EVALUATION OF THE LEVEL OF SOME IONIC POLLUTANTS IN WATER AND OF POPs IN FISH AND SEDIMENT IN THE YAOUNDE MUNICIPAL LAKE.

Présentée en vue de l'obtention du Diplôme de Professeur de l'Enseignement Secondaire deuxième grade

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I, the undersigned, **Pr. Charles FON ABI**, certify that the work carried out by the student TOKOH SYLVIA NGWATING, titled *"EVALUATION OF THE LEVEL OF SOME IONIC POLLUTANTS IN WATER AND OF POPs IN FISH AND SEDIMENT IN THE YAOUNDE MUNICIPAL LAKE"* is her original work, and was carried out under my supervision in the Inorganic and Organic Chemistry Laboratories of E.N.S Yaounde, University of Yaounde I.

Yaounde, the------------------

Pr Charles FON ABI

Associate Professor.

Head of Chemistry Department,

E.N.S Yaounde.

DEDICATION

To:

-My parents:

NDIMBEGHI JOHN TOKOH (of blessed memory)

NDIMBEGHI ANNA GHOGOMU.

-My elder brother: *TOKOH ELVIS TAPRIH*

And

-My Fiance: *NGWA LOUIS NGWA*

for their omnipresent love, support and encouragement.

ACKNOWLEDGEMENTS

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Evaluation Of The Level Of Some Ionic Pollutants In Water And Of POPs In Fish And Sediment In The Yaounde Municipal Lake.

ABSTRACT

An investigation was undertaken in this work to determine the level of contamination of water by some anionic and cationic pollutants (F^-;Cl^-;PO_4^{3-};SO_4^{2-};NO_3^-;NH_4^+;Ca^{2+};Mg^{2+};Na^+;K^+) and of fish and sediment by Persistent Organic Pollutants(POPs) in the Yaounde municipal lake. Samples of water were collected around the inlet streams (North and East points), outlet stream (south point) and the west point of the lake and analyzed using an ion chromatogram.Samples of fish and sediment collected and after having been air-dried for 5 days (sediments) or oven-dried at 55^0c for 3 days (fish) were subjected to solvent extraction using hexane and dichloromethane.The extracts were sent abroad for analysis using Gas chromatography and HPLC methods

The results obtained show that thefluoride (F^-) concentrations close to the two inlet points (North and East)are high (0.17 mg/L and 0.12 mg/L)and appear as traces towards the outlet,showing that these ions are consumed by aquatic organisms for the growth of their bones and skeletons. Similarly, the nitrate NO_3^- concentrations at inlet points (0.51 mg/L and 0.64 mg/L)and west point(0.19 mg/L) were found to be high but zeroat oulet, implying that this ion is consumed in the lake and contribute to high algal growth.PO_4^{3-} concentration was zero at all points meaning no contamination by these ion.SO_4^{2-} had an almost average concentration at all points of 1.8±0.1 mg/L which is far greater than the standard value recommended by EPA,showing high level of algal growth at all chosen points.Allcation concentrations show no negative effect to the water except for $NH_4^+$with an average concentration of 6.5±0.1 mg/L at all points.This value is far greater than that recommended by EPA ,indicating high level of eutrophication.

The colours of the Hexane and Dichloromethane extracts of fish and sediment samples range from light yellow to black which is indicative of the existence of organic pollutants in the lake.

Keywords : Concentration, ion chromatogram, eutrophication,pollutants, ions.

Evaluation Of The Level Of Some Ionic Pollutants In Water And Of POPs In Fish And Sediment In The Yaounde Municipal Lake.

RESUME

Une investigation a été menée dans ce travail pour déterminer le niveau contamination de l'eau par quelques polluants anioniques et cationiques(F^- ;Cl^- ;PO_4^{3-} ;SO_4^{2-} ;NO_3^- ;NH_4^+ ;Ca^{2+} ;Mg^{2+} ;Na^+ ;K^+) et de poissons et sédiments par polluants persistents organiques(POPs)provenant du lac municipal.Les échantillons d'eau étaient collectés autour des entrées (point Nord et Est),la sortie (point Sud) et au point Ouest du lac municipal, et analysés en utilisant un chromatogramme ionique. Les échantillons de poissons et sedimentcollectés du lac, après avoir séché à l'air libre pour 5 jours (sédiments) ou dans le four à 55^0c pendant 3 jours, étaient soumis à l'extraction solvant en utilisant l'hexane et le dichlorométhane.Ces extrait ont ête envoyé à l'étranger pour l'analyse par les methodes de chromatographie gazeuse et l'HPLC.

Les resultats obtenues montrent que la concentration de F^-était élevéeautour des entrées (0.17 mg/L et 0.12 mg/L)et apparait en traces à la sortie, ce qui montre la consommation des ions F^- par les organismes aquatiques pour la croissance de leur os et squelettes.Le meme,NO_3^- avait les valeurs de concentration élevée àtous les point(0.51 mg/L Nord,0.64 mg/L Est,0.19 mg/L Ouest) sauf à la sortie qui était zero,indiquant leur consommation dans le lac donc augmentation de la croissance des algues dans le lac.La concentration des ions PO_4^{3-} était zero à tous les points, donc pas de contamination du lac par ces ions. Les ions SO_4^{2-} avait presque les mêmes concentrations à tous les points avec une moyenne de 1.8±0.1 mg/L qui est extrêmement grande par rapport à la norme de l'APA, montrant un niveau élevé des algues dans le lac à tous les points. Toutes les concentrations des cations n'ont pas d'effet negatif sauf les ions NH_4^+qui a une concentration moyenne de 6.5±0.1 mg/L à tous les points choisit, qui est trèssupérieure àla norme proposée par l'APA indiquant un grand niveau d'eutrophication dans le lac.

Les couleurs d'extraits d'échantillons du poisson et sédiments en utilisant l'hexane et le dichlorométhane comme solvant d'extraction partent de légèrement jaune à noir.Ce qui montre clairement l'existence des polluants persitents organiques dans le lac.

Mots clés : les polluants, chromatogramme ionique, eutrophication, la concentration, ions.

LIST OF ABBREVIATIONS

BOD : Biochemical Oxygen Demand

$(C_2H_5)_4Pb$: Tetraethyllead

COD : Chemical Oxygen Demand

DDT : 1, 1, 1,-trichloro-2, 2-bis (p-chlorophenyl) ethane

EPA : Environmental Protection Agency, United States of America

HPLC : High Performance Liquid Chromatography

mg DDT/kg : milligramme DDT per kilogram

N_XO_Y : Nitrogen oxides

PCBs : Poly Chlorinated Biphenyls

POPs : Persistent Organic Pollutants

Ppm : part per million

S_XO_Y : Sulphur oxide

WHO : World Health Organization

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INTRODUCTION

1.INTRODUCTION

1.1. Context and justification of the work

In many developing countries, the expansion of urban centers is of considerable importance for socio-economic growth and this continuously modifies the physical, chemical and biological composition of our living environment.Thus, many people living within these urban centers are often exposed to such unnatural environment since they depend on resources from water, soil and air. (Ebot 2009).Prominent on the list of these problems is environmental pollution. Among the various types of pollution, water pollution comes second after air pollution in terms of effects (Fomenky 2003).Water pollution is alocal, regional and global problem related to how we use the land. The human environment therefore suffers degradation and this is largely due to the misuse of our water bodies. This misuse can be explained in the following ways: many industries do not have proper waste management systems and thus tend to drain their waste into water bodies which goes into rivers, canals and later to sea.This can be cations or anions which are capable of increasing the level of nutrient in the water and equally cause an increase in the BOD of the water since most aquatic organisms depend on this water for survival. Their consumption of the water which has been contaminated with toxic ions will have an effect on aquatic organisms, and equally on humans who feed on some of these aquatic organisms (such as fish).

