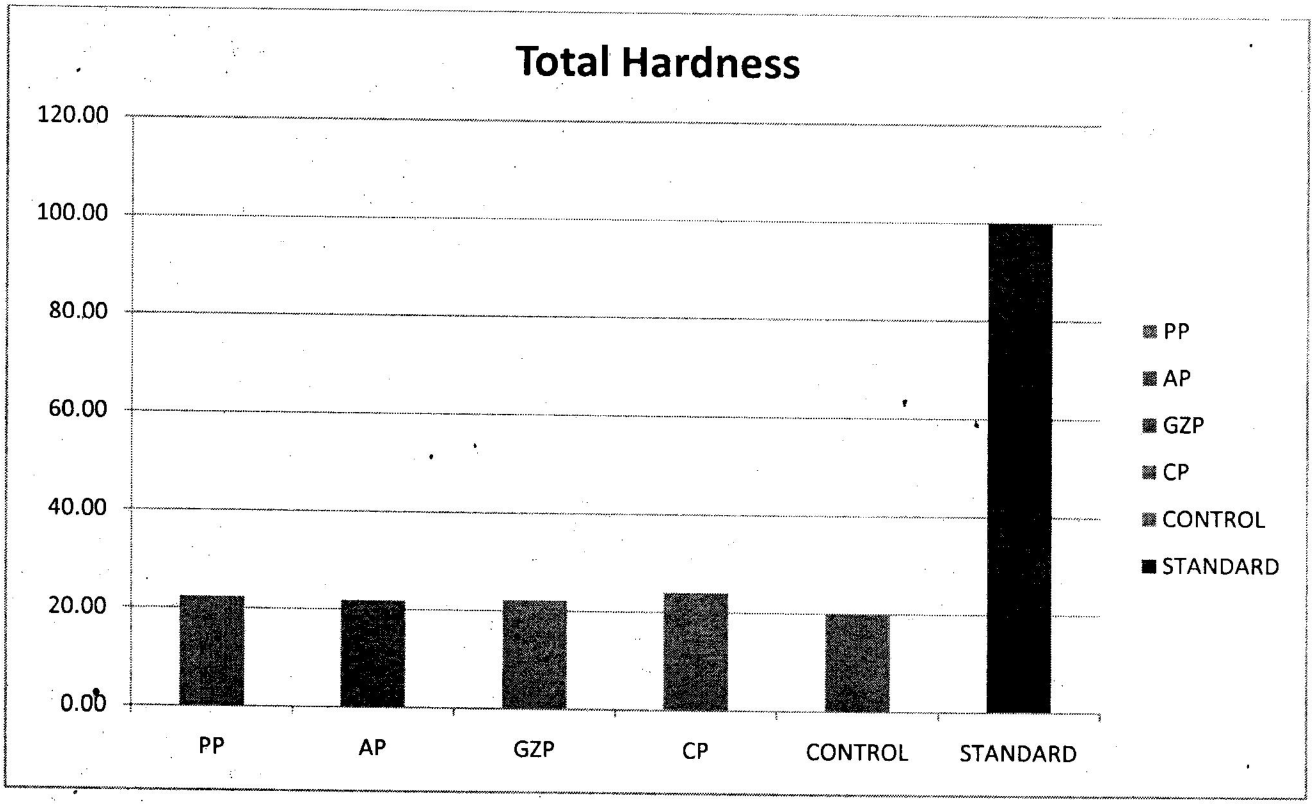
AP
GZP
CP
CONTROL
STANDARD
▨ PP
▨ AP
▨ GZP
▨ CP
▨ CONTROL
■ STANDARD

vi



Total Hardness
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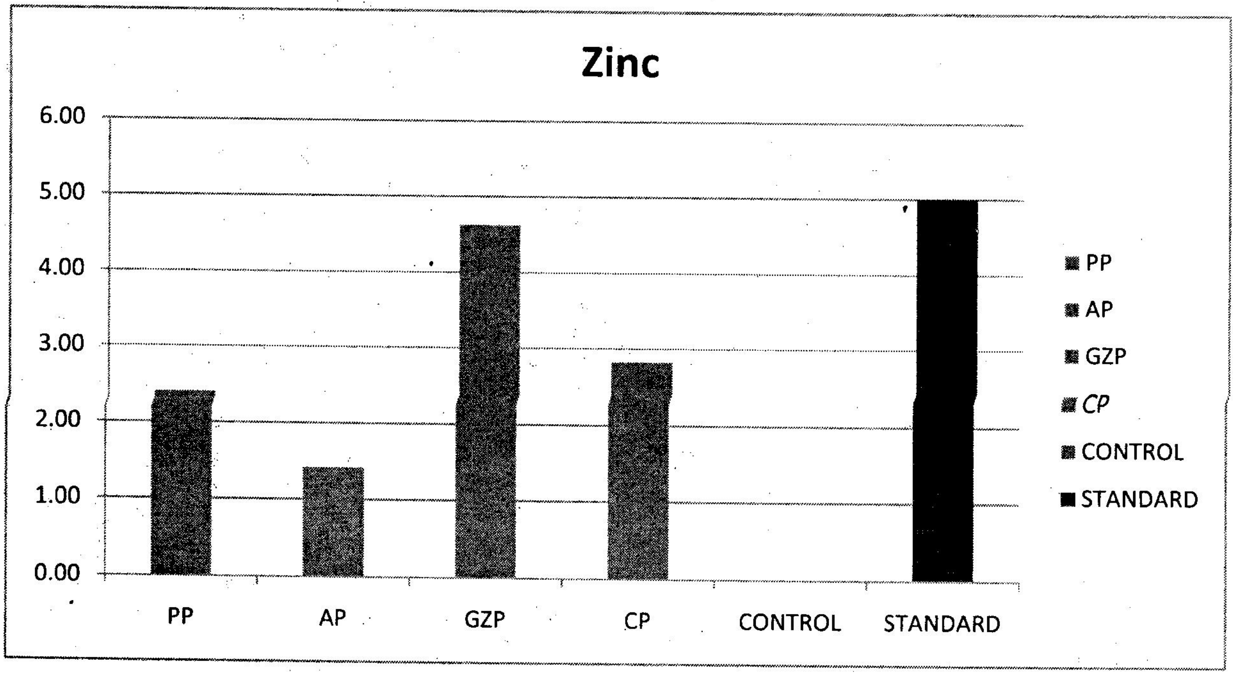
AP
GZP
CP
CONTROL
STANDARD
PP
AP
GZP
CP
CONTROL
STANDARD

