ASSESSMENT OF LEVELS OF SELECTED METAL POLLUTANTS IN AQUATIC SAMPLES ALONG LAKE VICTORIA SHORELINE FROM RIVERS KISAT TO KISIAN DISCHARGE POINTS, KENYA

BY

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DECLARATION

I declare that the material discussed in this thesis is my original work, and as far as I am aware, has not been presented for an award of a degree in any University and all referred information is fully acknowledged.

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This work is dedicated to my late dad Simon Kiema, my dear mom, my lovely daughters, my dear son Oscar and Darlin' Hellen Katola.

ABSTRACT

Lake Victoria is the largest freshwater and fishery lake in Africa. Kisumu City on the Winam Gulf has industrial activities that dispose of their effluents into the lake which may contaminate aquatic species thus threatening human health. It is not known fully if these anthropogenic activities adversely change the water quality and contribute heavy metal pollutants to the lake water and/or cause high accumulation of the metals in sediments and fish from the gulf. The study employed a three factor completely randomized design. Samples of water from Molasses Plant, Rivers Kisat and Kisian and lakewater, sediments and fish species (*Lates niloticus*, *Oreochromis niloticus*, *Synodontis victoriae and clarias batrachus*) were collected from Lake Victoria shoreline near the city. The samples were digested and analyzed using Atomic Absorption Spectrophotometer for heavy metals during wet (April-July 2013) and dry (Jan-Feb 2014) seasons to assess the influence of the anthropogenic activities within Kisumu City and adjacent environment on heavy metal levels in aquatic samples and water physicochemical parameters. The data was subjected to statistical analysis using MSTATC package at 95% confidence level. The heavy metal levels (µg/L) in river and lake waters recorded ranges were Cd (1.00 - 12.00), Cr (13.00 - 75.50), Cu (23.00 - 276.50), Fe (789.00 - 1050.50), Mn (452.50 - 2466.30), Pb (33.50 - 409.50), Zn (954.50 - 50.00) and Cd (0.20 - 1.30), Cr (21.00 - 55.00), Cu (8.00 - 25.00), Fe (127.50 - 225.00), Mn (76.00 - 334.00), Pb (5.00 - 10.00), Zn (9.00 - 21.00) respectively. The heavy metal levels in the water channels decreased ($p \leq 0.05$) in the order Kisat > Molasses > Kisian. River Kisat water was the most polluted. The levels of the heavy metals in lake and river waters varied ($p \leq 0.05$) with sites. Water from Kisat discharge point had levels above the recommended WHO acceptable limits for aquatic life and domestic use. The metal levels (µg/g in dry weight basis) in sediments were Cd (0.90 - 1.20), Cr (2.60 - 36.00), Cu (71.40 - 122.90), Fe (1283.40 - 1468.70), Mn (792.30 - 1631.20), Pb (61.80 - 181.00) and Zn (100.10 - 187.60). Heavy metal levels in River Kisat discharge point sediments were high ($p \leq 0.05$) compared to levels in sediments from River Kisian discharge point. The heavy metal ranges in the edible fish tissues (µg/g on dry weight basis) across the caught fish species were Cd (0.60 - 0.70), Cr (0.60 - 0.80), Cu (2.90 - 3.70), Fe (33.70 - 36.90), Mn (74.70 - 90.90), Pb (0.40 - 0.70) and Zn (31.30 - 41.20). The metal levels in fish were above international limits. The water physicochemical parameter levels varied ($p \leq 0.05$) with sites. Dissolved oxygen in lake water was below the WHO recommended limits for fisheries. The high metal levels in aquatic samples (water, fish and sediments) and deterioration of water quality parameters from the study area were due to intense anthropogenic activities. Use of water from Kisat discharge point and consumption of fish from the study area may pose health risks. Regular environmental assessment of heavy metal levels in water, sediments and fish, and water quality physicochemical parameters is recommended.

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LIST OF ABBREVIATIONS

AAS	Atomic Absorption Spectrophotometer
ANOVA	Analysis of Variance
ATSDR	Agency for Toxic Substances and Disease Registry
Cd	Cadmium
Cr	Chromium
Cu	Copper
DO	Dissolved oxygen
DOC	Dissolved organic carbon
EC	Electrical conductivity
ECDG	European Commission, Directorate General Environment
EPA	Environmental Protection Agency
EU	European Union
FAO	Food and Agricultural Organization
Fe	Iron
FEPA	Federal Environmental Protection Agency
g	Gram
IAEA	International Atomic Energy Agency
KEBS	Kenya Bureau of Standards
KEMRI	Kenya Medical Research Institute
KMFRI	Kenya Marine and Fisheries Research Institute
KWWTP	Kisat Waste Treatment Plant
L	Litre
LSD	Least significant difference
LVEMP	Lake Victoria Environmental Management Project
mg	Milligram
Mn	Manganese
NAS	National Academy of Science
NEMA	National Environment Management Authority
NTU	Nephelometric Turbidity Units

NWQMS	National Water Quality Management Strategy
Pb	Lead
pH	$-\log_{10}[H^+]$
TDS	Total Dissolved Solids
TOC	Total Organic Carbon
TOM	Total Organic Matter
TSS	Total Suspended Solids
μg	Microgram
UK	United Kingdom
UNESCO	United Nations Educational, Scientific and Cultural Organizations
UNICEF	United Nations Children's Funds
USA	United States of America
USDA	United States Department of Agriculture
USEPA	United States Environmental Protection Agency
WHO	World Health Organization
Zn	Zinc

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CHAPTER ONE

INTRODUCTION

1.1 Background of the study

Heavy metal pollution of aquatic ecosystems is a potential global problem (Mwita *et al*, 2011; Orlu and Gabriel, 2011). Many human activities due to global population increase and industrial developments are sources of pollution leading to increase in contamination of aquatic ecosystems by heavy metals (Franca *et al*., 2005; Sarma, 2011; Orlu and Gabriel, 2011). This has increased concerns about possible accumulation of heavy metals in aquatic sediments, water and biota ultimately threatening human life (Gibbs and Miskiewicz, 1995). In many instances, governments lack control measures to safeguard human health and environment from the anthropogenic heavy metal contamination. Therefore, some aquatic environment could rapidly become sources of death of aquatic species if the pollution is not controlled (Beyersmann and Hartwig, 2008; Earthwatch, 2009).

Freshwater bodies in developing countries were considered the least polluted (Ochieng *et al.*, 2008). But the scenario could be changing rapidly due to rapid industrial development (La Kenya and Edwards, 2011; Mwita *et al*., 2011). The aquatic environments increasingly experience heavy metal pollution as a result of increased anthropogenic activities that include mining, urbanization, agricultural and industrial developments (Ukonmaanaho *et al.*, 1998; Lwanga *et al*., 2003; Lalah *et al*., 2009a). Increase in the use or spillage of leaded gasoline from watercrafts and car washing also pollute the environment (Muohi *et al.*, 2003). Pollution of freshwater surfaces by heavy metals is a threatening problem and has reached an alarming rate in some freshwater surfaces (Mwita *et al.*, 2011). The heavy metal pollution to these freshwater bodies is less visible, but its effect on the ecosystem and humans can be intensive and extensive (Edem *et* *al*., 2008) compared to other forms of pollutants. Therefore, the abundance and quality of commercially important fish species, an important component of ecosystem service of the freshwater lakes may be at risk. Thus, it is necessary to understand sources and quantities of various heavy metal pollutants in the aquatic environment due to anthropogenic activities.

Lake Victoria is the largest freshwater lake in Africa covering an area of 68,800 km^2 (Van Densen and Witte, 1995). The lake is shared by three neighbouring countries, Kenya, Uganda and Tanzania. Winam Gulf is at the eastern end of the lake in Kenya. The lake shoreline is surrounded by many towns with different anthropogenic activities and regions with different geochemical processes that could be causing major variations in concentrations of heavy metals in its various parts (Lalah *et al.*, 2009a). Thus, maintenance of a healthy Lake Victoria ecosystem is a challenge to the concerned agencies.

Kisumu City is one of the many towns lying on the shoreline of Winam Gulf of Lake Victoria and is characterized with several anthropogenic activities. The City is surrounded by an area characterized with intense industrial activities from Kisumu Industrial Area with different industrial activities that include processing, manufacturing and packaging activities, among others. These industrial activities dispose of their effluents, either poorly treated or untreated directly or indirectly into the lake (Kishe and Machiwa, 2001). Kisumu Industrial Area also has commercial establishments which include Kisumu International Airport, Molasses Plant, Kenya Pipeline Depot, Cocacola Plant, Kenya Marine and Fisheries Research Institute (KMFRI), Kenya Medical Research Institute (KEMRI), Port Florence Hospital, Kisumu-Busia Highway and Kisumu-Butere Railway Line that run parallel to the lakeshore line. Two rivers, Rivers Kisat and Kisian, draining into Winam Gulf of Lake Victoria traverse the area. River Kisian flows through an area with few commercial and agricultural activities in the far west side of the city. River

Kisat traverses the Kisumu Industrial Area where it collects the industrial effluents as it drains into the lake. There are also informal settlements e.g. Bandani and Obunga slums within the area that dispose of their domestic wastes into River Kisat. Kisumu City Municipal discharges drain into the lake from Kisat Waste Water Treatment Plant (KWWTP) and may also be contributing to pollution of the immediate aquatic ecosystem. The aforementioned activities may be contributing to heavy metal pollution of the adjacent lake.

In the 1980s no significant metal pollution was detected in the lake (Onyari, 1985; Ochieng, 1987; Onyari and Wandiga, 1989*)*. However, recently, sediments, water and biota have shown a general trend of increased levels of heavy metal (Ochieng *et al*., 2008; Ongeri, 2008; Lalah *et al.*, 2009a; Mwita *et al.*, 2011). This trend was attributed to an increase in urbanization, agricultural activities, pharmaceutical discharges, industrial processes and municipal waste discharges (Ukonmaanaho *et al.*, 1998; Lwanga *et al.*, 2003; Muohi *et al*., 2003; Ochieng *et al.*, 2008; Lalah *et al.*, 2009a; Mwita *et al.*, 2011) among others.

The lakeshore of Winam Gulf in Lake Victoria near Kisumu City is characterized with varied anthropogenic activities ranging from urbanization, agriculture, fishing, car washing to manufacturing and processing industries that discharge their effluents into the lake (Ochieng *et al.*, 2008; Ongeri, 2008; Lalah *et al.*, 2009a; Mwita *et al.*, 2011). Natural processes including weathering of soils, rocks and volcanic eruptions also contribute heavy metal background concentrations in the aquatic environment (Lalah *et al*., 2009a; Nyakeya *et al.*, 2009). A consequence of these activities and processes has been the increase of concentrations of heavy metals (Lwanga *et al.*, 2003; Chaparro *et al.*, 2004; Sekabira *et al.*, 2010) into water, sediments and biota. Generally, levels of metallic pollutants in water, sediments and biota are greatest near towns, indicating their urban industrial origins (Tole and Shitsama, 2001). Traces of heavy metals find their way into the aquatic environment mostly through runoffs, inflowing rivers and direct waste discharges into the lake from the surrounding anthropogenic activities.

Sediments are important sinks for various pollutants like heavy metals and also play a significant role in the remobilization of contaminants in aquatic systems under favorable conditions and in interactions between water and sediment (Ozturk *et al*., 2009). Heavy metal levels in sediments increase downstream in rivers suggesting discharges from anthropogenic activities into the rivers (Ochieng *et al*., 2008; Ongeri, 2008). Heavy metal levels are greatest in sediments at the discharge points into the lake especially where a river drains an industrial area (Lalah *et al*., 2009a) suggesting heavy metals adsorbed on the suspended particulate matter in water settle at the bottom of the lake. It is not known which of the many anthropogenic activities found within and around Kisumu city is contributing significant amounts of heavy metals into the aquatic sediments from the Winam Gulf shoreline extending from the discharge point of River Kisat to River Kisian discharge point.

River Kisat draining into Lake Victoria traverses an area characterized with heavy industrial processes and *Jua Kali* metal entrepreneurs. The river may therefore be a possible conveyor of heavy metal loads into the lake. River Kisian on the other hand traverses an area with no industrial activities but has some small scale agricultural activities and human settlements. Therefore, River Kisian may be contributing insignificant heavy metal loads into the lake. The extent and locational variations of heavy metal inputs into aquatic samples as a result of the surrounding anthropogenic activities within the Kisumu City along Lake Victoria shoreline stretch; from the discharge point of River Kisat to the discharge point of River Kisian has not been established. It is not known if variations in anthropogenic activities are causing variations in the heavy metals in water in these rivers.

In river systems, heavy metal levels in water and sediments increase downstream during wet seasons indicating effects of discharges from anthropogenic activities into lakes (Okonkwo *et al*., 2009; Deheyn and Latz 2006; Nicolau *et al*., 2006; Ochieng *et al*., 2008; Ongeri, 2008). Seasonal variations in discharges of industrial wastes are also possible factors that contribute to variations in heavy metal loads in lake water, fish and sediments through changes in runoffs (Kishe and Machiwa, 2001; Deheyn and Latz, 2006; Nicolau *et al.*, 2006; Ochieng *et al.*, 2008; Lalah *et al*., 2009a). These anthropogenic activities and geochemical processes can be influenced by seasonal variations and may result to increased distribution of heavy metal pollution into the lake water, sediments and fish. Past studies indicated seasonal variations of heavy metal concentrations in sediments, water and fish in Winam Gulf (Ongeri *et al*., 2008; Lalah *et al*., 2009a). Anthropogenic outputs from Kisumu City and its immediate environments drain directly into the lake and may be contributing heavy metal loads into the sediments, water and fish from the lake area under study. The natural weathering of rocky catchments of Rivers Kisat and Kisian draining into the lake (Nyakeya *et al.*, 2009) may also be contributing to the heavy metal pollution to aquatic samples (water, fish and sediments). The increased levels of heavy metals due to seasonal variation may adversely affect the water and fish quality threatening human life. However, the influence of locational activities in heavy metal levels to the aquatic samples (water, sediments and fish) with seasonal variations within the lake area in the Winam Gulf near Kisumu City is unknown.

The physicochemical parameters of natural freshwaters such as dissolved oxygen (DO), temperature, pH, turbidity, electrical conductivity (EC), total organic matter (TOM) and alkalinity are important in defining the quality of drinking and fisheries waters (Deheyn and Latz, 2006; Lalah *et al.*, 2009a). Physicochemical parameters and trace metal analysis in freshwaters in developing countries are important because these ecosystems provide drinking water as well as habitat for aquatic life (Ochieng *et al.*, 2008). Anthropogenic inputs adversely affect the physico-chemical parameters of natural freshwaters (Kishe, 2004; Deheyn and Latz, 2006; Ochieng *et al*., 2008; Lalah *et al.*, 2009a). There has been little focus on the effects of the anthropogenic activities to the physicochemical parameters of water in the Winam Gulf of Lake Victoria near Kisumu City. Thus, there was also need for comprehensive data and information on water quality (Kishe, 2004) in the lake area of Winam Gulf near Kisumu City during my study.

Seasonal variations in water physicochemical parameters have been attributed to variations in anthropogenic discharges into the aquatic ecosystems through surface runoffs (Jain, 2004; Kishe, 2004; Deheyn and Latz, 2006; Ochieng *et al*., 2008; Lalah *et al.*, 2009a). The changes in physicochemical parameters of water may therefore change the heavy metal properties and toxicity on the aquatic ecosystem (Deheyn and Latz, 2006; Lalah *et al.*, 2009a). This can lead to heavy metal pollution in aquatic samples and more specifically, sediments, water and fish species. These water physicochemical parameters can be affected by the anthropogenic inputs that are either acidic or alkaline originating from the industries, hospitals, municipal wastes, domestic waste, runoffs from the busy highway, runoffs from the surrounding anthropogenic activities and the Kisumu International Airport among others. Pollution of Winam Gulf is well documented but little is known on how water physicochemical parameters vary with seasons and locations within the area of my study in Winam Gulf.

1.2 Statement of the research problem

Previous studies have demonstrated seasonal variations in anthropogenic discharges of heavy metals and an increasing trend in the heavy metal pollution in aquatic samples (sediments, water and fish) from the Winam Gulf of Lake Victoria caused by the surrounding anthropogenic activities. This is an indication that aquatic life in the waters and use of water from the region or consuming aquatic products from the area may put human life at risk. Kisumu City and its immediate environment comprises of different anthropogenic activities such as pharmaceutical, domestic, urban and industrial processes among others which are possible sources of heavy metals. Data on variations in anthropogenic discharges of heavy metal levels and their potential sources around the study area into the lake is lacking. River Kisat traverses industrial parts of Kisumu City as it collects industrial effluents and drains them into the lake which may cause deterioration of lake water quality, and, could be a likely contributor of heavy metal loads into the lake, while River Kisian traverses a non-industrial sector with isolated but minimal agricultural activities as well as human settlements. It is not known how and if the heavy metal loads of these two rivers vary, and, whether their discharges into the lake result to water quality deterioration. Although aquatic samples from the Winam Gulf of Lake Victoria have been documented to have seasonal variations in anthropogenic discharges of heavy metals and increasing heavy metal loads, the current levels, seasonal and locational variations of the heavy metal contributions in the sediments, waters and fish samples along the shoreline from the discharge point of River Kisat to the discharge point of River Kisian have not been determined. The water quality physicochemical parameters have also not been determined along the shoreline ranging from the discharge point of River Kisat to the discharge point of River Kisian.

1.3 Objectives:-

1.3.1 Broad objective: -

The broad objective was to assess the locational and seasonal variations of heavy metals (Zn, Cd, Cu, Pb, Mn, Fe and Cr) in aquatic samples and selected physicochemical parameters of water obtained from Winam Gulf of Lake Victoria shoreline extending from the discharge point of River Kisat to River Kisian discharge point.

1.3.2 Specific objectives

The specific objectives were to:-

1. Determine the seasonal variations of heavy metal levels in water discharged from the Molasses Plant, Rivers Kisat and Kisian within the shoreline of Winam Gulf of Lake Victoria around Kisumu City.

2. Determine the locational and seasonal variations of heavy metal levels (Zn, Cd, Cu, Pb, Mn, Fe and Cr) in lake water and sediments from the shoreline of the Winam Gulf around Kisumu City.

3. Determine the seasonal variations in heavy metal concentrations in fish species (*Lates niloticus, Oreochromis niloticus, Synodontis victoriae and Clarias batrachus*) obtained from the lake area of Winam Gulf shoreline from the discharge point of River Kisat to River Kisian discharge point into the lake.

4. Determine the effect of locational activities and seasonal variations in physicochemical parameter (dissolved oxygen (DO), total organic matter (TOM), alkalinity, pH, temperature, electrical conductivity (EC) and turbidity) levels of water obtained from the lake area of Winam Gulf around Kisumu City.

1.4 Null Hypotheses, H_o.

1. There are no seasonal variations in heavy metal levels in waters from the Molasses Plant, Rivers Kisat and Kisian within the shoreline of Winam Gulf of Lake Victoria around Kisumu City.

2. There are no relationships between seasons and the locations of discharge points with respect to heavy metal levels (Zn, Cd, Cu, Pb, Mn, Fe and Cr) in lake water and sediments from the Winam Gulf around Kisumu City.

3. There are no seasonal variations in heavy metal levels in fish obtained from the lake shoreline of Winam Gulf extending from River Kisat discharge point to River Kisian discharge point.

4. There are no locational and seasonal variations in the physicochemical parameter levels in water obtained from the lake area extending from River Kisat discharge point to River Kisian discharge point.

If null hypotheses do not hold, the alternative H_1 shall be accepted.

1.5 Justification of the study

The study will provide current data on heavy metal concentration distribution into the water, sediments and fish from the lake shoreline of Winam Gulf stretch extending from the discharge area of River Kisat, an area with high concentrations of industrial and other economic activities to the discharge area of River Kisian, an area with minimal industrial activities. The data will provide a basis of assessing the impact of the surrounding commercial activities on the immediate aquatic ecosystem and update on pollution status of the immediate shoreline of Winam Gulf of the lake near Kisumu City. It will also reveal the status of the quality of fish from the study area to the local, national and international market. The results will help in creation of relevant policies in the management of the water discharges into the Winam Gulf by relevant authorities e.g. LVEMP, NEMA, KMFRI among others and consumption of fish from the study area.

CHAPTER TWO

LITERATURE REVIEW

2.1 Heavy metal sources and their environmental impact

World population growth, increased urbanization, agricultural activities and industrial developments are sources of persistent pollutants that lead to increase in the contamination of the aquatic ecosystems by heavy metals, ultimately threatening all forms of life on earth (Linnik and Zubenko, 2000; Campbell, 2001; Lwanga *et al*., 2003; Franca *et al.,* 2005; Idrees, 2009; Sarma, 2011; Orlu and Gabriel, 2011). Heavy metals including both essential and non-essential elements have a particular significance in ecotoxicology, since they are highly persistent and have the potential to be toxic to living organisms (Storelli *et al.*, 2005). Heavy metal pollution to the aquatic environment is a worldwide concern (Pardo *et al.,* 1990; Warran and Zimmerman, 1993). The pollution has led to increased concerns about possible accumulation of heavy metals in sediments, water, biota and ultimately humans (Gibbs and Miskiewicz, 1995). This makes understanding of the effects of the surrounding anthropogenic sources of heavy metals on an aquatic environment vital and necessary.

Sources of heavy metals vary with anthropogenic activities that include industrial processes, mining, agriculture, municipal wastes and pharmaceutical wastes (Ukonmaanaho *et al.,* 1998; Lwanga *et al*., 2003; Mwita *et al.,* 2011) as well as natural sources such as weathering of soils, rocks and volcanic eruptions that contribute to the aquatic ecosystem pollution. Human activities cause heavy metal pollution of freshwater bodies and river systems through anthropogenic inputs. This is a source of concern due to the demand for acceptable domestic water quality (Jain, 2004; Deheyn and Latz, 2006; Nicolau *et al.,* 2006) and need to protect aquatic life from being polluted (Enderlein, 1996).

Seasonal variability of heavy metals in aquatic samples (water, sediments and biota) has been attributed to variations in discharges from anthropogenic activities (Ongeri, 2008; Lalah *et al*., 2009a). Seasonal variations in discharges of industrial wastes due to surface runoffs could cause variations in heavy metal loads in the aquatic species (Kishe and Machiwa, 2001; Deheyn and Latz, 2006; Nicolau *et al.*, 2006; Ochieng *et al.*, 2008; Lalah *et al*., 2009a) which may have detrimental effects to human health. The anthropogenic activities within and around an aquatic environment may therefore be influenced by seasonal variations. Past studies indicated seasonal variations in heavy metal levels in aquatic species i.e. water, sediments and fish (Ongeri, 2008; Lalah *et al*., 2009a), however, it is not known if seasons (dry and wet) cause variations in heavy metal levels in aquatic species from the lake near Kisumu City.

Lake Victoria is a freshwater body providing an important economic resource to three East African countries; Kenya, Uganda and Tanzania among which it is shared. Winam Gulf in Kenya is one of the gulfs within the lake at its eastern end. It receives anthropogenic discharges from many towns situated along its shoreline which could cause variations in heavy metal pollution into the lake at its various parts (Lalah *et al*., 2009a). Heavy metal pollution along the lake shoreline by wastewater discharges from the surrounding anthropogenic activities is an international concern as the lake is a major source of freshwater fish in the world market as well as water for domestic use by the riparian communities.

In the lake, no significant metal pollution was detected in the 1980s (Onyari, 1985; Ochieng, 1987; Onyari and Wandiga, 1989), but recent studies showed that water from the lake and rivers draining into the Winam Gulf of Lake Victoria, sediments, (Lalah *et al.,* 2008; Ochieng *et al*., 2008; Lalah *et al.*, 2009a; Mwita *et al.,* 2011) and different fish species: *Lates niloticus, Oreochromis niloticus and Rastrineobola argentea* (Ongeri, 2008) have recorded elevated heavy metal concentrations. This trend has been attributed to increase in population growth, urbanization, agricultural activities, pharmaceutical discharges, industrial processes, domestic and municipal waste discharges (Lwanga *et al.,* 2003; Muohi *et al*., 2003; Lalah *et al.,* 2009a; Mwita *et al.,* 2011). The data demonstrated that there may be potential pollution of water, sediments and fish from the lake near Kisumu city that should be checked. However, it has not been established which activity among the many contribute significant amounts of heavy metals into water, sediments and fish. Therefore, data to help formulate policy on the need for control is lacking. There is need for continuous regular assessment of heavy metals in the aquatic ecosystems that continuously receive discharges suspected to contain heavy metals from the immediate anthropogenic activities, to determine their levels and to help formulate relevant policies.

Rivers Kisat and Kisian drain into Lake Victoria at Winam Gulf near Kisumu City. River Kisat traverses an industrial part of Kisumu City and may be a contributor of heavy metal loads into the lake water, sediments and fish while River Kisian traverses a non-industrial sector with isolated and minimal agricultural activities and human settlements. River Kisian may therefore be contributing insignificant metal loads into the lake water, sediments and fish. Industrial effluents pose direct threat to Winam Gulf of Lake Victoria because effluents are discharged into surface water with little or no treatment (Kishe and Machiwa, 2001). Concentrations of metallic pollutants are greatest near towns, indicating their strong urban industrial relationship (Tole and Shitsama, 2001). Kisumu City has several anthropogenic activities such as industrial wastewater discharges, sewage wastewater, pharmaceutical discharges, municipal and domestic discharges, fuel combustion, painting, welding and atmospheric deposition among others that may be possible sources of heavy metal pollution to the aquatic species (water, sediments and fish).

However, there is no information on locational and seasonal variations in heavy metal levels in water samples from the channels draining into the lake from the stretch of Lake Victoria shoreline near Kisumu City extending from the discharge point of River Kisat to the discharge point of River Kisian. Also, it is not known if the heavy metal loads of these two rivers vary due to locational activities during wet and dry seasons. Consequently, it is not known if mitigation efforts to control the heavy metal pollution should be uniform for all rivers.

The levels of heavy metals in fish, water and sediments are useful in mapping out various highly polluted spots as well as for the identification of anthropogenic inputs (Lee *et al.*, 1997; Huang and Lin, 2003). Poor disposal methods of industrial, pharmaceutical, municipal and domestic wastes lead to increase and differential mortality of fish populations, impairment of reproduction and disruption of species composition and balance (UNESCO, 1972). Fish communities can be used to indicate congestion, contamination or wider effects of changes due to heavy metals on the aquatic environment because many fish species are relatively long-lived and mobile (Ongeri, 2008). Generally, fish represents the top of the food chain and are susceptible to bioaccumulation and biomagnification of heavy metals (Barbour *et al.*, 1999; Ongeri, 2008). Seasonal variations contribute into heavy metal increase through runoffs into aquatic ecosystems hence aquatic species (water, sediments and biota) (Kishe and Machiwa, 2001; Okonkwo *et al.*, 2005; Deheyn and Latz 2006; Nicolau *et al*., 2006; Ochieng *et al*., 2008; Ongeri, 2008; Lalah *et al.*, 2009a). The lake shore area of Winam Gulf around Kisumu City continuously receives industrial, domestic, pharmaceutical discharges and surface runoffs which may pollute the fish. The seasonal variations of heavy metal pollution in fish from Winam Gulf shoreline near Kisumu City due to the surrounding anthropogenic activities during wet and dry seasons is unkown.

In aquatic systems, sediments act as a sink for heavy metals (Luoma *et al.*, 1989), and these metals can cumulatively increase to several orders of magnitude greater than the overlaying water column. Heavy metal content in sediments is indicative of the degree of pollution in an aquatic ecosystem (Mwita *et al.*, 2011). Seasonal variations in anthropogenic activities cause variations in heavy metal depositions into the lakes through runoffs (Deheyn and Latz, 2006; Nicolau *et al.*, 2006; Ochieng *et al.*, 2008). Studies have demonstrated seasonal variations of heavy metal concentrations in sediments and that the levels increased downstream through runoffs indicating contribution of the anthropogenic activities into the lakes, seas and oceans (Okonkwo *et al*., 2005; Deheyn and Latz, 2006; Nicolau *et al.*, 2006; Ochieng *et al.*, 2008; Ongeri, 2008).

Past studies have indicated continuous increase in heavy metal levels in Winam Gulf sediments (Ochieng *et al*., 2008; Ongeri, 2008; Lalah *et al.*, 2009a; Mwita *et al.*, 2011). The Lake Victoria shoreline near Kisumu City is characterized with dense anthropogenic activities such as industrial wastes, urbanization, pharmaceutical, domestic and municipal wastes that discharge into the lake. These activities pose the risk of contaminating the lake sediments with heavy metals. It is therefore not known if locational anthropogenic activities and seasonal variations influence the heavy metal levels in sediments from the study area despite increase in anthropogenic activities since Kisumu City is realizing increase in industrial and commercial activities.

Physicochemical parameters and trace metal analysis in freshwaters in developing countries is necessary since these ecosystems provide drinking water and habitat for aquatic life (Ochieng *et al.*, 2008). The analysis of water quality physicochemical parameters such as dissolved oxygen (DO), temperature, pH, turbidity, electrical conductivity (EC), total organic matter (TOM) and alkalinity are important in defining the quality of drinking and fisheries waters (Deheyn and Latz, 2006; Lalah *et al.*, 2009a). Studies have demonstrated that the water quality physicochemical parameter levels can be adversely affected by anthropogenic inputs which are either acidic or alkaline (Kishe, 2004; Deheyn and Latz, 2006; Ochieng *et al*., 2008; Lalah *et al.*, 2009a). The changes in physicochemical parameters of water may change the heavy metal chemical properties and toxicity of the aquatic ecosystem (Jain, 2004; Deheyn and Latz, 2006; Lalah *et al.*, 2009a) that could lead to heavy metal pollution in fish species which may pose health risks to consumers.

Studies have further shown that seasonal variations in water physicochemical parameters have been attributed to variations in anthropogenic discharges into the aquatic ecosystems through surface runoffs (Jain, 2004; Kishe, 2004; Deheyn and Latz, 2006; Ochieng *et al*., 2008; Lalah *et al.*, 2009a). Anthropogenic inputs from municipal, pharmaceutical, domestic and industrial activities, runoffs from automobile oil spillages from the busy highway and the surrounding land use activities/changes within Kisumu City drain into the lake. The relationship between seasons, locations and anthropogenic inputs on physicochemical parameters of lake water around Kisumu City, especially the areas surrounded by industrial, municipal and domestic activities is unkown.

2.1.1 Lead

Lead is potentially toxic if present and taken up by living organisms in excessive amounts from the environment (ATSDR, 2005; Chakraborty *et al.,* 1988; Fairchild, 1978). Lead binds to soil and sediments due to its low water solubility within an appropriate alkaline pH range, which results to very low mobility (Davies, 1995). Lead binds to organic matter contained within soil, sediments, and suspended particulates within the water depending on high pH and temperature and in some cases, specifically interacting cations or anions (Stokinger, 1981). The organic matter of soils and sediments plays a major role in determining the bioavailability of heavy metals in water (Deheyn and Latz, 2006; Lalah *et al.*, 2009a). Microorganisms, certain aquatic plants and fish often concentrate toxic metals from dilute aqueous environments (Jain, 2004). Accepted maximum permissible levels of lead in water and food are 0.05 ppm (WHO, 2004). The municipal drainage water containing effluents of industrial discharges and runoffs in addition to sewage effluents supply the water bodies and sediment with huge quantities of inorganic anions and heavy metals such as lead (ECDG, 2002). The most anthropogenic sources of metals are industrial, pharmaceutical and agricultural activities, petroleum contamination and sewage disposal (Santos *et al.*, 2005). The shoreline within which Kisumu City is located, is characterized with different anthropogenic activities, which include Kisumu Industrial Area with processing, manufacturing and packaging industries, Kisumu International Airport, motor transport, Molasses and Cocacola Plants, Kenya Pipeline Depot, hospitals, *Jua Kali* entrepreneurs among others. The influence of locational and seasonal anthropogenic activities around the study area on lead levels in the aquatic samples is unkown.

2.1.2 Iron

Iron in water may be present in varying quantities and qualities depending upon the geological area and other chemical components of the waterway. Iron is mainly present in water in two forms: either the soluble ferrous iron or the insoluble ferric iron. Ferrous (Fe^{2+}) and ferric (Fe^{3+}) irons are primary forms of concern in the aquatic environment even though other forms may be in either organic or inorganic wastewater streams (Yang *et al.*, 2001). For the normal metabolism of fish, the essential metals such as iron must be taken up from water, food or sediment (Canli and Atli, 2003). These essential metals can also produce toxic effects when the metal intake is excessively elevated (Tuzen, 2003). Therefore iron has received considerable public attention from all over the world because of the concern that it will cause long-term damage to the environment (Smith, 1986). The ferrous form (Fe^{2+}) can persist in water void of dissolved oxygen and usually originates from ground water or from anthropogenic inputs (Zhang, 1999). Allowable limits for iron in drinking water in the UK, EU and USA are 0.2 ppm, 0.2 ppm and 0.3 ppm respectively (Neubauer and Wolf, 2004). However, the maximum allowable concentrations of iron in fisheries and aquatic life are 0.3 ppm and 0.1 ppm in Canada and Russia respectively (WHO, 1998). There are several activities within Kisumu City and along the shoreline stretch from the mouth of River Kisat to River Kisian that are potential sources of iron into the lake. The contribution of these anthropogenic activities to iron load into the lake and river waters in the shoreline of Winam Gulf from River Kisat discharge point to the discharge point of River Kisian near Kisumu City is not known.

2.1.3 Zinc

Zinc is an essential trace element that can be toxic to aquatic biota at elevated concentrations (Van Assche *et al.*, 1996). Zinc enters aquatic systems through aerial deposition or surface runoffs (Van Assche *et al.*, 1996). The strong affinity of zinc for aquatic particles, particularly iron and manganese oxides, and organic matter, results in its deposition in bed sediments in association with these materials (Campbell and Tessier, 1996). Adverse biological effects of elevated levels of Zn include decreased benthic invertebrate diversity and abundance, increased mortality, and behavioral changes (Environment Canada 1998). Zinc has low toxicity to man, though prolonged consumption of large doses can result in some health complications such as fatigue, dizziness, and neutropenia (Hess and Schmid, 2002). Zinc concentrations in aquatic ecosystems are raising unnaturally due to addition through human activities such as agriculture, municipal, domestic and industrial activities (Merian, 1991). These activities may result to elevated levels of Zn in aquatic ecosystems which may be above the WHO (2004) set allowable limits of 3.0 mg\L for drinking water. Within Kisumu City and its immediate environment, the activities that include manufacturing and processing industries, pharmaceutical, municipal and domestic waste discharges are potential sources of zinc pollution into River Kisat and Lake Victoria waters. However the contribution of these activities to zinc loads into the water and aquatic species including fish has not been quantified in the Winam Gulf shoreline near Kisumu City.

2.1.4 Chromium

Chromium usually appears commonly in the environment as a trivalent salt Cr^{3+} (ATSDR, 2003) found in air, water, soil and some foods. Chromium (III) is an essential nutrient for humans and shortages may cause heart conditions, disruptions of metabolisms and diabetes (Cheryl and Susan, 2000). Major factors governing the toxicity of chromium compounds are oxidation state and solubility. Chromium (Cr^{4+} or Cr^{6+}) is considered by USEPA to be a carcinogen, is readily absorbed by the body, and can lead to ulceration of the liver and nasal septum (ATSDR, 2003). WHO (2004) and (2008) recommended levels of Cr for drinking water and sediments are 0.05 mg\L and 37.5 mg\Kg respectively. Along the stretch of Lake Victoria shoreline from the mouth of River Kisat to River Kisian, there are different anthropogenic activities that are potential sources of chromium contamination; however the contribution of chromium into the Lake and River Kisat water from these anthropogenic activities is unknown.

2.1.5 Copper

Copper is an essential trace element to man and to all vertebrates (Wright and Welbourn, 2002). Copper in water has been noted to be exceedingly toxic to aquatic biota in contrast to its low toxicity to mammalian consumers of water (Wright and Welbourn, 2002). Whereas concentrations as low as 0.005 to 0.025 ppm are lethal to some invertebrate and fish species within 4 days, the recommended standard for public water supplies based on palatability is 1 ppm (USEPA, 1980). Undesirable taste and odour have been linked to aqueous concentrations greater than 1 ppm (USEPA, 1980). The greater sensitivity of most aquatic biota such as fish could be associated with high permeability of gills to surface area ratios in various fish species, which facilitate rapid uptake of large amounts of copper (Neubauer and Wolf, 2004). The maximum allowable concentrations of copper in fisheries and aquatic life are 0.005-0.112 ppm, 0.002-0.004 ppm and ≤ 0.001 ppm in EU, Canada and Russia respectively (Neubauer and Wolf, 2004). Along the shoreline there are land use practices such as minor agricultural activities with fertilizer applications and a variety of industries, which are potential sources of copper pollution into the lake. However no study has been done to evaluate their contribution of copper into the water in the shoreline stretching from the mouth of River Kisat to the mouth of River Kisian.