The means are not yet available in Cameroon and other developing countries where rigorous legislations to limit the level of pollutants in the environment do not exist. It is therefore not surprising to find Persistent Organic Pollutants (POPs) such as PCBs from obsolete transformers and other pollutants such as ions from workshops, garages, household wastes etc, which end up in waterways especially

in the sediments where fish feed and get themselves contaminated. The effect of persistent consumption of such fish on human beings could be very disastrous since some of the pollutants may bio accumulate in human tissues up to threshold levels to provoke such disease as liver cancer(Dobson 1993).Persistent organic pollutants are organic compounds that are resistant to environmental degradation through chemical,biological and photolytic processes.They are typically halogenated organic compounds and as such exhibit high lipid solubility.Thus,they bioaccumulate in fatty tissues with potential significant impacts(Fomenky 2003).

One of the waterways that have received great attention from researchers in the past is the Yaoundé Municipal Lake, located in the heart of the city and its main economic activity is fishing. Some researchers based their studies on eutrophication (Demanou 2001) and (Tene 2001), while others were interested in evaluating the level of heavy metals such as Pb, Zn, Cd, Hg and ions such as phosphate and ammonium ions contained in sediments and fish (Nsangou 2005) followed by (Avoto 2012) and (Ngop 2014).Recently, some work was done to evaluate the level of pollution by other heavy metals such as Ni, Fe, Cu (Nkot 2015)

However ,no study has been done on the evaluation of the concentration of anions such fluorides,Nitrates,sulfates,chlorides,phosphates and cations such as the sodium ion(Na^+),magnesium ion(Mg^{2+}),calcium ion (Ca^{2+}),potassium ion (K^+) and ammonium ion(NH_4^+) present in the water and equally the concentration of Persistent Organic Pollutants such as PCBs,DDT,Dioxins present in the fish sample and sediment.

This work is therefore aims at evaluating the concentration of sulfates,nitrates,fluorides,chlorides,phosphates, sodium ion (Na^+),magnesium

ion(Mg^{2+}),calcium ion (Ca^{2+}),potassium ion(K^+)and ammonium ion(NH_4^+) in water samples taken at different points of the lake and equally the concentration of POPs like PCBs,DDT,Dioxins,in the lake by evaluating sediment and lake fish sample(Tilapia).

I.2. Objectives

The objectives of this work are set as follows:

-Determine the concentration of anionic pollutants (NO_3^-;F^-;SO_4^{2-};Cl^-;PO_4^{3-}) and cationic pollutants (Mg^{2+};Na^+;Ca^{2+};K^+;NH_4^+) present in water samples taken at different points of the lake.

-Determine the concentration of POPs in the lake fish sample and sediment.

1.3. Methodology

-Collection of water samples using scrupulously clean polyethylene bottles at North (N), South(S), West (W) and East (E) points of the lake, at a depth of 30cm from the surface of the water for each chosen point, preserve at a temperature of 4^0C for a maximum holding time of 6 days and analysis using an ion chromatogram.

-Collection, drying and extraction of POPs from sediments followed by analysis of extracts using Gas Chromatography and HPLC methods.

-collection, drying and extraction of POPs from fish followed by analysis of extracts using Gas chromatography and HPLC methods.

1.4. Plan of work

This work is divided as follows: An introduction, chapter I (Review of literature), chapter II (Material and methods), chapter III (Results and discussion) and finally pedagogic interest, conclusion and recommendation.

General Introduction gives the justification, problem, objectives, research methodology and plan of this work.

Chapter 1 discusses literature review and definition of terms related to the work.

Chapter 2(material and methods) presents the material, reagents, procedure for the determination of the presence ofsome anions and cations in the watersamples, POPs in the lake fish sample and sediment.

Chapter 3(results and discussion) presents the results obtained and their interpretations

And finally pedagogic interest, conclusion and recommendation: which gives a summary of the work, recommendations and pedagogic interest.

CHAPTER I

REVIEW OF LITERATURE

1.1. Definition of some terms related to environmental pollution

1.1.1. Environment

Many definitions have been given to this word. We will discuss some of th below.

The environment is "that which surrounds'', meaning the biosphere, atmosphere, hydrosphere and geosphere (Lambi 2015).

The environment is "the total of conditions surrounding an organism or group of organisms, the complex of social and cultural conditions affecting the nature of an individual or community" (Fuller 1974). "The environment is anything outside an organism in which the organism lives''. It can be a geographical region, a certain climatic condition, the pollutants or the noise that surrounds an organism. Man's environment will include the country, region, town or house in which he lives. A parasite's environment will include the intestine of the host. A plant environment will include a type of soil at a certain altitude (Collins 1988).

An organism's environment can be divided into the abiotic (physical) and biotic (living) components. The physical environment embraces everything not associated with the presence of other organisms, temperature, water, humidity, wind, aircurrent,pH, mineral salts, salinity etc. The biotic environment comprises all other organisms with which it comes into contact.Thus, topics like parasitism, predation, competition and related associations are treated under the biotic environment (Atabong 1997).

I.1.2. Pollution

Pollution is "the introduction by man into the environment of substances or energy liable to cause hazards to human health, harm to living resources and ecological systems, damage to structures or amenities or interference with the legitimate uses of the environment''(Kargong 2000).Pollution could also be defined as the "contamination of man's environment(e.g atmosphere,soil,water and even food)by substances(e.g. metals or toxic elements,gases,chemicals and bacteria)of natural(e.g rain,rivers,winds and volcanic eruption, forest fires etc.) industrial and man-made origin"(e.g Co and Pb from automobile exhaust, fossil fuels like coke or coal, refineries like those of zinc and petrol emitting smoke and gases etc)(Kargong 2000).

I.1.3.Pollutant

A pollutant is any undesirable substance that is present in air, water, food or solid waste. The presence of undesirable heat is considered as thermal pollution.

A pollutant can equally be defined as a substance present in a plant, animal or environment in a superior quantity to the natural concentration. It could also be considered as a wrong substance in the wrong place.

A pollutant is any substance that is present in a greater concentration resulting from human activity (i.e. natural or man-made) and having a net detrimental effect upon its environment or upon something of value to that environment (Lambi 2015).

I.2. Types of pollutants

We can have primary and secondary pollutants (Lambi 2015).

I.2.1. Primary pollutants

These are generally sources or primary agents of pollution. They exert effects in the form in which they enter the environment e.g. N_XO_Y, S_XO_Y, C_XO_Y(Lambi 2015).

I.2.2.Secondary pollutants

They result from chemical processes often from less harmful precursors in the environment .e.g. H_2SO_4 in acid rain. They are substances formed from the combination of primary pollutants and water. Examples of secondary pollutants include $HNO_2, HNO_3, H_2SO_4, H_2CO_3, O_3$(Lambi 2015).

I.3.Classification of pollution

Classification can be done according to:

a) The nature of pollutant e.g.Persistent Organic Pollutant.

b) Source e.g. natural pollution and anthropogenic pollution i.e. human (Avoto 2012).

c) Media affected e.g atmospheric pollution, geospherical pollution and water pollution (Avoto 2012).

We shall focus on water pollution in this work.

I.4. Water pollution

Water pollution is one of the main types of pollution. It is second to air pollution in terms of effects (Kargong 2000).It is a global issue as it depends on how we use land and wastes. A pollutant deposited in acontinent can move through a nearby stream into a river and eventually into an ocean and reach another continent.