vii



Zinc
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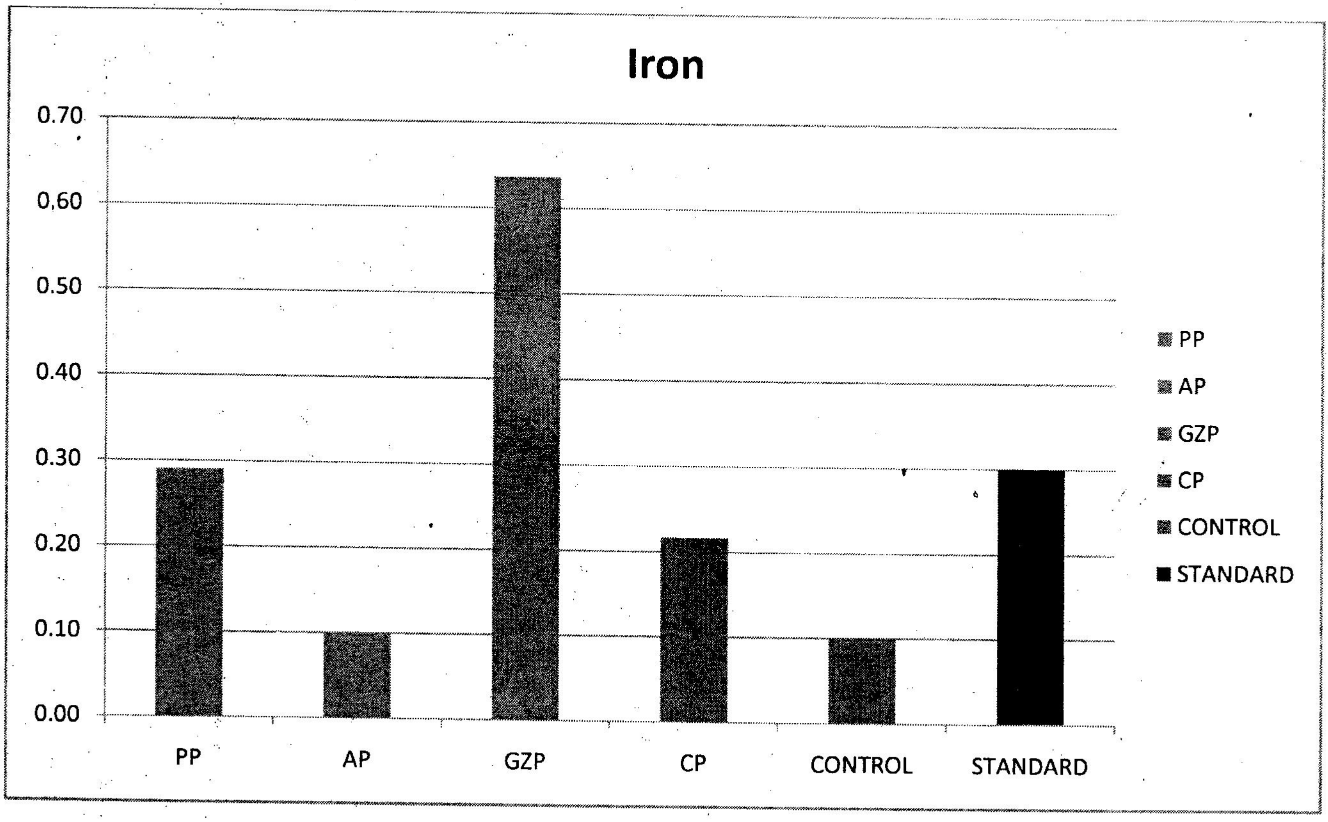
AP
GZP
CP
CONTROL
STANDARD
PP
AP
GZP
CP
CONTROL
STANDARD

viii



Iron