2.1.6 Cadmium

Cadmium occurs predominantly in the form of free divalent cations in most well oxygenated, low organic matter, fresh waters (EPA, 1985-Cd). Cadmium and solutions of its compounds are toxic, particularly in soluble forms (ATSDR, 2005) and it is a problem particularly because it is highly toxic with long biological half-life, and its toxicity is also cumulative at least in invertebrates and fish (Larson *et al.*, 1985; Heath, 1987). Cadmium affects the kidneys, blood, and bone marrow (ATSDR, 2005). Particulate matter may rapidly adsorb much of the cadmium entering fresh waters from industrial sources, and thus sediment may be a significant sink for cadmium emitted to the aquatic environment (Shevchenko *et al*., 2003). In aquatic ecosystems cadmium can bioaccumulate in mussels, oysters, shrimps, lobsters and fish (ATSDR, 2008). The susceptibility to cadmium can vary greatly between aquatic organisms (ATSDR, 2008). High levels of cadmium lead to Necrosis of epithelium of secondary lamellae of gills and this also affect the liver, heart and brain of fish (Bilinski and Jonas, 1973). The acute toxicity of cadmium of fish is increased by increase in temperature, water hardness and reduction in dissolved oxygen (Department of Environment, UK, 1972; EPA, 1985-Cd). The allowable limits of Cd in drinking water, fish and sediments set by WHO (2004) are 0.003 mg/L, 0.05mg/Kg and 4.9 mg/Kg respectively. Along Winam Gulf of Lake Victoria shoreline near Kisumu City there are small-scale agricultural practices, processing industries, municipal and domestic discharges that are possible sources of cadmium pollution into the lake. However, it is not known if these anthropogenic activities contribute cadmium into the aquatic ecosystem.

2.1.7 Manganese

Manganese is naturally ubiquitous in the environment making up about 0.1% of the earth's crust (NAS, 1980). In soil, natural manganese range from 0.6-0.9 mg/kg and its solubility increases with decreasing pH. In surface water, manganese is present at concentrations ranging from 0.001-0.04mg/L (Rouleau *et al.*, 1995). Elevated manganese levels are occasionally found in drinking water and specifically in well water (ATSDR, 2000). Manganese is also present in air and wastewater discharges from industrial activities, municipal and domestic discharges that drain into surface water bodies (ASTDR, 2000). "Manganism" refers to a set of symptoms associated with relatively high exposure to manganese, reported in adults occupational exposure studies, and includes muscle stiffness, lack of coordination, tremors, difficulties with breathing or swallowing and other neuromuscular problems (ATSDR, 2000). The maximum acceptable levels of Mn in drinking water set by WHO (2004) is 0.40 mg/L above which water is considered to be polluted. The current study area is characterized with different anthropogenic activities that include small-scale agricultural activities, processing industries; municipal and domestic waste discharges that are potential manganese contributors into the aquatic environment. It has not been established if locational activities cause the increase of manganese in the aquatic environment under study.

2.2 Water quality physicochemical parameters and their environmental impact

The water physicochemical parameters are important attributes that define water quality (Deheyn and Latz, 2006; Lalah *et al.*, 2009a). These include; dissolved oxygen (DO), turbidity, alkalinity, pH, and temperature, electrical conductivity (EC) and total organic matter (TOM) among others. These physicochemical parameters can be adversely affected by the anthropogenic inputs from the industries, hospital wastes, agricultural residues, domestic and municipal wastes, runoffs from the busy highway, and runoffs from the surrounding land use activities (Kishe, 2004; Ochieng *et al.*, 2008; Lalah *et al.*, 2009) within Kisumu City and its immediate environment. The changes in physicochemical parameters of water may significantly change the heavy metal chemistry and toxicity on the aquatic ecosystem (Jain, 2004; Deheyn and Latz, 2006; Lalah *et al.*, 2009a).

Seasonal variations in physicochemical parameters of freshwater bodies has been attributed to variations in anthropogenic discharges (Jain, 2004; Kishe, 2004; Deheyn and Latz, 2006;

Ochieng *et al.*, 2008; Lalah *et al.*, 2009a). Studies have also demonstrated that the water quality physicochemical parameter levels can be adversely affected by variations in seasonal anthropogenic inputs which are either acidic or alkaline through surface runoffs (Deheyn and Latz, 2006; Ochieng *et al*., 2008; Lalah *et al.*, 2009a). Data showing the relation of water quality parameters with locational and seasonal variations from the discharge point of River Kisat to River Kisian discharge point into the lake is not available.

2.2.1 Dissolved oxygen (DO)

Dissolved oxygen (DO) refers to microscopic bubbles of gaseous oxygen (O_2) that are mixed in water and available to aquatic organisms for respiration. Optimum oxygen levels in water are necessary to provide for aerobic life forms, which carry on natural stream purification processes (Ongeri, 2008). Adequate dissolved oxygen is necessary for good water quality. Environmental impact of total dissolved gas concentration in water should not exceed 110% (above 13-14 mg/L) (Manoj and Avinash, 2012). Low amounts of oxygen in water severely inhibit the activity and hence the growth of many aquatic organisms, especially fish and in extreme cases may lead to massive fish kills (Richard, 1991). As dissolved oxygen (DO) levels in water drop below 5.0 mg/L, aquatic life is put under stress thus the lower the concentration, the greater the stress (Hutchinson, 1957). Dissolved oxygen levels that remain below 1-2 mg/L for a few hours may lead to large fish kills (Tchobanoglous and Shroeder, 1985). Fish in waters containing excessive dissolved gases may suffer from "gas bubble disease"; even though, this is a very rare occurrence (Tchobanoglous and Shroeder, 1985) thus the bubbles or *emboli* may block the flow of blood through blood vessels causing death. Dissolved oxygen (DO) in water and dissolved heavy metals have a direct relationship due to re-oxidation of the metals that make dissolved oxygen reduce with increase in dissolved heavy metals (Duinker *et al.,* 1982). Anthropogenic sources of organic matter and heavy metals include industrial processes, domestic sewage and agricultural wastes (Chapman, 1996). The study area is characterized with different activities including industrial discharges, urbanization, municipal and domestic discharges that drain into the lake. No data exists indicating the influence of these anthropogenic activities on the amount of dissolved oxygen in the lake water from the study area.

2.2.2 Electrical conductivity (EC)

Electrical Conductivity is a measurement of the ability of an aqueous solution to carry an electrical current. It is used to determine mineralization, which is commonly called total dissolved solids. Total dissolved solids information is used to determine the overall ionic effect in a water source. The number of available ions in the water often affects certain physiological processes in plants and animals (NWQMS, 2000). Contamination due to industrial, sewage system, hospitals, municipal and domestic discharges into water bodies may change the water's electrical conductivity. The discharge of heavy metals into a water body can raise the conductivity as metallic ions are introduced into the waterway (NWQMS, 2000). Activities taking place within the Kisumu City area include processing and manufacturing industries, municipal and domestic discharges among others which drain into the lake. These activities are possible potential sources of cations and anions that affect the electrical conductivity of the lake water. There is no available data demonstrating the relationship between electrical conductivity and the potential sources of trace metal pollutants in the Winam Gulf of Lake Victoria.

2.2.3 pH

The pH is a measure of the acidic or basic (alkaline) nature of a solution. The concentration of the hydrogen ion [H^+] activity in a solution determines the pH. Waters more acidic than pH 5.0

and more alkaline than pH 8.5 to 9.0 should be viewed with suspicion (Craigs and D'Abramo, 2008). Any pH level outside these ranges may be an indication of nutritional imbalance or presence of toxic ions (Ayers and Westcot, 1985). Sudden changes in pH values serve as warning signals that water quality may be adversely affected through the introduction of contaminants (O'Connor *et al*., 2006). The pH of a water resource can be affected by industrial effluents, agricultural, hospital, domestic and urban discharges and atmospheric deposition of acid forming substances (Deborah and Kimstach, 1996). Most of fish populations live in a pH range of 6.3-9.0, though most of the water systems have a pH range of 6.7-8.6 (Ayers and Westcot, 1985). Kisumu City is fast growing with increasing industrial discharges, urban and domestic discharges draining into the lake area. Data indicating the effects of discharges due to anthropogenic activities within the study area on lake water pH is lacking.

2.2.4 Temperature

Temperature can be described as a condition that is responsible for the transfer of heat within bodies (EPA, 1976; Forstner and Wittlmann, 1979). Water temperature regulates the metabolism of the aquatic ecosystem. Temperature controls the rate of fundamental biochemical processes in organisms, and consequently, changes in the environmental temperature can influence population, species and community-level processes (O'Connor *et al*., 2006). Kisumu City has different anthropogenic activities including processing, manufacturing and packaging industries, hospital and domestic discharges in the study area draining into the lake. The lakeshore natural water temperature is likely to be affected by these discharges. High water temperatures stresses aquatic ecosystem by reducing the ability of water to hold essential dissolved gases like oxygen (O'Connor *et al*., 2006). There is no data showing the impact of wastewater discharges due to anthropogenic activities in the study area on lake water temperature.

2.2.5 Alkalinity

Alkalinity is the capacity of water to resist changes in pH that would make the water more acidic. This capacity is commonly known as "buffering capacity." A buffer is a solution to which an acid can be added without changing the concentration of available H^+ ions (without changing the pH) appreciably. It essentially absorbs the excess H^+ ions and protects the water body from fluctuations in pH. In most natural water bodies the buffering system is carbonate-bicarbonate (H_2CO_3, HCO_3^-, and CO_3^{-2}). Alkalinity in water resources is influenced by rocks and soils, salts, certain plant activities, and certain industrial wastewater discharges (Joint Municipal Water and Sewer Commission, 2012). Alkalinity is important for fish and aquatic life because it protects or buffers against rapid pH changes. Living organisms, especially aquatic life, function best in a pH range of 6.0 to 9.0 (Joint Municipal Water and Sewer Commission, 2012). Along the lakeshore from the discharge point of River Kisat to the discharge point of River Kisian into the lake, the surrounding anthropogenic activities are likely to influence the water alkalinity. These activities produce industrial, urban and domestic discharges that drain into the lake which are either acidic or basic. These discharges are likely to cause change in lake water alkalinity. Data providing information on the effect of the anthropogenic activities in the study area on lake water alkalinity is lacking.

2.2.6 Turbidity

Turbidity is a measure of the degree to which the water loses its transparency due to the presence of suspended particulates (ASTM International, 2003). Primary production of aquatic organisms is reduced in turbid waters as a result of decreased photosynthesis due to light scattering (Ryan, 1991). Large amounts of suspended matter may clog the gills of fish and shellfish and kill them directly, provide a place for harmful microorganisms to lodge and breeding ground for bacteria

(Wu *et al.,* 2004). The solids act as mobile substrates for the transportation of other pollutants such as heavy metals. Fish cannot see well in turbid water and so may have difficulty finding food. Suspended particles in water will eventually settle out and "blanket" the bottom of a waterway. When this occurs, habitat, fish spawning areas, and other important components of that waterway may be severely and negatively impacted (EPA, 1986). Total suspended solids (TSS) are a significant part of physical and aesthetic degradation and a good indicator of other pollutants, particularly nutrients and metals that are carried on the surface of sediments in suspension (Packman *et al.*, 1999). Different activities such as industrial processes, small-scale agricultural activities, urban and domestic discharges within Kisumu City and its immediate environment are potential activities that may cause increased turbidity in the Lake. There is no available data showing the influence of the anthropogenic activities in the study area on the total suspended solids in lake water.

2.2.7 Total Organic Matter (TOM)

Total organic matter content is typically measured as total organic carbon (TOC). Total organic carbon (TOC) is the carbon stored in soil organic matter and dissolved organic carbon (DOC), which is a fundamental component of the carbon cycle (Dojlido *et al.*, 1993; Zerbe, 1993). Organic carbon enters the soil through the decomposition of plant and animal residues, root exudates, living and dead microorganisms, and soil biota (USDA, 2009). TOC measurement provides information on all organic substance content in water or sediments (Dojlido *et al.*, 1993; Zerbe, 1993). The TOC content is proportional to organic matter, which has an affinity for trace metals. Organic contaminant in sediments has been used as an indicator of pollution and eutrophication rate (Folger, 1972; EPA, 2002). Anthropogenic inputs such as discharges from urban wastewater treatment plants, agriculture, processing industries, municipal and domestic are some of the sources of organic matter in the environment (Chapman, 1996; EPA 2002). Kisumu City has several industries and experiences other different human activities. Due to the location of the City on the lakeshore, Winam Gulf in Lake Victoria is the ultimate immediate recipient of the anthropogenic discharges. Data indicating the levels of organic content in aquatic sediments in the study area due to the seasonal variations and locational anthropogenic activities in the study area is not available.

CHAPTER THREE

MATERIALS AND METHODS

3.1 Study Area

The study area was within latitudes 00˚ 05’46. 00’’ to 00° 05’ 08.13’’ S and longitudes 34˚ 41’15. 96’’ to 34° 45’ 01.76’’ E (Kisumu County, Western Kenya) (Figure 1). The area is between two streams namely; Rivers Kisat and Kisian which are draining into Winam Gulf of Lake Victoria near Kisumu City. River Kisat flows through the eastern side of the area which has intense industrial activities while River Kisian flows through an area with minimal anthropogenic activities with Kenya Medical Research Institute (KEMRI) as the only establishment at the west side of the study area in the outskirts of Kisumu City. The eastern side of the study area was characterized with intense industrial activities of Kisumu Industrial Area which comprised of commercial establishments including Kisumu International Airport, Molasses Plant, Kenya Pipeline Depot, Cocacola Plant, Kenya Marine and Fisheries Research Institute (KMFRI) with Kisumu-Busia Highway and Kisumu-Butere Railway Line running parallel to it. There were informal settlements i.e. Bandani and Obunga slums within the area.

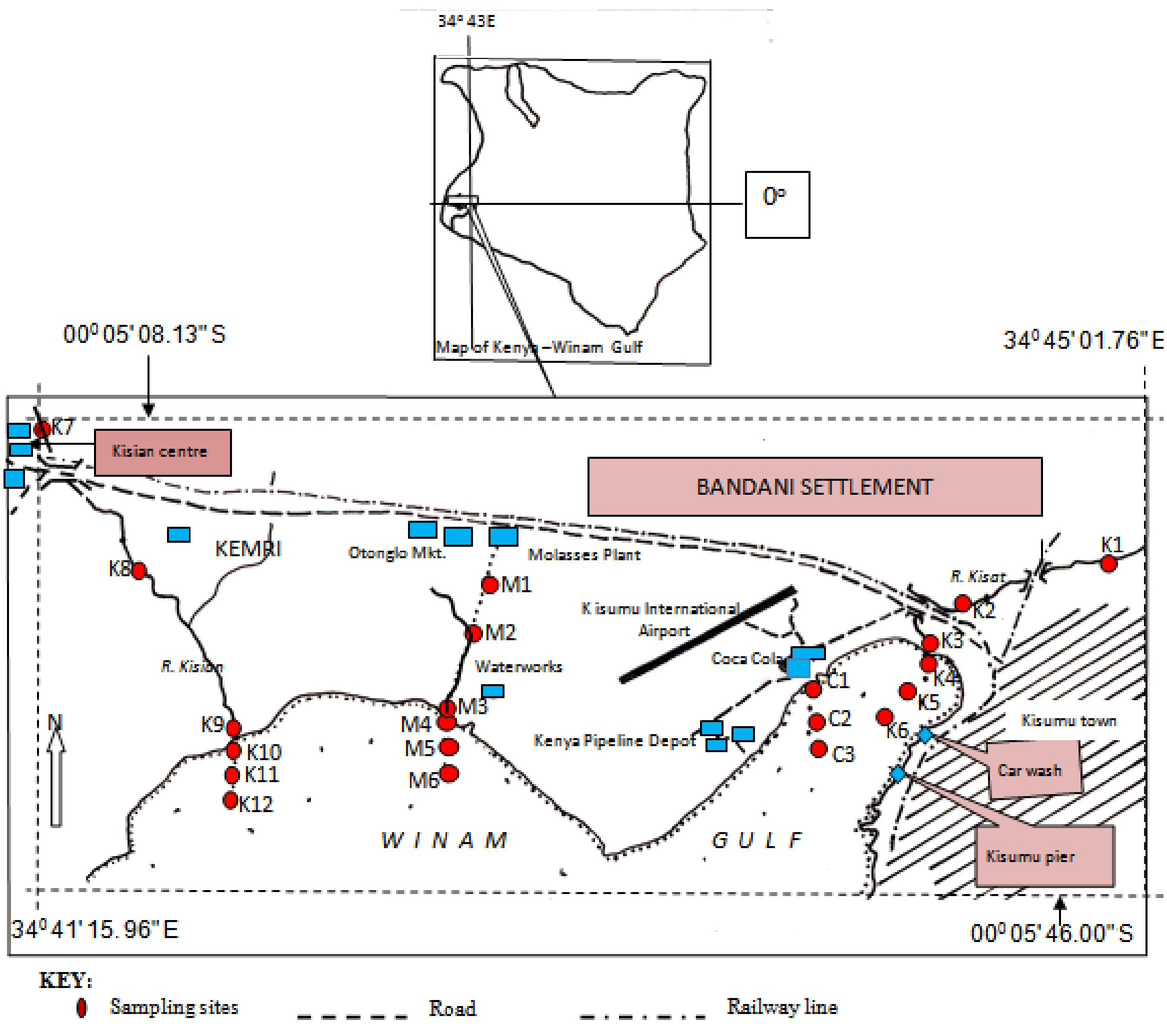

Figure 1: Map of sampling area from the discharge point of River Kisat to River Kisian discharge point

3.2 Study design

Completely randomized design was used in sampling where effluent discharge points of processing industries, pharmaceutical, municipal, and domestic activities within the area were considered. The sampling areas were chosen based on proximity to industrial and commercial activities. Water samples from the channels were collected in triplicates before entering the lake. Three sampling sites were identified along each of the selected channels i.e. along the Molasses Plant discharge channel, Rivers Kisat and Kisian (Fig. 1) based on the proximity of anthropogenic activities which included industrial, domestic, pharmaceutical, urban discharges among others. Samples were also obtained from the adjoining lake areas approximately 100 m inshore at each of the discharge points. An additional sampling area within the lake at the disharge point of Cocacola Plant was selected. Three sampling sites at each selected discharge point were identified at intervals of 50 m from the discharge points on the shoreline (0 m). The areas were :-

Sampling area - 1 (Figure 1) was an area from the uppermost sampling site (K1) on River Kisat before entry into industrial area, which was considered not to be contaminated with industrial wastewater discharges (control site for the river) to the discharge point of the river into the lake and the immediate adjacent lake area 100 m inshore. Two other sampling sites downstream along the river were identified i.e the middle sampling site (K2) was chosen based on the anthropogenic activities e.g industrial effluent discharges and runoffs from *Jua Kali* enterprenuers found within the adjacent environment which drain into the river and the third sampling site (K3) was the point at which the river entered the lake. Three horizontal sampling sites (K4, K5 and K6 respectively) at intervals of 50 m into the lake at this area were identified to show how the heavy metal levels in aquatic samples (water and sediments) and water physicochemical parameters change with location within the lake. This was an area where the river discharged into the lake. The site was also close to the Kisumu-Busia Highway. The sample area was named as Kisat.

Sampling area - 2 (Figure 1) was the lake area located adjacent to the Kisat area which received discharges from the Cocacola Plant and surface runoffs from the Kenya Pipeline Depot, Kisumu International Airport, Kenya Marine and Fisheries Research Institute (KMFRI) and domestic discharges from Bandani settlement. Three horizontal sampling sites from the shore (C1, C2 and C3 respectively) at interval of 50 m into the lake were identified to show how the heavy metal levels in aquatic samples (water and sediments) and water physicochemical parameters change with the increase in distance into the lake. The area was named Cocacola.

Sampling area - 3 (Figure 1) was the Molasses effluent channel and the adjacent lake area which was directly receiving the effluents of the Molasses Plant as well as the surface runoffs. Three sampling sites from the uppermost point (M1, M2 and M3) along the discharge channel were chosen for sampling based on the activities found around. The water samples from the uppermost site (M1) was purely discharge of the Molasses Plant as it came out of the pipe to an open surface; the middle sampling site (M2) was a point at which the effluent channel joined a seasonal stream near a Water Pump Station that supplies water to the Molasses Plant. The third sampling site (M3) was at the entry point of the Molasses Plant effluents into the lake. Three sampling sites from the shore (M4, M5 and M6 respectively) within the adjacent lake area were identified at intervals of 50 m apart to study the effects of increase in distance into the lake to the heavy metal levels in water and sediments as well as the water physicochemical parameters. The name given to the area was Molasses.

Sampling area - 4 (Figure 1) was along River Kisian to the point at which it enters the lake and the adjoining lake area approximately 100 m inshore. Three sampling sites along the river were identified; the uppermost site (K7), a point with no visible anthropogenic inputs from the surrounding environment was chosen to be the control of the study, middle site (K8) which was suspected to be receiving runoff discharges from the Kisumu-Busia Highway, Kisumu-Butere Railway Line, upcoming Kisian shopping centre and Kenya Medical Research Institute (KEMRI) which drain into the river. The third sampling site (K9) was at the entry point of the river into the lake. Three sampling sites in the lake from the entry point of the river were identified namely; K10, K11 and K12 at intervals of 50 m respectively inorder to study the effects of increased distance into the lake on metal levels in lake water and sediments as well as water physicochemical parameters. The area was named Kisian.

3.3 Sampling and sample preparation

3.3.1. Sampling

Samples of water, approximately 500 mL were taken by immersing the bottles to a depth of one metre and lifting up and then mixing with 2 mL of concentrated HNO_3 to lower the pH of the water to pH ≤ 2. The procedure was carried out to prevent microbial growth, flocculation and reduce any adsorption on the container surfaces according to Nichole and Mason (2001). The samples were then transported to the laboratory for storage in a refrigerator at 4^{o} C according to the method of Nichole and Mason (2001) before analysis. At each sampling site, analyses of electrical conductivity (EC), pH, alkalinity, temperature, dissolved oxygen (DO) and turbidity were done *in situ* using a multi-parameter YSI meter (CTD 90 Model) by dropping the probe below water surface and recording readouts for each parameter from the instrument.

Surface sediment (0-2 cm layer) samples, in triplicates, were taken from the same points (0 m, 50 m and 100 m) from the shoreline into the lake as for water samples using stainless steel Ekman grab sampler and stored in polythene bags. They were transported to the laboratory, dried and refrigerated at 4^{o} C awaiting processing for analysis. Fish samples (*Synodontis victoriae, Lates niloticus, Oreochromis niloticus and Clarias batrachus*) in triplicates were caught from the lake area of study using gill net of various sizes. The sampled fish species were stored in an ice box at 0^{o} C for transportation to the laboratory where they were rinsed with de-ionized water and stored in a deep freezer awaiting analysis.

3.3.2 Sample preparation

3.3.2.1 Analysis of water samples

The procedure adopted by Mzimela *et al.* (2003) and Ongeri (2008) was used. Due to expected low concentrations of the metals in the natural water samples, pre-concentration was done by evaporating 100 mL of the water sample to 15 mL and digested on a hot plate for 30 min after adding 20 mL of concentrated nitric acid (11.6 M Analar). A volume of 10 mL of concentrated hydrochloric acid (16 M Analar) was added and digestion continued until the solutions remained light brown or colourless. The remaining digested solution was filtered using 0.45 µm polyethersulfoon filter membrane into a 50 mL volumetric flask and diluted to the mark with de-ionized water after additions of 1.5 mg/mL of strontium chloride ready for metal analysis (Pb, Cu, Cr, Zn, Cd, Mn and Fe) using Atomic Absorption Spectrophotometer (AAS 6200 Shimadzu Model). Before analysis, the AAS machine was calibrated. Analar salts of potassium dichromate, lead nitrate, copper sulphate, zinc nitrate, cadmium nitrate, manganese nitrate and iron sulphate were used to prepare standards of known concentrations per salt in 100 mL flasks after additions of 1.5 mg/mL of strontium chloride. Strontium chloride was for eliminating absorption interferences of the specific metal by other metals at the same wavelength by acting as a buffer and to minimize ionization of the metal atoms (Ongeri, 2008). A calibration curve for each respective metal was drawn from the standards in the instrument before unknown samples were read.

3.3.2.2 Analysis of sediment samples

A procedure followed by Tack and Verloo (1999) and Ongeri (2008) was adopted. Sediment was dried in an oven at 104^{o}C, cooled in a desiccator and one gram was weighed before putting in a 100 mL Pyrex digestion tube and 10 mL mixture of concentrated nitric acid and concentrated hydrochloric acid (4:1, aqua ragia digestion) was added. Digestion was carried out for 3 hours at 100^oC; the digests were filtered through 0.45 µm polyethersulfoon filter membrane into a 50 mL volumetric flask and made up to volume with de-ionized water after addition of 1.5 mg/mL of strontium chloride (Analytical grade, $SrCl_2.6H_2O$). Before analysis, the AAS machine was calibrated. Salts (Analar grade in all cases) of potassium dichromate, lead nitrate, copper sulphate, zinc nitrate, cadmium nitrate, manganese nitrate and iron sulphate each were used to prepare known concentrations of 0 ppm , 2 ppm, 4 ppm, 8 ppm and 10 ppm per salt in 100 mL flasks after additions of 1.5 mg/mL of strontium chloride. These salts were used as standards and a calibration curve was drawn from them in the instrument before reading the concentrations of the unknown samples. The digests were analyzed for Pb, Cu, Cr, Zn, Cd, Mn and Fe using Atomic Absorption Spectrophotometer (AAS 6200 Shimadzu Model).

3.3.2.3 Analysis of fish samples

A procedure followed by Bolton *et al*. (2003) was adopted; edible fish tissue muscles of the different fish species (*Synodontis victoriae, Lates niloticus, Oreochromis niloticus and Clarias batrachus*) were dried to constant weight at 105^oC. One gram of the sub-sample of each fish species was homogenized and digested using a mixture of 5 mL of concentrated nitric acid and 5 mL of concentrated sulphuric acid (ratio: 1:1). The mixtures were slowly brought to a temperature of 280^oC and maintained at this temperature until the digests turned pale yellow/brown. The digests were cooled, filtered using 0.45 µm polyethersulfoon filter membrane and transferred into a 50 mL volumetric flask and the volumes brought to the mark using de-ionized water after additions of 1.5 mg/mL of strontium chloride. Before analysis, the Atomic Absorption Spectrophotometer (AAS 6200 Shimadzu model) was calibrated. The metal standards were prepared and calibration curves drawn from them in the instrument before the unknown samples were read. Heavy metal concentrations of Pb, Cu, Cr, Zn, Cd, Mn and Fe in the samples were determined using Atomic Absorption Spectroscopy as described above.

3.3.2.4 Measurements of physicochemical parameters

Water pH, dissolved oxygen (DO), alkalinity, turbidity, electrical conductivity (EC) and temperature were measured directly in the field using YSI multi-parameter meter (CTD 90 Model).

3.3.2.5 Determination of Total Organic Matter (TOM)

Total Organic Matter in the sediments was determined according to the procedure by Okalebo *et al.* (2002) where one gram of the oven dried sediments (104^{o}C) were ignited slowly in a muffle furnace (Vulcan 440 model) to a final temperature of 550^{o}C maintained for 2 h. The loss in weight represented the organic matter content of the sample.

3.4 Statistical analysis

The means and ranges of the data collected were determined. Statistical analysis was done for the study using Analysis of Variance (ANOVA) and student t-test ($p \leq 0.05$). Confidence limit of ($p \leq 0.05$) was applied to test the significance of the analytical data. The statistical analysis was performed using MSTATC three factor completely randomized design.

CHAPTER FOUR

RESULTS AND DISCUSSION

4.1 Concentration of heavy metals in upstream water, lake water and lake sediments

4.1.1 Heavy metal concentrations in Rivers (Kisat and Kisian) waters and Molasses Plant effluents

The seasonal and site metal concentrations in river water (Rivers Kisat and Kisian) and Molasses Plant effluents are summarized in Tables 1-7.

4.1.1.1 River Kisat

For all the metals analysed, there was a general increase ($P \leq 0.05$) of Pb, Mn and Cr metals in water samples of River Kisat from the uppermost part to the point the river is entering the lake indicating more heavy metal contamination downstream (Tables 1, 2 and 3)(Appendix i, pg 108). The heavy metal levels observed in River Kisat water were an indication of their urban origin as was the case on levels in water from River Buriganga flowing beside Dhaka, Bangladesh (Mohiuddin *et al.,* 2011) and industrial effluents from Kinawattaka stream draining into Lake Victoria near Kampala City, Uganda (Muwanga and Barifaijo, 2006) (Table 15). The heavy metal levels in River Kisat water were higher compared to levels obtained in water samples from the same river in similar past studies (Mwamburi, 2003) which ranged as follows:- 0.00 - 20.00, 2.00 - 1470.00 and 8.00 - 120.00 (µg\L) for Pb, Mn and Zn respectively and those obtained in another study on water from the same river (Ochieng *et al.,* 2008) for Cu, Pb, Mn, Zn, Cd and Cr which ranged as follows:- 5.0 - 157.5, nd - 60.00, 50.00 - 738.00, 25.00 - 219.50, nd - 8.00 and nd - 50.00 (µg\L) respectively (Table 15). Generally, River Kisat water recorded higher metal levels for all the analyzed metals than levels of same metals obtained in the water samples from the same river in previous studies (Ochieng *et al.,* 2008; Mwamburi, 2003) (Table 15). This shows that there was continuous increase of heavy metal loads into River Kisat water which is consistent with increase in anthropogenic activities.

Table 1. Seasonal and site variations of Pb (µg/L) in river waters (Kisat and Kisian) and Molasses Plant effluents

Site	Season	Sampling points along the rivers			Mean (season)	Mean (site)
		Uppermost	Middle	Mouth		
Kisat	Wet	273.50	302.00	334.50	303.00	245.50
	Dry	164.00	189.00	211.00	188.00	
Mean (distance)		219.00	245.50	272.50		
C.V. (%)		4.53				
LSD ($p \leq 0.05$)		27.68			66.49	
Molasses	Wet	34.50	35.50	44.00	38.00	34.50
	Dry	29.50	32.50	32.50	31.50	
Mean (distance)		32.0	34.00	38.00		
C.V. (%)		6.77				
LSD ($p \leq 0.05$)		5.78			NS	
Kisian	Wet	16.50	22.00	27.50	22.00	20.00
	Dry	13.50	18.00	23.00	18.00	
Mean (distance)		15.00	20.00	25.00		
C.V. (%)		14.41				
LSD ($p \leq 0.05$)		7.30			NS	
Mean (season) for all 4 sites	Wet	108.00	120.00	135.00	121.00	
	Dry	69.00	80.00	89.00	79.00	
Mean (distance) for all sites		88.50	100.00	112.00		
C.V. (%)		6.76				
LSD ($p \leq 0.05$)		9.74			23.36	9.74
Interactions		Site x Distance = 10.80, Site x Season = 13.70				

NS= Not significant

The increase is a manifestation of the increase in industrial, pharmaceutical, domestic, municipal, urbanization and other anthropogenic activities in the adjacent environment of River Kisat and Kisumu City. The metal increase in the river water downstream at different points may also be attributed to surface runoffs from Kisumu-Busia Highway, and the continuing construction of Kisumu-Busia by-pass within Kisumu City and the low operations of Kisat Wastewater Treatment Plant (KWWTP) as its maintenance continues. The result demonstrated a need to develop mitigation strategies that can stop/reduce the metal pollutants from reaching the River Kisat and entering into the Lake Victoria waters.

Table 2. Seasonal and site variations of Mn (µg/L) in river waters (Kisat and Kisian) and Molasses Plant effluents

Site	Season	Sampling points along the rivers			Mean (season)	Mean (site)
		Uppermost	Middle	Mouth		
Kisat	Wet	2469.50	2780.00	3898.50	3049.50	2466.00
	Dry	1402.00	1778.00	2469.50	1883.00	
Mean (distance)		1935.50	2279.00	3184.50		
C.V. (%)		7.61				
LSD ($p \leq 0.05$)		466.10			1123.96	
Molasses	Wet	172.00	188.50	204.00	188.00	137.50
	Dry	51.50	90.00	156.00	87.00	
Mean (distance)		112.00	121.00	180.00		
C.V. (%)		5.22				
LSD ($p \leq 0.05$)		17.95			43.13	
Kisian	Wet	38.00	42.00	48.00	42.00	40.50
	Dry	35.50	37.50	41.50	38.00	
Mean (distance)		36.50	39.50	44.50		
C.V. (%)		6.07				
LSD ($p \leq 0.05$)		6.09			NS	
Mean (season) for all 4 sites	Wet	893.00	1003.50	1383.50	1093.50	
	Dry	496.00	623.00	889.00	669.50	
Mean (distance) for all sites		694.50	813.50	1136.00		
C.V. (%)		12.30				
LSD ($p \leq 0.05$)		155.48			374.65	155.48
Interactions ($p \leq 0.05$)		Site x Distance = 173.72, Site x Season = 219.98, Site x Distance x season = 245.76				

NS= Not significant

Table 3. Seasonal and site variations of Cr (µg/L) in river waters (Kisat and Kisian) and Molasses Plant effluents

Site	Season	Sampling points along the rivers			Mean (season)	Mean (site)
		Uppermost	Middle	Mouth		
Kisat	Wet	72.00	83.50	97.50	84.50	72.50
	Dry	53.50	59.00	71.00	61.00	
Mean (distance)		63.00	71.50	84.00		
C.V. (%)		4.91				
LSD ($p \leq 0.05$)		8.82			21.56	
Molasses	Wet	36.50	38.00	46.00	40.00	38.50
	Dry	34.00	35.00	40.00	36.50	
Mean (distance)		35.50	36.50	43.00		
C.V. (%)		3.89				
LSD ($p \leq 0.05$)		3.65			NS	
Kisian	Wet	20.00	23.50	35.50	26.50	24.50
	Dry	16.50	18.50	32.00	22.50	
Mean (distance)		8.50	21.00	33.50		
C.V. (%)		8.67				
LSD ($p \leq 0.05$)		5.17			NS	
Mean (season) for all 4 sites	Wet	43.00	48.50	59.50	50.50	
	Dry	34.50	37.50	47.50	40.00	
Mean (distance) for all sites		39.00	43.00	53.50		
C.V. (%)		5.64				
LSD ($p \leq 0.05$)		3.65			NS	3.65
Interactions ($p \leq 0.05$)		Site x Distance = 4.12, Site x Season = 5.17				

NS = Not significant

Levels of Pb, Mn, Cd and Cr metals changed ($p \leq 0.05$) with seasons (Tables 1, 2, 3 and 7) in water samples from River Kisat. The levels of these metals were higher ($p \leq 0.05$) during the wet season than during the dry season. The current results were in agreement with the assertion by Okonkwo *et al.* (2005) that the heavy metal levels in river water during wet season were generally higher than the dry season in a study in South Africa. Similar results had also been observed in water samples from different rivers draining into Lake Victoria e.g. Nyando, Nzoia, Nyamasaria, Sondu-Miriu, Kuja, Awach and Nzoia (Lalah *et al*., 2009a; Ongeri, 2008; Ochieng *et al.*, 2008). The high levels of these metals in the river water during the wet season may be due to surface runoffs and leaching from the surrounding environment. The catchment area is characterized with rocky Kodiaga and Riat hills which may be contributing metal residues through runoffs into the aquatic ecosystem as a result of rock weathering (Nyakeya *et al.*, 2009). Lower heavy metal levels were recorded at the uppermost sampling point of the river compared to downstream sampling points (Tables 1, 2 and 3) indicating lesser anthropogenic activities upstream. The Pb, Mn and Cr levels increased ($p \leq 0.05$) from the uppermost point to the point the river entered the lake. These results were also in line with Saad *et al.* (1981) and Lalah *et al*. (2009a) who observed that high metal levels are associated with river discharge points into the lake where metals bound to particles settle especially if the river drains a contaminated area.

The uppermost part of the river seemingly had no anthropogenic activities at its vicinity which would have polluted the river water. However, as the river waded downstream, the heavy metal pollution levels increased as it collected anthropogenic discharges from industrial activities around the catchment area downstream.