Water pollution can also be defined as the physical, chemical and biological degradation of the natural quality of water by solid, liquid or gaseous wastes of diverse origin (Avoto 2012).

I.4.1.Physical pollution

Physical pollution removes useful qualities from water and in certain cases; they can cause death of aquatic species. This type of pollution can be observed through the following manifestations:

-Temperature variation

-Variable water coloration

-Presence of floating debris and foam (Avoto 2012).

I.4.2. Microbiological pollution

This is another form of pollution which is due to the presence of human and animal excreta in water which can contain pathogenic germs such as viruses, bacteria and parasites. By simple contact with water, we can contract diseases such as cholera, bilharzias, amoeba dysentery etc. In developed countries, these diseases do almost not exist, thanks to the proper care given to water (Avoto 2012).

I.4.3.Organic waste pollution

It is considered as the alteration of the quality of water due to the presence of pollutants of organic origin. These organic pollutants result from wastes coming from food and animal industries. Thefirst consequence of this pollution is the increase in the Biological Oxygen Demand (BOD) of the water by aquatic organisms which depend on oxygen for survival (Nsangou 2005).

I.4.4. Chemical pollution

Chemical pollution results from the presence of chemical substances in water. Water bodies are extremely vulnerable to toxic substances such as ions(nitrates,fluorides,phosphates,chlorides),acids,solvents,PCBs,DDTs,dioxins,heavy metals (Iron,Lead),,and substances from mining activities. These substances not only cause instant death but they can accumulate along the food chain provoking mutations and sterility in some animals. They can equally lead in a manner, to the destruction of the natural environment.(Kargong 2000).Here, we are going to be interested in heavy metals in the form of ionssuchasfluorides,nitrates,sulphates,phosphates,sulfates,chlorides,ammonium,sodiummagnesium, calcium, potassiumand persistent organic pollutants such as PCBs, DDT, and Dioxins.

I.5. Water pollution in the Yaounde municipal lake

Yaoundé is a large city. Though with few industries, there are many chemical laboratories (ministries, schools, organizations etc.)(Fomenky 2003). For years now (since 1980), the sanitation infrastructures located upstream are not operating.Thus, untreated water enters the lake. The pollution coming from the upstream part of the watershed is characterized by a continuous discharge of domestic wastewater (baths, emptying toilets, washing and dishwater).One of the main causes of pollution is the mal functioning of the wastewater treatment plant located before the lake. The pollution is accentuated by the use of pesticides and by livestock farming (pigs and chicken).These has promoted the proliferation of pollutants like

*solids (suspended solids and solid wastes)

*chemicals (heavy metals, detergents, solvents, hydrocarbons)

*microorganisms, viruses, bacteria.(https//Hal. Archives 2011)

I.5.1. Sources of pollution of the Yaounde municipal lake

Some work carried out classifies the sources of pollution of the lake in two groups: natural and artificial sources (Fomenky 2003)

I.5.1.1. Natural sources

The main natural source of pollution is rain water (which washes and transports pollutants from land and other sources into the lake) (Avoto 2012).

I.5.1.2. Artificial sources

There exist several artificial sources of pollution. We can mention road transport, agricultural activities, wasteswater, construction sites and stores (Avoto 2012).

However, the main sources of pollution of the municipal lake are:

-The inability of the Messa Camp SIC water treatment center to control all the affluent of the lake alone.

-Presence of septic tanks and buildings around the river, e.ghôtel des députés

-The practice of agricultural activities (fishing)

- Garages situated around the National Gendarmerie

-Smoke from vehicles

-oil spillage from tankers

I.5.2.Presentation of the Yaoundé municipal lake

The Yaoundé municipal lake is found at the heart of the city between the Atemengue Plateau and the administrative hill. It is a large artificial lake created in

1952 by the Greek KYRLAKIGES.It is found in the Northwest-Southeast direction resulting from the blockage of the Mingoa stream. The stream rises both from Madagascar and from the Melen –EligEffa region and is the principal affluent of the lake. At its borders, we can see the beautiful residence of the prime minister.The lake is located in the center of the Yaoundé city, between $3^0 51'31''$ and $3^0 52'27''$ of north latitude and between $11^0 29'46''$ and $11^0 30'49''$ of east longitude .Its relief is steep .It is part of the Mfoundi watershed; the river drains an important part of the town (Zebaze 2008).

I.5.3. Importance of the lake

It serves as a source of fresh air for the city as well as a source of employment and means of finance for fishermen. If well developed, it could be a good touristic site. In the academic domain, it is a nursery for environmental science investigation. The lake again plays an important role in sewage treatment (Niyitegeka 2001).

I.6. Ions studied

I.6.1. Sulfates (SO_4^{2-})

The sulfate or sulphate ion is a polyatomic anion with theformula SO_4^{2-}. Sulfate is the spelling recommended by IUPAC.The anion consists of a central sulfur atom surrounded by four equivalent oxygen atoms in a tetrahedral arrangement. The symmetry is the same as that of methane. The sulfur atom is in the +6 oxidation state while the four oxygen atoms are each in the −2 oxidationstate. The sulfate ion carries a negative two charge and is the conjugate base of the bisulfate (or hydrogen sulfate) ion, HSO_4^-, which is the conjugate base of H_2SO_4
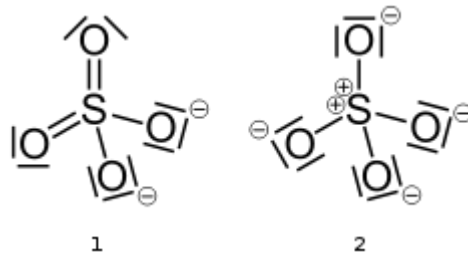
Figure 1 : Lewis Structures of the sulfate ion.

Sulfates occur naturally in minerals including barite $(BaSO_4)$,epsomite$(MgSO_4.7H_2O)$and gypsum$(CaSO_4.2H_2O)$(Greenwood and Earnshaw1984).These dissolved minerals contribute to the mineral content of many drinking water. Addition of calcium and magnesium sulfate to water was found to improve the taste (Zoeteman 1980).

I.6.1.1. Uses

-Sulfates and sulfuric acid products are used in the production of fertilizers,chemicals,dyes,glass,paper,soaps,textiles,fungicides,insecticides etc.They are also used in the mining, woodpulp, metal and plating industries.

-Aluminumsulfate (alum) is used as asedimentation agent in the treatment of drinking water.

-Calcium sulfate has been used for the control of algae in raw and public water supplies (Mcguire and al.1984)

I.6.1.2. Environmental Fate

Sulfates are discharged into water from mines and smelters, and from kraft pulp and paper mills, textile mills and tanneries. Atmospheric sulfur dioxide formed by the combustion of fossil fuel and in metallurgical roasting processes

may contribute to the sulfate content of the surface water. Sulfur trioxide produced by the photolytic or catalytic oxidation of sulfur dioxide, combines with water vapour to form dilute sulfuric acid which falls as ''acid rain''(Delisle and Schmidt 1977).Table 1 shows different water types and their respective concentrations.For aquatic life,a sulfate concentration of 100 mg/L is recommended.

Table 1 : Types of water and their respective sulfate concentrations.