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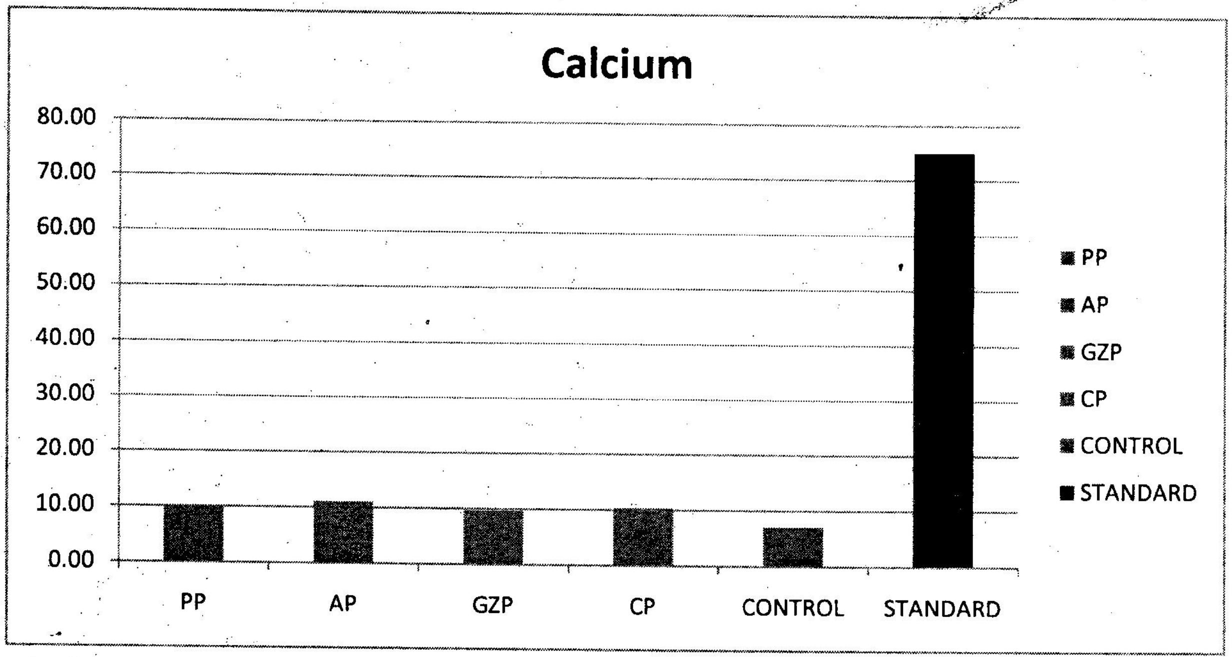
0.50
0.40
0.30
0.20
0.10
0.00
PP
AP
GZP
CP
CONTROL
STANDARD
PP
AP
GZP
CP
CONTROL
STANDARD