Table 4. Seasonal and site variations of Cu (µg/L) in river waters (Kisat and Kisian) and Molasses Plant effluents

Site	Season	Sampling points along the rivers			Mean (season)	Mean (site)
		Uppermost	Middle	Mouth		
Kisat	Wet	305.00	348.00	371.00	341.00	276.50
	Dry	208.50	213.50	212.50	211.50	
Mean (distance)		257.00	280.50	291.50		
C.V. (%)		19.23				
LSD ($p \leq 0.05$)		NS			NS	
Molasses	Wet	19.50	45.50	41.50	35.50	25.50
	Dry	17.00	15.00	16.00	16.00	
Mean (distance)		18.00	30.50	29.00		
C.V. (%)		7.16				
LSD ($p \leq 0.05$)		4.56			10.78	
Kisian	Wet	23.00	23.50	24.00	23.50	23.00
	Dry	22.00	22.00	23.50	22.50	
Mean (distance)		22.50	23.00	24.00		
C.V. (%)		20.32				
LSD ($p \leq 0.05$)		NS			NS	
Mean (season) for all 4 sites	Wet	116.00	137.50	147.00	133.50	
	Dry	82.00	84.00	84.00	86.00	
Mean (distance) for all sites		99.00	111.00	115.50		
C.V. (%)		28.44				
LSD ($p \leq 0.05$)		NS			NS	44.00
Interactions ($p \leq 0.05$)		Site x Season = 62.70				

NS = Not significant

Table 5. Seasonal and site changes of Fe (µg/L) in river waters (Kisat and Kisian) and Molasses Plant effluents

Site	Season	Sampling points along the rivers			Mean (seaon)	Mean (site)
		Uppermost	Middle	Mouth		
Kisat	Wet	1074.00	1087.00	1291.00	1150.50	1078.50
	Dry	859.50	979.00	1179.50	950.50	
Mean (distance)		966.50	1033.00	1235.50		
C.V. (%)		7.05				
LSD ($p \leq 0.05$)		NS			NS	
Molasses	Wet	855.00	978.50	1129.50	988.00	843.00
	Dry	615.00	684.50	794.50	698.00	
Mean (distance)		735.00	831.50	962.00		
C.V. (%)		6.62				
LSD ($p \leq 0.05$)		138.70			NS	
Kisian	Wet	677.50	734.00	1084.00	832.00	789.00
	Dry	590.50	672.00	960.50	741.00	
Mean (distance)		634.00	703.00	1022.50		
C.V. (%)		9.25				
LSD ($p \leq 0.05$)		180.70			NS	
Mean (season) for all 4 sites	Wet	869.00	933.00	1168.50	990.00	
	Dry	688.50	778.50	978.50	815.00	
Mean (distance) for all sites		778.50	856.00	1073.00		
C.V. (%)		7.62				
LSD ($p \leq 0.05$)		98.58			NS	98.58
Interactions ($p \leq 0.05$)		Site x Distance = 28.10, Site x Season=139.70				

NS=Not significant

The levels of heavy metals recorded in the current study for Cu, Pb, Mn, Zn, Cd, Cr and Fe in the river water were 276.50, 245.50, 2466.00, 508.00, 13.00, 72.50 and 1078.50 (µg\L) respectively, and were above the WHO (2004) recommended levels (Table 15) for aquatic and domestic purposes with an exception of Cu and Zn. The river water was generally polluted and therefore unsuitable for aquatic life and domestic use. This river water could be negatively affecting the levels of the same metals in the lake.

4.1.1.2 Molasses Plant channel

Levels of all the analyzed heavy metals in water samples (Tables 1-7) (Appendix i, pg 108) from the Molasses Plant increased ($p \leq 0.05$) along the drainage channel from the uppermost sampling point to the discharge point into the lake with an exception of Zn. The levels of heavy metals in Molasses Plant effluents were high an indication that the alcohol distillation processes within the plant increased the levels as compared to metal composition obtained for molasses from South Africa (Teclu, *et al*., 2009). The levels of Cu, Pb, Cd and Cr in water from the Molasses Plant were, however, lower than those obtained by Ochieng *et al.,* (2008) and current study in River Kisat (Table 15) an indication that the Molasses Plant discharges caused low metal pollution into the lake water compared to the other anthropogenic activities in the study area.

The Zn levels did not significantly increase along the discharge channel, an indication the activities within the Molasses Plant and along the discharge channel were not significantly contributing to the contamination of the metal into the aquatic ecosystem (Table 6). The presence of water pumping station located adjacent to the effluent drainage channel within which there were different water works activities taking place including runoffs of spilled diesel and oil used to run the pumping generators may explain the increase in levels of most of the studied heavy metals in the channel downstream. The Molasses Plant is located within an up-coming Otonglo

Market within which there are other anthropogenic activities such as welding, constructions, hospitals, scrap metal entrepreneurs and filling stations among others which may be contributing to the increase in heavy metal loads into the Plant effluents through surface runoffs. Water samples from Molasses Plant showed Cu and Mn changed ($p \leq 0.05$) with seasons (Tables 1 and 4). The levels of the two heavy metals were higher during the wet season. The lack of increase in levels of Pb, Cr, Fe, Zn and Cd in the Molasses Plant channel water during wet season suggested that there were few anthropogenic activities within the surrounding area which could be discharging these metals which may be washed into the Molasses Discharge Channel.

Table 6. Seasonal and site variations of Zn (μg/L) in river waters (Kisat and Kisian) and Molasses Plant effluents

Site	Season	Sampling points along the rivers			Mean (season)	Mean (site)
		Uppermost	Middle	Mouth		
Kisat	Wet	529.50	579.00	604.00	571.00	508.00
	Dry	432.00	458.00	446.50	445.50	
Mean (distance)		480.50	518.50	525.00		
C.V. (%)		3.63				
LSD ($p \leq 0.05$)		NS			NS	
Molasses	Wet	94.50	104.50	105.00	101.50	98.00
	Dry	94.00	94.00	97.00	95.00	
Mean (distance)		94.50	99.00	101.00		
C.V. (%)		13.12				
LSD ($p \leq 0.05$)		NS			NS	
Kisian	Wet	93.00	95.00	112.50	100.50	99.00
	Dry	86.50	91.50	114.00	97.50	
Mean (distance)		90.00	93.00	113.50		
C.V. (%)		19.62				
LSD ($p \leq 0.05$)		NS			NS	
Mean (season) for all 4 sites	Wet	239.50	259.50	273.50	257.50	
	Dry	204.00	214.50	219.00	212.50	
Mean (distance) for all sites		222.00	237.00	246.50		
C.V. (%)		9.07				
LSD ($p \leq 0.05$)		NS			NS	30.73
Interactions ($p \leq 0.05$)		Site x Season = 43.21				

NS = Not significant

The increase in levels of Cu and Mn may partly be due to inputs from the surrounding anthropogenic activities such as small scale agricultural activities especially within Kodiaga Prison, general constructions at the Otonglo shopping centre as it expands, and, soil erosion and geochemical processes through surface runoffs during rainy season as has been noted in past studies (Lalah *et al.,* 2009a; Nyakeya *et al*., 2009; Mwita *et al.,* 2011). Only Pb and Fe levels in Molasses Plant effluent water were above the WHO (2004) recommended permissible limits for the aquatic life and drinking purposes. These observations demonstrated that the Molasses Plant was not a significant source of all studied heavy metals with an exception of Pb and Fe.

4.1.1.3 River Kisian

The concentrations of Pb, Mn, Cr, Fe and Zn in water samples from River Kisian increased ($p \leq 0.05$) from the uppermost point at the different sampling points along the river downstream (Tables 1, 2, 3, 5 and 6) (Appendix i, pg 108) while concentrations of Zn and Cu showed no significant increase. The observed increase of heavy metal levels downstream was in agreement with the the results obtained in waters from rivers in South Africa (Okonkwo *et al*., 2005), and results from various rivers discharging into Lake Victoria (Ochieng *et al*., 2008; Ongeri, 2008; Lalah *et al*., 2009a).

Table 7. Seasonal and site levels of Cd (µg/L) in river waters (Kisat and Kisian) and Molasses Plant effluents

Site	**Season**	**Sampling points along the rivers**			**Mean (season)**	**Mean (site)**
		Uppermost	**Middle**	**Mouth**		
Kisat	Wet	15.50	16.00	17.50	16.50	13.00
	Dry	9.00	9.00	10.00	9.50	
Mean (distance)		12.50	12.50	14.00		
C.V. (%)		8.47				
LSD ($p \leq 0.05$)		NS			6.29	
Molasses	Wet	1.00	1.00	1.50	1.00	1.00
	Dry	0.50	0.50	1.00	1.00	
Mean (distance)		0.50	1.00	1.00		
C.V. (%)		9.56				
LSD ($p \leq 0.05$)		0.30			NS	
Kisian	Wet	1.00	2.00	2.50	1.50	1.50
	Dry	1.00	1.50	2.00	1.50	
Mean (distance)		1.00	1.50	2.00		
C.V. (%)		5.05				
LSD ($p \leq 0.05$)		0.30			NS	
Mean (season) for all 4 sites	Wet	3.50	4.00	4.50	4.00	
	Dry	2.00	2.50	3.00	2.50	
Mean (distance) for all sites		3.00	3.00	2.00		
C.V. (%)		12.36				
LSD ($p \leq 0.05$)		0.91			0.38	0.91
Interactions ($p \leq 0.05$)		Site x Season = 1.22				

NS= Not significant

The upstream activities along the river were relatively less intense while small scale farming activities (maize, tomatoes, millet, and kales) and human settlements downstream are evident. The upcoming Kisian shopping centre, a petrol filling station constructed near the river, runoffs of oil spillages from the busy Kisumu-Busia Highway, the Kisumu-Butere Railway Line that cross the river upstream and the presence of Kenya Medical Research Institute (KEMRI) within the area may be contributing to the observed levels of heavy metal in the river water. The increased heavy metal levels along the river downstream may also be partly attributed to the catchment area surrounded by Riat and Kodiaga Hills that have areas with rocks that release metal residues in the river water through weathering, soil erosion and surface runoffs (Nyakeya *et al*., 2009). Zn and Cu levels, however, showed no increase along the river, an indication that the activities downstream were not causing significant addition of these metals into the river water.

Levels of most of the studied heavy metals in River Kisian water did not change significantly ($p \leq 0.05$) with seasons (Tables 1-7) although the wet season generally recorded slightly higher levels. Metal levels in water samples from this river were lower compared with those obtained in water samples from River Kisat in this study. The variations in metal pollution level in water from these rivers were a reflection in variations of locational anthropogenic activities. These results were inconsistent with the observations made in water in some rivers in South Africa (Okonkwo *et al*., 2005) and various rivers draining into the Winam Gulf (Ongeri, 2008; Ochieng *et al.*, 2008; Lalah *et al*., 2009a). These results suggested that surface runoffs during wet season along the Kisumu-Busia highway and Kisumu-Butere Railway line, activities within the Kenya Medical Research Institute (KEMRI), and the cultivated and scattered small scale farms found downstream, did not increase the concentrations of the metals in the river water significantly during the wet season. The area was associated with no major anthropogenic activities. This observation confirms that the anthropogenic activities are the major cause of heavy metal pollution of waters draining into Winam Gulf.

Levels of Pb and Fe were above the national and international allowable limits for drinking water (WHO, 2004) (Tables 1, 5 and 15). This observation showed that River Kisian water was not safe for domestic use due to the elevated levels of Pb and Fe. However, the levels of Cu, Mn, Cd, Cr and Zn in the same water from the river were safe for aquatic life (WHO, 2004) (Table 15).

4.1.1.4 Comparison of heavy metal levels in Molasses Plant channel, Rivers Kisat and Kisian waters

Comparing Rivers Kisian and Kisat, Kisat River traverses through an industrial area and had higher heavy metal loads than River Kisian that traverses through an area with no industrial activities. Molasses Plant is located in an area with lesser anthropogenic activities than those found in the catchment area of River Kisat. The pollution levels of the studied heavy metals in the water from the three sites were generally in the order Kisat > Molasses > Kisian. Water from River Kisat was more polluted compared to water from the Molasses Plant channel and River Kisian. This was due to the intense industrial, pharmaceutical, municipal, domestic activities among others along River Kisat. This general observation was in line with findings obtained in previous studies (Tole and Shitsama, 2001; Ochieng *et al*., 2008, Lalah *et al*, 2009a). The anthropogenic activities along the Molasses Plant channel and its environment were fewer compared to those found in Kisat site hence the low metal levels registered in water samples for the studied metals. It is therefore evident that there was minimal metal discharge from the factory. River Kisian water samples recorded the lowest levels of the studied metals, since it was surrounded by an area with minimal anthropogenic activities except the Kenya Medical Research Institute (KEMRI), Kisumu-Busia Highway and Kisumu-Butere Railway Line traffic.

4.1.1.5 Interaction effects

In all the water channels (Molasses Plant channel, Rivers Kisat and Kisian), there were overall significant interaction ($p \leq 0.05$) effects between site and distance for the mean concentrations of Fe, Pb, Mn and Cr metals (Tables 2, 3, 4 and 7). This observation demonstrated that the variations of site activities and their to the sampling points of the aquatic samples (water) in the rivers influenced the increase in Fe, Pb, Mn and Cr levels in the river waters in different patterns. This observation explains the variations in metal concentrations recorded in water from the different sites. There were also overall interactions between site and seasons ($p \leq 0.05$) for all the analyzed metals (Tables 1-7). This observation suggested that the pattern of increase of metal levels in the river waters from the three sites (Molasses Plant channel, Rivers Kisat and Kisian) caused by seasons and the variations of locational activities was not the same. This observation was supported by the fact that the catchment area for each sampling site had unique anthropogenic activities. However, there were no significant ($p \leq 0.05$) interactions between distance and season for the concentrations of all the analyzed metals in all the sites. This observation suggested that the trends of increase of the analyzed metal concentrations in river waters due to variations in distances of the heavy metal sources to the sampling points in the rivers and seasonal variations were the same. Site, distance and season for all sites showed no significant interactions ($p \leq 0.05$) for concentrations of all analyzed metals except for the concentration of Mn, suggesting that the locational activities, variations of distances of metal sources to the sampling points and seasonal variations influenced the change in metal levels in water samples from the three sites in the same patterns for all the analyzed metals except Mn.

4.1.2 Effects of distance from the shore into the lake on heavy metal levels in lake water

4.1.2.1 Kisat discharge point

The levels (µg/L) of the seven analyzed heavy metals in water samples from the lake areas adjacent to the discharge points of River Kisat, Cocacola Plant, Molasses Plant and River Kisian are presented in Tables 8-14 (Appendix ii, pg 118). All heavy metals around the discharge point of River Kisat decreased ($p \leq 0.05$) with the increase in distance from the shore into the lake with an exception of Fe.

The levels of Pb, Mn, Cr, Cu, Zn and Cd in the lake water samples from this site were in the same pattern with previous studies in the Winam Gulf at different sites (Tole and Shitsama, 2001; Ongeri, 2008; Lalah *et al.,* 2009a; Mwita *et al.,* 2011) (Table 15). However, the values in this study were relatively higher (Table 15). The results confirm that there is continual metal loading into the lake by the surrounding anthropogenic activities. The levels of Fe remained the same as the distance increased into the lake from the shore which implied that its concentration in the lake water was uniform and probably the pollution may be due to the activities within the lake and the adjoining Kisumu City area. The Cr levels in water (Table 10) were above the recommended allowable threshold limit for aquatic life tolerance set by (WHO, 2004) and other countries such as EU and Canada (Neubauer and Wolf, 2004) (Table 15).

The anthropogenic activities in the lake and the adjoining environment were therefore causing high Cr pollution of the lake water. It is necessary to monitor and determine the point sources of Cr to enable deployment of appropriate mitigation measures. The decrease ($p \leq 0.05$) in metal concentrations in water samples, except Fe as the distance increased from the shore into the lake area around River Kisat discharge point was as a result to metal dilution and dispersion due to water currents and waves in the the lake. The constant Fe levels observed in water as the distance increased from the shore into the lake suggested that there were activities within the lake and the adjacent environment discharging the metal into the lake. Thus, monitoring the metal levels and determining its source(s) is important. In addition to pollution caused by water channels (Tables 1-7), the activities that could be contributing to heavy metal loads into the lake include direct industrial discharges, pharmaceutical discharges, surface urban runoffs from the *Jua Kali* battery and scrap metal entrepreneurs, the municipal, domestic wastewater, Kisumu-Busia Highway oil spillages and fuel exhausts from the automobiles in the city, motorised boats which are common in the lake area and car washing activities at directly opposite from this site at approximately a kilometre away. The strategic close proximity of Bandani and Obunga Settlements in Kisumu City may also be contributing to the observed elevated levels of these metals into the aquatic ecosystem.

The heavy metal levels noted in water samples from River Kisat discharge point did not show significant ($p \leq 0.05$) seasonal variations. These results were at variance with the results obtained in Winam Gulf water by Ongeri (2008) where the heavy metal levels varied with seasons. The results indicated that the activities around and within the lake area were uniform and continous during the two seasons. This observation suggested the possible direct discharges of the pollutants caused by non-seasonal events as the major cause of heavy metal pollution in the area.

4.1.2.2 Cocacola discharge point

All heavy metal levels except Zn (Tables 8-13) decreased ($p \leq 0.05$) with the increase in distance from the shore into the lake around the discharge point of the Cocacola Plant. There were same patterns as in previous studies (Tole and Shitsama, 2001; Lalah *et al.,* 2009a; Mwita *et al.,* 2011). The decreased metal concentrations with increased distance from the shore into the lake indicated dilution effects. The Pb levels in lake water (5.00-10.00 μg/L) from this site were low compared to 120.00 - 450.00 (μg/L) (Tole and Shitsama, 2001) and 190.00 - 200.00 (μg/L) (Tole and Shitsama, 2003) obtained in Winam Gulf previously. The reduction suggested either there was an improvement in Pb waste management practices or decrease in Pb related activities within the study area. The results were however, higher than those observed in water samples from the Kisumu car wash in the lake near Kisumu City (Lalah *et al.,* 2009a) (Table 15).

The Zn levels (9.00 - 21.00 μg/L) were lower than those recorded from Mwanza Gulf of Lake Victoria, Tanzania (Kisamo, 2003), but higher than results (6.4 μg/L) obtained in water samples from the Kisumu car wash on the lakeshore of Winam Gulf of the lake, Kenya (Lalah *et al.*, 2009a) (Table 15). These results demonstrated that there has been increase of Zn in the lake water five years later, implying activities within and/or around the site were releasing Zn into the environment causing concentration increase. This observation therefore suggested that there is need to monitor and determine the source in order to put the metal pollution in check. The Cd concentration (1.1 μg/L) was low compared to the 10.0 μg/L levels obtained in Winam Gulf water (Tole and Shitsama, 2001). There were either reduced activities related to Cd release into the environment and/or improved management of waste disposal. All the heavy metals in water samples were below the recommended allowable limit for aquatic life tolerance and for drinking purposes (WHO, 2004). The lake water from the site was therefore suitable for fisheries and domestic use.

There were no significant ($p \leq 0.05$) seasonal variations in levels of studied metals in water from this site except for Fe (Tables 8-14). This observation implied that the activities emitting heavy metals into the lake water from this point did not vary with seasons for all studied metals except Fe. These results were not in agreement for most heavy metals with those obtained (Ongeri, 2008) in water samples from the Winam Gulf of Lake Victoria where metal concentrations increased during the wet season. Thus the heavy metal pollution in the Winam Gulf seemed to be locational dependant.

Table 8. Seasonal and site variations of Pb (µg/L) in water from different sites in Winam Gulf of Lake Victoria

Site	Season	DISTANCE			Mean (season)	Mean (site)
		0 m	50 m	100 m		
Kisat	Wet	15.50	10.00	6.50	10.50	10.00
	Dry	15.00	8.50	5.50	9.50	
Mean (distance)		15.50	9.00	6.00		
C.V. (%)		10.79				
LSD ($p \leq 0.05$)		2.50			NS	
Molasses	Wet	7.00	5.50	5.50	6.00	6.00
	Dry	6.50	5.50	5.00	5.50	
Mean (distance)		7.00	5.50	5.00		
C.V. (%)		9.51				
LSD $P \leq 0.05$		1.50			NS	
Kisian	Wet	7.00	5.00	4.00	5.50	5.00
	Dry	7.00	4.50	3.50	5.00	
Mean (distance)		7.00	4.50	3.50		
C.V. (%)		6.98				
LSD ($p \leq 0.05$)		1.00			NS	
Cocacola	Wet	9.50	7.00	5.50	7.50	7.00
	Dry	8.00	6.50	4.50	6.50	
Mean (distance)		8.50	7.00	5.00		
C.V. (%)		4.23				
LSD ($p \leq 0.05$)		0.50			NS	
Mean (season) for all 4 sites	Wet	10.00	7.00	5.00	7.50	
	Dry	9.00	6.00	4.50	6.50	
Mean (distance) for all 4 sites		9.50	6.50	5.00		
C.V. (%)		9.52				
LSD ($p \leq 0.05$)		1.00			NS	0.50
Interactions ($p \leq 0.05$)		Site x distance = 1.00				

NS = Not significant

4.1.2.3 Molasses discharge point

The levels of all heavy metals (Tables 8-14) in lake water samples from the lake area around the Molasses Plant discharge point decreased ($P \leq 0.05$) with the increase in distance into the lake from the shore. The concentrations of the heavy metals in the water samples from this site generally compared well with the results obtained in previous studies done in various parts of Lake Victoria (Tole and Shitsama, 2001; Tole and Shitsama, 2003; Kisamo, 2003; Ongeri, 2008; Lalah *et al.,* 2009a; Mwita *et al.,* 2011) (Table 15) or other lakes such as Lake Kanyaboli in

Kenya which registered 4.4, 21.54 and 23.95 (µg/L) for Cd, Cr and Cu respectively (Lalah *et al.*, 2008).

Table 9. Seasonal and site changes of Fe (µg/L) in water from different sites in Winam Gulf of Lake Victoria

Site	Season	DISTANCE			Mean (season)	Mean (site)
		0 m	50 m	100 m		
Kisat	Wet	296.50	226.00	183.50	235.50	225.00
	Dry	281.50	210.00	153.50	215.00	
Mean (distance)		289.00	218.00	168.50		
C.V. (%)		2.21				
LSD ($p \leq 0.05$)		NS			NS	
Molasses	Wet	174.00	129.50	103.00	135.50	127.50
	Dry	153.00	114.00	90.50	119.50	
Mean (distance)		163.50	122.00	52.00		
C.V. (%)		4.93				
LSD ($p \leq 0.05$)		15.50			NS	
Kisian	Wet	227.50	195.00	145.00	189.00	183.50
	Dry	223.50	185.00	124.00	177.50	
Mean (distance)		225.50	190.00	134.50		
C.V. (%)		9.98				
LSD ($p \leq 0.05$)		45.50			NS	
Cocacola	Wet	202.00	177.50	173.00	184.00	170.50
	Dry	182.00	155.50	133.50	157.00	
Mean (distance)		192.00	166.50	153.50		
C.V. (%)		2.40				
LSD ($p \leq 0.05$)		10.00			0.05	
Mean (season) for all 4 sites	Wet	224.50	181.00	149.50	185.00	
	Dry	210.50	167.00	127.00	168.00	
Mean (distance) for all 4 sites		217.50	174.00	138.50		
C.V. (%)		6.54				
LSD ($p \leq 0.05$)		NS			NS	NS
Interactions ($p \leq 0.05$)		Site x distance = 16.00				

NS = Not significant

The Cu levels of 12.00 µg/L in lake water from this site were higher compared to 1.60 µg/L obtained in water samples from the Kisumu car wash (Lalah *et al.*, 2009a). The range of Pb in the lake water was low compared to ranges of 120.00 - 450.00 µg/L (Tole and Shitsama, 2001) and 190.00 - 200.00 µg/L (Tole and Shitsama, 2003) (Table 15) obtained in previous studies in lake water from the Winam Gulf, but higher compared to >3.84 µg/L results from Kisumu car wash (Lalah *et al.,* 2009a). The Zn levels were lower than those obtained in a previous study in the Winam Gulf (Mwita *et al*., 2011), but higher than the levels in water from Kisumu car wash

(Lalah *et al.,* 2009a) (Table 15) meaning the activities around and within the lake were contributing to the variations in the metal levels. The Cr in water samples were lower than levels obtained previously from the same lake area (Mwita *et al*., 2011). This observation implied either there was reduction of Cr emitting activities or an improvement in the management of Cr containing wastewaters. The levels of Cd in lake water were lower than the levels observed in water samples in previous studies in the Winam Gulf (Tole and Shitsama, 2001; Tole and Shitsama, 2003; Lalah *et al.,* 2009a) (Table 15). There was reduction in Cd levels over time an indication that there could be improved management of waste discharges and/or reduction in activities related to Cd pollution into the environment.

Table 10. Seasonal and site levels of Cr (μg/L) in water from different sites in Winam Gulf of Lake Victoria

Site	**Season**	**DISTANCE**			**Mean (season)**	**Mean (site)**
		0 m	**50 m**	**100 m**		
Kisat	Wet	65.00	56.50	46.50	55.00	55.00
	Dry	60.00	56.00	46.00	52.50	
Mean (distance)		62.50	56.00	46.50		
C.V. (%)		6.10				
LSD ($p \leq 0.05$)		11.50			NS	
Molasses	Wet	38.00	35.00	31.50	35.00	32.00
	Dry	33.50	29.00	24.00	29.00	
Mean (distance)		35.50	32	27.50		
C.V. (%)		4.26				
LSD $P \leq 0.05$		3.50			NS	
Kisian	Wet	32.50	24.50	12.50	23.00	21.00
	Dry	28.00	19.50	8.50	18.50	
Mean (distance)		30.00	21.50	10.50		
C.V. (%)		7.28				
LSD ($p \leq 0.05$)		3.50			NS	
Cocacola	Wet	44.00	38.00	41.00	41.00	39.00
	Dry	41.50	37.00	32.50	37.00	
Mean (distance)		43.00	37.50	36.50		
C.V. (%)		5.57				
LSD ($p \leq 0.05$)		5.50			NS	
Mean (season) for all 4 sites	Wet	44.50	38.50	33.50	39.00	
	Dry	41.00	35.00	27.00	34.50	
Mean (distance) for all 4 sites		43.00	37.00	30.50		
C.V. (%)		5.69				
LSD ($p \leq 0.05$)		7.00			NS	6.00
Interactions ($p \leq 0.05$)		Site x Distance = 3.00				

NS = Not significant

However, the lake water samples from this site had lower levels of the metal than the levels in water samples from Cocacola and Kisat lake area. The observed low levels of Cd can be correlated to low levels of the metal (1.00 µg/L) in the Molasses Plant water obtained in this study which was associated with lesser Cd producing anthropogenic activities found around or the seasonal changes were not drastic e.g. the amount of rainfall. These observations demonstrated that there were varied anthropogenic activities that were responsible for the levels of the studied metals at the discharge points. The heavy metal concentrations recorded at the Molasses Plant discharge point were below the national (KEBS, 1996) and international (WHO, 2004) set limits for drinking and fisheries water (Table 15). These results showed that the lake water from the site was safe for domestic use and aquatic life.

The levels of the studied heavy metals in water in the lake area around the Molasses Plant discharge point did not increase ($p \leq 0.05$) with seasons. The results contradict the observations made (Ongeri, 2008) in water samples from Winam Gulf where the metal concentration levels in water samples were significantly ($p \leq 0.05$) higher in the wet season than the dry season. These results suggested that the anthropogenic activities within the lake area and on the adjoining land were not exhibiting seasonal differences in the discharge of the heavy metals.

4.1.2.4 Kisian discharge point

The levels of Pb, Fe, Cr, Cd and Cu (Tables 8-12) in water samples from Kisian discharge point decreased ($p \leq 0.05$) as the distance into the lake from the shore increased. Pb, Cu, and Zn levels were higher than the levels obtained in a study in Winam Gulf at the Kisumu Car Wash (Lalah *et al*., 2009a) (Table 15). However, Pb, Zn, Fe, Cd and Cr levels were lower than those obtained in different sites of Lake Victoria water in Tanzania and Kenya (Kisamo, 2003; Tole and Shitsama, 2001; Mwita *et al.*, 2011) (Table 15).

Table 11: **S**easonal and site variations in concentrations (µg/L) of Cd in water from different sites in Winam Gulf of Lake Victoria

Site	Season	DISTANCE 0 m	50 m	100 m	Mean (season)	Mean (site)
Kisat	Wet	2.38	1.22	0.68	1.44	1.34
	Dry	2.10	1.05	0.62	1.26	
Mean (distance)		2.24	1.13	0.65		
C.V. (%)		8.00				
LSD ($p \leq 0.05$)		0.27			NS	
Molasses	Wet	0.28	0.20	0.12	0.20	0.20
	Dry	0.30	0.22	0.10	0.21	
Mean (distance)		0.29	0.21	0.11		
C.V. (%)		22.51				
LSD ($p \leq 0.05$)		0.11			NS	
Kisian	Wet	0.30	0.23	0.15	0.23	0.22
	Dry	0.30	0.20	0.15	0.22	
Mean (distance)		0.30	0.22	0.15		
C.V. (%)		21.21				
LSD ($p \leq 0.05$)		0.12			NS	
Cocacola	Wet	1.13	1.33	1.00	1.16	1.08
	Dry	1.17	1.05	0.82	1.01	
Mean (distance)		1.25	1.09	0.91		
C.V. (%)		7.38				
LSD ($p \leq 0.05$)		0.20			NS	
Mean (season) for all 4 sites	Wet	1.06	0.70	0.49	0.75	
	Dry	0.97	0.63	0.42	0.67	
Mean distance for all 4 sites		1.02	0.66	0.45		
C.V. (%)		9.28				
LSD ($p \leq 0.05$)		NS			NS	0.07
Interactions ($p \leq 0.05$)		Site x distance = 0.09 Site x season = 0.10				

NS=Not significant

Range of Pb levels (5.00 - 10.00 µg/L) in water samples in the current study was comparable to that from Kisumu car wash (Lalah *et al.,* 2009a) (Table 15). However, the levels were much lower compared to those from Mwanza Gulf (350.00 - 630.00 µg/L) in Tanzania (Kisamo, 2003) (Table 15). These results demonstrated that the anthropogenic activities in these areas may be different or the intensity of the activities found in each area may be different. However, the differences in metal levels in the areas demonstrated either few activities or lack of activities emitting Pb into the water system. The Zn (9.00 - 21.00 µg/L) levels were higher compared to levels (6.37 µg/L) in water samples from the Kisumu car wash (Lalah *et al.*, 2009a) an indication that there was an unknown source in the lake around River Kisian discharge point which caused the pollution. There is therefore need to determine and monitor the source of this metal to enable appropriate mitigation measures.

Table 12: Seasonal and site variations of Cu (µg/L) in water from different sites in Winam Gulf of Lake Victoria

Site	Season	DISTANCE			Mean (season)	Mean (site)
		0 m	**50 m**	**100 m**		
Kisat	Wet	36.50	27.00	14.00	26.00	25.00
	Dry	33.50	25.50	13.50	24.00	
Mean (distance)		35.00	26.50	14.00		
C.V. (%)		3.41				
LSD (p≤ 0.05)		2.00			NS	
Molasses	Wet	18.00	13.00	7.00	12.50	12.00
	Dry	16.50	10.50	6.00	11.00	
Mean (distance)		17.50	11.50	6.50		
C.V. (%)		3.91				
LSD P ≤ 0.05		1.00			NS	
Kisian	Wet	17.00	6.50	2.00	8.50	8.00
	Dry	14.50	5.50	1.50	7.00	
Mean (distance)		15.50	6.00	2.00		
C.V. (%)		12.14				
LSD (p≤ 0.05)		2.50			NS	
Cocacola	Wet	34.00	30.50	14.00	26.00	24.50
	Dry	33.00	24.50	12.00	23.50	
Mean (distance)		33.50	27.50	13.00		
C.V. (%)		4.23				
LSD (p≤ 0.05)		2.50			NS	
Mean (season) for all 4 sites	Wet	26.00	23.50	9.00	19.50	
	Dry	24.50	16.50	8.50	16.50	
Mean (distance) for all 4 sites		25.00	20.00	9.00		
C.V. (%)		9.09				
LSD (p ≤ 0.05)		2.00			NS	2.00
Interactions (p ≤ 0.05)		Site x distance =2.00, Site x Season = 2.50, Distance x Season = 2.50, Site x distance x Season = 3.50				

NS= Not significant

However, these levels were lower than those obtained in water samples from Mwanza Gulf (Kisamo, 2003) (Table 15). The water samples from this site also had lower levels of Cd and Fe, at 0.20 and 183.50 µg/L respectively, compared to levels obtained in water samples from the Kisumu car wash area which had >1.78 and 2440.00 µg/L, respectively (Lalah *et al*,. 2009a) (Table 15). Thus, there were activities within and around the area which were discharging insignificant loads of these heavy metals into the lake water.

All the heavy metal concentrations for all the analyzed metals in the lake water samples from this site were within the national (KEBS, 1996) and international (WHO, 2004) allowable levels for drinking water and aquatic life (Table 15). The lake water from this site was safe for fisheries and domestic use. The heavy metal levels did not show seasonal variations (Tables 8-14) although wet season recorded higher levels for all studied metals. These results contradicted the observed results (Ongeri, 2008) in water samples from the Winam Gulf where heavy metal levels varied with seasons. These results were similar to those observed in water samples from Kisat, Cocacola Plant and Molasses Plant discharge points in this study.

4.1.2.5 Comparison of heavy metal levels in lake water from different studied sites

Overall, levels of Pb, Cr, Cu, Mn and Zn in the lake water for all the four sites decreased ($p \leq 0.05$) with the increase in distances into the lake from the shore with an exception of Fe and Cd metals (Tables 8-14). These results were in agreement with the observations made for water samples draining into the Winam Gulf at the river deltas of Rivers Nyamasaria, Sondu-Miriu, Kuja, Awach,Yala, Sio, Nyando and Nzoia (Ochieng *et al.,* 2008; Ongeri, 2008; Lalah *et al*., 2009a) where dilution effects were observed as the distance increased into the lake. The metals in water samples from the four sites did not exhibit significant ($p \leq 0.05$) seasonal variations (Tables 8-14). These observations were in variance with previous data (Ongeri, 2008) on lake water which showed seasonal variations. This observation implied that seasonal runoffs from the area did not influence the heavy metal pollution of the studied metals into the lake water samples even though there was a general effect of season seen for all studied metals during the wet season despite being insignificant. The results demonstrated that the non-seasonal events within the sites were the major sources of heavy metal pollution into the lake.

Table 13 : Seasonal and site variations of Mn (µg/L) in water from different sites in Winam Gulf of Lake Victoria

Site	Season	DISTANCE			Mean (season)	Mean (site)
		0 m	50 m	100 m		
Kisat	Wet	403.50	327.00	294.50	341.50	334.00
	Dry	374.00	308.50	290.50	324.50	
Mean (distance)		388.50	318.00	300.00		
C.V. (%)		5.13				
LSD ($p \leq 0.05$)		42.50			NS	
Molasses	Wet	95.50	76.00	64.50	78.50	76.00
	Dry	89.50	73.50	58.50	74.00	
Mean (distance)		92.50	74.50	61.50		
C.V. (%)		13.18				
LSD ($p \leq 0.05$)		25.00			NS	
Kisian	Wet	108.50	88.50	81.00	92.50	89.50
	Dry	95.00	85.50	77.00	86.00	
Mean (distance)		102.00	87.00	79.00		
C.V. (%)		15.66				
LSD ($p \leq 0.05$)		NS			NS	
Cocacola	Wet	250.50	186.00	147.50	194.50	190.50
	Dry	254.50	164.00	140.50	186.50	
Mean (distance)		252.50	175.00	144.00		
C.V. %		16.09				
LSD $P \leq 0.05$		76.00			NS	
Mean (season) for all 4 sites	Wet	214.50	169.50	147.00	177.00	
	Dry	203.50	158.00	141.50	167.50	
Mean (distance) for all 4 sites		209.00	163.50	144.50		
C.V. (%)		11.03				
LSD ($p \leq 0.05$)		23.50			NS	20.50
Interactions ($p \leq 0.05$)		Site x distance = 27.00				

NS = Not significant

The levels of all analyzed heavy metals in water varied significantly ($p \leq 0.05$) among the sites, except for the concentration levels of Fe (Tables 8-14). These results were in agreement with results obtained in various parts of Lake Victoria in Kenya (Tole and Shitsama, 2001; Tole and Shitsama, 2003; Lalah *et al.*, 2009a; Mwita *et al.*, 2011) and Tanzania (Kisamo, 2003). The significant site variations ($p \leq 0.05$) observed in all the sites for the analyzed metals reflected the differences in the anthropogenic activities responsible for the heavy metal pollution at the sites.

There were significant interactions ($p \leq 0.05$) effects between site and distance in all analyzed heavy metals. Thus, the trend of change in heavy metal concentrations in water due to variations of site activities and variations in distances of the discharge sources to sampling points of water samples were not uniform. This was due to the variations in anthropogenic activities along the channels draining water to the different sites.

Table 14: Seasonal and site differences of Zn (µg/L) in water from different sites in Winam Gulf of Lake Victoria

Site	**Season**	**DISTANCE**			**Mean (season)**	**Mean (site)**
		0 m	**50 m**	**100 m**		
Kisat	Wet	33.50	18.00	17.00	23.00	21.00
	Dry	30.00	16.00	10.50	19.00	
Mean (distance)		32.00	17.00	13.50		
C.V. (%)		20.55				
LSD ($p \leq 0.05$)		18.50			NS	
Molasses	Wet	20.50	13.00	12.50	15.50	14.50
	Dry	18.50	12.00	10.50	13.50	
Mean (distance)		19.50	12.5	11.50		
C.V. (%)		14.41				
LSD ($p \leq 0.05$)		5.00			NS	
Kisian	Wet	11.00	9.50	8.00	9.50	9.00
	Dry	9.00	8.50	7.00	8.00	
Mean (distance)		10.00	9.00	7.50		
C.V. (%)		25.61				
LSD ($p \leq 0.05$)		NS			NS	
Cocacola	Wet	17.50	16.50	16.00	16.50	16.00
	Dry	16.00	15.50	15.00	15.50	
Mean (distance)		16.50	16.00	15.50		
C.V. (%)		6.27				
LSD ($p \leq 0.05$)		NS			NS	
Mean (season) for all 4 sites	Wet	20.50	14.50	14.50	16.50	
	Dry	18.50	13.00	11.00	14.00	
Mean (distance) for all 4 sites		19.50	13.50	12.50		
C.V. (%)		15.43				
LSD ($p \leq 0.05$)		3.00			NS	2.50
Interactions ($p \leq 0.05$)		Site x distance = 3.50				

NS= Not significant

The levels of Cd and Cu in water samples showed significant interactions ($p \leq 0.05$) effects between sites and seasons at all sites. Thus, the patterns of seasonal changes in the levels at locations and seasons variations were not the same. The observed results may be attributed to variations in sources of heavy metals into the ecosystem at the different sites and in different seasons. Cu in water samples showed significant interaction ($p \leq 0.05$) effects between season and distance in all sites. These observations indicated that the trends of change in Cu levels due to variations in seasons and the different distances of the activities emitting the metal to the sampling points of the water samples was not uniform.