Water type	Concentrations(mg/L)
Very soft water	128
Soft or moderately soft	218
Moderately soft-hard	309
Very hard	429

I.6.2. Phosphates (PO_4^{3-})

Phosphorus is one of the key elements necessary for the growth of plants and animals. Phosphates (PO_4^{3-}) are formed from this element. Phosphates exist in three forms: orthophosphate, metaphosphate (or polyphosphate) and organically bound phosphate. Each compound contains phosphorous in a different chemical formula. Ortho forms are produced by natural processes and are found in sewage. Poly forms are used for treating boiler waters and in detergents. In water, they change into the ortho form. Organic phosphates are important in nature. Their occurrence may result from the breakdown of organic pesticides which contain phosphates. They may exist in solution, as particles, loose fragments or in the bodies of aquatic organisms (US environmental protection Agency 1986).

I.6.2.1. Environmental Impact

Rainfall can cause varying amounts of phosphates to wash from farm soils into nearby waterways. Phosphate will stimulate the growth of plankton and aquatic plants which provide food for fish. This may cause an increase in the fish population and improve the overall water quality. However, if an excess of phosphate enters the waterway, algae, and aquatic plants will grow wildly, choke up the waterway and use up large amounts of oxygen. This condition is known as eutrophication or over-fertilization of receiving waters. This rapid growth of aquatic vegetation eventually dies and as it decays, it uses up oxygen. This process in turn causes the death of aquatic life because of the lowering of dissolved oxygen levels(John1993).

Phosphates are not toxic to people or animals unless they are present in very high levels. Digestive problems could occur from extremely high levels of phosphate.Levels of phosphate above 0.1mg/l can stimulate plant growth above its natural rate (US Environmental Protection Agency 1986).

I.6.3.Nitrates (NO_3^-)

Nitrates are naturally occurring ions that are part of the nitrogen cycle.The nitrate ion is the stable form of combined nitrogen and oxygenated systems.Although chemically unreactive,it can be reduced by microbial action.

I.6.3.1. Physico-chemical properties
The physico-chemical properties of nitrates are presented in table 2 below.

Table 2 : Physico-chemical properties of nitrate.

PROPERTY	NITRATE
Acid	Conjugate base of a strong acid(HNO_3),PKa=1.3
Salts	Very soluble in water
Reactivity	Unreactive

Nitrate is used mainly in inorganic fertilizers. It is also used as an oxidizing agent in the production of explosives. Purified potassium nitrate is used in glass making.Sodium nitrate is used as a food preservative, especially in cured metals. Nitrate is sometimes added to food to serve as a reservoir for nitrite.Nitrates occur naturally in plants, for which it is a key nutrient(Böhlke 2002).

Nitrate can reach both surface water and ground water as aconsequence of agricultural activity (including excess application of inorganic nitrogenous fertilizers and manures) from wastewater treatment and from oxidation of nitrogenous waste products in humanand animal excreta, including septic tanks (Suthar and al. 2009).

The nitrate concentration in surface water is normally low but can read high levels as a result of agricultural runoff or contamination with human and animal wastes.The concentration often fluctuates with the season and may increase when the river is fed by Nitrate-rich equifers (Young and Morgan-jones 1980).

I.6.4. Chlorides (Cl⁻)

Chlorides are widely distributed in nature as salts of sodium (NaCl), potassium (KCl) andcalcium (CaCl$_2$).The threshold taste of the chloride ion in water is dependent on the associated cation.Taste thresholds for sodium chloride and calcium chloride in water are in the range 200-300mg/litre (Zoeteman 1980).

I.6.4.1. Uses

-Sodium chloride is widely used in the production of industrial chemicals such as caustic soda, chlorine, sodium chlorite and sodium hypochlorite.

-Calcium chloride, sodium chloride and magnesium chloride are extensively used in snow and ice control.

-Potassium chlorideis used in the production of fertilizers (Ottawa 1978).

Chlorides are leached from various rocks into soil and water by weathering. The chloride ion is highly mobile and is transported to closed basins or oceans. Chlorides get into water through natural and anthropogenic sources, such as run-off containing road de-icing salts, the use of inorganic fertilizers, landfill leachates, septic tank effluents, animal feeds, industrial effluents, irrigation drainage, and seawater intrusion in coastal areas (Ottawa 1978).

Chloride toxicity has not been observed in humans except in the special case of impaired sodium chloride metabolism e.g in congestive heart failure(Wesson 1969).Healthy individuals can tolerate the intake of large quantities of chloride provided there is a concomitant intake of fresh water(Ottawa 1978). But if water contains a lot of decaying materials,free chlorine can combine with them to form compounds called trihalomethanes(THMs).Some THMs in high concentration are carcinogenic to people.They are persistent and can cause health threats to living

things for a long time(US Environmental protection Agency 1976).As concerns water,chloride increases the electrical conductivity of water and thus increases its corrosivity.In metal pipes,chloride reacts with metal ions to form soluble salts(Brooker 1984)thus increasing levels of metals in drinking water.In lead pipes,a protective oxide layer is built up ,but chloride enhances galvanic corrosion(Gregory 1990).It can also increase the rate of pitting corrosion of metal pipes(Brooker 1984).

Chloride concentrations in excess of about 250 mg/L can give rise to detectable taste in water, but the threshold depends upon the associated cations.Consumers can however, become accustomed to concentrations in excess of 250 mg/L.No health-based guideline value is proposed for chloride in drinking water but a maximum no effect concentration of chlorine required for fish and aquatic life is 0.01 mg/L (US Environmental Protection Agency 1976).

I.6.5. Fluorides (F⁻)

Fluoride is present in the environment as the stable form of the super reactiveelement fluorine. Fluorine is the 17th most abundant element in the earth's crust, with fluoride detectable in almost all minerals.

The main minerals are fluorspar-CaF_2, Cryolite-Na_3AlF_6 and fluorapatite -CaF_2 $(PO4)_6$. Fluoride naturally enters the aquatic system through weatheringof alkalic and silicic igneous and sedimentary rocks, primarily shales, as well as from emissions during volcanic activity. Fluoride is typically found in freshwater at concentrations less than 1.0 mg/L; however, natural concentrations may exceed even 50.0mg/L (McNeely and al.1979).

The benefits of fluoride are seen mostly inthe hardening of teeth and the protection from caries (Barbier and al.2010).

I.6.5.1. Effects

-Disruption of enzyme activity (mostly inhibition), inhibition of protein.Secretion and synthesis, generation of reactive oxygen species (ROS), and alteration of gene expression. (Barbier and al.2010).Fluoride at micromolar concentrations can act as an anabolic agent and promote cell proliferation, whereas at millimolar concentrations it acts as an enzyme inhibitor on e.g. phosphatases, which play an important role in the ATP (cellular energy) production cycle and cellular respiration.(Barbier and al.2010).The WHO recommends a concentration of 0.01-0.03 mg/L in water.

I.6.6.Sodium ion (Na^+)

Sodium compounds naturally end up in water. Sodium stems from rocks and soils. Not only seas, but also rivers and lakes contain significant amounts of sodium. Concentrations however aremuch lower, depending on geological conditions and wastewatercontamination. (Sax 1987).

I.6.6.1. Uses

Metallic sodium is used in:

-The manufacture of tetraethyllead and sodium hydride.

-In titanium production.

-As a catalyst for synthetic rubber.

-As a laboratory reagent.

- As a coolant in nuclear reactors, in electric power cables, in nonglare lighting for roads, and as a heat-transfermedium in solar-powered electric generators (Sax 1987).

Sodium salts are used in water treatment, including softening, disinfection, corrosion control, pH adjustment, and coagulation (National Academic Press

1980), in road de-icing and in the paper, glass, soap, pharmaceutical, chemical, and food industries.

Sodium salts are generally highly soluble in water and are leached from the terrestrial environment to groundwater and surface water.