ix



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40.00
30.00
20.00
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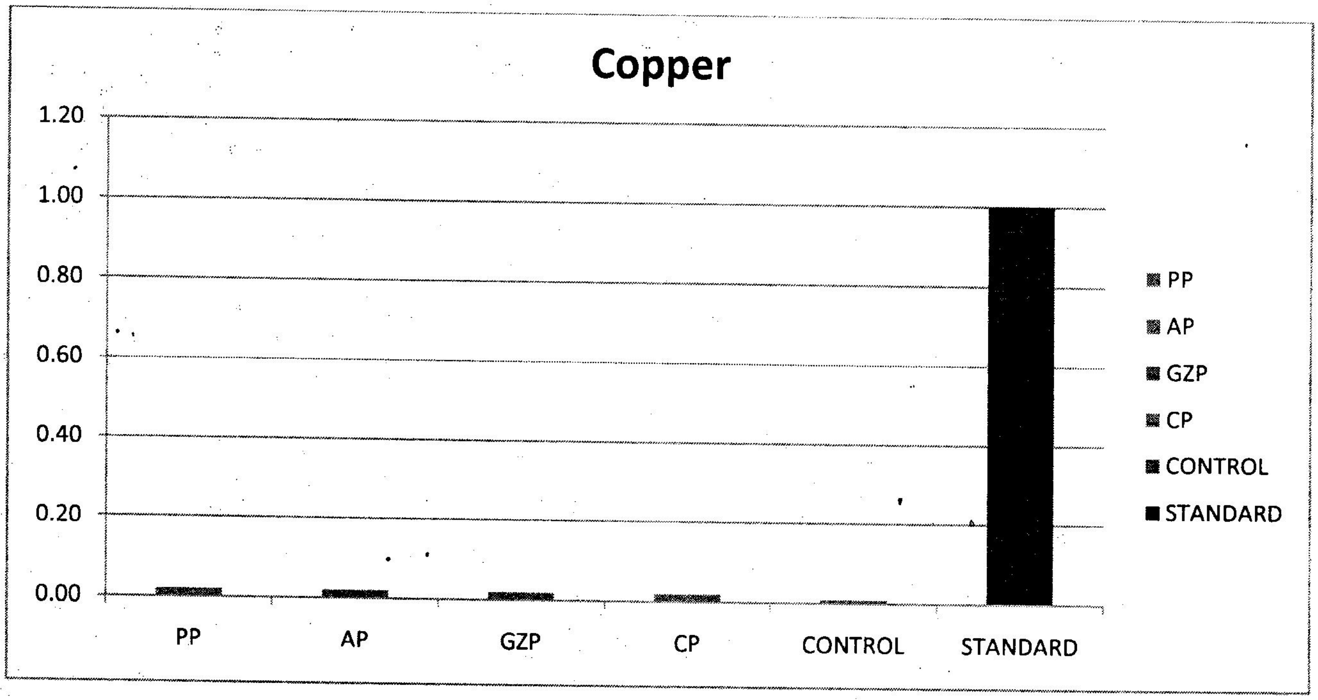
0.00
PP
AP
GZP
CP
CONTROL
STANDARD
PP
AP
GZP
CP
CONTROL
STANDARD