Table 15: Comparing levels (μg/L) of heavy metals in river water, lake water and effluents with past studies and maximum national and international allowable limits for aquatic life and other uses

Reference/ Study limit	Water use	Cu	Pb	Mn	Zn	Cd	Cr	Fe
Tole and Shitsama, 2001(Winam Gulf) (μg/L)		-	120.00-450.00	-	-	10.00	160.00-1820.00	-
Kisamo, 2003 (μg/L) L. Victoria, Tanzania		-	350.00-630.00	-	40.00-80.00	-	-	10.00-5620.00
Mwamburi (2003) (River Kisat) (μg/L)		-	0.00 - 20.00	2.00-1470.00	8.00-120.00	nd	-	-
Tole and Shitsama, 2003 (μg/L) (Winam Gulf)		-	190.00-200.00	-	-	10.00	-	-
Muwanga and Barifaijo, 2006 (Lake Victoria, Uganda) (μg/L)		60.00	1440.00	1170.00	10.00	1.00	20.00	-
Ochieng *et al.*, 2008. (R. Kisat) (μg/L)		5.00-157.50	nd-60.00	50.00-738.00	25.0-219.50	nd-8.00	nd-50.00	-
Lalah *et al.*, 2009a (μg/L) (Kisumu car wash)		1.62	>3.84	-	6.37	>1.79	-	2440.00
Lalah *et al.*, 2009a. (R. Nyamasaria) (μg/L)		3.83	3.83	-	7.90	1.78	-	1012.00
Mwita *et al.*, 2011 (Lake area near River Kisat) (μg/L)		-	-	-	36.00	-	157.00	-
Mohiuddin *et al.*, 2011(μg/L)		2225.00	365.00	-	240.00	190.00	1695.00	-
River Kisian water (μg/L)[a]		**23.00**	**20.00**	**40.50**	**99.00**	**1.50**	**24.50**	**789.00**
Molasses effluents (μg/L)[a]		**25.50**	**34.50**	**137.50**	**98.00**	**1.00**	**38.50**	**843.00**
Rivers Kisat water (μg/L)[a]		**276.50**	**245.50**	**2466.00**	**508.00**	**13.00**	**72.50**	**1078.00**
Kisian discharge point (μg/L)[a]		**8.00**	**5.00**	**89.50**	**9.00**	**0.20-1.34**	**21.00**	**183.50**
Molasses discharge point (μg/L)[a]		**12.00**	**6.00**	**76.00**	**14.50**	**0.20**	**32.00**	**127.50**
Cocacola discharge point (μg/L)[a]		**24.50**	**7.00**	**190.50**	**16.00**	**1.08**	**39.00**	**170.50**
Kisat discharge point (μg/L)[a]		**25.00**	**10.00**	**334.00**	**21.00**	**1.34**	**55.00**	**225.00**
TC[b] (μg/L)	Aquatic Life	2.00 - 104.00	100.00	-	100.00	10.00	50.00	-
EU[b] (μg/L)	Aquatic Life	5-112	-	-	30.00-2000.00	-	-	-
Canada[b] (μg/L)	Aquatic Life	2.00 - 4.00	1.00 - 7.00	-	30.00	0.20- 1.80	-	300.00
Canada[b] (μg/L)	Drinking water standards	1000.00	50.00	-	5000.00	5.00	-	300.00
WHO (2004) (μg/L)		1000.00	10.00	400.00	5000.00	3.00	50.00 (provisional)	300.00
KEBS (1996) (μg/L)		100.00	50.00	-	5000.00	-	-	300.00

Source: International and national data of standards obtained from Lalah *et al.*, 2009a

nd: not detected, TC: threshold concentration for aquatic life tolerance (for most fishes), Neubauer and Wolf (2004).

[a] Present study, 2014 Kenya.

[b] Neubauer and Wolf (2004).

4.1.3 Variations in heavy metal levels in lake sediments with increased distance from the shoreline into the lake

All the analyzed heavy metals in sediment samples from Kisat discharge point decreased ($p \leq 0.05$) in their concentrations as the distance increased into the lake from the shore (Tables 16-22) (Appendix iii, pg 129) while only Mn in sediments from the Molasses Plant discharge point (Table 21) decreased ($p \leq 0.05$) as the distance increased into the lake from the shore. This was an indication that the heavy metals released into the lake sediments were not in equilibrium with the levels in lake water column above. Similar results showing decrease in metal levels with increased distance into the lake from the shore had been obtained in previous studies on sediment samples in lakes from different regions such as Lake Avsar in Turkey (Ozturk *et al*., 2009) and Uppanar estuary, Nagapattinam, India (Rajkumar *et al*., 2009) and Mwanza Gulf (Kishe and Machiwa, 2001) in Lake Victoria in Tanzania (Table 23). The decrease in levels of the heavy metals in sediments as inshore distances increased could be due to the metals desorbing from the lake sediments into the lake water. The fate of metals depend on the pH, salinity, DO and the amount of suspended solids (Simpson *et al*., 2004) in water column above. Sediments found deeper in the lake from the shore had longer contact period with water currents hence an equivalent desorption time.

The levels of Fe, Zn, Cr, Cd, Cu and Pb in the sediments at the Molasses Plant lake area did not vary ($p \leq 0.05$) with the increased distance from the shore into the lake, an indication that the metals were in equilibrium to the levels in the overlying water column (Tables 16-22). These levels were higher than levels obtained previously in Lake Victoria sediments (Ochieng, 1987; Onyari and Wandiga, 1989; Kishe and Machiwa, 2001; Tole and Shitsama, 2003; Kisamo, 2003) (Table 23). This observation suggested probable anthropogenic inputs of metals from activities in the lake such as motorized boating and possibly the nature of geochemical composition of the soil and rocks from the catchment basin (Nyakeya *et al.,* 2009). The increased land use activities such as sand harvesting along the lakeshore at the site were probably influencing the heavy metal contributions into the lake and eventually into the sediments. Cr, Cu and Zn levels in sediments from Cocacola Plant discharge point decreased ($p \leq 0.05$) with increased distance from the shore into the lake (Tables 17, 18 and 19). Levels of all analyzed heavy metals in sediments from Kisat and Cocacola Plant discharge areas (Tables 16-22) exhibited similar trend of elevated levels as those recorded near urban centres in previous studies at Winam Gulf (Tole and Shitsama, 2003) in Kenya and Mwanza Gulf of Lake Victoria (Kishe and Machiwa, 2001; Kisamo, 2003) in Tanzania, and in Lake Muhazi in Rwanda (Umaru *et al.,* 2012) (Table 23). However, the levels of Cd, Pb, Cu and Mn in sediments from Kisat discharge area were relatively higher compared to previous results in other studies on sediments in Winam (Ochieng, 1987; Onyari and Wandiga, 1989; Tole and Shitsama, 2003) (Table 23) while the metals in the sediments from Cocacola Plant site were higher than those obtained in sediments from Mwanza Gulf in Lake Victoria Tanzania (Kisamo, 2003) and those obtained in various parts of Winam Gulf of Lake Victoria in Kenya (Ochieng, 1987; Onyari and Wandiga, 1989; Tole and Shitsama, 2003; Lalah *et al.,* 2009a; Mwita *et al*., 2011) (Table 23). The range of heavy metals in sediments from the Cocacola Plant discharge point for most analyzed metals were also in agreement with the results obtained in another study (Ongeri, 2008) (Table 23) on sediments from Lake Victoria, and some of the metal levels were in almost same range as those recorded from Lake Manzala in Egypt (Saeed *et al.,* 2008), although Fe levels were ten fold lower (Table 23). The results confirmed that water bodies or sediments from water bodies close to urban centres have high heavy metal levels, due to intense anthropogenic activities in the urban centres. The levels of Fe, Cu, Zn, Mn and Cd in sediments from the Kisian lake area decreased ($p \leq 0.05$) with increased distance into the lake from the shore (Table 16, 17, 18, 19, 21 and 22). The observed levels of most of the studied metals in this site were lower than results obtained in related studies (Lalah *et al*., 2009a; Saeed *et al*., 2008) on sediments from Winam Gulf and Lake Manzala in Egypt, respectively. However, the levels of the metals in sediments from other parts of Winam Gulf and Mwanza Gulf in Lake Victoria (Ochieng, 1987; Onyari and Wandiga, 1989; Kishe and Machiwa, 2001; Tole and Shitsama 2003; Lalah *et al*., 2009a; Mwita *et al*,. 2011) were comparatively higher.

Table 16: Seasons and site differences of Pb (µg/g) in sediments from different sites in Winam Gulf of Lake Victoria

Site	Season	DISTANCE			Mean (season)	Mean (site)
		0 m	50 m	100 m		
Kisat	Wet	199.70	192.05	157.90	183.25	181.00
	Dry	197.70	184.10	154.50	178.75	
Mean (distance)		198.70	188.10	156.20		
C.V. (%)		4.57				
LSD ($p \leq 0.05$)		20.54			NS	
Cocacola	Wet	183.75	168.35	106.35	152.80	142.45
	Dry	149.95	142.45	103.90	132.10	
Mean (distance)		166.85	155.40	105.10		
C.V. (%)		17.53				
LSD ($p \leq 0.05$)		NS			NS	
Molasses	Wet	159.90	130.80	140.90	143.90	141.20
	Dry	148.45	137.15	129.85	138.50	
Mean (distance)		154.15	134.00	135.40		
C.V. (%)		13.40				
LSD ($p \leq 0.05$)		NS			NS	
Kisian	Wet	70.80	61.50	57.55	63.30	61.75
	Dry	64.00	60.25	56.40	60.20	
Mean (distance)		67.40	60.90	56.95		
C.V. (%)		2.32				
LSD ($p \leq 0.05$)		3.56			NS	
Mean (season) for all 4 sites	Wet	153.55	138.20	115.70	135.80	
	Dry	140.05	131.00	111.15	127.40	
Mean (distance) for all sites		146.80	134.60	113.40		
C.V. (%)		12.33				
LSD ($p \leq 0.05$)		20.14			NS	17.21
Interactions ($p \leq 0.05$)		Site x distance = 22.91				

NS= Not significant

Comparison of heavy metal levels in sediments with the Shale standard is usually quick method of identifying heavy metal enrichment in the environment (Jain, 2004). The levels of all heavy metals in the lake sediments (Table 23) were higher compared with background levels at Naples

Harbour in Italy (Adamo *et al.*, 2005) and Shale standard levels (Jain, 2004). The high levels of heavy metals in sediments were indicators that anthropogenic activities around and within Lake Victoria shoreline from River Kisat discharge point to the discharge point of River Kisian are a major cause of pollution. Therefore the wastewater discharges from these anthropogenic activities should be treated to reduce/remove heavy metal pollutants before draining into the aquatic ecosystems.

Table 17: Seasons and site differences of Cr (µg/g) in sediments from different sites in Winam Gulf of Lake Victoria

Site	Season	DISTANCE			Mean (season)	Mean (site)
		0 m	50 m	100 m		
Kisat	Wet	3.60	3.55	3.60	3.60	3.60
	Dry	3.60	3.55	3.55	3.55	
Mean (distance)		3.60	3.55	3.55		
C.V. (%)		0.61				
LSD ($p \leq 0.05$)		0.61			NS	
Cocacola	Wet	3.60	3.50	3.45	3.55	3.50
	Dry	3.55	3.50	3.45	3.50	
Mean (distance)		3.60	3.50	3.45		
C.V. (%)		0.79				
LSD ($p \leq 0.05$)		0.06			NS	
Molasses	Wet	3.55	3.55	3.50	3.55	3.50
	Dry	3.55	3.50	3.45	3.5	
Mean (distance)		3.55	3.50	3.50		
C.V. (%)		1.13				
LSD ($p \leq 0.05$)		NS			NS	
Kisian	Wet	2.70	2.60	2.55	2.60	2.55
	Dry	2.65	2.45	2.46	2.50	
Mean (distance)		2.65	2.50	2.50		
C.V. (%)		1.18				
LSD ($p \leq 0.05$)		0.06			NS	
Mean for all 4 sites (season)	Wet	3.40	3.30	3.25	3.30	
	Dry	3.35	3.25	3.25	3.25	
Mean (distance) for all sites		3.35	3.25	3.25		
C.V. (%)		0.93				
LSD $P \leq 0.05$		0.03			NS	0.023
Interactions ($p \leq 0.05$)		Site x Distance = 0.05, Site x Season = 0.05				

NS=Not significant

The Zn, Fe, Mn and Cd levels in sediments from the Kisat area showed significant ($p \leq 0.05$) seasonal variations (Tables 19, 20, 21 and 22). At Cocacola Plant discharge lake area, there were significant ($p \leq 0.05$) seasonal variations in Zn, Fe and Cd. There was slight increase in metal levels in sediments from Molasses Plant discharge point during wet season though not significant ($p \leq 0.05$) with an exception of Zn which was significant. The results in Molasses Plant lake area contradicted a similar study (Ongeri, 2008) in Winam Gulf in which there were variations in heavy metals with seasons. Only Zn and Cd levels in sediments from Kisian discharge area showed significant ($p \leq 0.05$) seasonal variations.

Table 18: Seasons and site differences of Cu (µg/g) in sediments from different sites in Winam Gulf of Lake Victoria

Site	**Season**	**DISTANCE**			**Mean (season)**	**Mean (site)**
		0 m	**50 m**	**100 m**		
Kisat	Wet	157.50	136.80	93.15	129.15	122.85
	Dry	134.50	125.95	89.50	116.60	
Mean (distance)		145.95	131.35	91.35		
C.V. (%)		10.09				
LSD ($p \leq 0.05$)		30.80			NS	
Cocacola	Wet	312.20	317.90	196.00	275.40	267.78
	Dry	315.50	284.10	180.85	260.15	
Mean (distance)		313.85	301.00	188.40		
C.V. (%)		4.99				
LSD ($p \leq 0.05$)		33.23			NS	
Molasses	Wet	138.75	119.35	104.65	120.9	118.6
	Dry	130.9	115.8	102.2	116.3	
Mean (distance)		134.8	117.55	103.45		
C.V. (%)		21.11				
LSD ($p \leq 0.05$)		NS			NS	
Kisian	Wet	85.20	80.30	72.90	79.45	71.35
	Dry	68.10	61.35	60.35	63.25	
Mean (distance)		76.65	70.80	66.60		
C.V. (%)		3.91				
LSD $P \leq 0.05$		6.95			NS	
Mean (season) for all 4 sites	Wet	173.40	163.6	116.70	138.15	
	Dry	162.20	146.80	108.20	134.30	
Mean (distance) for all sites		167.80	155.20	112.45		
C.V. (%)		10.71				
LSD ($p \leq 0.05$)		19.32			NS	16.49
Interactions		Site x Distance = 21.98				

NS = Not significant

The wet season in the four sites recorded higher metal levels in sediments although were not significant ($p \leq 0.05$). This observation implied that the seasonal variations in anthropogenic activities discharging heavy metals into the sediments showed a similar trend. These results suggested that there were activities in the lake releasing the metal or within the catchment area possibly *Jua Kali* enterprenuers and scrap metals among others that released the metal into the environment which then were washed and drained through surface runoffs into the lake and eventually into the sediments.

Table 19: Seasons and site variations of Zn (µg/g) in sediments from different sites in Winam Gulf of Lake Victoria

Site	**Season**	**DISTANCE**			**Mean (season)**	**Mean (site)**
		0 m	**50 m**	**100 m**		
Kisat	Wet	335.70	280.80	278.85	298.45	187.55
	Dry	82.65	76.75	70.60	76.65	
Mean (distance)		209.20	178.75	174.7		
C.V. (%)		2.22				
LSD ($p \leq 0.05$)		10.35			0.500	
Cocacola	Wet	297.50	274.05	272.10	281.20	175.70
	Dry	74.25	69.65	66.75	70.20	
Mean (distance)		185.90	171.85	169.40		
C.V. (%)		1.48				
LSD ($p \leq 0.05$)		6.45			15.55	
Molasses	Wet	283.50	276.75	266.50	275.60	171.90
	Dry	74.50	69.10	61.05	68.20	
Mean (distance)		179.00	172.90	163.80		
C.V. (%)		3.81				
LSD ($p \leq 0.05$)		NS			0.785	
Kisian	Wet	133.25	127.50	125.55	128.75	100.10
	Dry	71.40	70.90	69.10	70.65	
Mean (distance)		102.55	99.20	97.35		
C.V. (%)		1.65				
LSD ($p \leq 0.05$)		4.10			9.9	
Mean (season) for all 4 sites	Wet	262.5	240.40	235.75	246.20	
	Dry	75.85	71.60	66.85	71.45	
Mean (distance)		169.15	156.0	151.30		
C.V. (%)		2.63				
LSD ($p \leq 0.05$)		5.25			12.60	4.45
Interactions ($p \leq 0.05$)		Site x Season = 6.30, Site x Distance = 5.95, Distance x Season = 7.40, Site x Season x Distance =8.40				

NS = Not significant

The magnitude of the heavy metals in sediments from the four sites observed to be decreasing in the order; Mn > Fe > Zn > Pb > Cu > Cr > Cd, Fe > Mn > Cu > Zn > Pb > Cr > Cd, Fe > Mn > Zn > Pb > Cu > Cr > Cd and Fe > Mn > Zn > Cu > Pb > Cr > Cd for lake areas around the discharge points of River Kisat, Cocacola Plant, Molasses Plant and River Kisian respectively. The order of heavy metal levels in the sediments showed a general similarity in the order of magnitude of the heavy metal composition in the lake sediments for the four sites. This observation therefore suggested that the discharges from the anthropogenic activities present in the study area responsible of metal pollution into sediments were similar.

Table 20: Seasons and site variations of Fe (μg/g) in sediments from different sites in Winam Gulf of Lake Victoria

Site	Season	DISTANCE			Mean (season)	Mean (site)
		0 m	50 m	100 m		
Kisat	Wet	1540.90	1521.85	1497.40	1520.05	1468.65
	Dry	1440.50	1411.95	1399.10	1417.20	
Mean (distance)		1490.70	1466.90	1448.25		
C.V. (%)		0.49				
LSD ($p \leq 0.05$)		17.95			43.3	
Cocacola	Wet	1504.25	1491.00	1489.20	1495.05	1448.20
	Dry	1421.30	1397.15	1385.55	1401.35	
Mean (distance)		1462.75	1444.45	1437.35		
C.V. (%)		0.79				
LSD ($p \leq 0.05$)		NS			68.65	
Molasses	Wet	1436.05	1377.35	1313.95	1375.80	1313.65
	Dry	1307.90	1252.40	1194.20	1251.50	
Mean (distance)		1371.95	1314.85	1254.10		
C.V. (%)		9.78				
LSD ($p \leq 0.05$)		NS			NS	
Kisian	Wet	1315.30	1296.65	1291.30	1301.05	1283.35
	Dry	1268.75	1266.80	1261.45	1265.60	
Mean (distance)		1292.00	1281.70	1276.35		
C.V. (%)		0.520				
LSD ($p \leq 0.05$)		NS			NS	
Mean (season) for all 4 sites	Wet	1449.00	1421.90	1397.95	1423.00	
	Dry	1359.60	1332.05	1310.10	1333.90	
Mean (distance) for all sites		1404.35	1377.00	1354.00		
C.V. (%)		4.69				
LSD ($p \leq 0.05$)		NS			NS	68.55

NS = Not significant

There were significant interactions ($p \leq 0.05$) effects between site and distance in the concentrations of all studied metals in sediments from all the sites. This observation indicated that the various activities found in each site and the distance variations of these activities from the sampling points of sediments were influencing the metal levels into the aquatic ecosystem in different patterns. Thus, the pattern of change of concentrations of studied metals in sediments from the various sites activities and distance variations from the sampling points was not uniform.

Significant interactions ($p \leq 0.05$) effects were observed for Fe, Zn, Mn and Cd metals between site and season for all sites. These observations suggested that the change of concentrations of these metals in the sediments were not influenced by change of site activities and seasons in the same pattern. The Pb, Cr and Cu concentrations showed no significant ($p \leq 0.05$) interactions between site and seasons, an indication that the trends of change of their concentrations due to different site activities and seasonal variations were uniform. There were significant interactions ($p \leq 0.05$) effects between distances of the activities to the sampling points and seasonal variations for Zn and Cd metals in sediments from all the studied sites.

Table 21: Seasons and site differences of Mn (μg/g) in sediments from different sites in Winam Gulf of Lake Victoria

Site	Season	DISTANCE			Mean (season)	Mean (site)
		0 m	50 m	100 m		
Kisat	Wet	1690.70	1669.85	1653.95	1671.50	1631.20
	Dry	1615.25	1593.10	1564.50	1590.95	
Mean (distance)		1803.00	1631.45	1609.20		
C.V. (%)		1.11				
LSD ($p \leq 0.05$)		44.80			36.55	
Cocacola	Wet	1028.10	999.95	965.85	997.95	913.65
	Dry	860.30	827.25	800.45	829.30	
Mean (distance)		944.20	913.60	883.15		
C.V. (%)		5.92				
LSD ($p \leq 0.05$)		NS			NS	
Molasses	Wet	899.85	773.45	705.80	793.00	763.35
	Dry	828.85	719.90	652.20	733.65	
Mean (distance)		864.35	746.70	679.00		
C.V. (%)		1.93				
LSD ($p \leq 0.05$)		36.55			NS	
Kisian	Wet	829.55	801.15	797.95	809.55	792.25
	Dry	783.85	771.8	769.25	774.95	
Mean (distance)		806.70	786.45	783.60		
C.V. (%)		1.09				
LSD ($p \leq 0.05$)		21.35			NS	
Mean (season) for all 4 sites	Wet	1112.05	1061.10	1030.90	1068.00	
	Dry	1022.05	978.00	946.60	982.25	
Mean (distance) for all 4 sites		1067.05	1019.55	988.75		
C.V. (%)		2.90				
LSD ($p \leq 0.05$)		36.95			85.15	31.55
Interactions ($p \leq 0.05$)		Site x Distance = 42.05, Site x Season = 44.65				

NS = Not significant

These observations demonstrated that the patterns of change of these heavy metal levels in the studied sediments at the different distances of the sampling points to the heavy metal sources were not the same during wet and dry season. Distance and season showed no significant interactions for the concentrations of Pb, Fe, Cu, Cr and Mn levels in the lake sediments from all studied sites, suggesting that the patterns of change of the concentrations of these metals in the sediments as a result of various distances of the metal sources to the sampling points and seasonal variations were the same.

Table 22: Seasons and site differences of Cd (μg/L) in sediments from different sites in Winam Gulf of Lake Victoria

Site	Season	DISTANCE			Mean (season)	Mean (site)
		0 m	50 m	100 m		
Kisat	Wet	1.90	1.65	1.60	1.70	1.20
	Dry	0.70	0.65	0.60	0.65	
Mean (distance)		1.30	1.15	1.10		
C.V. (%)		2.41				
LSD ($p \leq 0.05$)		0.06			0.18	
Cocacola	Wet	1.60	1.55	1.55	1.55	1.05
	Dry	0.60	0.60	0.55	0.60	
Mean (distance)		1.10	1.10	1.05		
C.V. (%)		2.17				
LSD ($p \leq 0.05$)		NS			0.18	
Molasses	Wet	1.30	1.65	1.55	1.50	1.05
	Dry	0.70	0.60	0.60	0.65	
Mean (distance)		1.00	1.15	1.10		
C.V. (%)		22.33				
LSD ($p \leq 0.05$)		NS			NS	
Kisian	Wet	1.30	1.15	1.05	1.20	0.90
	Dry	0.65	0.60	0.60	0.60	
Mean (distance)		1.00	0.90	0.85		
C.V. (%)		2.03				
LSD ($p \leq 0.05$)		0.03			0.09	
Mean (season) for all 4 sites	Wet	1.55	1.50	1.45	1.50	
	Dry	0.65	0.60	0.60	0.60	
Mean (distance) for all sites		1.10	1.05	1.00		
C.V. (%)		11.45				
LSD ($p \leq 0.05$)		1.50			0.36	0.14
Interactions ($p \leq 0.05$)		Site x Season = 0.18, Site x Distance x Season = 2.40				

NS = Not significant

Table 23: Range of concentrations of some studied metals in sediments from the study area compared with results from related studies in Lake Victoria and other lakes in other regions, background and Shale standard concentrations

Study	Cd	Pb	Zn	Cr	Fe	Cu	Mn
Ochieng, 1987. Winam Gulf (µg/g)	0.19-1.35	1.949-44.35	nl	nl	nl	nl	nl
Onyari and Wandiga, 1989. Winam Gulf (µg/g)	0.55-1.02	6.02-69.40	2.54-265.00	nl	1.18-52.90 ($x10^3$)	0.96-78.60	53.10-616.00
Kishe and Machiwa, 2001 Mwanza Gulf(Tanzania) (µg/g)	7.00	54.60	8.30	12.90	nl	26.10	nl
Tole and Shitsama, 2003. Kisumu Port. (µg/g)	0.40-2.80	16.80-76.80	nl	nl	nl	nl	nl
Kisamo, 2003. Lake Victoria, Tanzania (µg/g)	0.16-0.55	4.80-65.60	9.00-137.00	1.60 - 0.55	0.01- 0.28	1.70-26.10	nl
Ochieng *et al*., 2008. River Kisat, at river mouth (µg/g)	1.78	66.06	217.90	3.90	nl	150.22	3014.00
Ongeri, 2008 (µg/g)	0.26-2.40	8.10-152.20	37.70-441.60	nl	960.00-70619.30	18.50-93.10	nl
Lalah *et al*, 2009a Kisumu car wash, Lake Victoria, Kenya. (µg\g)	1.91	138.00	443.00	nl	73200.00	100.00	nl
Ozturk *et al*., 2009. Lake Avsar, Turkey (µg\g)	Nl	0.64-6.35	nl	9.41-19.90	19680.00-28560.00	18.20-38.40	nl
Rajkumar *et al.*, 2010. Uppanar, India. (µg\g)	2.25-10.06	nl	22.47-75.42	nl	nl	5.02-81.27	nl
Mwita *et al.*, 2011. Winam Gulf , Kisat area. (µg\g)	0.00	0.51	2.25	0.18	nl	nl	nl
Saeed *et al*., 2008. Lake Manzala, Egypt. (µg\g)	33.00-110.00	78.00-174.00	202.00-576.00	nl	20018.00-56212.00	106.00-412.00	nl
Background Levels Adamo, *et al*., 2005. (µg\g)	0.20±0.10	23.00± 3.70	56.00±25.00	21.60 ±6.90	nl	21.00±6.40	479.00± 64.00
Shale standards. (Jain, 2004). (µg\g)	0.30	20.00	95.00	nl	nl	45.00	nl
Kisat discharge point[a] (µg/g)	**1.20**	**181.00**	**187.55**	**3.60**	**1468.65**	**122.85**	**1631.20**
Cocacola discharge point[a] (µg/g)	**1.05**	**142.45**	**175.70**	**3.50**	**1448.20**	**267.78**	**913.65**
Molasses discharge point[a] (µg/g)	**1.05**	**141.20**	**171.90**	**3.50**	**1313.65**	**118.6**	**763.35**
Kisian discharge point[a] (µg/g)	**0.90**	**61.75**	**100.10**	**2.55**	**1283.35**	**71.35**	**792.25**

nl= not in literature cited
[a]Present study

4.1.4 Evaluation of heavy metals in fish

The dry weight (µg/g) levels of metals (Pb, Cd, Cu, Zn, Mn, Cr and Fe) in muscle tissues of four fish species (*Lates niloticus, Synodontis victoriae, Oreochromis niloticus and Clarias batrachus)* are presented in (Table 24) (Appendix iv, pg 141). Fe and Cd levels in all the four fish species were not significantly different. Levels of Fe in *Lates niloticus* and *Oreochromis niloticus* of 33.70 and 36.90 µg/g, respectively, were close to 45.70 and 48.00 µg/g obtained in a previous study (Ongeri, 2008) on the same fish species from Winam Gulf (Table 25). However, the Fe levels in *Lates niloticus* and *Oreochromis niloticus* were higher than levels obtained in a similar study (Achionye-Nzeh *et al*., 2011) in Nigeria. The levels of Cd in *Lates niloticus* and *Oreochromis niloticus* were within the range obtained (Tole and Shitsama, 2003) in the same fish species from Lake Victoria (Table 25). The levels of Fe in the tissues of all analyzed fish species were below the acceptable levels for human consumption (Wyse *et al*., 2003) (Table 26). The Cd levels in tissues of all analyzed fish species were above the international recommended levels 0.05 µg/g (FAO/WHO, 2004) (Table 26). Fe levels in the fish were safe. However, consumption of fish from the lake shall have health risks due to Cd. Zn levels in tissues from *Lates niloticus, Synodontis victoriae and Oreochromis niloticus* fish species were not different from one fish species to the other (Table 24). The Zn levels in tissues of *Clarias batrachus* were lower ($p \leq 0.05$) than the levels noted in the *Lates niloticus* (Table 24). These levels were close to results obtained in a study (Ongeri, 2008) on Zn levels in *Oreochromis niloticus* and *Lates niloticus* tissues from Winam Gulf in Lake Victoria. However, the Zn levels in *Lates niloticus* tissues in the current study were higher than levels obtained in previous similar studies (Machiwa, 2003; Ongeri, 2008) on the same fish species from Lake Victoria and freshwater fish bought from the market in Nigeria (Achionye-Nzeh *et al*., 2011) (Table 25). The Zn metal concentrations in the tissues of the studied fish species were above the WHO recommended acceptable levels in human diet (FAO/WHO, 2004). Consumption of fish from the lake may therefore cause Zn related health problems such as fatigue, dizziness and netropenia (Hess and Schmid, 2002).

Levels of Pb (0.65 µg/g) in tissues of *Lates niloticus* were significantly ($p \leq 0.05$) different from those observed in tissues of *Synodontis victoriae* (0.40 µg/g) and *Clarias batrachus* (0.50 µg/g) fish while were not significantly ($p \leq 0.05$) different from the levels noted in *Oreochromis niloticus* (0.60 µg/g). The levels of Pb in *Lates niloticus* and *Oreochromis niloticus* fish tissues were lower than the levels obtained in a previous study (Tole and Shitsama, 2003) on the same fish species from Lake Victoria (Table 25). However, Pb levels in *Lates niloticus* and *Oreochromis niloticus* tissues were close to the levels obtained in a previous study (Ongeri, 2008) on the same fish species (Table 25). This observation indicated possible reduction in Pb levels in these two fish species since 2008. These results suggested that there has been reduction in Pb related activities which caused the metal contamination in the fish. However, the levels of Pb in *Oreochromis niloticus* tissues were higher than the levels obtained for the same fish species from River Okumeshi, Nigeria (Ekeanyanwu *et al*., 2010).

The concentrations of Cr of 0.80 µg/g in tissues of *Lates niloticus* and *Oreochromis niloticus* each, were significantly ($p \leq 0.05$) different to the levels observed in tissues of *Clarias batrachus*. Generally, Cr levels in the tissues of *synodontis victoriae, Lates niloticus* and *Oreochromis niloticus* were significantly ($p \leq 0.05$) the same (Table 24). However, the Cr levels in the tissues of all fish species were higher than in *Oreochromis niloticus* (0.06 µg/g) from River Okumeshi in Delta State, Nigeria (Ekeanyanwu *et al*., 2010). The Cu levels in *Lates niloticus* tissues were significantly ($p \leq 0.05$) different from the levels recorded in *Clarias* *batrachus* tissues, while were not different from the levels in *Synodontis victoriae* and *Oreochromis niloticus* (Table 24). The Cu levels of 3.35 µg/g in S*ynodontis victoriae* tissues were not significantly ($p \leq 0.05$) different from 3.50 µg/g of those recorded in *Oreochromis niloticus*. The Cu levels obtained in tissues of *Lates niloticus* in this study were higher compared to levels in a study (Machiwa, 2003; Ongeri, 2008) on heavy metals in the same fish species in Lake Victoria and freshwater fish from Nigeria (Achionye-Nzeh *et al*., 2011) (Table 25).

Table 24: Seasonal heavy metal variations in concentrations (µg/g in dry weight) in different fish species obtained from Winam Gulf of Lake Victoria

Metal	Season	*L. niloticus*	*S. victoriae*	*O. niloticus*	*C. batrachus*	Mean (seasons)
Fe	Wet	35.15	36.35	35.35	37.75	36.15
	Dry	32.25	36.85	38.50	35.10	35.65
Mean (species)		33.70	36.60	36.90	36.40	
C.V. (%)		19.80				
LSD ($p \leq 0.05$)		NS				NS
Zn	Wet	42.30	38.60	40.85	32.00	38.45
	Dry	40.05	36.95	38.55	30.65	36.55
Mean (species)		41.20	37.80	39.70	31.30	
C.V. (%)		12.62				
LSD ($p \leq 0.05$)		8.70				NS
Pb	Wet	0.65	0.35	0.60	0.55	0.55
	Dry	0.60	0.40	0.60	0.50	0.50
Mean (species)		0.65	0.40	0.60	0.50	
C.V. (%)		15.10				
LSD ($p \leq 0.05$)		0.15				NS
Cr	Wet	0.90	0.70	0.80	0.60	0.75
	Dry	0.75	0.60	0.80	0.55	0.70
Mean (species)		0.80	0.65	0.80	0.55	
C.V. (%)		15.36				
LSD $P \leq 0.05$		0.20				NS
Cu	Wet	3.75	3.45	3.60	2.85	3.40
	Dry	3.55	3.25	3.40	2.85	3.25
Mean (species)		3.65	3.35	3.50	2.85	
C.V. (%)		12.75				
LSD ($p \leq 0.05$)		0.80				NS
Cd	Wet	0.70	0.70	0.70	0.55	0.65
	Dry	0.70	0.65	0.65	0.65	0.65
Mean (species)		0.70	0.65	0.65	0.60	
C.V. (%)		14.77				
LSD ($P \leq 0.05$)		NS				NS
Mn	Wet	76.15	80.55	92.65	85.00	83.60
	Dry	73.20	79.10	89.10	81.30	80.70
Mean (species)		74.70	79.85	90.85	83.15	
C.V. (%)		5.24				
LSD ($p \leq 0.05$)		7.90				NS

NS = Not significant

Therefore, Cu levels in *Lates niloticus* showed an increase. Mn levels in *Lates niloticus* tissues differed significantly ($p \leq 0.05$) from the levels in *Oreochromis niloticus* and *Clarias batrachus* tissues, while there was no significant ($p \leq 0.05$) difference between *Synodontis victoriae.*

The concentration range of Mn metal of 74.70 - 90.85 µg/g in the tissues of the studied fish species was narrow compared to a wide range of 81.50 - 132.70 µg/g in *Oreochromis niloticus* from Athi-Galana-Sabaki tributaries, Kenya (Nawiri *et al*., 2012).

The heavy metal concentrations in fish tissues varied significantly ($p \leq 0.05$) among the fish species for all analyzed metals except Fe and Cd (Table 24). The differences in metal concentrations in the different fish tissues may be attributed to the different fish species and their feeding behavior among other characteristics (Tuzen, 2003). Abiotic ecological factors such as season, place of development, nutrient availability, temperature and pH of the water may also contribute to the inconsistency of heavy metal concentrations in the fish tissue (Clearwater *et al*., 2002; Tuzen, 2003).

The Pb and Mn levels in all fish species were below the international set levels acceptable for human consumption (FAO/WHO, 2004) while Cr and Cu levels were above recommended acceptable levels by IAEA-407 (Wyse *et al.*, 2003).

The levels of all analyzed heavy metals in the fish species did not show seasonal variations (Table 24). These results contradict earlier results (Ongeri, 2008) in fish from Winam Gulf where heavy metal levels in fish showed seasonal variations. These results confirmed that the anthropogenic activities around and within the lake were causing heavy metal pollution to the analyzed fish and therefore consumption of the fish from the lake may pose health risks. This observation therefore calls for an improvement of the existing policies by putting in place appropriate mitigation measures by the relevant agencies to curb further heavy metal pollution of the lake and advice on consumption of fish from the Winam Gulf.