Most water supplies contain less than 20 mg of sodiumper litre, but in some countries levels can exceed 250 mg/litre. Saline intrusion, mineral deposits, seawater spray, sewage effluents, and salts used in road de-icing can all contribute significant quantities of sodium to water. In addition, water-treatment chemicals, such as sodium fluoride, sodium bicarbonate, and sodium hypochlorite, can together result in sodiumlevels as high as 30 mg/litre. Domestic water softeners can give levels of over 300 mg/litre, but much lower ones are usually found. (http/www.euro reports,2014).

Food is the main source of daily exposure to sodium, primarily as sodium chloride.

The estimation of daily intake from food is difficult because of the wide variation in concentrations and the fact that many people add salt to their food. In Western Europe and North America, the estimated overall consumption of dietary sodium chloride is 5–20 g/day (2–8 g of sodium per day), the average being 10 g/day (4 g of sodium) (http/www.euro reports, 2014). People on a low-sodium diet need to restrict their sodium intake to less than 2 g/day (National Academy Press 1977). The consumption of drinking-water containing 20 mg of sodium per litre would lead to a daily intake of about 40mg of sodium.

Sodium is excreted principally in the urine in amounts reflecting the dietary intake (Guthrie 1989).

I.6.7) Calcium ion (Ca^{2+})

Calciumoccurs in water naturally. Seawater contains approximately 400 ppm calcium. One of the main reasons for the abundance of calcium in water is its natural occurrence in the earth's crust. Calcium is also a constituent of coral. Rivers generally contain 1-2 ppm calcium, but in lime areas, rivers may contain calcium concentrations as high as 100 ppm.).

In a watery solution calcium is mainly present as Ca^{2+} (aq), but it may also occur as $CaOH^+$ (aq) or,$Ca(OH)_2$(aq),as$CaSO_4$ in seawater.(Brown and al.1997)
Calcium is an important determinant of water hardness, and it also functions as a pH stabilizer, because of its buffering qualities. Calcium also gives water a better taste.

Calcium compounds are more or less water soluble.Table 3 below shows the solubility of some major calcium compounds.

Table 3 : Calcium compounds and their respective water solubilities.

Calcium compound	Solubility in water(mg/L)
Calcium carbonate($CaCO_3$)	14
Calcium phosphate($Ca_3(PO4)_2$)	20
Calcium fluoride(CaF_2)	16
Calcium chromate($CaCrO_3$)	170

Calcium is naturally present in water. It may dissolve from rocks such as limestone, marble, calcite, dolomite, gypsum, fluorite and apatite. Calcium is a determinant of water hardness, because it can be found in water as Ca^{2+}ions (Brown and al.1997).Some calcium compounds have different applications (see table 4).

Table 4 : Applications of some calcium compounds.

Compounds of calcium	Application
Calcium hypochloride	Used as bleach and for disinfection In glass and porcelain industries As flocculants in waste water treatment
Calcium phosphate	-Turbidity agent in enamel industry
Calcium polysulphide and hydroxide	-In UV –spectroscopy
Calcium fluoride	-Raw material for fluid acid production

Calcium may also be applied for removal of carbon and sulphur from iron and iron alloys, and for dewatering oil. Limestone is applied as paper filler, causing paper to colour whiter, and in plastics to improve stability. Calcium often positively affects soil quality and various calciumcompounds are applied as a fertilizer. For example, $CaCl_2$ or $Ca(NO)_3$ solutions are applied in horticulture. Calcium oxide is a dehydrating molluscicide (Brown 1997).

I.6.7.1.Environmental effects of calcium in water

Calcium is a dietary requirement for all organisms apart from some insects and bacteria. Calcium carbonate is a building stone of the skeletons of most marine organisms, and eye lenses.Water hardness influences aquatic organisms concerning metal toxicity. In softer water, membrane permeability in the gills is increased. Calcium also competes with other ions for binding spots in the gills. Consequently, hard water better protects fishes from direct metal uptake. pH values of 4.5-4.9 may harm salmon eggs and grown salmons, when the calcium, sodium and chlorinecontentis low(Bohmer 2000).

Various calcium compounds may be toxic. The LD_{50} of rats for calcium arsenite is 20 mg/ kg body weight. Calcium carbide forms flammable ethyn when it comes in contact with water and is therefore considered hazardous. Some environmental effects of water hardness include hardening of domestic equipment, because high temperatures cause carbonate hardness. This may dramatically decrease the lifespan of equipments, and cause an increase in domestic waste. Calcium carbonate interacts with detergents and cleansing agents. Complex formation causes a decrease in detergent efficiency, resulting in requirement for increased detergent application and softener purchases Softening is often carried out by means of ion exchangers. These must be regenerated with kitchen salt, and therefore burden wastewater (Bohmer 2000).

There are six stable calcium isotopes. Today, we know of eight instable calcium isotopes. ^{45}Ca is highly radioactive and toxic.

Calcium is a dietary mineral that is present in the human body in amounts of about 1.2 kg. No other element is more abundant in the body. Calcium phosphate is a

supporting substance, and it causes bone and tooth growth, together with vitamin D. Calcium is also present in muscle tissue and in the blood. It is required for cell membrane development and cell division, and it is partially responsible for muscle contractions and blood clotting. Calcium regulates membrane activity, it assists nerve impulse transfer and hormone release, stabilizes the pH of the body, and is an essential part of conception. In order to stimulate these body functions a daily intake of about 1000 mg of calcium is recommended for adults. This may be achieved by consuming dairy, grains and green vegetables.

Calcium carbonate works as a stomach acid remedy and may be applied to resolve digestive failure. Calcium lactate may aid the body during periods of calcium deficiency, and calcium chloride is a diuretic (Brown 1997).

Hard water may assist in strengthening bones and teeth because of its high calcium concentration. It may also decrease the risk of heart conditions. Drinking water hardness must be above 8.4 °dH. Calcium carbonate has a positive effect on lead water pipes, because it forms a protective lead (II) carbonate coating. This prevents lead from dissolving in drinking water, and thereby prevents it from entering the human body.

When one takes up large amounts of calcium this may negatively influence human health. The lethal dose of oral uptake is about 5-50 mg/ kg body weight. Metallic calcium corrodes the skin when it comes in contact with skin, eyes and mucous membranes.

Removing calcium ions from water is carried out by water softeners. These are ion exchangers that usually contain Na^+ ions, which are released and substituted by Ca^{2+} and Mg^{2+} ions.

Calcium compounds may be applied for wastewater treatment. Drinking water pH and hardness may be altered by means of calcium carbonate and calcium hydroxide (http: www.lenntech).

I.6.8. Magnesium ion (Mg^{2+})

Magnesium is present in seawater in amounts of about 1300 ppm. After sodium, it is the most commonly found cation in oceans. Rivers contains approximately 4 ppm of magnesium, marine algae: 6000-20,000 ppm, andoysters: 1200 ppm. Magnesium and other alkali earth metals are responsible for water hardness. Water containing large amounts of alkali earth ions is called hard water, and water containing low amounts of these ions is called soft water (Stitt and al.1973).

Magnesium metals are not affected by water at room temperature. Magnesium generally is a slow-reacting element, but reactivity increases with oxygen levels. An example of a magnesium compound is magnesium phosphide (Mg_3P_2), an odorous, grey solid. When this compound comes in contact with water or moist air, it is decomposed and phosphine (PH_3) is formed. This is a toxic compound, and it is also very flammable in air.