x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0.80
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0.40
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0.00
PP
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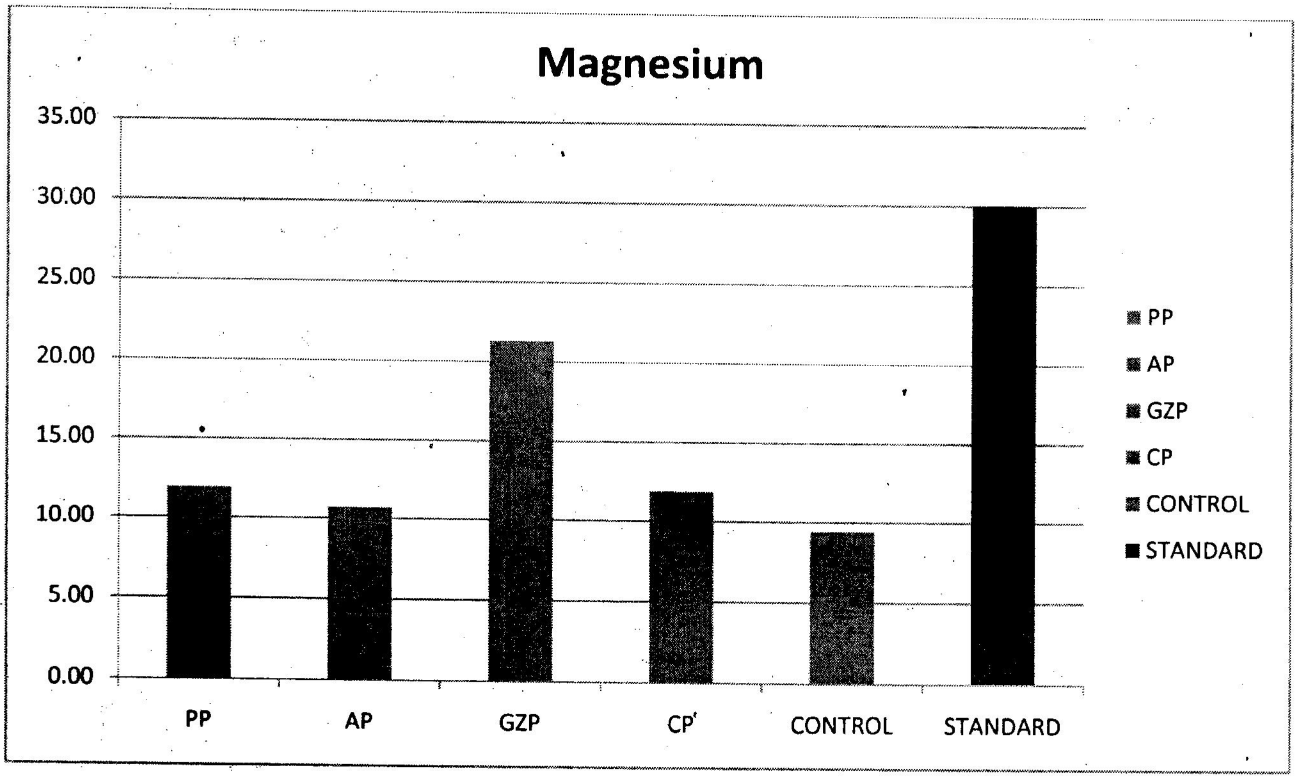
GZP
CP
CONTROL
STANDARD
PP
AP
GZP
CP
CONTROL
STANDARD