Table 25: Comparison of levels of heavy metals (µg/g in dry weight) in the fish species (*Oreochromis niloticus and Lates niloticus)* with data from previous similar studies

	Fish species	Pb	Cd	Cu	Zn	Fe	Mn
Onyari, 1985	*L. niloticus*	0.40-33.70	0.04-3.10	-	-	-	-
Tole and Shitsama, 2003	*O. niloticus*	3.60-20.30	0.30-1.40	-	-	-	-
	L. niloticus	13.80-15.80	0.60-0.90	-	-	-	-
Machiwa, 2003	*L. niloticus*	0.13	0.00	0.70	8.80	-	-
Ongeri, 2008	*O. niloticus*	0.61	0.21	2.70	35.90	48.00	
	L. niloticus	0.87	0.21	3.40	36.40	45.70	
Achionye-Nzeh *et al*., 2011	*L. niloticus*	-	-	0.30-0.40	0.70-0.90	5.70-5.90	0.9-8.0
	O. niloticus	-	-	0.1-0.2	0.4-0.6	5-6.0	6.4-12.6
Current study	*O. niloticus*	0.60	0.65	3.50	39.70	36.90	-
	L. niloticus	0.65	0.70	3.65	41.20	33.70	-
Ekeanyanwu *et al*., 2010	*O. niloticus*	< 0.01	0.62	-	-	-	1.97

Table 26: Comparison of heavy metal levels (µg/g in dry weight) in tissues of different fish species with national and international permissible limits

	Lates niloticus	*Synodontis victoriae*	*Oreochromis niloticus*	*Clarias batrachus*	Wyse *et al*., 2003 (IAEA-407) (µg/g)	FAO/WHO 2004 (ug/g)
Fe	33.70	36.60	36.90	36.4	146.00	nl
Zn	41.20	37.80	39.70	31.30	nl	0.30-10
Pb	0.65	0.40	0.60	0.50	0.12	0.20
Cr	0.80	0.65	0.80	0.55	0.73	0.15
Cu	3.65	3.35	3.50	2.85	3.28	nl
Cd	0.70	0.65	0.65	0.60	0.18	0.05
Mn	74.70	79.85	90.85	83.15	11.00	nl

nl = not in literature

4.1.5 Physicochemical parameters of lake water in the study area

The results of physicochemical parameters (dissolved oxygen (DO), turbidity, electrical conductivity (EC), alkalinity, pH and temperature) of water at each site (lake areas around discharge points of River Kisat, Cocacola Plant, Molasses Plant and Kisian into the lake) from three different points along distances (0 m, 50 m and 100 m) into the lake are presented in Tables 27-31(Appendix v, pg 150).

At the lake areas next to the discharge points of River Kisat and Cocacola Plant respectively, the dissolved oxygen in lake water decreased significantly ($p \leq 0.05$) as the distances increased from the shoreline into the lake while at Kisian and Molasses Plant discharge points the pattern reversed (Table 27). The levels of DO in the lake water compared well with the outcome of previous similar studies in India (Kavita and Sheela, 2012) for pond water, on wetlands of Lake Victoria Basin in Uganda (Muwanga and Barifaijo, 2006), Mwanza Gulf (Kishe, 2004) in Tanzania and Winam Gulf (Ongeri, 2008) in Kenya (Table 33).

Table 27: Seasonal and site variations in levels **(**mg/L) of dissolved oxygen in lake water at different distances in different sites along the lake shoreline

Site	Season	DISTANCE			Mean (season)	Mean (site)
		0 m	50 m	100 m		
Kisat	Wet	4.66	4.11	4.19	4.32	4.28
	Dry	4.52	4.07	4.12	4.23	
Mean (distance)		4.59	4.09	4.15		
C.V. (%)		1.54				
LSD ($p \leq 0.05$)		0.16			NS	
Cocacola	Wet	4.64	4.64	4.57	4.62	4.59
	Dry	4.58	4.58	4.54	4.57	
Mean (distance)		4.61	4.61	4.56		
C.V. (%)		0.480				
LSD ($p \leq 0.05$)		0.05			NS	
Molasses	Wet	4.54	5.55	4.19	4.761	4.61
	Dry	4.52	4.76	4.07	4.451	
Mean (distance)		4.53	5.16	4.13		
C.V. (%)		0.76				
LSD ($p \leq 0.05$)		0.12			0.21	
Kisian	Wet	4.57	4.70	6.28	5.19	4.86
	Dry	4.17	4.54	4.90	4.54	
Mean (distance)		4.37	4.62	5.59		
C.V. %		4.83				
LSD $P \leq 0.05$		0.583			NS	
Mean (season) for all 4 sites	Wet	4.60	4.75	4.81	4.72	
	Dry	4.45	4.49	4.41	4.45	
Mean (distance) for all 4 sites		4.53	4.62	4.61		
C.V. (%)		2.70				
LSD ($p \leq 0.05$)		NS			NS	0.13
Interactions ($p \leq 0.05$)		Site x Season = 0.19, Site x Distance = 0.18, Season x Distance = 0.22, Site x Season x Distance = 0.25				

NS = Not significant

However, the levels were lower than those observed in a previous study (Soltan *et al*., 2005) in Lake Nasser, Egypt. This observation suggested that the level of DO around this lake area was depleted. The low dissolved oxygen indicated possibility of high oxygen demand by the microorganisms in the wastewater and organic or inorganic materials originating from the surrounding anthropogenic activities. The levels of DO in the lake water in this study were in the range 4.30-4.90 mg/L. The levels varied significantly ($p \leq 0.05$) from one site to another (Table 27), suggesting that there were different anthropogenic activities on the adjoining land at each site or in the lake at each site. These levels were much lower than those obtained in a similar study (Ochieng, 1987) in Winam Gulf water (Table 33). Wastewater discharges are rich in organic and inorganic matter and are known to cause depletion of dissolved gases especially at the lake and sea beds due to decomposition of organic matter by biological organisms (Gindy, 2001). The recorded low amount of dissolved oxygen in water in the lake area under study is a manifestation that the area continuously receives discharges rich in organic or inorganic matter from the anthropogenic activities taking place around and within the lake.

The dissolved oxygen concentration recorded in water was below the international recommended standards for water supply conservation, fisheries and recreation (FEPA, 1991, KEBS, 1996, Ochieng *et al.*, 2008) indicating that the levels in the lake water from this site were not conducive for aquatic life and human use (Table 33). However, the level of DO in the same water was safe for industrial, agricultural and environmental conservation (Ochieng, 1987) (Table 34). The low DO obtained in this study therefore confirmed that the anthropogenic activities around and within the lakeshore were causing pollution of the lake area in Winam Gulf. There were no changes in the levels of dissolved oxygen in the lake water from the Cocacola Plant, Rivers Kisat and Kisian discharge areas with seasonal variations (Table 27) except for water from the Molasses Plant discharge area. The dissolved oxygen in water was the same ($p \leq 0.05$) in the wet and dry seasons in these three lake areas. This was in contradiction to results obtained in a study (Muniyan *et al.*, 2012) in water from Tranquebar Coastal Nagapattinam, Tamilnadu, India. The site levels of dissolved oxygen of 4.61 mg/L in Molasses Plant discharge area lake water was comparable to values obtained in a similar study (Kishe, 2004) in water from Lake Victoria in Tanzanian side which had a range of 4.00 - 9.00 mg/L. However, the dissolved oxygen levels were higher compared to values obtained in water from Kisat and Cocacola lake areas in this study (Table 27) indicating an improvement of water quality in terms of DO at Molasses discharge point. The site dissolved oxygen level was below the WHO (1998) recommended levels for aquatic life (Table 33). This observation indicated that the water from this site was not favourable for aquatic life. These results therefore confirmed that locational activities were responsible to the deterioration of the lake water quality in the study area.

The recorded alkalinity (mg/L $CaCO_3$) levels of lake water in this study are given in Table 28. The levels recorded in the lake areas around the discharge points of River Kisat, Cocacola Plant, Molasses Plant and River Kisian decreased ($p \leq 0.05$) with increased distances from the shoreline into the lake. The decrease in water alkalinity with increase in the distance into the lake from the shore suggested dilution effect. The average alkalinity level of 65.50 mg/L was comparable with 61.8 0 mg/L recorded previously (Ochieng, 1987) in Winam Gulf. However, the levels were higher than 47.80 mg/L obtained in 2008 (Ongeri, 2008) (Table 33). The alkalinity levels in these sites ranged from 54.40 - 76.20 mg/L, the lowest being for water from the lake area around the Molasses discharge point and the highest from the discharge point of River Kisat (Table 28). These results demonstrated that waste discharges into the lake through River Kisat had high levels of metallic cations compared to discharges from the three other sites.

The effluents from the Molasses Plant were contributing minimal metal cations into the lake water. These observations demonstrated that the anthropogenic activities around and within each site were different. The alkalinity levels were within the WHO (1998) recommended levels (Table 33). Thus, in terms of alkalinity, the lake water from the study area was safe for human use and aquatic life.

There were no significant ($p \leq 0.05$) seasonal differences in the water alkalinities at all sites. The anthropogenic activities around and within the discharge points into the lake were not influenced by seasonal changes.

Table 28: Seasonal levels of alkalinity (mg/L $CaCO_3$) in water at different sites in Winam Gulf of Lake Victoria

Site	Season	DISTANCE			Mean (season)	Mean (site)
		0 m	50 m	100 m		
Kisat	Wet	79.33	77.33	68.00	74.89	76.22
	Dry	81.33	80.68	70.67	77.56	
Mean (distance)		80.33	79.00	69.33		
C.V. (%)		3.35				
LSD ($p \leq 0.05$)		6.36			NS	
Cocacola	Wet	79.67	63.33	60.67	67.89	68.67
	Dry	80.33	65.00	63.00	69.44	
Mean (distance)		80.00	64.17	61.83		
C.V. (%)		2.33				
LSD ($p \leq 0.05$)		3.97			NS	
Molasses	Wet	51.67	50.67	59.00	53.78	54.44
	Dry	52.67	52.33	60.33	55.11	
Mean (distance)		52.17	51.50	59.67		
C.V. %		2.08				
LSD ($p \leq 0.05$)		2.81			NS	
Kisian	Wet	80.33	77.33	64.67	74.11	74.78
	Dry	81.00	80.00	65.33	75.44	
Mean (distance)		80.67	78.67	65.00		
C.V. (%)		2.85				
LSD ($p \leq 0.05$)		5.30			NS	
Mean (season) for all 4 sites	Wet	72.75	67.17	63.08	67.67	
	Dry	73.83	69.50	64.83	69.39	
Mean (distance) for all 4 sites		73.29	68.33	63.96		
C.V. (%)		2.81				
LSD ($p \leq 0.05$)		2.39			NS	2.04
Interactions ($p \leq 0.05$)		Site x Season = NS, Site x Distance = 2.72, Season x Distance = NS, Site x Season x Distance = NS				

NS = Not significant

These results indicated that the contributions of metal salts into the lake by the anthropogenic activities were constant and continuous. Site and distance from the shore showed significant interactions ($p \leq 0.05$) effects. Thus, the pattern of change in water alkalinities due to different site activities and distance variations of the metal ion sources to the sampling sites were not the same. This observation further demonstrates that there were unique anthropogenic activities in each site. Site and seasons had no significant interaction effects in the water alkalinities in all sites. This implied that the trend of change of the lake water alkalinity levels due to various site activities and seasonal variations were the same. Distance and season also showed no significant interactions effects. This was an indication that the pattern of change of the lake water alkalinity due to distance variations of the sources of metal salts to the sampling points and change in seasons was influenced in a similar manner.

The electrical conductivities in water from Kisat, Cocacola Plant and Kisian discharge areas did not increase ($p \leq 0.05$) with the increased distances except in water from the Molasses Plant discharge area (Table 29). The increased electrical conductivity in lake water within Molasses lake area as the distance increased to 50 m then reducing at 100 m into the lake suggested unkown source of metallic ions probably the sand harvesting along the shore that cause disturbances in sediments that may release the adsorbed metals into water. The range 171.00 - 349.00 µS/cm obtained was wide compared to 122.00 - 236.00 µS/cm in a previous study (Van *et al.,* 2002) in water from the Manly Lagoon, Sydney. However, the levels were similar with another study (Soltan *et al.*, 2005) in Lake Nasser, Egypt. Electrical conductivities differed ($p \leq 0.05$) with sites (Table 29) suggesting variations in anthropogenic activities between the sites. The lowest and highest recorded levels were obtained from the discharge points of Rivers Kisat and Kisian respectively. The average conductivity of 231.00 µS/cm was high compared with those obtained in similar studies (Ochieng, 1987; Ongeri, 2008) from Winam Gulf (Table 33). This implied increase in metallic ions in wastewater discharges into the lake with time. The levels of electrical conductivities in all sites did not change significantly ($p \leq 0.05$) with seasons (Table 29) implying the activities found in each site were responsible to the observed levels of electrical conductivity and were not significantly influenced by seasonal variations.

The significant interactions ($p \leq 0.05$) between site and distance in all the sites indicated that the patterns of change in electrical conductivities due to various site activities emitting varying levels/type of metallic ions and variations in their distances to the sampling points of water were not the same (Table 29).

Table 29: Seasonal electrical conductivity levels (µS/cm) of water from different sites of Winam Gulf of Lake Victoria.

Site	Season	DISTANCE			Mean (season)	Mean (site)
		0 m	50 m	100 m		
Kisat	Wet	347.00	347.00	340.00	344.00	349.00
	Dry	353.00	357.00	350.00	353.00	
Mean (distance)		350.00	352.00	345.00		
C.V. (%)		2.14				
LSD ($p \leq 0.05$)		NS			NS	
Cocacola	Wet	220.00	220.00	220.00	220.00	226.00
	Dry	233.00	230.00	230.00	231.00	
Mean (distance)		226.50	225.00	225.00		
C.V. (%)		2.09				
LSD ($p \leq 0.05$)		NS			NS	
Molasses	Wet	170.00	180.00	170.00	173.00	178.00
	Dry	180.00	187.00	180.00	182.00	
Mean (distance)		175.00	183.00	175.00		
C.V. (%)		1.33				
LSD ($p \leq 0.05$)		6.00			NS	
Kisian	Wet	163.00	163.00	170.00	166.00	171.00
	Dry	177.00	173.00	177.00	173.00	
Mean (distance)		170.00	168.00	173.00		
C.V. (%)		3.09				
LSD ($p \leq 0.05$)		NS			NS	
Mean (season) for all 4 sites	Wet	225.00	228.00	225.00	226.00	
	Dry	236.00	237.00	234.00	236.00	
Mean (distance) for all 4 sites		230.00	232.00	230.00		
C.V. (%)		2.28				
LSD ($p \leq 0.05$)		NS			NS	5.00
Interactions ($p \leq 0.05$)		Site x Season = NS, Site x Distance = 8.00, Season x Distance = NS, Site x Season x Distance = NS				

NS = not significant

There were no significant interaction effects between site and season, and distance and season implying the trend of change in water electrical conductivity caused by various site activities and seasonal variations was the same. And consequently, distance variations of the metal sources and seasonal variations implied a similar trend was observed.

The turbidity levels of water in lake area around the mouth of River Kisat, the Cocacola Plant and the Molasses Plant discharge points did not change ($p \leq 0.05$) as the distances increased from the shoreline into the lake except in water from River Kisian discharge point (Table 30).

Table 30: Seasonal and site variations of lake water turbidities (NTU) for different sites in Winam Gulf of Lake Victoria

Site	Season	DISTANCE			Mean (season)	Mean (site)
		0 m	50 m	100 m		
Kisat	Wet	130.86	131.44	132.62	131.64	131.21
	Dry	130.08	130.93	131.32	130.78	
Mean (distance)		130.47	131.18	131.97		
C.V. (%)		1.03				
LSD ($p \leq 0.05$)		NS			NS	
Cocacola	Wet	142.64	142.63	143.70	142.64	142.67
	Dry	142.10	142.65	142.28	142.34	
Mean (distance)		142.37	142.64	142.99		
C.V. (%)		1.00				
LSD ($p \leq 0.05$)		NS			NS	
Molasses	Wet	131.35	129.25	125.77	128.79	127.75
	Dry	127.59	127.67	124.85	126.70	
Mean (distance)		129.47	128.46	125.31		
C.V. (%)		2.13				
LSD ($p \leq 0.05$)		NS			NS	
Kisian	Wet	186.71	129.07	111.33	142.37	137.24
	Dry	158.00	128.03	110.30	132.11	
Mean (distance)		172.36	128.55	110.82		
C.V. (%)		7.69				
LSD ($p \leq 0.05$)		26.24			NS	
Mean (season) for all 4 sites	Wet	147.89	128.35	132.32	136.45	
	Dry	133.10	139.44	127.19	132.98	
Mean (distance) for all 4 sites		143.67	132.71	127.77		
C.V. (%)		4.11				
LSD ($p \leq 0.05$)		6.88			NS	5.877
Interactions ($p \leq 0.05$)		Site x Season = 8.31, Site x Distance = 7.83, Season x Distance = 9.73, Site x Season x Distance = 11.07				

NS = Not significant

This observation implied that the lake water turbidity in River Kisat, Cocacola and Molasses Plant discharge areas was uniform suggesting that the activities within the lake and the adjoining land were uniform and continuous. The observed turbidity levels in this study were higher compared to levels obtained in a previous study (Ochieng, 1987) in Winam Gulf water. Though there are no clear international and national guidelines on turbidity levels, high turbidity levels affect fish feeding, growth and gill functioning in some fish are impaired after 5-10 days of exposure to a turbidity level of 25.00 NTU (Barnes *et al*., 1998). The significant decrease in turbidity as the distance increased into the lake from the shore observed in River Kisian discharge area implied that the water transparency increased as the distance into the lake from the shoreline increased. The range of lake water turbidity levels in this study was 127.80 - 142.70 NTU.

The lowest and highest values recorded were in water from the lake areas around the Molasses and Cocacola Plant discharge points respectively. The turbidity levels in all the sites significantly ($p \leq 0.05$) differed between seasons (Table 30). This observation implied that the surface runoffs due to seasonal variations were contributing equally to change in water turbidity levels in all studied sites. This observation further demonstrated that there were different anthropogenic activities from one site to another. There were significant interaction ($p \leq 0.05$) effects of turbidities between site and season. This observation implied that the pattern of change in water turbidity levels due to different site activities and seasonal variations were not uniform. The interactions ($p \leq 0.05$) in water turbidity levels between the site and distance indicated that the different site activities and their variations in distances to sampling points caused the change in different patterns. Distance and season showed significant interaction ($p \leq 0.05$) effects. The trends of change in turbidity levels in all the sites due to distance variations of the anthropogenic activities to the sampling points and seasonal variations were not the same.

Levels of temperature in lake water from all sites decreased ($p \leq 0.05$) with increased distances from the shore into the lake except for water at the River Kisat discharge lake area (Table 31). These levels were higher compared to a study (Kishe, 2004) on water in Mwanza Gulf of Lake Victoria in Tanzania. However, the levels were lower than results recorded previously (Ongeri, 2008) on water from Winam Gulf of Lake Victoria, Kenya. The decrease in water temperatures as inshore distances increased suggested that the lake water temperatures were lower than the temperatures of discharges from the anthropogenic activities in the adjoining environment at each site. The continual drainage of anthropogenic discharges into the lake may raise the lake water temperatures with time.

Table 31: Seasonal and site temperatures (ºC) of lake water at different sites along Winam Gulf of Lake Victoria shoreline between the discharge points of Rivers Kisat and Kisian

Site	Season	DISTANCE			Mean (season)	Mean (site)
		0 m	50 m	100 m		
Kisat	Wet	26.43	25.75	26.13	26.10	26.31
	Dry	26.51	26.52	26.51	26.52	
Mean (distance)		26.47	26.14	26.32		
C.V. %		1.42				
LSD ($p \leq 0.05$)		NS			NS	
Cocacola	Wet	27.23	27.19	26.85	27.09	27.21
	Dry	27.48	27.49	27.04	27.34	
Mean (distance)		27.35	27.34	26.95		
C.V. (%)		0.33				
LSD ($p \leq 0.05$)		0.23			NS	
Molasses	Wet	25.43	25.18	25.20	25.27	25.37
	Dry	25.50	25.46	25.45	25.47	
Mean (distance)		25.46	25.32	25.32		
C.V. (%)		0.11				
LSD ($p \leq 0.05$)		0.07			0.167	
Kisian	Wet	25.24	25.11	25.17	25.17	25.30
	Dry	25.41	25.38	25.46	25.42	
Mean (distance)		25.33	25.25	25.31		
C.V. %		0.08			`	
LSD ($p \leq 0.05$)		0.05			0.24	
Mean (season) for all 4 sites	Wet	26.08	25.81	25.84	25.91	
	Dry	26.23	26.21	26.12	26.18	
Mean (distance) for all 4 sites		26.15	26.01	25.98		
C.V. (%)		0.74				
LSD ($p \leq 0.05$)		NS			NS	0.21
Interactions ($p \leq 0.05$)		Site x Season = NS, Site x Distance = 0.27, Season x Distance = 0.34, Site x Season x Distance = NS				

NS = Not significant

However, the temperatures in lake water around the River Kisat discharge area remained the same as the inshore distance increased. This observation implied that the river discharges were at the same temperatures as the lake water temperatures. The results indicated that the lake area was continuously receiving anthropogenic discharges from unknown source(s). The results therefore suggested that there is the need for identifying the sources of the discharges causing the temperature increase of the lake water at this site inorder to inform the concerned agencies to put in place relevant mitigation measures to minimize/prevent the temperature increase of the lake. The lowest water temperature of 25.3^{o}C was recorded in River Kisian discharge area and the highest of 27.20^{o}C in the Cocacola Plant discharge area. Consequently, this observation indicated that Cocacola Plant discharges had elevated temperatures which suggested the Plant may be contributing to the increased temperatures in the lake water. The lake water temperature range was within set acceptable aquatic temperature range suitable for aquatic life (WHO, 1998, FEPA, 1991).

There were no significant ($p \leq 0.05$) changes in water temperature from Kisat and Cocacola lake areas with change in seasons while water from the Molasses Plant and River Kisian discharge areas showed significant ($p \leq 0.05$) change (Table 31). The dry season recorded the highest water temperatures in all sites. The seasonal variations in water temperatures observed in Molasses Plant and River Kisian discharge points were similar to observations made in a study (Kavita and Sheela, 2012) on Bharawas Pond, Rewari, Haryana in India. The temperatures of water differed ($p \leq 0.05$) between sites (Table 31). These results demonstrated that there were variations in anthropogenic activities from one site to another.

There were no significant interaction ($p \leq 0.05$) effects between site and season. This observation indicated that the trend of change in water temperatures due to variations in site activities and seasonal variations was the same. Site and distance showed significant ($p \leq 0.05$) interactions. These results implied that the variation of site activities and the distance variations of the anthropogenic activities to the sampling points were causing the temperature changes in water in different patterns. Distance and seasons showed significant ($p \leq 0.05$) interaction effects. This observation demonstrated that the variations of distances of the anthropogenic activities to the sampling points and seasonal variations influenced the change in lake water temperatures in different patterns.

The pH of water from the lake areas around the Cocacola Plant, Molasses Plant and River Kisian discharge points decreased ($p \leq 0.05$) with increased distances into the lake from the shoreline with an exception of water from River Kisat discharge points (Table 32).

Table 32: Seasonal pH levels of lake water at different sites in Winam Gulf of Lake Victoria.

Site	Season	DISTANCE			Mean (season)	Mean (site)
		0 m	50 m	100 m		
Kisat	Wet	8.29	7.95	8.29	8.19	8.24
	Dry	8.31	8.31	8.30	8.31	
Mean (distance)		8.32	8.13	8.30		
C.V. (%)		3.00				
LSD ($p \leq 0.05$)		NS			NS	
Cocacola	Wet	8.13	8.100	8.08	8.10	8.18
	Dry	8.30	8.29	8.20	8.26	
Mean (distance)		8.22	8.19	8.14		
C.V. (%)		0.31				
LSD ($p \leq 0.05$)		0.06			0.15	
Molasses	Wet	7.97	8.00	7.94	7.97	7.99
	Dry	8.00	8.06	7.98	8.01	
Mean (distance)		7.99	8.03	7.96		
C.V. %		0.14				
LSD ($p \leq 0.05$)		0.03			NS	
Kisian	Wet	7.98	7.91	7.91	7.93	7.95
	Dry	7.99	7.96	7.96	7.97	
Mean (distance)		7.99	7.94	7.93		
C.V. (%)		0.07				
LSD ($p \leq 0.05$)		0.02			0.03	
Mean (season) for all 4 sites	Wet	8.09	7.99	8.05	8.05	
	Dry	8.15	8.16	8.11	8.14	
Mean (distance) for all 4 sites		8.12	8.07	8.08		
C.V. (%)		1.53				
LSD ($p \leq 0.05$)		NS			NS	0.13
Interactions ($p \leq 0.05$)		Site x Season = NS, Site x Distance = NS, Season x Distance = NS, Site x Season x Distance = NS				

NS = Not significant

This observation implied that the River Kisat discharge point lake water was alkaline. The pH recorded a narrow range of 8.00 - 8.20 in the lake water within the sites in the study area. The pH range recorded was narrower than the ranges of 7.10 - 8.10 and 6.50 - 8.80 reported in previous studies (Ochieng, 1987; Ongeri, 2008) in Winam Gulf of Lake Victoria respectively. However, the pH values obtained in this study were high an indication that the lake water is gradually becoming more alkaline. This observation confirmed that there has been an increase in the anthropogenic activities responsible for the elevated pH levels in the lake water. The discharges into the lake were alkaline as was demonstrated by increased pH values. The pH levels of lake water around the Cocacola Plant and River Kisian discharge areas showed significant ($p \leq 0.05$) change between seasons while pH values in water from Kisat and Molasses Plant discharge points did not change. This observation demonstrated that seasonal change in the anthropogenic activities in Cocacola Plant and River Kisian discharge points and the adjoining environments was causing change in water pH levels. Consequently, the pH levels in water around Kisat and Molasses Plant discharge points were the same ($p \leq 0.05$) during both seasons implying the anthropogenic activities in these areas were constant and continuous. Overall, the site pH levels in water from all sites were different ($p \leq 0.05$). This observation suggested that there were different activities along the channels discharging water into the lake. There were no significant interaction ($p \leq 0.05$) effects in the lake water pH levels between any two factors and distance, season and site. This observation indicated that the trend of change in water pH due to variations of the site activities, distances of the sources of the pollutants and seasonal variations was uniform. The pH values obtained in lake water in this study were within the national and international standards set by KEBS (1996), FEPA (1991) and WHO (1998) (Table 33). The lake water pH levels in this study were therefore favourable for aquatic life and domestic use.

Table 33: Comparison of physicochemical parameters of lake water with recommended national and international standards and related studies.

Study/Reference	Temperature (°C)	Electrical conductivity (µS/cm)	pH	Alkalinity (mg/L $CaCO_3$)	Dissolved oxygen (mg/L)	Turbidity (NTU)
WHO (1998)	15.00-29.40	nl	6.50-9.50	30.00-500.00	3.00-4.00	nl
FEPA(1991)	20.00-33.00	nl	6.00- 9.00	nl	6.80	nl
KEBS (1996)	nl	nl	6.50-8.50	nl	nl	5.00
Soltan *et al*., 2005. (Lake Nasser, Egypt)	nl	178.00	nl	nl	7.7.00-9.40	nl
Ochieng (1987) (Winam Gulf)	nl	129.80	7.05-8.05	61.80	7.48	10.00-37.00
Kishe, 2004 (Lake Victoria, Tanzanian side)	24.50-25.80	94.20-110.50	nl	nl	4.00-9.00	nl
Kavita and Sheela, 2012(India)	nl	nl	nl	nl	4.0-5.9	nl
Muwanga and Barifaijo, 2006 (Lake Victoria, Uganda)	nl	80.50-45000.00	5.60-9.50	nl	nl	9.74-898.40
Ongeri, 2008 (Winam Gulf)	26.00-29.00	145.30	6.50-8.80	26.00-88.00	4.95	190.40
Current study (2015)	25.30-27.21	171.00-349.00	7.95-8.24	54.44-76.22	4.28-4.86	127.75-142.67

nl= not in literature cited

Table 34: Comparing some of the limnological data of lake water with international standard requirements for living environment for lakes

Purpose of utilization	pH	Turbidity (NTU)	DO (mg/L)
Fisheries and recreation	6.50-8.50	≤ 50.00	≥ 5.00
Industrial/agricultural and conservation of the environment	6.00-8.50	≤ 100.00 No observable floating matter	≥ 2.00
Current study	7.99-8.24	127.75-142.67	4.28-4.86

Data obtained from Ochieng, (1987)

4.1.5.1 Total Organic Matter (TOM)

The amount of total organic matter in lake sediments from Kisat and Molasses discharge points decreased ($p \leq 0.05$) as the distances increased from the shoreline into the lake while in sediments from the Cocacola Plant and River Kisian discharge points did not decrease (Table 35) (Appendix vi, pg 152). The levels of organic matter in the sediments in this study showed similar trend as the results obtained previously (Machiwa *et al.*, 2003) on sediments from Mwanza Gulf (Mara and Nyikonga Bays) in Tanzania. However, the levels were higher compared to those obtained in Winam Gulf sediments (Mwamburi, 2003; Ongeri, 2008). The decrease in organic matter with the increase in distance from the shoreline into the lake at Kisat and Molasses discharge points demonstrated that there were depositions of organic matter into the lake sediments with time.

The total organic matter in sediments did not vary ($p \leq 0.05$) with seasons in all sites (Table 35). These results implied that the levels of organic matter being discharged by non-seasonal activities such as manufacturing, processing and packaging industries among others in the sediments from the sites were the same during wet and dry seasons.

Table 35: Total organic matter (g) in different lake sediments (1g dry weight each) from different sampling sites in Winam Gulf of Lake Victoria

Site	Season	DISTANCE			Mean (season)	Mean (site)
		0 m	**50 m**	**100 m**		
Kisat	Wet	0.13	0.12	0.09	0.11	0.11
	Dry	0.13	0.11	0.08	0.10	
Mean (distance)		0.13	0.11	0.08		
C.V. (%)		12.20				
LSD ($p \leq 0.05$)		0.03			NS	
Cocacola	Wet	0.26	0.25	0.19	0.23	0.22
	Dry	0.25	0.21	0.18	0.22	
Mean (distance)		0.26	0.23	0.19		
C.V. (%)		13.86				
LSD ($p \leq 0.05$)		NS			NS	
Molasses	Wet	0.09	0.08	0.04	0.07	0.06
	Dry	0.07	0.05	0.04	0.05	
Mean (distance)		0.08	0.07	0.04		
C.V. (%)		13.36				
LSD ($p \leq 0.05$)		0.02			NS	
Kisian	Wet	0.13	0.13	0.12	0.13	0.12
	Dry	0.13	0.12	0.12	0.12	
Mean (distance)		0.13	0.12	0.12		
C.V. (%)		5.44				
LSD ($p \leq 0.05$)		NS			NS	
Mean (seasons) for all 4 sites	Wet	0.15	0.14	0.11	0.14	0.13
	Dry	0.14	0.12	0.10	0.12	
Mean (distance) for all 4 sites		0.15	0.13	0.11		
C.V. (%)		13.70				
LSD ($p \leq 0.05$)		0.04			NS	0.02
Interactions ($p \leq 0.05$)		Site x distance = 0.03				

NS = Not significant

The total organic matter (g) of the sediments from the lake area recorded a range of 0.06 - 0.22 with a mean of 0.13 (Table 35). The lowest and highest values were recorded at Molasses Plant and Cocacola Plant discharge points respectively (Table 35). The observation indicated that the anthropogenic activities around and within the Cocacola Plant lake area discharged high amounts of organic matter into the lake than in Kisat, Molasses and Kisian discharge lake areas. The levels of organic matter in sediments varied significantly ($p \leq 0.05$) from one site to another (Table 35). These results indicated that within and/or around each site, the anthropogenic activities discharged different amounts of organic matter into the lake sediments. There were significant interactions ($p \leq 0.05$) effects in organic matter between site and distance in sediments from all sites (Table 35). This observation indicated that the pattern of change in levels of organic matter in sediments due to different site activities and variations in distances of these activities to the sampling points of sediments were not the same. These results implied that the various sources of organic matter at different distances to the aquatic samples (sediments) influenced the levels of organic matter in the sediments differently. In all sites, there were no significant interaction ($p \leq 0.05$) effects between site and season. This observation implied that the trend of change of organic matter in the sediments due to variations of site activities and seasonal variations were uniform. Distance and season showed no significant interactions ($p \leq 0.05$) effects in levels of organic matter in sediments from all sites. The results indicated that the levels of organic matter in sediments due to the different distances of the anthropogenic activities to the sampling points (sediments) in the different sites and seasonal variations changed in a uniform trend.

CHAPTER FIVE

SUMMARY, CONCLUSIONS, RECOMMENDATIONS AND SUGGESTIONS FOR FUTURE STUDIES

This study was set to determine the locational and seasonal variations of heavy metals (Zn, Cd, Cu, Pb, Mn, Fe and Cr) in aquatic samples and physicochemical parameters of water obtained from Lake Victoria shoreline extending from River Kisat discharge point to River Kisian discharge point. From the study, the following summary, conclusions and recommendations may be drawn:

5.1 Summary

1. Seasonal variations caused changes in Pb, Mn, Cr and Cd levels in water from River Kisat as well as Mn and Cu levels in water from Molasses Plant with wet season recording higher levels. River Kisat water had high heavy metal loads compared to levels in Molasses Plant water which had higher levels than River Kisian water. This was a reflection of the intensity of anthropogenic activities found in each site. Heavy metal levels increased ($p \leq 0.05$) downstream in all sites.
2. The heavy metal levels in lake water in the study area did not exhibit seasonal variations ($p \leq 0.05$), though in general, the levels were slightly higher in wet season showing a similar trend. There were seasonal variations ($p \leq 0.05$) in levels of Cd, Mn, Fe, Zn; Zn, Fe, Cd; Cd, Zn and Zn in sediments from River Kisat, Cocacola Plant, River Kisian and Molasses Plant discharge points respectively. High heavy metal levels in aquatic samples (water and sediments) corresponded to areas with intense anthropogenic activities and low levels to areas with minimal activities. The extent of pollution by heavy metals into the aquatic samples was dependent to the intensity of locational anthropogenic activities. The heavy

metal levels in lake water and sediments in the study area decreased from River Kisat discharge point to Cocacola Plant discharge point then to Molasses Plant discharge point and lastly River Kisian discharge point. The differences in heavy metal levels were attributed to locational activities.

3. There were no seasonal variations ($p \leq 0.05$) in levels of all analyzed heavy metals in the studied fish species though wet season recorded higher levels showing similar seasonal trend. This was an indication that anthropogenic activities were the major sources of heavy metals into the lake. Levels of heavy metals in fish from the shore of Winam Gulf near Kisumu City were above the WHO recommended acceptable levels for human consumption.
4. Seasonal variations did not change ($p \leq 0.05$) the levels of DO, alkalinity, electrical conductivity, turbidity in lake water and total organic matter in sediments from all sites. However, there were seasonal variations ($p \leq 0.05$) in water temparatures at Molasses Plant and River Kisian discharge points while variations in pH were observed in water from Cocacola Plant and River Kisian discharge points. Site variations were significantly different ($p \leq 0.05$) for all studied physicochemical parameters. The water physicochemical parameters were adversely affected more in the lake areas adjacent to areas with intense anthropogenic activities e.g. Kisat and Cocacola discharge points than areas with lesser activities e.g. Molasses Plant and Kisian discharge points. This was an indication that anthropogenic activities were a major cause of deterioration of water quality.

5.2 Conclusions

1. Anthropogenic activities along the water channels were not contributing equally to heavy metal pollution of the lake water. Seasons are not contributing significantly ($p \leq 0.05$) to the pollution of the lake whereas anthropogenic activities were the major sources of heavy metal

pollution. River Kisat was a significant polluter of the lake water while Molasses Plant and River Kisian were insignificant polluters.

2. Seasons were generally not influencing change in the heavy metal loads into the lake water and sediments. Therefore, locational anthropogenic activities were the major contributors of heavy metals into the lake water and sediments.
3. The heavy metal levels in fish were not influenced by both seasons. Thus the anthropogenic activities were the main sources of heavy metals in fish. Consumption of fish from Winam Gulf may pose health risks with respect to these heavy metals.
4. Locational anthropogenic activities were the major sources of pollutants causing deterioration of the lake water quality physicochemical parameters.

5.3 Recommendations

1. Industrial wastewater treatment and monitoring plant should be installed along River Kisat to remove/reduce heavy metal pollutants before draining into the aquatic environment since the river is the heaviest polluter in the sampled region.

2. Use of motorized boats in the lake and sand harvesting from the lake shoreline should be banned/minimized/discouraged.

3. Ban of consumption of fish from the study area is recommended until further studies confirm that levels have been controlled.

4. The existing biological wastewater methods for removal of organic waste should be enhanced to improve the efficiency.

5.4 Suggestions for future studies

1. Investigations to determine the specific anthropogenic sources of Zn in Cocacola and Kisian discharge points as well as anthropogenic sources in Kisat discharge point responsible to increased water temperatures.
2. Regular environmental monitoring of the aquatic ecosystem to determine heavy metal levels in lake water, fish and water physicochemical parameters.