Magnesium is mainly present as Mg^{2+} (aq) in watery solutions, but also as $MgOH^+$ (aq) and $Mg(OH)_2$(aq). In seawater it can also be found as $MgSO_4$.
Water solubility of magnesium hydroxide is 12 mg/L. Other magnesium compounds are clearly more water soluble, for example magnesium carbonate (600 mg/L). Magnesium sulphate adds a bitter flavour to water, and has a water solubility of 309 g/L at 10°C.

Magnesium is washed from rocks and subsequently ends up in water. Magnesium has many different purposes and consequently may end up in water in many different ways. Chemical industries add magnesium to plastics and other materials as a fire protection measure or as filler. It also ends up in the environment from fertilizer application and from cattle feed. Magnesium sulphate is applied in beer breweries, and magnesium hydroxide is applied as a flocculant in wastewater treatment plants. Magnesium is also a mild laxative. Magnesium alloys are applied in car and plane bodies.

During World War II magnesium was applied in fire bombs, to cause major fires in cities. The development of these bombs introduced a method to extract magnesium from seawater.

I.6.8.1. Environmental effects of magnesium in water

Magnesium is a dietary mineral for any organism but insects. It is a central atom of the chlorophyll molecule, and is therefore a requirement for plant photosynthesis. Magnesium cannot only be found in seawater, but also in rivers and rain water.Environmental problems indirectly caused by magnesium in water are caused by applying softeners. Calcium and magnesium ions (particularly calcium) negatively influence cleansing power of detergents, because these form nearly insoluble salts with soap. Consequently, about 40% softener is added to soap (Stitt and al.1973).

I.6.8.2. Health effects of magnesium in water

The human body contains about 25 g of magnesium, of which 60% is present in the bones and 40% is present in muscles and other tissues. It is a dietary mineral

for humans, one of the micro elements that are responsible for membrane function, nerve stimulant transmission, muscle contraction, protein construction and DNA replication. Magnesium is an ingredient of many enzymes. Magnesium and calcium often perform the same functions within the human body and are generally antagonistic.

There are no known cases of magnesium poisoning. At large oral doses magnesium may cause vomiting and diarrhoea. High doses of magnesium in medicine and food supplements may cause muscle slackening, nerve problems, depressions and personality changes.

As was mentioned before, it is unusual to introduce legal limits for magnesium in drinking water, because there is no scientific evidence of magnesium toxicity. In other compounds, for example asbestos, magnesium may be harmful.

Magnesium compounds are usually removed from water, because of the role magnesium plays in water hardness. This is achieved by means of water softening. Magnesium hydroxide is applied as a flocculant in water purification.

I.6.9. Potassium ion (K^+)

Seawater contains about 400 ppm potassium. It tends to settle, and consequently ends up in sediment mostly. Rivers generally contain about 2-3 ppm potassium. This difference is mainly caused by a large potassium concentration in oceanic basalts. Calcium rich granite contains up to 2.5% potassium. In water this element is mainly present as $K^+_{(aq)}$ ions (Powell 1987).

^{40}K is a naturally abundant radioactive potassium isotope. Seawater contains a natural concentration of about $4.5.10^{-5}$ g/L.

Potassium reacts rapidly and intensely with water, forming a colourless basic potassium hydroxide solution and hydrogengas, according to the following reaction mechanism:

$$2K_{(s)} + 2H_2O_{(l)} \rightarrow 2KOH_{(aq)} + H_{2(g)}$$
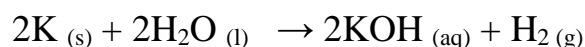
Potassium is non-water soluble, but it does react with water . Potassium compounds may be water soluble.

I.6.9.1. Examples of potassium compounds and their respective water solubility

Table 5 shows some potassium compounds and their respective solubilities.

Table 5 : Potassium compounds and their respective water solubilities.

Potassium compound	Water solubility(g/L)
Potassium dichromate	115
Potassium permanganate	76
Potassium iodide	92-1480

Potassium occurs in various minerals, from which it may be dissolved through weathering processes. Examples are feldspars (orthoclase and microcline), which are however not very significant for potassium compound production, and chlorine minerals, carnalite and sylvite, which are most favourable for production purposes. Some clay minerals contain potassium. It ends up in seawater through natural processes, where it mainly settles in sediments.

A number of potassium compounds, mainly potassium nitrate, are popular synthetic fertilizers.95% of commercially applied potassium is added to synthetic

fertilizers. Potassium salts and mixtures of magnesium and calcium compounds are also applied regularly. Regeneration releases wastewater that is hazardous when discharged on surface water, and that is difficult to purify (Powell 1987). Potassium is applied in glass production to make it stronger and solid. This glass is mainly applied in television screens. Other potassium compounds are applied in fluid soap production, added to medicines or infusions, or applied in photography or tanning. In most cases potassium is not the active ingredient, but rather the adjacent anion. This also applies to potassium chlorate application in matches and fireworks, and for potassium nitrate in powder. Potassium alums are bases for paper glue and are applied as a filler of synthetic rubber.

Potassium compounds are the most reactive basic chemical compounds, which for example applies to potassium hydroxides and nitrates. Potassium hydroxide forms caustic potash and is applied in detergents, softeners, green soap, de-sulphurization of oil and carbon dioxide absorbers.

Other examples ofpotassium compound application include potassium iodide for waste sample oxidative capacity measurements, potassium dichromate for organic matter oxidative capacity measurements in soil science and biological wastewater treatment, and potassium dicyano aureate, which is an extremely toxic water soluble gold compound that is applied for technical gilding. Potassium compounds may end up in wastewater through urine. An unusual application is increasing the amount of rain in dry regions by potassium chloride. It is released just below the clouds from planes, rises up and doubles the amount of moist in clouds, causing it to start raining harder.

As potassium release from landfills for domestic waste is usually exceptionally high, this compound may be applied as an indicator for other toxic compounds in

groundwater.

I.6.9.2. Environmental effects of potassium in water

Potassium is a dietary requirement for nearly all organisms, because it plays an important role in nerve functions.Potassium plays a central role in plant growth, and it often limits it. Potassium from dead plant and animal material is often bound to clay minerals in soils, before it dissolves in water. Thus, it is readily taken up by plants again. Ploughing may disturb this natural process. Consequently, potassium fertilizers are often added to agricultural soils. Potassium salts may kill plant cells because of high osmotic activity.

Potassium is weakly hazardous in water, but it does spread pretty rapidly, because of its relatively high mobility and low transformation potential. Potassium toxicity is usually caused by other components in a compound, for example cyanide in potassium cyanide (Grimm and al.1990).

The LD_{50} value for rats is 5 mg/kg. For potassium bromate this is 321 mg/kg, and for potassium fluoride this is 245 mg/kg. Examples of LD_{50} values for water organisms include 132 mg/L for fish and 1.16 mg/L for daphnia. One of three naturally occurring potassium isotopes is ^{40}K, which is radioactive. It is suspected this compound causes plant and animal gene modifications. However, it does not have a radio toxicity class, because of its natural origin. There is a total of twelve instable potassium isotopes.

I.6.9.3. Health effects of potassium in water

Potassium shortages are relatively rare, but may lead to depression, muscle weakness, heart rhythm disorder and confusion. Potassium loss may be a

consequence of chronic diarrhoea or kidney disease, because the physical potassium balance is regulated by the kidneys. When kidneys operate insufficiently, potassium intake must be limited to prevent greater losses. Skin contact with potassium metals results in caustic potash corrosion. This is more hazardous than acid corrosion, because it continues unlimitedly. Caustic potash drops are very damaging to the eyes.