xi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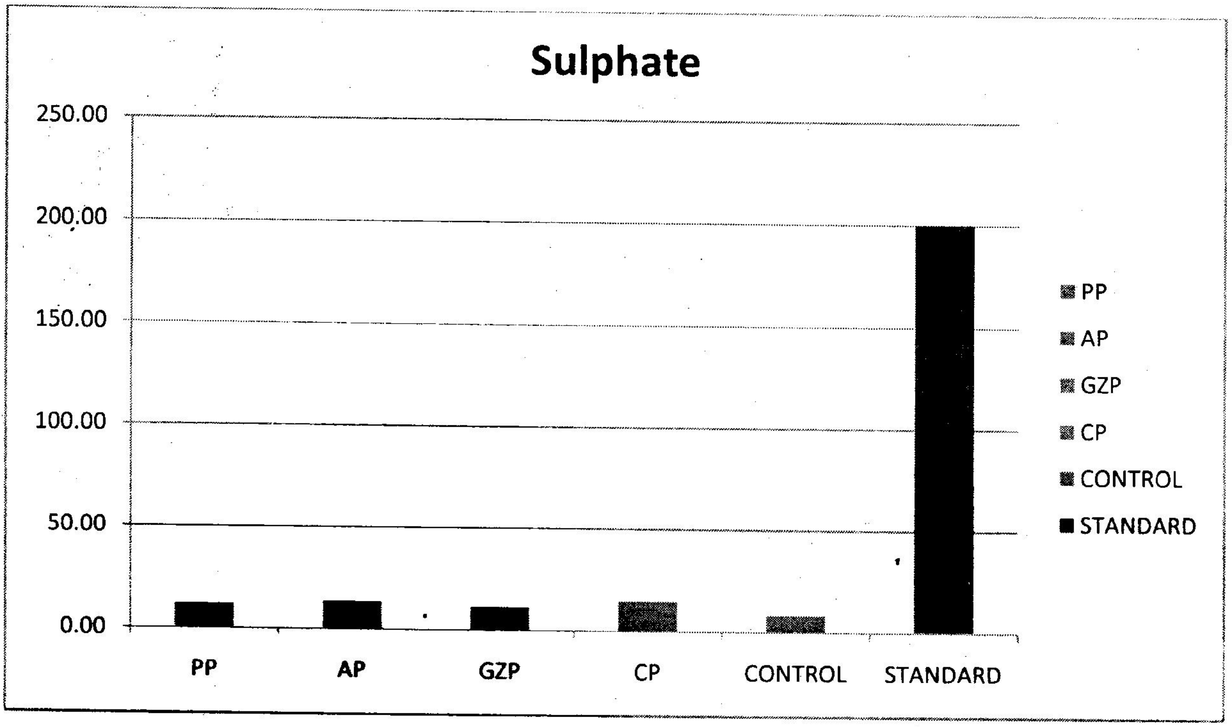
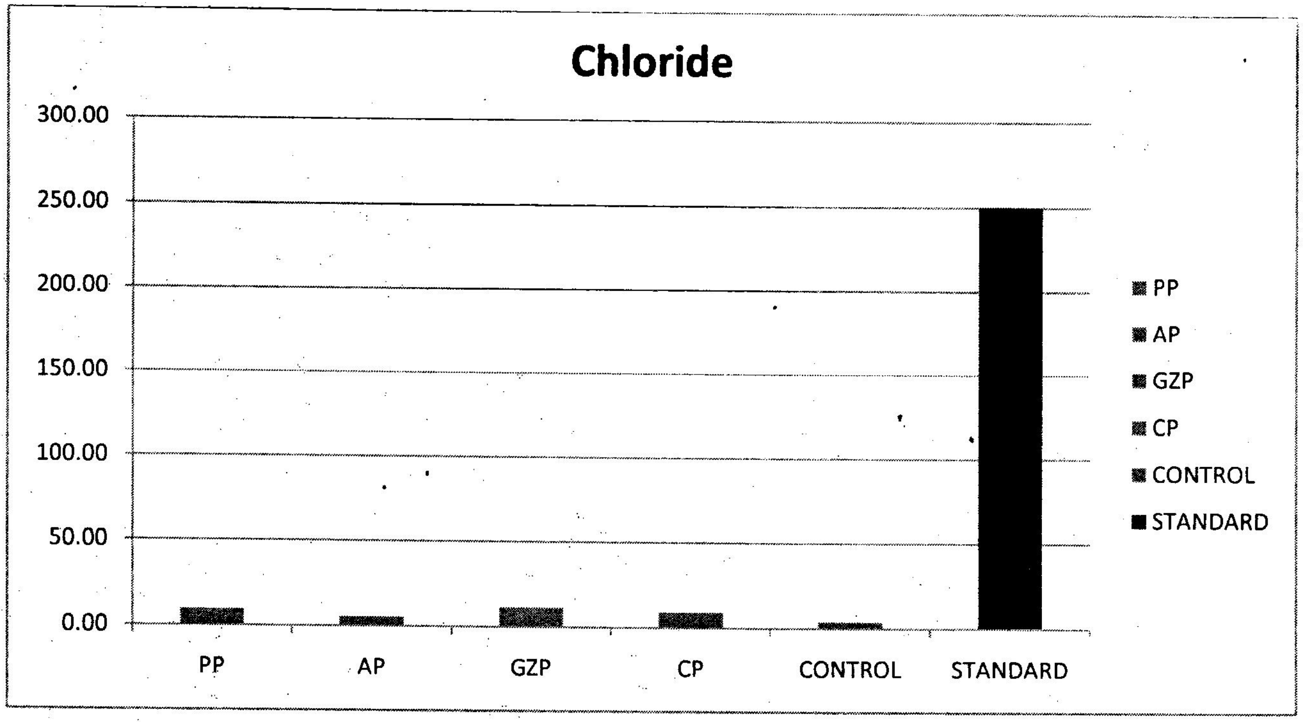
25.00
20.00
15.00
10.00
5.00
0.00
PP
AP
GZP
CP
CONTROL
STANDARD
PP
AP
GZP
CP
CONTROL
STANDARD