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APPENDICES

Appendix i

Comparison of heavy metals in rivers during wet and dry seasons
Function: FACTOR
Experiment Model Number 3:
Three Factor Completely Randomized Design
Data case no. 1 to 54.
Factorial ANOVA for the factors:
Replication (Var 1: Rep) with values from 1 to 3
Factor A (Var 2: Site(1=R.Kisat,2=Molasses water,3=R. Kisian)) with values from 1 to 3
Factor B (Var 3:Sampling points(1=Uppermost,2=Middle,3=Mouth)) with values from 1 to 3
Factor C (Var 4: Seasons(1=Wet,2=Dry)) with values from 1 to 2

Variable 5: Cu
Grand Mean = 0.217 Grand Sum = 11.707 Total Count = 54

T A B L E O F M E A N S

1	2	3	4	5	Total
*	1	*	*	0.553	9.951
*	2	*	*	0.051	0.926
*	3	*	*	0.046	0.831
*	*	1	*	0.198	3.560
*	*	2	*	0.222	3.988
*	*	3	*	0.231	4.159
*	1	1	*	0.514	3.082
*	1	2	*	0.561	3.369
*	1	3	*	0.583	3.500
*	2	1	*	0.034	0.206
*	2	2	*	0.058	0.346
*	2	3	*	0.062	0.374
*	3	1	*	0.045	0.272
*	3	2	*	0.046	0.274
*	3	3	*	0.048	0.285
*	*	*	1	0.267	7.206
*	*	*	2	0.167	4.501
*	1	*	1	0.682	6.142
*	1	*	2	0.423	3.809
*	2	*	1	0.071	0.639
*	2	*	2	0.032	0.287
*	3	*	1	0.047	0.425
*	3	*	2	0.045	0.405
*	*	1	1	0.232	2.086
*	*	1	2	0.164	1.474
*	*	2	1	0.275	2.477
*	*	2	2	0.168	1.512
*	*	3	1	0.294	2.644
*	*	3	2	0.168	1.515
*	1	1	1	0.610	1.830
*	1	1	2	0.417	1.252
*	1	2	1	0.696	2.087
*	1	2	2	0.427	1.282
*	1	3	1	0.742	2.225
*	1	3	2	0.425	1.275

*	2	1	1	0.039	0.117
*	2	1	2	0.030	0.090
*	2	2	1	0.083	0.248
*	2	2	2	0.032	0.097
*	2	3	1	0.091	0.274
*	2	3	2	0.034	0.101
*	3	1	1	0.046	0.139
*	3	1	2	0.044	0.132
*	3	2	1	0.047	0.141
*	3	2	2	0.044	0.133
*	3	3	1	0.048	0.145
*	3	3	2	0.047	0.140

A N A L Y S I S O F V A R I A N C E T A B L E

K Value	Source	Degrees of Freedom	Sum of Squares	Mean Square	F Value	Prob
2	Factor A	2	3.049	1.524	401.0072	0.0000
4	Factor B	2	0.011	0.005	1.3929	0.2614
6	AB	4	0.007	0.002	0.4819	
8	Factor C	1	0.135	0.135	35.6377	0.0000
10	AC	2	0.174	0.087	22.8715	0.0000
12	BC	2	0.008	0.004	1.0200	0.3708
14	ABC	4	0.006	0.002	0.4009	
-15	Error	36	0.137	0.004		
	Total	53	3.527			

Coefficient of Variation: 28.44%

$s_{\bar{y}}$ for means group 2: 0.0145 Number of Observations: 18

$s_{\bar{y}}$ for means group 4: 0.0145 Number of Observations: 18

$s_{\bar{y}}$ for means group 6: 0.0252 Number of Observations: 6

$s_{\bar{y}}$ for means group 8: 0.0119 Number of Observations: 27

$s_{\bar{y}}$ for means group 10: 0.0206 Number of Observations: 9

$s_{\bar{y}}$ for means group 12: 0.0206 Number of Observations: 9

$s_{\bar{y}}$ for means group 14: 0.0356 Number of Observations: 3

===

Variable 6: Fe

Grand Mean = 1.805 Grand Sum = 97.478 Total Count = 54

T A B L E O F M E A N S

1	2	3	4	6	Total
*	1	*	*	2.157	38.818
*	2	*	*	1.686	30.347
*	3	*	*	1.573	28.312
*	*	1	*	1.557	28.026

*	*	2	*	1.712	30.811
*	*	3	*	2.147	38.640
*	1	1	*	1.933	11.598
*	1	2	*	2.066	12.394
*	1	3	*	2.471	14.825
*	2	1	*	1.470	8.821
*	2	2	*	1.663	9.980
*	2	3	*	1.924	11.547
*	3	1	*	1.268	7.607
*	3	2	*	1.406	8.437
*	3	3	*	2.045	12.268
*	*	*	1	1.980	53.465
*	*	*	2	1.630	44.013
*	1	*	1	2.301	20.711
*	1	*	2	2.012	18.107
*	2	*	1	1.976	17.780
*	2	*	2	1.396	12.568
*	3	*	1	1.664	14.975
*	3	*	2	1.482	13.337
*	*	1	1	1.738	15.638
*	*	1	2	1.377	12.389
*	*	2	1	1.866	16.797
*	*	2	2	1.557	14.014
*	*	3	1	2.337	21.030
*	*	3	2	1.957	17.610
*	1	1	1	2.148	6.443
*	1	1	2	1.719	5.156
*	1	2	1	2.174	6.521
*	1	2	2	1.958	5.873
*	1	3	1	2.582	7.747
*	1	3	2	2.359	7.078
*	2	1	1	1.710	5.130
*	2	1	2	1.230	3.691
*	2	2	1	1.957	5.871
*	2	2	2	1.369	4.108
*	2	3	1	2.259	6.778
*	2	3	2	1.589	4.768
*	3	1	1	1.355	4.065
*	3	1	2	1.181	3.542
*	3	2	1	1.468	4.405
*	3	2	2	1.344	4.032
*	3	3	1	2.168	6.505
*	3	3	2	1.921	5.763

ANALYSIS OF VARIANCE TABLE

K Value	Source	Degrees of Freedom	Sum of Squares	Mean Square	F Value	Prob
2	Factor A	2	3.449	1.725	91.1492	0.0000
4	Factor B	2	3.365	1.682	88.9208	0.0000
6	AB	4	0.262	0.065	3.4578	0.0172
8	Factor C	1	1.655	1.655	87.4506	0.0000
10	AC	2	0.380	0.190	10.0410	0.0003
12	BC	2	0.012	0.006	0.3184	
14	ABC	4	0.071	0.018	0.9339	
-15	Error	36	0.681	0.019		

Total	53	9.874

Coefficient of Variation: 7.62%

s_ for means group 2: 0.0324 Number of Observations: 18
y

s_ for means group 4: 0.0324 Number of Observations: 18
y

s_ for means group 6: 0.0562 Number of Observations: 6
y

s_ for means group 8: 0.0265 Number of Observations: 27
y

s_ for means group 10: 0.0459 Number of Observations: 9
y

s_ for means group 12: 0.0459 Number of Observations: 9
y

s_ for means group 14: 0.0794 Number of Observations: 3
y

Variable 7: Pb
Grand Mean = 0.200 Grand Sum = 10.814 Total Count = 54

T A B L E O F M E A N S

1	2	3	4	7	Total
*	1	*	*	0.491	8.843
*	2	*	*	0.069	1.251
*	3	*	*	0.040	0.720
*	*	1	*	0.177	3.189
*	*	2	*	0.200	3.593
*	*	3	*	0.224	4.031
*	1	1	*	0.438	2.626
*	1	2	*	0.491	2.945
*	1	3	*	0.545	3.272
*	2	1	*	0.064	0.384
*	2	2	*	0.068	0.408
*	2	3	*	0.076	0.458
*	3	1	*	0.030	0.179
*	3	2	*	0.040	0.240
*	3	3	*	0.050	0.302
*	*	*	1	0.242	6.537
*	*	*	2	0.158	4.277
*	1	*	1	0.606	5.458
*	1	*	2	0.376	3.385
*	2	*	1	0.076	0.686
*	2	*	2	0.063	0.564
*	3	*	1	0.044	0.393
*	3	*	2	0.036	0.327
*	*	1	1	0.216	1.947
*	*	1	2	0.138	1.243

*	*	2	1	0.240	2.157
*	*	2	2	0.160	1.436
*	*	3	1	0.270	2.434
*	*	3	2	0.178	1.598
*	1	1	1	0.547	1.641
*	1	1	2	0.328	0.985
*	1	2	1	0.604	1.811
*	1	2	2	0.378	1.134
*	1	3	1	0.669	2.006
*	1	3	2	0.422	1.266
*	2	1	1	0.069	0.208
*	2	1	2	0.059	0.176
*	2	2	1	0.071	0.214
*	2	2	2	0.065	0.194
*	2	3	1	0.088	0.263
*	2	3	2	0.065	0.194
*	3	1	1	0.033	0.098
*	3	1	2	0.027	0.082
*	3	2	1	0.044	0.131
*	3	2	2	0.036	0.108
*	3	3	1	0.055	0.164
*	3	3	2	0.046	0.137

A N A L Y S I S   O F   V A R I A N C E   T A B L E

K Value	Source	Degrees of Freedom	Sum of Squares	Mean Square	F Value	Prob
2	Factor A	2	2.295	1.147	6261.3536	0.0000
4	Factor B	2	0.020	0.010	53.7410	0.0000
6	AB	4	0.017	0.004	22.9302	0.0000
8	Factor C	1	0.095	0.095	516.4547	0.0000
10	AC	2	0.145	0.073	396.1148	0.0000
12	BC	2	0.001	0.000	1.5783	0.2203
14	ABC	4	0.000	0.000	0.3987	
-15	Error	36	0.007	0.000		
	Total	53	2.578			

Coefficient of Variation: 6.76%

$s_{\bar{y}}$ for means group 2: 0.0032 Number of Observations: 18

$s_{\bar{y}}$ for means group 4: 0.0032 Number of Observations: 18

$s_{\bar{y}}$ for means group 6: 0.0055 Number of Observations: 6

$s_{\bar{y}}$ for means group 8: 0.0026 Number of Observations: 27

$s_{\bar{y}}$ for means group 10: 0.0045 Number of Observations: 9

$s_{\bar{y}}$ for means group 12: 0.0045 Number of Observations: 9

$s_{\bar{y}}$ for means group 14: 0.0078 Number of Observations: 3

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Variable 8: Mn

Grand Mean = 1.763   Grand Sum = 95.193   Total Count = 54

T A B L E   O F   M E A N S

1	2	3	4	8	Total
*	1	*	*	4.932	88.784
*	2	*	*	0.275	4.956
*	3	*	*	0.081	1.453
*	*	1	*	1.389	25.011
*	*	2	*	1.627	29.280
*	*	3	*	2.272	40.902
*	1	1	*	3.871	23.228
*	1	2	*	4.558	27.349
*	1	3	*	6.368	38.207
*	2	1	*	0.224	1.343
*	2	2	*	0.242	1.455
*	2	3	*	0.360	2.158
*	3	1	*	0.073	0.440
*	3	2	*	0.079	0.476
*	3	3	*	0.089	0.536
*	*	*	1	2.187	59.042
*	*	*	2	1.339	36.151
*	1	*	1	6.099	54.887
*	1	*	2	3.766	33.897
*	2	*	1	0.376	3.388
*	2	*	2	0.174	1.568
*	3	*	1	0.085	0.766
*	3	*	2	0.076	0.686
*	*	1	1	1.786	16.077
*	*	1	2	0.993	8.934
*	*	2	1	2.007	18.062
*	*	2	2	1.246	11.218
*	*	3	1	2.767	24.904
*	*	3	2	1.778	15.999
*	1	1	1	4.939	14.817
*	1	1	2	2.804	8.411
*	1	2	1	5.560	16.679
*	1	2	2	3.556	10.669
*	1	3	1	7.797	23.391
*	1	3	2	4.939	14.816
*	2	1	1	0.344	1.033
*	2	1	2	0.103	0.309
*	2	2	1	0.377	1.131
*	2	2	2	0.108	0.324
*	2	3	1	0.408	1.224
*	2	3	2	0.312	0.935
*	3	1	1	0.076	0.227
*	3	1	2	0.071	0.213
*	3	2	1	0.084	0.251
*	3	2	2	0.075	0.225
*	3	3	1	0.096	0.289
*	3	3	2	0.083	0.248

A N A L Y S I S   O F   V A R I A N C E   T A B L E

K Value	Source	Degrees of Freedom	Sum of Squares	Mean Square	F Value	Prob
2	Factor A	2	271.593	135.797	2886.9790	0.0000
4	Factor B	2	7.515	3.758	79.8871	0.0000
6	AB	4	12.510	3.128	66.4915	0.0000
8	Factor C	1	9.704	9.704	206.3011	0.0000
10	AC	2	14.959	7.479	159.0091	0.0000
12	BC	2	0.138	0.069	1.4655	0.2444
14	ABC	4	0.524	0.131	2.7853	0.0410
-15	Error	36	1.693	0.047		
	Total	53	318.637			

Coefficient of Variation: 12.30%

$s_{\bar{y}}$ for means group 2: 0.0511 Number of Observations: 18

$s_{\bar{y}}$ for means group 4: 0.0511 Number of Observations: 18

$s_{\bar{y}}$ for means group 6: 0.0885 Number of Observations: 6

$s_{\bar{y}}$ for means group 8: 0.0417 Number of Observations: 27

$s_{\bar{y}}$ for means group 10: 0.0723 Number of Observations: 9

$s_{\bar{y}}$ for means group 12: 0.0723 Number of Observations: 9

$s_{\bar{y}}$ for means group 14: 0.1252 Number of Observations: 3

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Variable 9: Zn

Grand Mean = 0.470 Grand Sum = 25.386 Total Count = 54

T A B L E   O F   M E A N S

1	2	3	4	9	Total
*	1	*	*	1.016	18.292
*	2	*	*	0.196	3.532
*	3	*	*	0.198	3.562
*	*	1	*	0.444	7.983
*	*	2	*	0.474	8.531
*	*	3	*	0.493	8.872
*	1	1	*	0.961	5.769
*	1	2	*	1.037	6.223
*	1	3	*	1.050	6.301
*	2	1	*	0.189	1.132
*	2	2	*	0.198	1.190
*	2	3	*	0.202	1.210
*	3	1	*	0.180	1.082
*	3	2	*	0.186	1.119
*	3	3	*	0.227	1.361
*	*	*	1	0.515	13.905
*	*	*	2	0.425	11.482
*	1	*	1	1.142	10.274
*	1	*	2	0.891	8.018

*	2	*	1	0.203	1.823
*	2	*	2	0.190	1.709
*	3	*	1	0.201	1.807
*	3	*	2	0.195	1.755
*	*	1	1	0.479	4.307
*	*	1	2	0.408	3.676
*	*	2	1	0.519	4.671
*	*	2	2	0.429	3.860
*	*	3	1	0.547	4.927
*	*	3	2	0.438	3.945
*	1	1	1	1.059	3.176
*	1	1	2	0.864	2.592
*	1	2	1	1.158	3.475
*	1	2	2	0.916	2.748
*	1	3	1	1.208	3.623
*	1	3	2	0.893	2.678
*	2	1	1	0.189	0.568
*	2	1	2	0.188	0.564
*	2	2	1	0.209	0.626
*	2	2	2	0.188	0.564
*	2	3	1	0.210	0.629
*	2	3	2	0.194	0.582
*	3	1	1	0.187	0.562
*	3	1	2	0.173	0.520
*	3	2	1	0.190	0.570
*	3	2	2	0.183	0.549
*	3	3	1	0.225	0.675
*	3	3	2	0.229	0.686

A N A L Y S I S   O F   V A R I A N C E   T A B L E

K Value	Source	Degrees of Freedom	Sum of Squares	Mean Square	F Value	Prob
2	Factor A	2	8.053	4.026	2214.2307	0.0000
4	Factor B	2	0.022	0.011	6.1463	0.0051
6	AB	4	0.013	0.003	1.8384	0.1428
8	Factor C	1	0.109	0.109	59.7754	0.0000
10	AC	2	0.175	0.088	48.1423	0.0000
12	BC	2	0.003	0.002	0.9423	
14	ABC	4	0.008	0.002	1.1233	0.3608
-15	Error	36	0.065	0.002		
	Total	53	8.449			

Coefficient of Variation: 9.07%

$s_{\bar{y}}$ for means group 2: 0.0101 Number of Observations: 18

$s_{\bar{y}}$ for means group 4: 0.0101 Number of Observations: 18

$s_{\bar{y}}$ for means group 6: 0.0174 Number of Observations: 6

$s_{\bar{y}}$ for means group 8: 0.0082 Number of Observations: 27

$s_{\bar{y}}$ for means group 10: 0.0142 Number of Observations: 9

s_ for means group 12:   0.0142   Number of Observations: 9
y

s_ for means group 14:   0.0246   Number of Observations: 3
y

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Variable 10: Cd
Grand Mean = 0.010   Grand Sum = 0.552   Total Count = 54

T A B L E   O F   M E A N S

1	2	3	4	10	Total
*	1	*	*	0.026	0.462
*	2	*	*	0.002	0.033
*	3	*	*	0.003	0.057
*	*	1	*	0.009	0.168
*	*	2	*	0.010	0.178
*	*	3	*	0.011	0.206
*	1	1	*	0.025	0.149
*	1	2	*	0.025	0.148
*	1	3	*	0.028	0.165
*	2	1	*	0.001	0.008
*	2	2	*	0.002	0.010
*	2	3	*	0.002	0.015
*	3	1	*	0.002	0.011
*	3	2	*	0.003	0.020
*	3	3	*	0.004	0.026
*	*	*	1	0.013	0.341
*	*	*	2	0.008	0.211
*	1	*	1	0.033	0.293
*	1	*	2	0.019	0.169
*	2	*	1	0.002	0.018
*	2	*	2	0.002	0.015
*	3	*	1	0.003	0.030
*	3	*	2	0.003	0.027
*	*	1	1	0.012	0.104
*	*	1	2	0.007	0.064
*	*	2	1	0.012	0.111
*	*	2	2	0.007	0.067
*	*	3	1	0.014	0.126
*	*	3	2	0.009	0.080
*	1	1	1	0.031	0.093
*	1	1	2	0.018	0.055
*	1	2	1	0.032	0.095
*	1	2	2	0.018	0.053
*	1	3	1	0.035	0.104
*	1	3	2	0.020	0.061
*	2	1	1	0.002	0.005
*	2	1	2	0.001	0.004
*	2	2	1	0.002	0.005
*	2	2	2	0.001	0.004
*	2	3	1	0.003	0.008
*	2	3	2	0.002	0.007
*	3	1	1	0.002	0.006

*	3	1	2	0.002	0.005
*	3	2	1	0.004	0.011
*	3	2	2	0.003	0.009
*	3	3	1	0.005	0.014
*	3	3	2	0.004	0.012

A N A L Y S I S O F V A R I A N C E T A B L E

K Value	Source	Degrees of Freedom	Sum of Squares	Mean Square	F Value	Prob
2	Factor A	2	0.006	0.003	2025.2453	0.0000
4	Factor B	2	0.000	0.000	13.2249	0.0000
6	AB	4	0.000	0.000	1.5735	0.2023
8	Factor C	1	0.000	0.000	197.2183	0.0000
10	AC	2	0.001	0.000	168.8331	0.0000
12	BC	2	0.000	0.000	0.3856	
14	ABC	4	0.000	0.000	0.2124	
-15	Error	36	0.000	0.000		
	Total	53	0.007			

Coefficient of Variation: 12.36%

s_y for means group 2: 0.0003 Number of Observations: 18

s_y for means group 4: 0.0003 Number of Observations: 18

s_y for means group 6: 0.0005 Number of Observations: 6

s_y for means group 8: 0.0002 Number of Observations: 27

s_y for means group 10: 0.0004 Number of Observations: 9

s_y for means group 12: 0.0004 Number of Observations: 9

s_y for means group 14: 0.0007 Number of Observations: 3

Variable 11: Cr

Grand Mean = 0.090 Grand Sum = 4.875 Total Count = 54

T A B L E O F M E A N S

1	2	3	4	11	Total
*	1	*	*	0.145	2.619
*	2	*	*	0.077	1.379
*	3	*	*	0.049	0.877
*	*	1	*	0.078	1.398
*	*	2	*	0.086	1.546
*	*	3	*	0.107	1.930
*	1	1	*	0.126	0.755
*	1	2	*	0.143	0.855
*	1	3	*	0.168	1.009
*	2	1	*	0.071	0.423
*	2	2	*	0.073	0.439
*	2	3	*	0.086	0.517
*	3	1	*	0.037	0.220
*	3	2	*	0.042	0.253
*	3	3	*	0.067	0.405
*	*	*	1	0.101	2.717

*	*	*	2	0.080	2.157
*	1	*	1	0.169	1.518
*	1	*	2	0.122	1.100
*	2	*	1	0.080	0.724
*	2	*	2	0.073	0.655
*	3	*	1	0.053	0.475
*	3	*	2	0.045	0.402
*	*	1	1	0.086	0.773
*	*	1	2	0.069	0.625
*	*	2	1	0.097	0.870
*	*	2	2	0.075	0.677
*	*	3	1	0.119	1.074
*	*	3	2	0.095	0.856
*	1	1	1	0.144	0.433
*	1	1	2	0.107	0.322
*	1	2	1	0.167	0.501
*	1	2	2	0.118	0.354
*	1	3	1	0.195	0.584
*	1	3	2	0.142	0.425
*	2	1	1	0.073	0.220
*	2	1	2	0.068	0.204
*	2	2	1	0.076	0.227
*	2	2	2	0.070	0.211
*	2	3	1	0.092	0.277
*	2	3	2	0.080	0.240
*	3	1	1	0.040	0.121
*	3	1	2	0.033	0.099
*	3	2	1	0.047	0.141
*	3	2	2	0.037	0.112
*	3	3	1	0.071	0.213
*	3	3	2	0.064	0.192

A N A L Y S I S   O F   V A R I A N C E   T A B L E

K Value	Source	Degrees of Freedom	Sum of Squares	Mean Square	F Value	Prob
2	Factor A	2	0.089	0.045	1722.1497	0.0000
4	Factor B	2	0.008	0.004	161.7382	0.0000
6	AB	4	0.001	0.000	11.1521	0.0000
8	Factor C	1	0.006	0.006	223.9696	0.0000
10	AC	2	0.004	0.002	86.0061	0.0000
12	BC	2	0.000	0.000	2.6443	0.0848
14	ABC	4	0.000	0.000	1.3291	0.2779
-15	Error	36	0.001	0.000		
	Total	53	0.110			

Coefficient of Variation: 5.64%

$s_{\bar{y}}$ for means group 2: 0.0012 Number of Observations: 18

$s_{\bar{y}}$ for means group 4: 0.0012 Number of Observations: 18

$s_{\bar{y}}$ for means group 6: 0.0021 Number of Observations: 6

$s_{\bar{y}}$ for means group 8: 0.0010 Number of Observations: 27

s_ for means group 10: 0.0017 Number of Observations: 9
y

s_ for means group 12: 0.0017 Number of Observations: 9
y

s_ for means group 14: 0.0029 Number of Observations: 3
y

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Appendix ii

Seasonal variations in concentrations of heavy metals in lake water
Function: FACTOR
Experiment Model Number 3:
Three Factor Completely Randomized Design
Data case no. 1 to 72.
Factorial ANOVA for the factors:
Replication (Var 1: Rep) with values from 1 to 3
Factor A (Var 2: Site (1=Kisat,2=Cocacola,3=Molasses,4=Kisian)) with values from 1 to 4
Factor B (Var 3: Sampling distance(1=0m,2=50m,3=100m)) with values from 1 to 3
Factor C (Var 4: Seasons (1=Wet,2=Dry)) with values from 1 to 2
Variable 5: Pb
Grand Mean = 0.014 Grand Sum = 1.006 Total Count = 72

T A B L E O F M E A N S

1	2	3	4	5	Total
*	1	*	*	0.020	0.365
*	2	*	*	0.014	0.247
*	3	*	*	0.012	0.209
*	4	*	*	0.010	0.185
*	*	1	*	0.019	0.454
*	*	2	*	0.013	0.314
*	*	3	*	0.010	0.238
*	1	1	*	0.031	0.184
*	1	2	*	0.018	0.110
*	1	3	*	0.012	0.071
*	2	1	*	0.017	0.105
*	2	2	*	0.014	0.083
*	2	3	*	0.010	0.060
*	3	1	*	0.014	0.081
*	3	2	*	0.011	0.066
*	3	3	*	0.010	0.063
*	4	1	*	0.014	0.084
*	4	2	*	0.009	0.056
*	4	3	*	0.007	0.044
*	*	*	1	0.015	0.525
*	*	*	2	0.013	0.481
*	1	*	1	0.021	0.191
*	1	*	2	0.019	0.173
*	2	*	1	0.015	0.132
*	2	*	2	0.013	0.116
*	3	*	1	0.012	0.107
*	3	*	2	0.011	0.102
*	4	*	1	0.011	0.095
*	4	*	2	0.010	0.090

*	*	1	1	0.020	0.235
*	*	1	2	0.018	0.219
*	*	2	1	0.014	0.165
*	*	2	2	0.012	0.149
*	*	3	1	0.010	0.125
*	*	3	2	0.009	0.113
*	1	1	1	0.031	0.094
*	1	1	2	0.030	0.090
*	1	2	1	0.020	0.060
*	1	2	2	0.017	0.050
*	1	3	1	0.013	0.038
*	1	3	2	0.011	0.033
*	2	1	1	0.019	0.056
*	2	1	2	0.016	0.049
*	2	2	1	0.014	0.043
*	2	2	2	0.013	0.039
*	2	3	1	0.011	0.032
*	2	3	2	0.009	0.027
*	3	1	1	0.014	0.041
*	3	1	2	0.013	0.040
*	3	2	1	0.011	0.033
*	3	2	2	0.011	0.032
*	3	3	1	0.011	0.032
*	3	3	2	0.010	0.030
*	4	1	1	0.014	0.043
*	4	1	2	0.014	0.041
*	4	2	1	0.010	0.029
*	4	2	2	0.009	0.027
*	4	3	1	0.008	0.023
*	4	3	2	0.007	0.022

A N A L Y S I S O F V A R I A N C E T A B L E

K Value	Source	Degrees of Freedom	Sum of Squares	Mean Square	F Value	Prob
2	Factor A	3	0.001	0.000	199.4590	0.0000
4	Factor B	2	0.001	0.000	281.2939	0.0000
6	AB	6	0.000	0.000	40.7039	0.0000
8	Factor C	1	0.000	0.000	15.1320	0.0003
10	AC	3	0.000	0.000	1.5801	0.2064
12	BC	2	0.000	0.000	0.1051	
14	ABC	6	0.000	0.000	0.3239	
-15	Error	48	0.000	0.000		
	Total	71	0.003			

Coefficient of Variation: 9.52%

s_ for means group 2: 0.0003 Number of Observations: 18
y
s_ for means group 4: 0.0003 Number of Observations: 24
y
s_ for means group 6: 0.0005 Number of Observations: 6
y
s_ for means group 8: 0.0002 Number of Observations: 36
y
s_ for means group 10: 0.0004 Number of Observations: 9
y
s_ for means group 12: 0.0004 Number of Observations: 12
y
s_ for means group 14: 0.0008 Number of Observations: 3
y

Variable 6: Fe
Grand Mean = 0.353   Grand Sum = 25.435   Total Count = 72

TABLE OF MEANS

1	2	3	4	6	Total
*	1	*	*	0.450	8.106
*	2	*	*	0.341	6.141
*	3	*	*	0.255	4.588
*	4	*	*	0.367	6.600
*	*	1	*	0.435	10.440
*	*	2	*	0.348	8.356
*	*	3	*	0.277	6.638
*	1	1	*	0.578	3.467
*	1	2	*	0.436	2.617
*	1	3	*	0.337	2.022
*	2	1	*	0.384	2.303
*	2	2	*	0.333	1.998
*	2	3	*	0.307	1.839
*	3	1	*	0.327	1.963
*	3	2	*	0.244	1.462
*	3	3	*	0.194	1.163
*	4	1	*	0.451	2.707
*	4	2	*	0.380	2.278
*	4	3	*	0.269	1.614
*	*	*	1	0.370	13.323
*	*	*	2	0.336	12.112
*	1	*	1	0.462	4.162
*	1	*	2	0.438	3.944
*	2	*	1	0.368	3.313
*	2	*	2	0.314	2.827
*	3	*	1	0.271	2.441
*	3	*	2	0.239	2.147
*	4	*	1	0.378	3.406
*	4	*	2	0.355	3.193
*	*	1	1	0.449	5.393
*	*	1	2	0.421	5.048
*	*	2	1	0.362	4.346
*	*	2	2	0.334	4.011
*	*	3	1	0.299	3.585
*	*	3	2	0.254	3.054
*	1	1	1	0.590	1.770
*	1	1	2	0.566	1.697
*	1	2	1	0.445	1.334
*	1	2	2	0.428	1.283
*	1	3	1	0.353	1.058
*	1	3	2	0.321	0.964
*	2	1	1	0.404	1.212
*	2	1	2	0.364	1.091
*	2	2	1	0.355	1.064
*	2	2	2	0.311	0.934
*	2	3	1	0.346	1.037
*	2	3	2	0.267	0.802
*	3	1	1	0.348	1.045
*	3	1	2	0.306	0.918
*	3	2	1	0.259	0.777
*	3	2	2	0.228	0.685

*	3	3	1	0.206	0.619
*	3	3	2	0.181	0.544
*	4	1	1	0.455	1.366
*	4	1	2	0.447	1.341
*	4	2	1	0.390	1.170
*	4	2	2	0.370	1.109
*	4	3	1	0.290	0.871
*	4	3	2	0.248	0.744

ANALYSIS OF VARIANCE TABLE

K Value	Source	Degrees of Freedom	Sum of Squares	Mean Square	F Value	Prob
2	Factor A	3	0.350	0.117	218.3666	0.0000
4	Factor B	2	0.302	0.151	282.9572	0.0000
6	AB	6	0.048	0.008	14.9030	0.0000
8	Factor C	1	0.020	0.020	38.1365	0.0000
10	AC	3	0.003	0.001	1.6984	0.1799
12	BC	2	0.001	0.001	0.9532	
14	ABC	6	0.002	0.000	0.5093	
-15	Error	48	0.026	0.001		
	Total	71	0.751			

Coefficient of Variation: 6.54%

s_ for means group 2: 0.0054 Number of Observations: 18
y

s_ for means group 4: 0.0047 Number of Observations: 24
y

s_ for means group 6: 0.0094 Number of Observations: 6
y

s_ for means group 8: 0.0039 Number of Observations: 36
y

s_ for means group 10: 0.0077 Number of Observations: 9
y

s_ for means group 12: 0.0067 Number of Observations: 12
y

s_ for means group 14: 0.0133 Number of Observations: 3
y

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Variable 7: Cr

Grand Mean = 0.073 Grand Sum = 5.282 Total Count = 72

TABLE OF MEANS

1	2	3	4	7	Total
*	1	*	*	0.110	1.981
*	2	*	*	0.078	1.407
*	3	*	*	0.064	1.145
*	4	*	*	0.042	0.749
*	*	1	*	0.086	2.054
*	*	2	*	0.074	1.772
*	*	3	*	0.061	1.456
*	1	1	*	0.125	0.749
*	1	2	*	0.112	0.675
*	1	3	*	0.093	0.556
*	2	1	*	0.086	0.514
*	2	2	*	0.075	0.452
*	2	3	*	0.073	0.440
*	3	1	*	0.071	0.427
*	3	2	*	0.064	0.385

*	3	3	*	0.055	0.333
*	4	1	*	0.060	0.363
*	4	2	*	0.043	0.260
*	4	3	*	0.021	0.126
*	*	*	1	0.078	2.802
*	*	*	2	0.069	2.480
*	1	*	1	0.114	1.024
*	1	*	2	0.106	0.957
*	2	*	1	0.082	0.739
*	2	*	2	0.074	0.668
*	3	*	1	0.070	0.627
*	3	*	2	0.058	0.518
*	4	*	1	0.046	0.413
*	4	*	2	0.037	0.337
*	*	1	1	0.089	1.072
*	*	1	2	0.082	0.981
*	*	2	1	0.077	0.926
*	*	2	2	0.070	0.846
*	*	3	1	0.067	0.804
*	*	3	2	0.054	0.653
*	1	1	1	0.129	0.386
*	1	1	2	0.121	0.363
*	1	2	1	0.115	0.345
*	1	2	2	0.110	0.330
*	1	3	1	0.098	0.293
*	1	3	2	0.088	0.263
*	2	1	1	0.088	0.264
*	2	1	2	0.083	0.250
*	2	2	1	0.076	0.229
*	2	2	2	0.074	0.223
*	2	3	1	0.082	0.246
*	2	3	2	0.065	0.194
*	3	1	1	0.076	0.227
*	3	1	2	0.067	0.200
*	3	2	1	0.070	0.210
*	3	2	2	0.058	0.175
*	3	3	1	0.063	0.190
*	3	3	2	0.048	0.143
*	4	1	1	0.065	0.195
*	4	1	2	0.056	0.168
*	4	2	1	0.048	0.143
*	4	2	2	0.039	0.117
*	4	3	1	0.025	0.074
*	4	3	2	0.017	0.052

ANALYSIS OF VARIANCE TABLE

K Value	Source	Degrees of Freedom	Sum of Squares	Mean Square	F Value	Prob
2	Factor A	3	0.044	0.015	848.9442	0.0000
4	Factor B	2	0.007	0.004	213.1495	0.0000
6	AB	6	0.002	0.000	15.8614	0.0000
8	Factor C	1	0.001	0.001	82.8648	0.0000
10	AC	3	0.000	0.000	1.1199	0.3503
12	BC	2	0.000	0.000	3.4384	0.0402
14	ABC	6	0.000	0.000	1.3268	0.2637
-15	Error	48	0.001	0.000		

Total 71 0.056

Coefficient of Variation: 5.69%

s_ for means group 2: 0.0010 Number of Observations: 18
y
s_ for means group 4: 0.0009 Number of Observations: 24
y
s_ for means group 6: 0.0017 Number of Observations: 6
y
s_ for means group 8: 0.0007 Number of Observations: 36
y
s_ for means group 10: 0.0014 Number of Observations: 9
y
s_ for means group 12: 0.0012 Number of Observations: 12
y
s_ for means group 14: 0.0024 Number of Observations: 3
y

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Variable 8: Cd

Grand Mean = 0.713 Grand Sum = 51.300 Total Count = 72

T A B L E O F M E A N S

1	2	3	4	8	Total
*	1	*	*	1.342	24.150
*	2	*	*	1.083	19.500
*	3	*	*	0.203	3.650
*	4	*	*	0.222	4.000
*	*	1	*	1.021	24.500
*	*	2	*	0.662	15.900
*	*	3	*	0.454	10.900
*	1	1	*	2.242	13.450
*	1	2	*	1.133	6.800
*	1	3	*	0.650	3.900
*	2	1	*	1.250	7.500
*	2	2	*	1.092	6.550
*	2	3	*	0.908	5.450
*	3	1	*	0.292	1.750
*	3	2	*	0.208	1.250
*	3	3	*	0.108	0.650
*	4	1	*	0.300	1.800
*	4	2	*	0.217	1.300
*	4	3	*	0.150	0.900
*	*	*	1	0.753	27.100
*	*	*	2	0.672	24.200
*	1	*	1	1.428	12.850
*	1	*	2	1.256	11.300
*	2	*	1	1.156	10.400
*	2	*	2	1.011	9.100
*	3	*	1	0.200	1.800
*	3	*	2	0.206	1.850
*	4	*	1	0.228	2.050
*	4	*	2	0.217	1.950
*	*	1	1	1.075	12.900
*	*	1	2	0.967	11.600
*	*	2	1	0.696	8.350
*	*	2	2	0.629	7.550
*	*	3	1	0.487	5.850

*	*	3	2	0.421	5.050
*	1	1	1	2.383	7.150
*	1	1	2	2.100	6.300
*	1	2	1	1.217	3.650
*	1	2	2	1.050	3.150
*	1	3	1	0.683	2.050
*	1	3	2	0.617	1.850
*	2	1	1	1.333	4.000
*	2	1	2	1.167	3.500
*	2	2	1	1.133	3.400
*	2	2	2	1.050	3.150
*	2	3	1	1.000	3.000
*	2	3	2	0.817	2.450
*	3	1	1	0.283	0.850
*	3	1	2	0.300	0.900
*	3	2	1	0.200	0.600
*	3	2	2	0.217	0.650
*	3	3	1	0.117	0.350
*	3	3	2	0.100	0.300
*	4	1	1	0.300	0.900
*	4	1	2	0.300	0.900
*	4	2	1	0.233	0.700
*	4	2	2	0.200	0.600
*	4	3	1	0.150	0.450
*	4	3	2	0.150	0.450