The intake of a number of potassium compounds may be particularly harmful. At high doses potassium chloride interferes with nerve impulses, which interrupts with virtually all bodily functions and mainly affects heart functioning. Potassium alum may cause stomach complaints and nausea at concentrations as low as 2g, and may be corrosive and even lethal in higher concentrations. Potassium carbonate is lethal to adults at doses above 15g. The same goes for potassium tartrate at 1g, and for potassium cyanide at only 50mg. Potassium dichromate is lethal at between 6 and 8g, and 30g of potassium nitrate causes severe intoxication, which may result in death. Because of its strongly corrosive mechanism potassium hydroxide concentrations between 10 and 12 ml in a 15% caustic may be lethal. Potassium permanganate is applied in bleaches and disinfection, and is lethal at between 5 and 8g (Grimm and al.1990).

Potassium may be removed from water by means of reverse osmosis. Potassium is applied in water purification. For example, potassium permanganate is applicable for oxidation of waterborne compounds, such as: for iron or manganese removal, and disinfection. This is however not generally recommended. Potassium permanganate application makes it possible to determine the oxidative capacity of organic matter in water. Generally this exceeds BOD. Potassium dichromate is applied for COD determination

I.6.10.Ammonium ion (NH$_4^+$)

Ammonium ions are the primary form of wide spread nitrogen pollution in the hydrosphere and cause a remarkable increase of oxygen demand and biological eutrophication in local and aquatic sources (Sprynskyy and al.2005).Results proved that increased in concentration of this beyond a permissible level cause damage to aquatic life (For example, ammonia is toxicto fish and other forms of aquatic life in very low concentration, about 0.2 mg/L) (Randall and Tsui 2002,Haralambousand al. 1992).Thus the major concern regarding ammonia toxicity must be in aquatic systems,particularly in regions of high human habitation and/or large numbers of farm animals (Ip and al.2001)

Hence, the removal of ammonium from municipal land industrial wastewater prior to discharge is now obligatory. Many methods are being used to remove ammonium ions.toxicity and source of ammonium ions. Molecular nitrogen (N$_2$) present in the earth's atmosphere has to be reduced to ammonia (NH$_3$) bynitrogen-fixing bacteria living independently in the soilor in the root of leguminous plants before it is utilizedby humans. Ammonia dissolves in water to formammonium ions (NH$_4^+$) and this form of reduced nitrogenis assimilated into amino acids and other nitrogen-containing molecules. In aqueous solutions, ammoniais a base (any compound accepting hydrogen ions) forming a conjugated pair with the ammonium ion (Ip and al.2001),

Ammonia has a hazardous and toxic effect onhuman health and biotic resources also, only if the

Intake becomes higher than the capacity to detoxify and predefine permissible limits. If ammonia isadministered in the form of its ammonium salts, theeffects of the anion must also be taken into account.With ammonium chloride, the acidotic

effects of thechloride ion seem to be of greater importance thanthose of the ammonium ion (RyerPowder 1991). At a dose of more than 100 mg/kg of body weight per day (33.7 mg of ammonium ion per kg of body weight perday), ammonium chloride influences metabolism byshifting the acid–base equilibrium disturbing theglucose tolerance, and reducing the tissue sensitivityto insulin (Lamm and al.1999,Sadegh and al. 2014).

There are certain levels of contaminants considered acceptable by some organizations.One of these organizations is the American Environmental Protection Agency (EPA).Table 6 below gives the EPA Maximum Contaminant Levels for the ions studied.

Table 6 : EPA Maximum Contaminant Levels (MCLs) for the ions studied.

ION	MCL(mg/L)
F^-	—
Cl^-	0.01
NO_3^-	0.06
PO_4^{3-}	<0.1
SO_4^{2-}	<0.5
Ca^{2+}	—
Mg^{2+}	—
K^+	—
Na^+	—

NH_4^+	0.2

I.7. Targeted organic pollutants

I.7.1. Pesticides (e, g DDT) and their residues

A pesticide or phytosanitary product, with the exclusion of pharmaceutical and veterinary products, is a substance or preparation capable of eliminating living things, plants or animals, pest to humans directly or indirectly. Based on their use, pesticides are classified into herbicides, insecticides, fungicides, Nematocides, molluscides (Dongo 2002)

Pesticides have been spread through out the environment, they are found in the air we breathe, in streams, lakes, and clothing and indeed in our very bodies (Kargong2000)

I.7.1.1.The case of DDT.

The discovery of dichlorodiphenyltrichloroethane (DDT) in 1940, marked the beginning of pesticide era .Its systematic name is 1, 1, 1-trichloro-2,2-bis-(p-chlorophenyl) ethane.

This is an insecticide that has been banned in most countries including Cameroon because it is not biodegradable and because of its disastrous effects on man and the environment. It was banned alongside aldrin, dieldrin and chlordane by EPA in the 1970s (Graham 1992).

It is obtained from the following reaction:
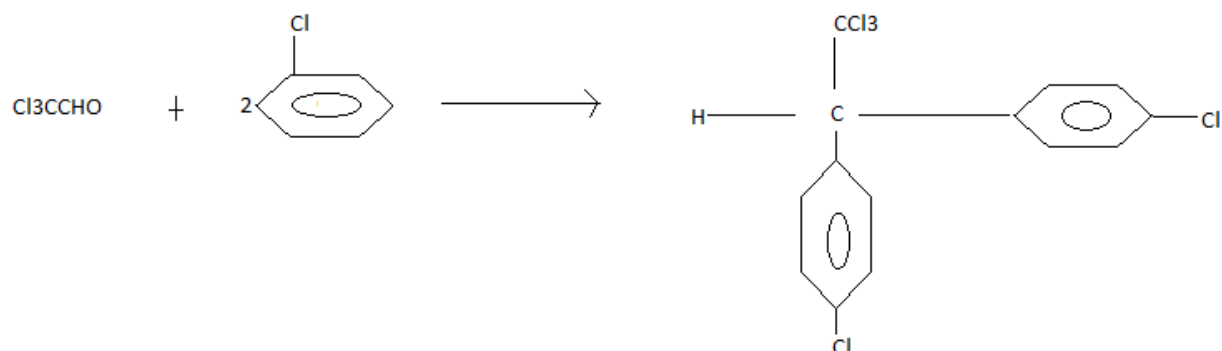
A single dose of 10mgDDT/Kg body weight may result in sweating, headache, and nausea while a dose of 16mgDDT/Kg body weight may lead to convulsion (http:/www.cla.sc.edu/geog).

I.7.1.2) Effects of Pesticides on animals

The effects of pesticides on animals are mostly on the nervous system. Table 7 below summarizes the effects of pesticides.

Table 7 : Effects of pesticides.

Types of effects	Examples of compounds
Inhibition of acetycholinesterase	Organophosphates;carbamates
	Nicotinoids
Inhibiition of neuromuscular junction	
	Pyrethoids;chlorinated and brominated hydrocarbons.
Neurotoxication with only partially known causes	

I.7.2) Polychlorinated Biphenyls (PCBs)

PCBs are a group of about 70 different but closely related chlorinated hydrocarbons (Chang 1991).They do not occur in nature and as such their levels in the atmosphere, soil and water can be attributed to man's activities. Table 8 presents the levels of PCBs found in the environment

Table 8 : Levels of PCBs found in the environment.

Milieu	Concentration ng/m^3	Species	Concentration mg/kg
Air	0.1-20	Planktons	0.01-20
		Invertebrates	0.01-10
Water	0.1-3000	Fish	0.01-25
		Bird's egg	0.01-500
		Man	0.1-10

Table 8 reveals that the principal source of man's accumulation of PCBs is from contaminated fish.