xii



Sulphate
250.00
200.00
150.00
100.00
50.00
0.00
PP
AP
GZP
CP
CONTROL
STANDARD
PP
AP
GZP
CP
CONTROL
STANDARD

xiii



Chloride
300.00
250.00
200.00
150.00
100.00
50.00
0.00
PP
AP
GZP
CP
CONTROL
STANDARD
PP
AP
GZP
CP
CONTROL
STANDARD

TABLE A

(PEARSON'S CORRELATION COEFFICIENTS BETWEEN PAIRS OF VARIABLES)

	pH	TUR	CON	TDS	ALK	THD	Zn	Fe	Ca	Pb	Al	Cu	Mg	Na	Cl	CAR	BCAR	SUL
pH	1																	
TUR	.042	1																
CON	.335	-.524	1															
TDS	.361	-.447	.994**	1														
ALK	.649	-.196	.783	.771	1													
THD	.127	.038	.717	.723	.780	1												
Zn	-.061	.778	-.040	.011	.237	.628	1											
Fe	-.243	.925*	-.413	-.350	-.184	.251	.903*	1										
Ca	.380	.054	.387	.353	.825	.736	.486	.129	1									
Pb	.^{a}	.^{a}	.^{a}	.^{a}	.^{a}	.^{a}	.^{a}	.^{a}	.^{a}	1								
Al	.323	.537	-.243	-.252	.389	.312	.612	.488	.776	.^{a}	1							
Cu	.122	.269	.278	.261	.668	.813	.735	.428	.933*	.^{a}	.777	1						
Mg	-.041	.977**	-.417	-.347	-.101	.220	.891*	.977**	.180	.^{a}	.578	.429	1					
Na	-.131	-.029	-.212	-.292	.214	.183	.199	.076	.683	.^{a}	.720	.654	.058	1				
Cl	-.309	.667	-.033	.004	.128	.637	.963**	.881*	.412	.^{a}	.481	.707	.811	.231	1			
CAR	.361	.287	.548	.568	.821	.930*	.745	.393	.838	.^{a}	.582	.887*	.428	.251	.666	1		
BCAR	.651	-.244	.754	.733	.995**	.737	.181	-.239	.843	.^{a}	.413	.664	-.153	.282	.074	.782	1	
SUL	.409	-.168	.734	.708	.953*	.885*	.376	-.053	.909*	.^{a}	.464	.826	-.022	.399	.328	.882*	.950*	1

*. Correlation is significant at the 0.05 level (2-tailed).

**. Correlation is significant at the 0.01 level (2-tailed).

a. *Correlations for Pb were not calculated as the values were all about 0.001 mg/l