A N A L Y S I S O F V A R I A N C E T A B L E

K Value	Source	Degrees of Freedom	Sum of Squares	Mean Square	F Value	Prob
2	Factor A	3	18.604	6.201	1417.4495	0.0000
4	Factor B	2	3.943	1.972	450.6666	0.0000
6	AB	6	4.567	0.761	173.9894	0.0000
8	Factor C	1	0.117	0.117	26.6984	0.0000
10	AC	3	0.111	0.037	8.4762	0.0001
12	BC	2	0.007	0.003	0.7937	
14	ABC	6	0.039	0.007	1.4921	0.2011
-15	Error	48	0.210	0.004		
	Total	71	27.599			

Coefficient of Variation: 9.28%

$s_{\bar{y}}$ for means group 2: 0.0156 Number of Observations: 18

$s_{\bar{y}}$ for means group 4: 0.0135 Number of Observations: 24

$s_{\bar{y}}$ for means group 6: 0.0270 Number of Observations: 6

$s_{\bar{y}}$ for means group 8: 0.0110 Number of Observations: 36

$s_{\bar{y}}$ for means group 10: 0.0220 Number of Observations: 9

$s_{\bar{y}}$ for means group 12: 0.0191 Number of Observations: 12

$s_{\bar{y}}$ for means group 14: 0.0382 Number of Observations: 3

Variable 9: Cu
Grand Mean = 0.036   Grand Sum = 2.587   Total Count = 72

TABLE OF MEANS

1	2	3	4	9	Total
*	1	*	*	0.055	0.990
*	2	*	*	0.049	0.889
*	3	*	*	0.024	0.427
*	4	*	*	0.016	0.280
*	*	1	*	0.050	1.205
*	*	2	*	0.040	0.960
*	*	3	*	0.018	0.422
*	1	1	*	0.068	0.407
*	1	2	*	0.070	0.418
*	1	3	*	0.028	0.165
*	2	1	*	0.067	0.402
*	2	2	*	0.055	0.331
*	2	3	*	0.026	0.156
*	3	1	*	0.035	0.207
*	3	2	*	0.023	0.140
*	3	3	*	0.013	0.080
*	4	1	*	0.031	0.188
*	4	2	*	0.012	0.071
*	4	3	*	0.004	0.021
*	*	*	1	0.039	1.412
*	*	*	2	0.033	1.175
*	1	*	1	0.063	0.563
*	1	*	2	0.048	0.428
*	2	*	1	0.052	0.470
*	2	*	2	0.047	0.419
*	3	*	1	0.025	0.227
*	3	*	2	0.022	0.200
*	4	*	1	0.017	0.152
*	4	*	2	0.014	0.128
*	*	1	1	0.052	0.622
*	*	1	2	0.049	0.583
*	*	2	1	0.047	0.569
*	*	2	2	0.033	0.391
*	*	3	1	0.018	0.220
*	*	3	2	0.017	0.202
*	1	1	1	0.070	0.209
*	1	1	2	0.066	0.198
*	1	2	1	0.090	0.270
*	1	2	2	0.049	0.148
*	1	3	1	0.028	0.083
*	1	3	2	0.027	0.082
*	2	1	1	0.068	0.204
*	2	1	2	0.066	0.198
*	2	2	1	0.061	0.183
*	2	2	2	0.049	0.148
*	2	3	1	0.028	0.083
*	2	3	2	0.024	0.073
*	3	1	1	0.036	0.107
*	3	1	2	0.033	0.100
*	3	2	1	0.026	0.077

*	3	2	2	0.021	0.063
*	3	3	1	0.014	0.043
*	3	3	2	0.012	0.037
*	4	1	1	0.034	0.102
*	4	1	2	0.029	0.086
*	4	2	1	0.013	0.039
*	4	2	2	0.011	0.032
*	4	3	1	0.004	0.011
*	4	3	2	0.003	0.010

A N A L Y S I S   O F   V A R I A N C E   T A B L E

K Value	Source	Degrees of Freedom	Sum of Squares	Mean Square	F Value	Prob
2	Factor A	3	0.020	0.007	623.4050	0.0000
4	Factor B	2	0.013	0.007	625.8216	0.0000
6	AB	6	0.003	0.000	40.6940	0.0000
8	Factor C	1	0.001	0.001	73.3826	0.0000
10	AC	3	0.000	0.000	13.9914	0.0000
12	BC	2	0.001	0.000	29.5461	0.0000
14	ABC	6	0.001	0.000	15.5983	0.0000
-15	Error	48	0.001	0.000		
	Total	71	0.039			

Coefficient of Variation: 9.09%

s_ for means group 2: 0.0008 Number of Observations: 18
y
s_ for means group 4: 0.0007 Number of Observations: 24
y
s_ for means group 6: 0.0013 Number of Observations: 6
y
s_ for means group 8: 0.0005 Number of Observations: 36
y
s_ for means group 10: 0.0011 Number of Observations: 9
y
s_ for means group 12: 0.0009 Number of Observations: 12
y
s_ for means group 14: 0.0019 Number of Observations: 3
y

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Variable 10: Mn

Grand Mean = 0.345 Grand Sum = 24.804 Total Count = 72

T A B L E   O F   M E A N S

1	2	3	4	10	Total
*	1	*	*	0.666	11.987
*	2	*	*	0.381	6.859
*	3	*	*	0.152	2.745
*	4	*	*	0.179	3.214
*	*	1	*	0.418	10.026
*	*	2	*	0.327	7.853
*	*	3	*	0.289	6.925
*	1	1	*	0.777	4.664
*	1	2	*	0.636	3.813
*	1	3	*	0.585	3.509
*	2	1	*	0.505	3.030

*	2	2	*	0.350	2.099
*	2	3	*	0.288	1.730
*	3	1	*	0.185	1.111
*	3	2	*	0.149	0.896
*	3	3	*	0.123	0.738
*	4	1	*	0.204	1.221
*	4	2	*	0.174	1.045
*	4	3	*	0.158	0.948
*	*	*	1	0.354	12.736
*	*	*	2	0.335	12.068
*	1	*	1	0.683	6.149
*	1	*	2	0.649	5.838
*	2	*	1	0.389	3.504
*	2	*	2	0.373	3.355
*	3	*	1	0.157	1.416
*	3	*	2	0.148	1.329
*	4	*	1	0.185	1.668
*	4	*	2	0.172	1.546
*	*	1	1	0.429	5.146
*	*	1	2	0.407	4.880
*	*	2	1	0.339	4.065
*	*	2	2	0.316	3.788
*	*	3	1	0.294	3.525
*	*	3	2	0.283	3.400
*	1	1	1	0.807	2.421
*	1	1	2	0.748	2.243
*	1	2	1	0.654	1.962
*	1	2	2	0.617	1.851
*	1	3	1	0.589	1.766
*	1	3	2	0.581	1.743
*	2	1	1	0.501	1.502
*	2	1	2	0.509	1.528
*	2	2	1	0.372	1.116
*	2	2	2	0.328	0.983
*	2	3	1	0.295	0.886
*	2	3	2	0.281	0.844
*	3	1	1	0.191	0.574
*	3	1	2	0.179	0.537
*	3	2	1	0.152	0.455
*	3	2	2	0.147	0.440
*	3	3	1	0.129	0.386
*	3	3	2	0.117	0.352
*	4	1	1	0.217	0.650
*	4	1	2	0.190	0.571
*	4	2	1	0.177	0.531
*	4	2	2	0.171	0.514
*	4	3	1	0.162	0.487
*	4	3	2	0.154	0.461

A N A L Y S I S O F V A R I A N C E T A B L E

K Value	Source	Degrees of Freedom	Sum of Squares	Mean Square	F Value	Prob
2	Factor A	3	3.043	1.014	702.1929	0.0000
4	Factor B	2	0.211	0.106	73.0646	0.0000
6	AB	6	0.076	0.013	8.7634	0.0000
8	Factor C	1	0.006	0.006	4.2954	0.0436
10	AC	3	0.002	0.001	0.3802	

12	BC	2	0.001	0.000	0.2064
14	ABC	6	0.004	0.001	0.4576
-15	Error	48	0.069	0.001	
	Total	71	3.412		

Coefficient of Variation: 11.03%

s_ for means group 2: 0.0090 Number of Observations: 18
y
s_ for means group 4: 0.0078 Number of Observations: 24
y
s_ for means group 6: 0.0155 Number of Observations: 6
y
s_ for means group 8: 0.0063 Number of Observations: 36
y
s_ for means group 10: 0.0127 Number of Observations: 9
y
s_ for means group 12: 0.0110 Number of Observations: 12
y
s_ for means group 14: 0.0219 Number of Observations: 3
y

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Variable 11: Zn

Grand Mean = 0.031 Grand Sum = 2.199 Total Count = 72

TABLE OF MEANS

1	2	3	4	11	Total
*	1	*	*	0.042	0.751
*	2	*	*	0.032	0.579
*	3	*	*	0.029	0.523
*	4	*	*	0.019	0.346
*	*	1	*	0.039	0.934
*	*	2	*	0.027	0.655
*	*	3	*	0.025	0.609
*	1	1	*	0.064	0.381
*	1	2	*	0.034	0.205
*	1	3	*	0.027	0.165
*	2	1	*	0.033	0.198
*	2	2	*	0.032	0.192
*	2	3	*	0.031	0.188
*	3	1	*	0.039	0.235
*	3	2	*	0.025	0.151
*	3	3	*	0.023	0.137
*	4	1	*	0.020	0.120
*	4	2	*	0.018	0.107
*	4	3	*	0.020	0.119
*	*	*	1	0.033	1.179
*	*	*	2	0.028	1.019
*	1	*	1	0.046	0.413
*	1	*	2	0.038	0.338
*	2	*	1	0.033	0.299
*	2	*	2	0.031	0.280
*	3	*	1	0.031	0.276
*	3	*	2	0.027	0.246
*	4	*	1	0.021	0.191
*	4	*	2	0.017	0.154
*	*	1	1	0.041	0.494

*	*	1	2	0.037	0.440
*	*	2	1	0.029	0.342
*	*	2	2	0.026	0.313
*	*	3	1	0.029	0.344
*	*	3	2	0.022	0.266
*	1	1	1	0.067	0.202
*	1	1	2	0.060	0.180
*	1	2	1	0.036	0.108
*	1	2	2	0.032	0.097
*	1	3	1	0.034	0.103
*	1	3	2	0.021	0.062
*	2	1	1	0.035	0.104
*	2	1	2	0.032	0.095
*	2	2	1	0.033	0.098
*	2	2	2	0.031	0.094
*	2	3	1	0.032	0.097
*	2	3	2	0.030	0.091
*	3	1	1	0.041	0.123
*	3	1	2	0.037	0.112
*	3	2	1	0.026	0.079
*	3	2	2	0.024	0.072
*	3	3	1	0.025	0.075
*	3	3	2	0.021	0.062
*	4	1	1	0.022	0.066
*	4	1	2	0.018	0.054
*	4	2	1	0.019	0.057
*	4	2	2	0.017	0.051
*	4	3	1	0.023	0.069
*	4	3	2	0.017	0.050

A N A L Y S I S   O F   V A R I A N C E   T A B L E

K Value	Source	Degrees of Freedom	Sum of Squares	Mean Square	F Value	Prob
2	Factor A	3	0.005	0.002	69.9322	0.0000
4	Factor B	2	0.003	0.001	57.7785	0.0000
6	AB	6	0.003	0.000	21.0401	0.0000
8	Factor C	1	0.000	0.000	16.0269	0.0002
10	AC	3	0.000	0.000	1.4755	0.2330
12	BC	2	0.000	0.000	1.1306	0.3313
14	ABC	6	0.000	0.000	0.3072	
-15	Error	48	0.001	0.000		
	Total	71	0.012			

Coefficient of Variation: 15.43%

s_ for means group 2: 0.0011 Number of Observations: 18
y
s_ for means group 4: 0.0010 Number of Observations: 24
y
s_ for means group 6: 0.0019 Number of Observations: 6
y
s_ for means group 8: 0.0008 Number of Observations: 36
y
s_ for means group 10: 0.0016 Number of Observations: 9
y
s_ for means group 12: 0.0014 Number of Observations: 12
y
s_ for means group 14: 0.0027 Number of Observations: 3
y

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Appendix iii

Seasonal variations of heavy metal levels in sediments
Function: FACTOR
Experiment Model Number 3:
Three Factor Completely Randomized Design
Data case no. 1 to 72.
Factorial ANOVA for the factors:
Replication (Var 1: Rep) with values from 1 to 3
Factor A (Var 2: Site(1=Kisat,2=Kisian,3=Molasses,4=Cocacola)) with values from 1 to 4
Factor B (Var 3: Sampling distances(1=0M,2=50M,3=100M)) with values from 1 to 3
Factor C (Var 4: Season (1=Wet,2=Dry)) with values from 1 to 2
Variable 6: Pb(ppm)
Grand Mean = 2.632 Grand Sum = 189.504 Total Count = 72

T A B L E O F M E A N S

1	2	3	4	6	Total
*	1	*	*	3.620	65.160
*	2	*	*	1.235	22.232
*	3	*	*	2.824	50.827
*	4	*	*	2.849	51.284
*	*	1	*	2.936	70.456
*	*	2	*	2.692	64.605
*	*	3	*	2.268	54.442
*	1	1	*	3.974	23.845
*	1	2	*	3.762	22.569
*	1	3	*	3.124	18.746
*	2	1	*	1.348	8.088
*	2	2	*	1.218	7.307
*	2	3	*	1.139	6.837
*	3	1	*	3.083	18.500
*	3	2	*	2.680	16.079
*	3	3	*	2.708	16.248
*	4	1	*	3.337	20.022
*	4	2	*	3.108	18.650
*	4	3	*	2.102	12.612
*	*	*	1	2.716	97.778
*	*	*	2	2.548	91.725
*	1	*	1	3.665	32.981
*	1	*	2	3.575	32.179
*	2	*	1	1.266	11.392
*	2	*	2	1.204	10.839
*	3	*	1	2.878	25.899
*	3	*	2	2.770	24.929
*	4	*	1	3.056	27.506
*	4	*	2	2.642	23.778
*	*	1	1	3.071	36.848
*	*	1	2	2.801	33.608
*	*	2	1	2.764	33.165
*	*	2	2	2.620	31.440
*	*	3	1	2.314	27.765
*	*	3	2	2.223	26.677
*	1	1	1	3.994	11.983
*	1	1	2	3.954	11.863
*	1	2	1	3.841	11.523
*	1	2	2	3.682	11.046

*	1	3	1	3.158	9.475
*	1	3	2	3.090	9.270
*	2	1	1	1.416	4.248
*	2	1	2	1.280	3.840
*	2	2	1	1.230	3.691
*	2	2	2	1.205	3.616
*	2	3	1	1.151	3.453
*	2	3	2	1.128	3.383
*	3	1	1	3.198	9.593
*	3	1	2	2.969	8.907
*	3	2	1	2.616	7.849
*	3	2	2	2.743	8.230
*	3	3	1	2.819	8.457
*	3	3	2	2.597	7.791
*	4	1	1	3.675	11.024
*	4	1	2	2.999	8.998
*	4	2	1	3.367	10.102
*	4	2	2	2.849	8.548
*	4	3	1	2.127	6.380
*	4	3	2	2.078	6.233

A N A L Y S I S O F V A R I A N C E T A B L E

K Value	Source	Degrees of Freedom	Sum of Squares	Mean Square	F Value	Prob
2	Factor A	3	54.206	18.069	171.6926	0.0000
4	Factor B	2	5.472	2.736	25.9967	0.0000
6	AB	6	2.798	0.466	4.4318	0.0012
8	Factor C	1	0.509	0.509	4.8357	0.0327
10	AC	3	0.368	0.123	1.1669	0.3321
12	BC	2	0.102	0.051	0.4842	
14	ABC	6	0.365	0.061	0.5778	
-15	Error	48	5.051	0.105		
	Total	71	68.872			

Coefficient of Variation: 12.33%

s_ for means group 2: 0.0765 Number of Observations: 18
y

s_ for means group 4: 0.0662 Number of Observations: 24
y

s_ for means group 6: 0.1324 Number of Observations: 6
y

s_ for means group 8: 0.0541 Number of Observations: 36
y

s_ for means group 10: 0.1081 Number of Observations: 9
y

s_ for means group 12: 0.0936 Number of Observations: 12
y

s_ for means group 14: 0.1873 Number of Observations: 3
y

==

Variable 7: Cr(ppm)

Grand Mean = 0.066 Grand Sum = 4.741 Total Count = 72

T A B L E O F M E A N S

1	2	3	4	7	Total
*	1	*	*	0.072	1.288
*	2	*	*	0.051	0.922
*	3	*	*	0.070	1.265
*	4	*	*	0.070	1.267

*	*	1	*	0.067	1.609
*	*	2	*	0.065	1.572
*	*	3	*	0.065	1.560
*	1	1	*	0.072	0.432
*	1	2	*	0.071	0.428
*	1	3	*	0.071	0.427
*	2	1	*	0.053	0.320
*	2	2	*	0.050	0.302
*	2	3	*	0.050	0.300
*	3	1	*	0.071	0.426
*	3	2	*	0.070	0.421
*	3	3	*	0.070	0.418
*	4	1	*	0.072	0.431
*	4	2	*	0.070	0.421
*	4	3	*	0.069	0.415
*	*	*	1	0.066	2.388
*	*	*	2	0.065	2.353
*	1	*	1	0.072	0.646
*	1	*	2	0.071	0.641
*	2	*	1	0.052	0.470
*	2	*	2	0.050	0.452
*	3	*	1	0.071	0.637
*	3	*	2	0.070	0.628
*	4	*	1	0.071	0.635
*	4	*	2	0.070	0.631
*	*	1	1	0.068	0.810
*	*	1	2	0.067	0.799
*	*	2	1	0.066	0.792
*	*	2	2	0.065	0.780
*	*	3	1	0.065	0.786
*	*	3	2	0.065	0.774
*	1	1	1	0.072	0.217
*	1	1	2	0.072	0.215
*	1	2	1	0.071	0.214
*	1	2	2	0.071	0.214
*	1	3	1	0.072	0.215
*	1	3	2	0.071	0.212
*	2	1	1	0.054	0.162
*	2	1	2	0.053	0.158
*	2	2	1	0.052	0.155
*	2	2	2	0.049	0.147
*	2	3	1	0.051	0.153
*	2	3	2	0.049	0.147
*	3	1	1	0.071	0.214
*	3	1	2	0.071	0.212
*	3	2	1	0.071	0.213
*	3	2	2	0.070	0.209
*	3	3	1	0.070	0.210
*	3	3	2	0.069	0.207
*	4	1	1	0.072	0.217
*	4	1	2	0.071	0.214
*	4	2	1	0.070	0.211
*	4	2	2	0.070	0.210
*	4	3	1	0.069	0.208
*	4	3	2	0.069	0.208

A N A L Y S I S   O F   V A R I A N C E   T A B L E

K Value	Source	Degrees of Freedom	Sum of Squares	Mean Square	F Value	Prob
2	Factor A	3	0.005	0.002	4586.6704	0.0000
4	Factor B	2	0.000	0.000	73.0611	0.0000
6	AB	6	0.000	0.000	6.7331	0.0000
8	Factor C	1	0.000	0.000	46.4136	0.0000
10	AC	3	0.000	0.000	5.5818	0.0023
12	BC	2	0.000	0.000	0.0048	
14	ABC	6	0.000	0.000	1.2069	0.3191
-15	Error	48	0.000	0.000		
	Total	71	0.005			

Coefficient of Variation: 0.93%

s_ for means group 2: 0.0001   Number of Observations: 18
y

s_ for means group 4: 0.0001   Number of Observations: 24
y

s_ for means group 6: 0.0003   Number of Observations: 6
y

s_ for means group 8: 0.0001   Number of Observations: 36
y

s_ for means group 10: 0.0002   Number of Observations: 9
y

s_ for means group 12: 0.0002   Number of Observations: 12
y

s_ for means group 14: 0.0004   Number of Observations: 3
y

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Variable 8: Cu(ppm)

Grand Mean = 2.903   Grand Sum = 209.016   Total Count = 72

T A B L E   O F   M E A N S

1	2	3	4	8	Total
*	1	*	*	2.457	44.235
*	2	*	*	1.427	25.690
*	3	*	*	2.372	42.697
*	4	*	*	5.355	96.394
*	*	1	*	3.356	80.548
*	*	2	*	3.104	74.491
*	*	3	*	2.249	53.977
*	1	1	*	2.919	17.511
*	1	2	*	2.627	15.763
*	1	3	*	1.827	10.960
*	2	1	*	1.533	9.198
*	2	2	*	1.416	8.498
*	2	3	*	1.332	7.995
*	3	1	*	2.696	16.177
*	3	2	*	2.351	14.108
*	3	3	*	2.069	12.411
*	4	1	*	6.277	37.662
*	4	2	*	6.020	36.121
*	4	3	*	3.768	22.611
*	*	*	1	3.024	108.882
*	*	*	2	2.781	100.134

*	1	*	1	2.583	23.247
*	1	*	2	2.332	20.988
*	2	*	1	1.589	14.303
*	2	*	2	1.265	11.388
*	3	*	1	2.418	21.764
*	3	*	2	2.326	20.933
*	4	*	1	5.508	49.568
*	4	*	2	5.203	46.826
*	*	1	1	3.468	41.619
*	*	1	2	3.244	38.929
*	*	2	1	3.272	39.259
*	*	2	2	2.936	35.231
*	*	3	1	2.334	28.004
*	*	3	2	2.164	25.973
*	1	1	1	3.150	9.450
*	1	1	2	2.687	8.061
*	1	2	1	2.736	8.208
*	1	2	2	2.519	7.556
*	1	3	1	1.863	5.589
*	1	3	2	1.790	5.371
*	2	1	1	1.704	5.112
*	2	1	2	1.362	4.086
*	2	2	1	1.606	4.817
*	2	2	2	1.227	3.681
*	2	3	1	1.458	4.374
*	2	3	2	1.207	3.620
*	3	1	1	2.775	8.324
*	3	1	2	2.618	7.854
*	3	2	1	2.387	7.160
*	3	2	2	2.316	6.948
*	3	3	1	2.093	6.280
*	3	3	2	2.044	6.131
*	4	1	1	6.244	18.733
*	4	1	2	6.310	18.929
*	4	2	1	6.358	19.075
*	4	2	2	5.682	17.046
*	4	3	1	3.920	11.760
*	4	3	2	3.617	10.851

A N A L Y S I S O F V A R I A N C E T A B L E

K Value	Source	Degrees of Freedom	Sum of Squares	Mean Square	F Value	Prob
2	Factor A	3	156.090	52.030	537.9850	0.0000
4	Factor B	2	16.160	8.080	83.5472	0.0000
6	AB	6	11.840	1.973	20.4041	0.0000
8	Factor C	1	1.063	1.063	10.9901	0.0017
10	AC	3	0.149	0.050	0.5132	
12	BC	2	0.086	0.043	0.4465	
14	ABC	6	0.466	0.078	0.8027	
-15	Error	48	4.642	0.097		
	Total	71	190.496			

Coefficient of Variation: 10.71%

s_ for means group 2: 0.0733 Number of Observations: 18
y

s_ for means group 4: 0.0635 Number of Observations: 24
y

$s_{\bar{y}}$ for means group 6: 0.1270 Number of Observations: 6

$s_{\bar{y}}$ for means group 8: 0.0518 Number of Observations: 36

$s_{\bar{y}}$ for means group 10: 0.1037 Number of Observations: 9

$s_{\bar{y}}$ for means group 12: 0.0898 Number of Observations: 12

$s_{\bar{y}}$ for means group 14: 0.1795 Number of Observations: 3

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Variable 9: Zn(ppm)

Grand Mean = 3.174 Grand Sum = 228.555 Total Count = 72

T A B L E O F M E A N S

1	2	3	4	9	Total
*	1	*	*	3.751	67.520
*	2	*	*	1.994	35.892
*	3	*	*	3.438	61.884
*	4	*	*	3.514	63.259
*	*	1	*	3.383	81.196
*	*	2	*	3.114	74.730
*	*	3	*	3.026	72.630
*	1	1	*	4.184	25.101
*	1	2	*	3.575	21.453
*	1	3	*	3.494	20.966
*	2	1	*	2.051	12.309
*	2	2	*	1.984	11.904
*	2	3	*	1.947	11.679
*	3	1	*	3.580	21.480
*	3	2	*	3.458	20.749
*	3	3	*	3.276	19.655
*	4	1	*	3.718	22.306
*	4	2	*	3.437	20.624
*	4	3	*	3.388	20.329
*	*	*	1	4.920	177.125
*	*	*	2	1.429	51.431
*	1	*	1	5.969	53.722
*	1	*	2	1.533	13.798
*	2	*	1	2.575	23.178
*	2	*	2	1.413	12.714
*	3	*	1	5.512	49.604
*	3	*	2	1.364	12.280
*	4	*	1	5.624	50.620
*	4	*	2	1.404	12.639
*	*	1	1	5.250	62.997
*	*	1	2	1.517	18.198
*	*	2	1	4.795	57.545
*	*	2	2	1.432	17.185
*	*	3	1	4.715	56.582
*	*	3	2	1.337	16.047
*	1	1	1	6.714	20.143
*	1	1	2	1.653	4.959
*	1	2	1	5.616	16.848
*	1	2	2	1.535	4.605
*	1	3	1	5.577	16.732

*	1	3	2	1.412	4.235
*	2	1	1	2.665	7.994
*	2	1	2	1.438	4.315
*	2	2	1	2.550	7.650
*	2	2	2	1.418	4.254
*	2	3	1	2.511	7.534
*	2	3	2	1.382	4.145
*	3	1	1	5.670	17.009
*	3	1	2	1.490	4.470
*	3	2	1	5.535	16.604
*	3	2	2	1.382	4.146
*	3	3	1	5.330	15.991
*	3	3	2	1.221	3.664
*	4	1	1	5.950	17.851
*	4	1	2	1.485	4.455
*	4	2	1	5.481	16.443
*	4	2	2	1.393	4.180
*	4	3	1	5.442	16.326
*	4	3	2	1.335	4.004

ANALYSIS OF VARIANCE TABLE

K Value	Source	Degrees of Freedom	Sum of Squares	Mean Square	F Value	Prob
2	Factor A	3	34.398	11.466	1642.8759	0.0000
4	Factor B	2	1.661	0.831	119.0034	0.0000
6	AB	6	0.736	0.123	17.5706	0.0000
8	Factor C	1	219.430	219.430	31440.4122	0.0000
10	AC	3	32.743	10.914	1563.8221	0.0000
12	BC	2	0.527	0.263	37.7248	0.0000
14	ABC	6	0.507	0.085	12.1160	0.0000
-15	Error	48	0.335	0.007		
	Total	71	290.336			

Coefficient of Variation: 2.63%

$s_{\bar{y}}$ for means group 2: 0.0197 Number of Observations: 18

$s_{\bar{y}}$ for means group 4: 0.0171 Number of Observations: 24

$s_{\bar{y}}$ for means group 6: 0.0341 Number of Observations: 6

$s_{\bar{y}}$ for means group 8: 0.0139 Number of Observations: 36

$s_{\bar{y}}$ for means group 10: 0.0278 Number of Observations: 9

$s_{\bar{y}}$ for means group 12: 0.0241 Number of Observations: 12

$s_{\bar{y}}$ for means group 14: 0.0482 Number of Observations: 3

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Variable 10: Fe(ppm)

Grand Mean = 27.569 Grand Sum = 1984.969 Total Count = 72

TABLE OF MEANS

1	2	3	4	10	Total
*	1	*	*	29.373	528.705
*	2	*	*	25.667	462.002
*	3	*	*	26.273	472.908
*	4	*	*	28.964	521.353
*	*	1	*	28.087	674.095

*	*	2	*	27.539	660.944
*	*	3	*	27.080	649.930
*	1	1	*	29.814	178.885
*	1	2	*	29.338	176.029
*	1	3	*	28.965	173.792
*	2	1	*	25.840	155.043
*	2	2	*	25.632	153.795
*	2	3	*	25.527	153.164
*	3	1	*	27.439	164.635
*	3	2	*	26.297	157.784
*	3	3	*	25.082	150.489
*	4	1	*	29.255	175.533
*	4	2	*	28.889	173.336
*	4	3	*	28.747	172.485
*	*	*	1	28.460	1024.557
*	*	*	2	26.678	960.412
*	1	*	1	30.401	273.611
*	1	*	2	28.344	255.094
*	2	*	1	26.021	234.193
*	2	*	2	25.312	227.809
*	3	*	1	27.516	247.640
*	3	*	2	25.030	225.268
*	4	*	1	29.901	269.113
*	4	*	2	28.027	252.241
*	*	1	1	28.982	347.787
*	*	1	2	27.192	326.309
*	*	2	1	28.438	341.259
*	*	2	2	26.640	319.685
*	*	3	1	27.959	335.511
*	*	3	2	26.202	314.418
*	1	1	1	30.818	92.454
*	1	1	2	28.810	86.431
*	1	2	1	30.437	91.312
*	1	2	2	28.239	84.716
*	1	3	1	29.948	89.845
*	1	3	2	27.982	83.946
*	2	1	1	26.306	78.917
*	2	1	2	25.375	76.126
*	2	2	1	25.933	77.798
*	2	2	2	25.332	75.997
*	2	3	1	25.826	77.478
*	2	3	2	25.229	75.686
*	3	1	1	28.721	86.162
*	3	1	2	26.158	78.473
*	3	2	1	27.547	82.642
*	3	2	2	25.048	75.143
*	3	3	1	26.279	78.837
*	3	3	2	23.884	71.652
*	4	1	1	30.085	90.254
*	4	1	2	28.426	85.278
*	4	2	1	29.836	89.507
*	4	2	2	27.943	83.829
*	4	3	1	29.784	89.351
*	4	3	2	27.711	83.134

A N A L Y S I S   O F   V A R I A N C E   T A B L E

K Value	Source	Degrees of Freedom	Sum of Squares	Mean Square	F Value	Prob
2	Factor A	3	188.961	62.987	37.6798	0.0000
4	Factor B	2	12.198	6.099	3.6486	0.0335
6	AB	6	7.784	1.297	0.7761	
8	Factor C	1	57.148	57.148	34.1869	0.0000
10	AC	3	7.787	2.596	1.5527	0.2131
12	BC	2	0.005	0.003	0.0016	
14	ABC	6	0.302	0.050	0.0301	
-15	Error	48	80.239	1.672		
	Total	71	354.424			

Coefficient of Variation: 4.69%

$s_{\bar{y}}$ for means group 2: 0.3047 Number of Observations: 18

$s_{\bar{y}}$ for means group 4: 0.2639 Number of Observations: 24

$s_{\bar{y}}$ for means group 6: 0.5278 Number of Observations: 6

$s_{\bar{y}}$ for means group 8: 0.2155 Number of Observations: 36

$s_{\bar{y}}$ for means group 10: 0.4310 Number of Observations: 9

$s_{\bar{y}}$ for means group 12: 0.3732 Number of Observations: 12

$s_{\bar{y}}$ for means group 14: 0.7465 Number of Observations: 3

===

Variable 11: Mn(ppm)

Grand Mean = 20.502 Grand Sum = 1476.167 Total Count = 72

T A B L E   O F   M E A N S

1	2	3	4	11	Total
*	1	*	*	32.624	587.240
*	2	*	*	15.845	285.212
*	3	*	*	15.267	274.804
*	4	*	*	18.273	328.910
*	*	1	*	21.341	512.187
*	*	2	*	20.391	489.385
*	*	3	*	19.775	474.595
*	1	1	*	33.060	198.359
*	1	2	*	32.629	195.777
*	1	3	*	32.184	193.104
*	2	1	*	16.134	96.803
*	2	2	*	15.729	94.374
*	2	3	*	15.672	94.034
*	3	1	*	17.287	103.722
*	3	2	*	14.934	89.602
*	3	3	*	13.580	81.480
*	4	1	*	18.884	113.302
*	4	2	*	18.272	109.631
*	4	3	*	17.663	105.977
*	*	*	1	21.360	768.962
*	*	*	2	19.645	707.205
*	1	*	1	33.430	300.868

*	1	*	2	31.819	286.372
*	2	*	1	16.191	145.718
*	2	*	2	15.499	139.494
*	3	*	1	15.860	142.744
*	3	*	2	14.673	132.061
*	4	*	1	19.959	179.632
*	4	*	2	16.586	149.278
*	*	1	1	22.241	266.890
*	*	1	2	20.441	245.297
*	*	2	1	21.222	254.661
*	*	2	2	19.560	234.724
*	*	3	1	20.618	247.411
*	*	3	2	18.932	227.184
*	1	1	1	33.814	101.443
*	1	1	2	32.305	96.916
*	1	2	1	33.397	100.190
*	1	2	2	31.862	95.587
*	1	3	1	33.079	99.236
*	1	3	2	31.290	93.869
*	2	1	1	16.591	49.772
*	2	1	2	15.677	47.031
*	2	2	1	16.023	48.068
*	2	2	2	15.436	46.307
*	2	3	1	15.959	47.878
*	2	3	2	15.385	46.156
*	3	1	1	17.997	53.990
*	3	1	2	16.577	49.732
*	3	2	1	15.469	46.407
*	3	2	2	14.398	43.195
*	3	3	1	14.116	42.347
*	3	3	2	13.044	39.133
*	4	1	1	20.562	61.685
*	4	1	2	17.206	51.617
*	4	2	1	19.999	59.997
*	4	2	2	16.545	49.635
*	4	3	1	19.317	57.950
*	4	3	2	16.009	48.026

A N A L Y S I S   O F   V A R I A N C E   T A B L E

K Value	Source	Degrees of Freedom	Sum of Squares	Mean Square	F Value	Prob
2	Factor A	3	3618.290	1206.097	3403.4670	0.0000
4	Factor B	2	29.887	14.943	42.1686	0.0000
6	AB	6	19.874	3.312	9.3470	0.0000
8	Factor C	1	52.972	52.972	149.4811	0.0000
10	AC	3	18.381	6.127	17.2899	0.0000
12	BC	2	0.065	0.033	0.0920	
14	ABC	6	0.256	0.043	0.1203	
-15	Error	48	17.010	0.354		
	Total	71	3756.735			

Coefficient of Variation: 2.90%

$s_{\bar{y}}$ for means group 2: 0.1403 Number of Observations: 18

$s_{\bar{y}}$ for means group 4: 0.1215 Number of Observations: 24

$s_{\bar{y}}$ for means group 6: 0.2430 Number of Observations: 6

s_ for means group 8: 0.0992 Number of Observations: 36
y

s_ for means group 10: 0.1984 Number of Observations: 9
y
s_ for means group 12: 0.1718 Number of Observations: 12
y
s_ for means group 14: 0.3437 Number of Observations: 3
y

==

Variable 12: Cd(ppm)
Grand Mean = 0.021 Grand Sum = 1.521 Total Count = 72

T A B L E O F M E A N S

1	2	3	4	12	Total
*	1	*	*	0.024	0.426
*	2	*	*	0.018	0.323
*	3	*	*	0.021	0.384
*	4	*	*	0.021	0.387
*	*	1	*	0.022	0.525
*	*	2	*	0.021	0.508
*	*	3	*	0.020	0.488
*	1	1	*	0.026	0.157
*	1	2	*	0.023	0.137
*	1	3	*	0.022	0.133
*	2	1	*	0.020	0.117
*	2	2	*	0.018	0.106
*	2	3	*	0.017	0.100
*	3	1	*	0.020	0.119
*	3	2	*	0.023	0.135
*	3	3	*	0.022	0.130
*	4	1	*	0.022	0.132
*	4	2	*	0.022	0.129
*	4	3	*	0.021	0.125
*	*	*	1	0.030	1.073
*	*	*	2	0.012	0.447
*	1	*	1	0.034	0.309
*	1	*	2	0.013	0.117
*	2	*	1	0.024	0.212
*	2	*	2	0.012	0.112
*	3	*	1	0.030	0.271
*	3	*	2	0.013	0.114
*	4	*	1	0.031	0.282
*	4	*	2	0.012	0.105
*	*	1	1	0.031	0.367
*	*	1	2	0.013	0.158
*	*	2	1	0.030	0.360
*	*	2	2	0.012	0.148
*	*	3	1	0.029	0.346
*	*	3	2	0.012	0.141
*	1	1	1	0.038	0.115
*	1	1	2	0.014	0.041
*	1	2	1	0.033	0.098
*	1	2	2	0.013	0.039
*	1	3	1	0.032	0.095
*	1	3	2	0.012	0.037

*	2	1	1	0.026	0.078
*	2	1	2	0.013	0.039
*	2	2	1	0.023	0.070
*	2	2	2	0.012	0.037
*	2	3	1	0.021	0.064
*	2	3	2	0.012	0.036
*	3	1	1	0.026	0.079
*	3	1	2	0.014	0.041
*	3	2	1	0.033	0.098
*	3	2	2	0.012	0.037
*	3	3	1	0.031	0.094
*	3	3	2	0.012	0.036
*	4	1	1	0.032	0.095
*	4	1	2	0.012	0.037
*	4	2	1	0.031	0.094
*	4	2	2	0.012	0.035
*	4	3	1	0.031	0.093
*	4	3	2	0.011	0.032

A N A L Y S I S   O F   V A R I A N C E   T A B L E

K Value	Source	Degrees of Freedom	Sum of Squares	Mean Square	F Value	Prob
2	Factor A	3	0.000	0.000	17.2442	0.0000
4	Factor B	2	0.000	0.000	2.4645	0.0957
6	AB	6	0.000	0.000	2.1758	0.0617
8	Factor C	1	0.005	0.005	931.2962	0.0000
10	AC	3	0.000	0.000	15.4977	0.0000
12	BC	2	0.000	0.000	0.0826	
14	ABC	6	0.000	0.000	2.4029	0.0413
-15	Error	48	0.000	0.000		
	Total	71	0.006			

Coefficient of Variation: 11.45%

$s_{\bar{y}}$ for means group 2: 0.0006 Number of Observations: 18

$s_{\bar{y}}$ for means group 4: 0.0005 Number of Observations: 24

$s_{\bar{y}}$ for means group 6: 0.0010 Number of Observations: 6

$s_{\bar{y}}$ for means group 8: 0.0004 Number of Observations: 36

$s_{\bar{y}}$ for means group 10: 0.0008 Number of Observations: 9

$s_{\bar{y}}$ for means group 12: 0.0007 Number of Observations: 12

$s_{\bar{y}}$ for means group 14: 0.0014 Number of Observations: 3

Appendix iv

Comparison of heavy metals in fish during wet and dry seasons
Function: FACTOR
Experiment Model Number 1:
Two Factor Completely Randomized Design
Data case no. 1 to 24.
Factorial ANOVA for the factors:
Replication (Var 1: REP) with values from 1 to 3
Factor A (Var 2: Fish species (1=*L. niloticus*, 2=*S.victoriae*.,3=*O. niloticus*, 4=*C. batrachus*)) with values from 1 to 4
Factor B (Var 3: Season (1=Wet,2=Dry)) with values from 1 to 2
Variable 5: Fe(ppm)
Grand Mean = 0.718 Grand Sum = 17.237 Total Count = 24

T A B L E O F M E A N S

1	2	3	5	Total
*	1	*	0.674	4.045
*	2	*	0.732	4.393
*	3	*	0.738	4.430
*	4	*	0.728	4.370
*	*	1	0.723	8.676
*	*	2	0.713	8.562
*	1	1	0.703	2.109
*	1	2	0.645	1.936
*	2	1	0.727	2.181
*	2	2	0.737	2.211
*	3	1	0.707	2.120
*	3	2	0.770	2.310
*	4	1	0.755	2.265
*	4	2	0.702	2.105

A N A L Y S I S O F V A R I A N C E T A B L E

K Value	Source	Degrees of Freedom	Sum of Squares	Mean Square	F Value	Prob
2	Factor A	3	0.016	0.005	0.2613	
4	Factor B	1	0.001	0.001	0.0268	
6	AB	3	0.015	0.005	0.2453	
-7	Error	16	0.324	0.020		
	Total	23	0.355			

Coefficient of Variation: 19.80%
s_ for means group 2: 0.0581 Number of Observations: 6
y
s_ for means group 4: 0.0411 Number of Observations: 12
y
s_ for means group 6: 0.0821 Number of Observations: 3
y

==

Variable 6: Zn(ppm)
Grand Mean = 0.750 Grand Sum = 17.998 Total Count = 24

T A B L E O F M E A N S

1	2	3	6	Total
*	1	*	0.824	4.942
*	2	*	0.756	4.535
*	3	*	0.794	4.764
*	4	*	0.626	3.757

1 2 3	7	Total
* * 1	0.769	9.226
* * 2	0.731	8.772
* 1 1	0.846	2.539
* 1 2	0.801	2.403
* 2 1	0.772	2.317
* 2 2	0.739	2.217
* 3 1	0.817	2.451
* 3 2	0.771	2.313
* 4 1	0.640	1.919
* 4 2	0.613	1.838

A N A L Y S I S O F V A R I A N C E T A B L E

K Value	Source	Degrees of Freedom	Sum of Squares	Mean Square	F Value	Prob
2	Factor A	3	0.136	0.045	5.0806	0.0116
4	Factor B	1	0.009	0.009	0.9594	
6	AB	3	0.000	0.000	0.0146	
-7	Error	16	0.143	0.009		
	Total	23	0.289			

Coefficient of Variation: 12.62%

s_ for means group 2: 0.0386 Number of Observations: 6
y

s_ for means group 4: 0.0273 Number of Observations: 12
y

s_ for means group 6: 0.0546 Number of Observations: 3
y

===

Variable 7: Pb(ppm)

Grand Mean = 0.011 Grand Sum = 0.254 Total Count = 24

T A B L E O F M E A N S

1 2 3	7	Total
* 1 *	0.013	0.076
* 2 *	0.008	0.045
* 3 *	0.012	0.072
* 4 *	0.010	0.061
* * 1	0.011	0.129
* * 2	0.010	0.126
* 1 1	0.013	0.038
* 1 2	0.012	0.037
* 2 1	0.007	0.022
* 2 2	0.008	0.023
* 3 1	0.012	0.036
* 3 2	0.012	0.036
* 4 1	0.011	0.032
* 4 2	0.010	0.030

A N A L Y S I S O F V A R I A N C E T A B L E

K Value	Source	Degrees of Freedom	Sum of Squares	Mean Square	F Value	Prob
2	Factor A	3	0.000	0.000	12.1581	0.0002
4	Factor B	1	0.000	0.000	0.1665	
6	AB	3	0.000	0.000	0.1418	
-7	Error	16	0.000	0.000		

Total 23 0.000

Coefficient of Variation: 15.10%

s_ for means group 2: 0.0007 Number of Observations: 6
y
s_ for means group 4: 0.0005 Number of Observations: 12
y
s_ for means group 6: 0.0009 Number of Observations: 3
y

===

Variable 8: Cr(ppm)

Grand Mean = 0.014 Grand Sum = 0.340 Total Count = 24

T A B L E O F M E A N S

1	2	3	8	Total
*	1	*	0.016	0.098
*	2	*	0.013	0.078
*	3	*	0.016	0.095
*	4	*	0.011	0.068
*	*	1	0.015	0.178
*	*	2	0.014	0.162
*	1	1	0.018	0.053
*	1	2	0.015	0.046
*	2	1	0.014	0.041
*	2	2	0.012	0.037
*	3	1	0.016	0.048
*	3	2	0.016	0.047
*	4	1	0.012	0.035
*	4	2	0.011	0.033

A N A L Y S I S O F V A R I A N C E T A B L E

K Value	Source	Degrees of Freedom	Sum of Squares	Mean Square	F Value	Prob
2	Factor A	3	0.000	0.000	7.1504	0.0029
4	Factor B	1	0.000	0.000	2.0623	0.1702
6	AB	3	0.000	0.000	0.2181	
-7	Error	16	0.000	0.000		
	Total	23	0.000			

Coefficient of Variation: 15.36%

s_ for means group 2: 0.0009 Number of Observations: 6
y
s_ for means group 4: 0.0006 Number of Observations: 12
y
s_ for means group 6: 0.0013 Number of Observations: 3
y

===

Variable 9: Cu(ppm)

Grand Mean = 0.067 Grand Sum = 1.604 Total Count = 24

T A B L E O F M E A N S

1	2	3	9	Total
*	1	*	0.073	0.438
*	2	*	0.067	0.402
*	3	*	0.070	0.422
*	4	*	0.057	0.341

1	2	3	10	Total
*	*	1	0.068	0.818
*	*	2	0.065	0.786
*	1	1	0.075	0.225
*	1	2	0.071	0.213
*	2	1	0.069	0.206
*	2	2	0.065	0.196
*	3	1	0.072	0.217
*	3	2	0.068	0.205
*	4	1	0.057	0.170
*	4	2	0.057	0.171

A N A L Y S I S   O F   V A R I A N C E   T A B L E

K Value	Source	Degrees of Freedom	Sum of Squares	Mean Square	F Value	Prob
2	Factor A	3	0.001	0.000	4.1368	0.0238
4	Factor B	1	0.000	0.000	0.5881	
6	AB	3	0.000	0.000	0.0893	
-7	Error	16	0.001	0.000		
	Total	23	0.002			

Coefficient of Variation: 12.75%

s_ for means group 2: 0.0035 Number of Observations: 6
y
s_ for means group 4: 0.0025 Number of Observations: 12
y
s_ for means group 6: 0.0049 Number of Observations: 3
y

===

Variable 10: Cd(ppm)

Grand Mean = 0.013 Grand Sum = 0.315 Total Count = 24

T A B L E   O F   M E A N S

1	2	3	10	Total
*	1	*	0.014	0.084
*	2	*	0.013	0.079
*	3	*	0.013	0.081
*	4	*	0.012	0.071
*	*	1	0.013	0.160
*	*	2	0.013	0.155
*	1	1	0.014	0.043
*	1	2	0.014	0.041
*	2	1	0.014	0.041
*	2	2	0.013	0.038
*	3	1	0.014	0.043
*	3	2	0.013	0.038
*	4	1	0.011	0.033
*	4	2	0.013	0.038

A N A L Y S I S   O F   V A R I A N C E   T A B L E

K Value	Source	Degrees of Freedom	Sum of Squares	Mean Square	F Value	Prob
2	Factor A	3	0.000	0.000	1.4577	0.2635
4	Factor B	1	0.000	0.000	0.3241	
6	AB	3	0.000	0.000	0.8980	
-7	Error	16	0.000	0.000		

Total 23 0.000

Coefficient of Variation: 14.77%

s_ for means group 2: 0.0008 Number of Observations: 6
y

s_ for means group 4: 0.0006 Number of Observations: 12
y

s_ for means group 6: 0.0011 Number of Observations: 3
y

===

Variable 11: Mn(ppm)

Grand Mean = 1.643 Grand Sum = 39.425 Total Count = 24

T A B L E O F M E A N S

1	2	3	11	Total
*	1	*	1.494	8.963
*	2	*	1.597	9.580
*	3	*	1.817	10.904
*	4	*	1.663	9.978
*	*	1	1.672	20.062
*	*	2	1.614	19.363
*	1	1	1.523	4.569
*	1	2	1.464	4.393
*	2	1	1.611	4.834
*	2	2	1.582	4.746
*	3	1	1.853	5.558
*	3	2	1.782	5.345
*	4	1	1.700	5.100
*	4	2	1.626	4.878

A N A L Y S I S O F V A R I A N C E T A B L E

K Value	Source	Degrees of Freedom	Sum of Squares	Mean Square	F Value	Prob
2	Factor A	3	0.331	0.110	14.8712	0.0001
4	Factor B	1	0.020	0.020	2.7431	0.1172
6	AB	3	0.002	0.001	0.0845	
-7	Error	16	0.119	0.007		
	Total	23	0.472			

Coefficient of Variation: 5.24%

s_ for means group 2: 0.0352 Number of Observations: 6
y

s_ for means group 4: 0.0249 Number of Observations: 12
y

s_ for means group 6: 0.0497 Number of Observations: 3
y

===

Appendix v

Seasonal variations of water physicochemical parameters
Function: FACTOR
Experiment Model Number 3:
Three Factor Completely Randomized Design
Data case no. 1 to 72.
Factorial ANOVA for the factors:
Replication (Var 1: Rep) with values from 1 to 3
Factor A (Var 2: Site(1=Kisat,2=Cocacola,3=Molasses,4=Kisian)) with values from 1 to 4
Factor B (Var 3: Season(1=wet,2=dry)) with values from 1 to 2
Factor C (Var 4: Sampling distance(1=0m,2=50m,3=100m)) with values from 1 to 3

Variable 5: DO
Grand Mean = 4.585 Grand Sum = 330.120 Total Count = 72

T A B L E O F M E A N S

1	2	3	4	5	Total
*	1	*	*	4.278	77.000
*	2	*	*	4.594	82.690
*	3	*	*	4.606	82.910
*	4	*	*	4.862	87.520
*	*	1	*	4.722	169.980
*	*	2	*	4.448	160.140
*	1	1	*	4.321	38.890
*	1	2	*	4.234	38.110
*	2	1	*	4.618	41.560
*	2	2	*	4.570	41.130
*	3	1	*	4.761	42.850
*	3	2	*	4.451	40.060
*	4	1	*	5.187	46.680
*	4	2	*	4.538	40.840
*	*	*	1	4.527	108.650
*	*	*	2	4.621	110.900
*	*	*	3	4.607	110.570
*	1	*	1	4.590	27.540
*	1	*	2	4.090	24.540
*	1	*	3	4.153	24.920
*	2	*	1	4.613	27.680
*	2	*	2	4.613	27.680
*	2	*	3	4.555	27.330
*	3	*	1	4.532	27.190
*	3	*	2	5.158	30.950
*	3	*	3	4.128	24.770
*	4	*	1	4.373	26.240
*	4	*	2	4.622	27.730
*	4	*	3	5.592	33.550
*	*	1	1	4.604	55.250
*	*	1	2	4.753	57.040
*	*	1	3	4.808	57.690
*	*	2	1	4.450	53.400
*	*	2	2	4.488	53.860
*	*	2	3	4.407	52.880
*	1	1	1	4.660	13.980
*	1	1	2	4.113	12.340
*	1	1	3	4.190	12.570

*	1	2	1	4.520	13.560
*	1	2	2	4.067	12.200
*	1	2	3	4.117	12.350
*	2	1	1	4.643	13.930
*	2	1	2	4.643	13.930
*	2	1	3	4.567	13.700
*	2	2	1	4.583	13.750
*	2	2	2	4.583	13.750
*	2	2	3	4.543	13.630
*	3	1	1	4.540	13.620
*	3	1	2	5.553	16.660
*	3	1	3	4.190	12.570
*	3	2	1	4.523	13.570
*	3	2	2	4.763	14.290
*	3	2	3	4.067	12.200
*	4	1	1	4.573	13.720
*	4	1	2	4.703	14.110
*	4	1	3	6.283	18.850
*	4	2	1	4.173	12.520
*	4	2	2	4.540	13.620
*	4	2	3	4.900	14.700

A N A L Y S I S O F V A R I A N C E T A B L E

K Value	Source	Degrees of Freedom	Sum of Squares	Mean Square	F Value	Prob
2	Factor A	3	3.092	1.031	67.4558	0.0000
4	Factor B	1	1.345	1.345	88.0233	0.0000
6	AB	3	1.026	0.342	22.3959	0.0000
8	Factor C	2	0.123	0.062	4.0263	0.0242
10	AC	6	8.986	1.498	98.0330	0.0000
12	BC	2	0.183	0.092	5.9943	0.0047
14	ABC	6	1.608	0.268	17.5389	0.0000
-15	Error	48	0.733	0.015		
	Total	71	17.097			

Coefficient of Variation: 2.70%

s_ for means group 2: 0.0291 Number of Observations: 18
y

s_ for means group 4: 0.0206 Number of Observations: 36
y

s_ for means group 6: 0.0412 Number of Observations: 9
y

s_ for means group 8: 0.0252 Number of Observations: 24
y

s_ for means group 10: 0.0505 Number of Observations: 6
y

s_ for means group 12: 0.0357 Number of Observations: 12
y

s_ for means group 14: 0.0714 Number of Observations: 3
y

==

Variable 6: Alkalinity

Grand Mean = 68.528 Grand Sum = 4934.000 Total Count = 72

T A B L E O F M E A N S

1	2	3	4	6	Total
*	1	*	*	76.222	1372.000

*	2	*	*	68.667	1236.000
*	3	*	*	54.444	980.000
*	4	*	*	74.778	1346.000
*	*	1	*	67.667	2436.000
*	*	2	*	69.389	2498.000
*	1	1	*	74.889	674.000
*	1	2	*	77.556	698.000
*	2	1	*	67.889	611.000
*	2	2	*	69.444	625.000
*	3	1	*	53.778	484.000
*	3	2	*	55.111	496.000
*	4	1	*	74.111	667.000
*	4	2	*	75.444	679.000
*	*	*	1	73.292	1759.000
*	*	*	2	68.333	1640.000
*	*	*	3	63.958	1535.000
*	1	*	1	80.333	482.000
*	1	*	2	79.000	474.000
*	1	*	3	69.333	416.000
*	2	*	1	80.000	480.000
*	2	*	2	64.167	385.000
*	2	*	3	61.833	371.000
*	3	*	1	52.167	313.000
*	3	*	2	51.500	309.000
*	3	*	3	59.667	358.000
*	4	*	1	80.667	484.000
*	4	*	2	78.667	472.000
*	4	*	3	65.000	390.000
*	*	1	1	72.750	873.000
*	*	1	2	67.167	806.000
*	*	1	3	63.083	757.000
*	*	2	1	73.833	886.000
*	*	2	2	69.500	834.000
*	*	2	3	64.833	778.000
*	1	1	1	79.333	238.000
*	1	1	2	77.333	232.000
*	1	1	3	68.000	204.000
*	1	2	1	81.333	244.000
*	1	2	2	80.667	242.000
*	1	2	3	70.667	212.000
*	2	1	1	79.667	239.000
*	2	1	2	63.333	190.000
*	2	1	3	60.667	182.000
*	2	2	1	80.333	241.000
*	2	2	2	65.000	195.000
*	2	2	3	63.000	189.000
*	3	1	1	51.667	155.000
*	3	1	2	50.667	152.000
*	3	1	3	59.000	177.000
*	3	2	1	52.667	158.000
*	3	2	2	52.333	157.000
*	3	2	3	60.333	181.000
*	4	1	1	80.333	241.000
*	4	1	2	77.333	232.000
*	4	1	3	64.667	194.000
*	4	2	1	81.000	243.000

*	4	2	2	80.000	240.000
*	4	2	3	65.333	196.000

A N A L Y S I S   O F   V A R I A N C E   T A B L E

K Value	Source	Degrees of Freedom	Sum of Squares	Mean Square	F Value	Prob
2	Factor A	3	5339.278	1779.759	479.9351	0.0000
4	Factor B	1	53.389	53.389	14.3970	0.0004
6	AB	3	5.500	1.833	0.4944	
8	Factor C	2	1046.694	523.347	141.1273	0.0000
10	AC	6	1677.306	279.551	75.3845	0.0000
12	BC	2	4.694	2.347	0.6330	
14	ABC	6	3.083	0.514	0.1386	
-15	Error	48	178.000	3.708		
	Total	71	8307.944			

Coefficient of Variation: 2.81%

s_ for means group 2: 0.4539 Number of Observations: 18
y
s_ for means group 4: 0.3210 Number of Observations: 36
y
s_ for means group 6: 0.6419 Number of Observations: 9
y
s_ for means group 8: 0.3931 Number of Observations: 24
y
s_ for means group 10: 0.7862 Number of Observations: 6
y
s_ for means group 12: 0.5559 Number of Observations: 12
y
s_ for means group 14: 1.1118 Number of Observations: 3
y

===

Variable 7: EC

Grand Mean = 0.231 Grand Sum = 16.610 Total Count = 72

T A B L E   O F   M E A N S

1	2	3	4	7	Total
*	1	*	*	0.349	6.280
*	2	*	*	0.226	4.060
*	3	*	*	0.178	3.200
*	4	*	*	0.171	3.070
*	*	1	*	0.226	8.130
*	*	2	*	0.236	8.480
*	1	1	*	0.344	3.100
*	1	2	*	0.353	3.180
*	2	1	*	0.220	1.980
*	2	2	*	0.231	2.080
*	3	1	*	0.173	1.560
*	3	2	*	0.182	1.640
*	4	1	*	0.166	1.490
*	4	2	*	0.176	1.580
*	*	*	1	0.230	5.530
*	*	*	2	0.232	5.570
*	*	*	3	0.230	5.510
*	1	*	1	0.350	2.100

*	1	*	2	0.352	2.110
*	1	*	3	0.345	2.070
*	2	*	1	0.227	1.360
*	2	*	2	0.225	1.350
*	2	*	3	0.225	1.350
*	3	*	1	0.175	1.050
*	3	*	2	0.183	1.100
*	3	*	3	0.175	1.050
*	4	*	1	0.170	1.020
*	4	*	2	0.168	1.010
*	4	*	3	0.173	1.040
*	*	1	1	0.225	2.700
*	*	1	2	0.228	2.730
*	*	1	3	0.225	2.700
*	*	2	1	0.236	2.830
*	*	2	2	0.237	2.840
*	*	2	3	0.234	2.810
*	1	1	1	0.347	1.040
*	1	1	2	0.347	1.040
*	1	1	3	0.340	1.020
*	1	2	1	0.353	1.060
*	1	2	2	0.357	1.070
*	1	2	3	0.350	1.050
*	2	1	1	0.220	0.660
*	2	1	2	0.220	0.660
*	2	1	3	0.220	0.660
*	2	2	1	0.233	0.700
*	2	2	2	0.230	0.690
*	2	2	3	0.230	0.690
*	3	1	1	0.170	0.510
*	3	1	2	0.180	0.540
*	3	1	3	0.170	0.510
*	3	2	1	0.180	0.540
*	3	2	2	0.187	0.560
*	3	2	3	0.180	0.540
*	4	1	1	0.163	0.490
*	4	1	2	0.163	0.490
*	4	1	3	0.170	0.510
*	4	2	1	0.177	0.530
*	4	2	2	0.173	0.520
*	4	2	3	0.177	0.530

A N A L Y S I S   O F   V A R I A N C E   T A B L E

K Value	Source	Degrees of Freedom	Sum of Squares	Mean Square	F Value	Prob
2	Factor A	3	0.367	0.122	4409.2491	0.0000
4	Factor B	1	0.002	0.002	61.2500	0.0000
6	AB	3	0.000	0.000	0.1833	
8	Factor C	2	0.000	0.000	1.4000	0.2565
10	AC	6	0.000	0.000	2.6000	0.0291
12	BC	2	0.000	0.000	0.2000	
14	ABC	6	0.000	0.000	0.3333	
-15	Error	48	0.001	0.000		
	Total	71	0.371			

Coefficient of Variation: 2.28%

s_ for means group 2: 0.0012 Number of Observations: 18
y

s_ for means group 4: 0.0009 Number of Observations: 36
y
s_ for means group 6: 0.0018 Number of Observations: 9
y
s_ for means group 8: 0.0011 Number of Observations: 24
y
s_ for means group 10: 0.0022 Number of Observations: 6
y
s_ for means group 12: 0.0015 Number of Observations: 12
y
s_ for means group 14: 0.0030 Number of Observations: 3
y

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Variable 8: Turbidity
Grand Mean = 134.715 Grand Sum = 9699.490 Total Count = 72

T A B L E O F M E A N S

1	2	3	4	8	Total
*	1	*	*	131.207	2361.730
*	2	*	*	142.666	2567.980
*	3	*	*	127.747	2299.440
*	4	*	*	137.241	2470.340
*	*	1	*	136.446	4912.060
*	*	2	*	132.984	4787.430
*	1	1	*	131.637	1184.730
*	1	2	*	130.778	1177.000
*	2	1	*	142.988	1286.890
*	2	2	*	142.343	1281.090
*	3	1	*	128.789	1159.100
*	3	2	*	126.704	1140.340
*	4	1	*	142.371	1281.340
*	4	2	*	132.111	1189.000
*	*	*	1	143.666	3447.990
*	*	*	2	132.708	3184.990
*	*	*	3	127.771	3066.510
*	1	*	1	130.470	782.820
*	1	*	2	131.183	787.100
*	1	*	3	131.968	791.810
*	2	*	1	142.368	854.210
*	2	*	2	142.638	855.830
*	2	*	3	142.990	857.940
*	3	*	1	129.468	776.810
*	3	*	2	128.462	770.770
*	3	*	3	125.310	751.860
*	4	*	1	172.358	1034.150
*	4	*	2	128.548	771.290
*	4	*	3	110.817	664.900
*	*	1	1	147.888	1774.660
*	*	1	2	133.097	1597.160
*	*	1	3	128.353	1540.240
*	*	2	1	139.444	1673.330
*	*	2	2	132.319	1587.830
*	*	2	3	127.189	1526.270
*	1	1	1	130.857	392.570
*	1	1	2	131.437	394.310

*	1	1	3	132.617	397.850
*	1	2	1	130.083	390.250
*	1	2	2	130.930	392.790
*	1	2	3	131.320	393.960
*	2	1	1	142.637	427.910
*	2	1	2	142.630	427.890
*	2	1	3	143.697	431.090
*	2	2	1	142.100	426.300
*	2	2	2	142.647	427.940
*	2	2	3	142.283	426.850
*	3	1	1	131.347	394.040
*	3	1	2	129.250	387.750
*	3	1	3	125.770	377.310
*	3	2	1	127.590	382.770
*	3	2	2	127.673	383.020
*	3	2	3	124.850	374.550
*	4	1	1	186.713	560.140
*	4	1	2	129.070	387.210
*	4	1	3	111.330	333.990
*	4	2	1	158.003	474.010
*	4	2	2	128.027	384.080
*	4	2	3	110.303	330.910

A N A L Y S I S   O F   V A R I A N C E   T A B L E

K Value	Source	Degrees of Freedom	Sum of Squares	Mean Square	F Value	Prob
2	Factor A	3	2348.186	782.729	25.4951	0.0000
4	Factor B	1	215.731	215.731	7.0268	0.0108
6	AB	3	282.714	94.238	3.0695	0.0366
8	Factor C	2	3176.854	1588.427	51.7384	0.0000
10	AC	6	8929.737	1488.289	48.4767	0.0000
12	BC	2	223.851	111.926	3.6457	0.0336
14	ABC	6	550.714	91.786	2.9897	0.0146
-15	Error	48	1473.654	30.701		
	Total	71	17201.441			

Coefficient of Variation: 4.11%

s_ for means group 2: 1.3060 Number of Observations: 18
y
s_ for means group 4: 0.9235 Number of Observations: 36
y
s_ for means group 6: 1.8470 Number of Observations: 9
y
s_ for means group 8: 1.1310 Number of Observations: 24
y
s_ for means group 10: 2.2620 Number of Observations: 6
y
s_ for means group 12: 1.5995 Number of Observations: 12
y
s_ for means group 14: 3.1990 Number of Observations: 3
y

Variable 9: Temperature

Grand Mean = 26.047 Grand Sum = 1875.350 Total Count = 72

TABLE OF MEANS

1	2	3	4	9	Total
*	1	*	*	26.310	473.580
*	2	*	*	27.213	489.830
*	3	*	*	25.368	456.630
*	4	*	*	25.295	455.310
*	*	1	*	25.909	932.720
*	*	2	*	26.184	942.630
*	1	1	*	26.103	234.930
*	1	2	*	26.517	238.650
*	2	1	*	27.090	243.810
*	2	2	*	27.336	246.020
*	3	1	*	25.268	227.410
*	3	2	*	25.469	229.220
*	4	1	*	25.174	226.570
*	4	2	*	25.416	228.740
*	*	*	1	26.153	627.670
*	*	*	2	26.010	624.250
*	*	*	3	25.976	623.430
*	1	*	1	26.472	158.830
*	1	*	2	26.137	156.820
*	1	*	3	26.322	157.930
*	2	*	1	27.352	164.110
*	2	*	2	27.340	164.040
*	2	*	3	26.947	161.680
*	3	*	1	25.463	152.780
*	3	*	2	25.318	151.910
*	3	*	3	25.323	151.940
*	4	*	1	25.325	151.950
*	4	*	2	25.247	151.480
*	4	*	3	25.313	151.880
*	*	1	1	26.081	312.970
*	*	1	2	25.808	309.700
*	*	1	3	25.838	310.050
*	*	2	1	26.225	314.700
*	*	2	2	26.212	314.550
*	*	2	3	26.115	313.380
*	1	1	1	26.430	79.290
*	1	1	2	25.750	77.250
*	1	1	3	26.130	78.390
*	1	2	1	26.513	79.540
*	1	2	2	26.523	79.570
*	1	2	3	26.513	79.540
*	2	1	1	27.227	81.680
*	2	1	2	27.193	81.580
*	2	1	3	26.850	80.550
*	2	2	1	27.477	82.430
*	2	2	2	27.487	82.460
*	2	2	3	27.043	81.130
*	3	1	1	25.427	76.280
*	3	1	2	25.177	75.530
*	3	1	3	25.200	75.600

*	3	2	1	25.500	76.500
*	3	2	2	25.460	76.380
*	3	2	3	25.447	76.340
*	4	1	1	25.240	75.720
*	4	1	2	25.113	75.340
*	4	1	3	25.170	75.510
*	4	2	1	25.410	76.230
*	4	2	2	25.380	76.140
*	4	2	3	25.457	76.370

A N A L Y S I S O F V A R I A N C E T A B L E

K Value	Source	Degrees of Freedom	Sum of Squares	Mean Square	F Value	Prob
2	Factor A	3	44.177	14.726	395.6625	0.0000
4	Factor B	1	1.364	1.364	36.6489	0.0000
6	AB	3	0.120	0.040	1.0725	0.3696
8	Factor C	2	0.421	0.211	5.6623	0.0062
10	AC	6	0.657	0.109	2.9417	0.0159
12	BC	2	0.203	0.101	2.7251	0.0757
14	ABC	6	0.213	0.036	0.9548	
-15	Error	48	1.786	0.037		
	Total	71	48.942			

Coefficient of Variation: 0.74%

s_ for means group 2: 0.0455 Number of Observations: 18
y
s_ for means group 4: 0.0322 Number of Observations: 36
y
s_ for means group 6: 0.0643 Number of Observations: 9
y
s_ for means group 8: 0.0394 Number of Observations: 24
y
s_ for means group 10: 0.0788 Number of Observations: 6
y
s_ for means group 12: 0.0557 Number of Observations: 12
y
s_ for means group 14: 0.1114 Number of Observations: 3
y

===

Variable 10: pH

Grand Mean = 8.092 Grand Sum = 582.610 Total Count = 72

T A B L E O F M E A N S

1	2	3	4	10	Total
*	1	*	*	8.242	148.360
*	2	*	*	8.183	147.290
*	3	*	*	7.991	143.840
*	4	*	*	7.951	143.120
*	*	1	*	8.045	289.620
*	*	2	*	8.139	292.990
*	1	1	*	8.177	73.590
*	1	2	*	8.308	74.770
*	2	1	*	8.101	72.910
*	2	2	*	8.264	74.380
*	3	1	*	7.970	71.730
*	3	2	*	8.012	72.110
*	4	1	*	7.932	71.390

*	4	2	*	7.970	71.730
*	*	*	1	8.122	194.920
*	*	*	2	8.071	193.710
*	*	*	3	8.082	193.980
*	1	*	1	8.300	49.800
*	1	*	2	8.130	48.780
*	1	*	3	8.297	49.780
*	2	*	1	8.215	49.290
*	2	*	2	8.193	49.160
*	2	*	3	8.140	48.840
*	3	*	1	7.987	47.920
*	3	*	2	8.027	48.160
*	3	*	3	7.960	47.760
*	4	*	1	7.985	47.910
*	4	*	2	7.935	47.610
*	4	*	3	7.933	47.600
*	*	1	1	8.093	97.120
*	*	1	2	7.988	95.850
*	*	1	3	8.054	96.650
*	*	2	1	8.150	97.800
*	*	2	2	8.155	97.860
*	*	2	3	8.111	97.330
*	1	1	1	8.293	24.880
*	1	1	2	7.947	23.840
*	1	1	3	8.290	24.870
*	1	2	1	8.307	24.920
*	1	2	2	8.313	24.940
*	1	2	3	8.303	24.910
*	2	1	1	8.130	24.390
*	2	1	2	8.097	24.290
*	2	1	3	8.077	24.230
*	2	2	1	8.300	24.900
*	2	2	2	8.290	24.870
*	2	2	3	8.203	24.610
*	3	1	1	7.973	23.920
*	3	1	2	7.997	23.990
*	3	1	3	7.940	23.820
*	3	2	1	8.000	24.000
*	3	2	2	8.057	24.170
*	3	2	3	7.980	23.940
*	4	1	1	7.977	23.930
*	4	1	2	7.910	23.730
*	4	1	3	7.910	23.730
*	4	2	1	7.993	23.980
*	4	2	2	7.960	23.880
*	4	2	3	7.957	23.870

A N A L Y S I S   O F   V A R I A N C E   T A B L E

K Value	Source	Degrees of Freedom	Sum of Squares	Mean Square	F Value	Prob
2	Factor A	3	1.095	0.365	23.7364	0.0000
4	Factor B	1	0.158	0.158	10.2573	0.0024
6	AB	3	0.054	0.018	1.1730	0.3298
8	Factor C	2	0.034	0.017	1.0931	0.3434
10	AC	6	0.121	0.020	1.3167	0.2680
12	BC	2	0.049	0.025	1.5976	0.2129

14	ABC	6	0.081	0.013	0.8779
-15	Error	48	0.738	0.015	
	Total	71	2.330		

Coefficient of Variation: 1.53%

s_y for means group 2: 0.0292 Number of Observations: 18

s_y for means group 4: 0.0207 Number of Observations: 36

s_y for means group 6: 0.0413 Number of Observations: 9

s_y for means group 8: 0.0253 Number of Observations: 24

s_y for means group 10: 0.0506 Number of Observations: 6

s_y for means group 12: 0.0358 Number of Observations: 12

s_y for means group 14: 0.0716 Number of Observations: 3

Appendix vi

Total organic matter in sediments during wet and dry seasons
Function: FACTOR
Experiment Model Number 3:
Three Factor Completely Randomized Design
Data case no. 1 to 72.
Factorial ANOVA for the factors:
Replication (Var 1: Rep) with values from 1 to 3
Factor A (Var 2: Site(1=Kisat,2=Cocacola,3=Molasses,4=Kisian)) with values from 1 to 4
Factor B (Var 3: Distances(1=0m,2=50m,3=100m)) with values from 1 to 3
Factor C (Var 4: Season (1=wet,2=Dry)) with values from 1 to 2
Variable 5: Organic matter
Grand Mean = 0.129 Grand Sum = 9.295 Total Count = 72

TABLE OF MEANS

1	2	3	4	5	Total
*	1	*	*	0.109	1.960
*	2	*	*	0.224	4.031
*	3	*	*	0.061	1.100
*	4	*	*	0.122	2.204
*	*	1	*	0.148	3.564
*	*	2	*	0.132	3.164
*	*	3	*	0.107	2.567
*	1	1	*	0.130	0.780
*	1	2	*	0.113	0.680
*	1	3	*	0.083	0.500
*	2	1	*	0.257	1.541
*	2	2	*	0.227	1.360
*	2	3	*	0.188	1.130
*	3	1	*	0.080	0.480
*	3	2	*	0.065	0.390
*	3	3	*	0.038	0.230
*	4	1	*	0.127	0.763
*	4	2	*	0.122	0.734
*	4	3	*	0.118	0.707
*	*	*	1	0.135	4.865

*	*	*	2	0.123	4.430
*	1	*	1	0.113	1.020
*	1	*	2	0.104	0.940
*	2	*	1	0.233	2.100
*	2	*	2	0.215	1.931
*	3	*	1	0.069	0.620
*	3	*	2	0.053	0.480
*	4	*	1	0.125	1.125
*	4	*	2	0.120	1.079
*	*	1	1	0.153	1.835
*	*	1	2	0.144	1.729
*	*	2	1	0.142	1.700
*	*	2	2	0.122	1.464
*	*	3	1	0.111	1.330
*	*	3	2	0.103	1.237
*	1	1	1	0.133	0.400
*	1	1	2	0.127	0.380
*	1	2	1	0.117	0.350
*	1	2	2	0.110	0.330
*	1	3	1	0.090	0.270
*	1	3	2	0.077	0.230
*	2	1	1	0.260	0.780
*	2	1	2	0.254	0.761
*	2	2	1	0.247	0.740
*	2	2	2	0.207	0.620
*	2	3	1	0.193	0.580
*	2	3	2	0.183	0.550
*	3	1	1	0.090	0.270
*	3	1	2	0.070	0.210
*	3	2	1	0.077	0.230
*	3	2	2	0.053	0.160
*	3	3	1	0.040	0.120
*	3	3	2	0.037	0.110
*	4	1	1	0.128	0.385
*	4	1	2	0.126	0.378
*	4	2	1	0.127	0.380
*	4	2	2	0.118	0.354
*	4	3	1	0.120	0.360
*	4	3	2	0.116	0.347

A N A L Y S I S O F V A R I A N C E T A B L E

K Value	Source	Degrees of Freedom	Sum of Squares	Mean Square	F Value	Prob
2	Factor A	3	0.253	0.084	270.0502	0.0000
4	Factor B	2	0.021	0.010	33.5514	0.0000
6	AB	6	0.005	0.001	2.9228	0.0164
8	Factor C	1	0.003	0.003	8.4066	0.0056
10	AC	3	0.001	0.000	0.5551	
12	BC	2	0.001	0.000	0.8334	
14	ABC	6	0.001	0.000	0.4919	
-15	Error	48	0.015	0.000		
	Total	71	0.299			

Coefficient of Variation: 13.70%

$s_{\bar{y}}$ for means group 2: 0.0042 Number of Observations: 18

$s_{\bar{y}}$ for means group 4: 0.0036 Number of Observations: 24

y
s_ for means group 6: 0.0072 Number of Observations: 6
y
s_ for means group 8: 0.0029 Number of Observations: 36
y
s_ for means group 10: 0.0059 Number of Observations: 9
y

s_ for means group 12: 0.0051 Number of Observations: 12
y
s_ for means group 14: 0.0102 Number of Observations: 3
y
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