Globally, PCBs are found in the air in concentrations of 0.002 up to 15 ng/m^3.In industrial areas, levels are higher. In rain water and snow, the range is 1ng-250 ng/l.Human food has become contaminated with PCBs by 3 main routes:

a) Uptake from the environment by fish, birds, livestock (via food chain) and crops

b) Migration from packaging materials into food, 1 mg/kg-10 mg/kg; and

c) Direct contamination of food or animal feed by an industrial accident (Dobson 1993)

PCBs concentrate in human adipose tissue and breast milk.

I.7.2.1. Chemical formula and structure

They have the general formula $C_{12}H_{10-n}Cl_n$ where n can range from 1 to 10.The conventional numbering of substituent positions is as shown below.
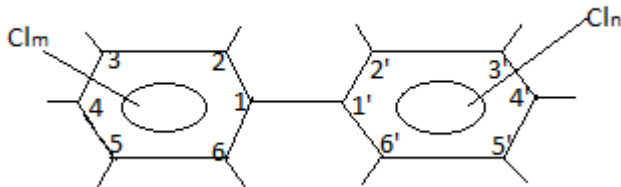
A typical compound in the PCB category is

2,4,6,2',4'-pentachlorobiphenyl
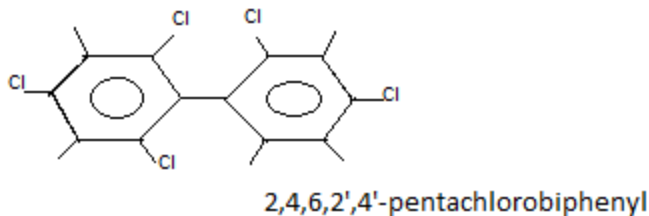
I.7.2.2) Manufacture

The commercial production of PCBs began in 1930.By the end of 1990,the total world production of PCBs were over 1 million tones(Dobson 1993).They are manufactured commercially by the progressive chlorination of biphenyl in the presence of a suitable catalyst (e.g Iron(III) chloride).The yield is always a mixture

of different isomers and congeners. Hence there are 209 different theoretical congeners but only 130 likely occur in commercial products.

The technical products are known by a variety of trade names including Aroclor,Oyranol,Pyrochor(USA),Phenochlor,Pyralene(France),Clophen,Elaol(Germany),Kanechlor,Santotherm(Japan),Fenchlor,Apirolio(Italy)and Sovol(USSR)(Dobson 1993).

I.7.2.3) Physical and Chemical properties

Physical properties
1) They are lipophilic and have very low water solubility. As a result, they easily enter the food chain and accumulate in fatty tissues.

2) Commercial PCB mixtures are light yellow or dark yellow in color.

3) They do not crystallize even at low temperatures but turn into solid resins.

4) They form vapour heavier than air.

5) They have very low electrical conductivity but high thermal conductivity.

6) They have extremely high resistance to thermal breakdown.

Chemical properties
PCBs are chemically very stable under normal conditions, hence they are

1) Resistant to fire

2) Do not form explosive mixtures with air.

However, when heated, other toxic compounds such as polychlorinated dibenzofurans (PCDFs) can be produced under laboratory conditions of temperature (550-700^{0}c) (Dobson 1993)

I.7.2.4. Biodegradation
Research studies on the biodegradation of PCBs reveal the following:

-The growth of pseudomonas sp. on a 3-methylbenzoate substrate improves degradation of the biphenyls.

-Congeners with high degree of chlorination are selectively dechlorinated by anaerobic organisms. Congeners with lower chlorination are readily degraded by aerobic bacteria.

-The soil fungus *Rhizopus japonius* degrades 4 chlorobiphenyl or 4,4dichlorobiphenylto a hydroxyl derivative(Dobson 1993)

I.7.2.5. Photo degradation
Simple chlorinated biphenyls, as well as complex commercial PCB mixtures undergo photo reduction in organic solvents. Under real environmental conditions, higher chlorinated PCB congeners might be degraded in water by the action of sunlight (Dobson 1993).

I.7.2.6. Bioaccumulation
PCBs accumulate in almost all organisms because of their high lipid solubility and slow rate of metabolism and elimination.

I.7.2.7. Uses and sources

1) They are widely used as insulating and cooling fluids in electrical transformers and capacitors.

2) They are also used in the production of plastics, paints, rubber, adhesives and carbonless copy paper.

3) They are used as fire-resistant liquid in nominally closed systems (chang 1991).

I.7.2.8.Effects of PCBs on humans

In 1968, it was reported that some people in Japan suffered from liver and kidney damage after they had eaten food contaminated with PCBs (Chang 1991).

Much data can be got from the reports of the YushoYu-cheng intoxication incidents which probably reflect effects of exposure to both PCDFs and PCBs.According to these reports, the signs shown by the patients were:

1) Swelling of the eyelids and pigmentation of the nails and mucus membranes, occasionally with fatigue, nausea and vomiting.

2) Darkening of the skin.

3) Oedema of arms and legs.

4) Liver enlargement and disorders

5) Central nervous disorder

6) Respiratory problems, and

7) Changes in immune status of patients.
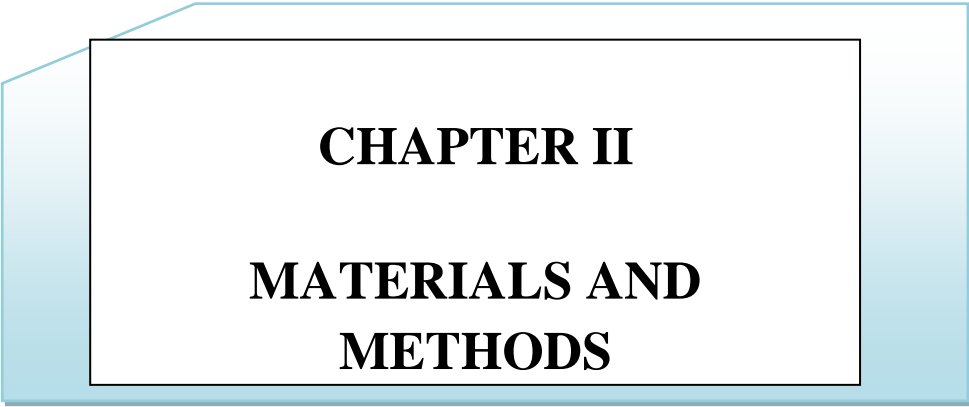
Chloracne is one of the most prevalent findings among PCB exposed workers (Dobson 1993).Long- term exposure to high concentrations of PCBs may cause skin irritations, such as acne and rashes and has been shown to cause liver, stomach and thyroid damage and cancer in animals. Based on laboratory testing of animals exposed to high doses of PCBs, the EPA has determined that PCBs are probable human carcinogens (http://www.epa.gov/1997)

It can be seen that the effects are tremendous so people must avoid being exposed to high concentrations of PCBs.

CHAPTER II

MATERIALS AND METHODS

II.1. Materials Used

The materials and equipment used can be divided into two parts namely: those that were used for collection and preservation of water samples, sediment and fish samples and those used for the preparation and analysis of the samples (Fomenky 2003).

II.1.1. Materials used for collection, preservation and analysis of water samples, and their functions

-**Plastic containers**: To collect water samples at different points of the lake.

-**Fridge:** To store water at 4^0C in order to avoid alteration of concentration of ions

-**Ion chromatogram**: To analyse the water samples

II.I.2. Materials used for fish and sedimentsample collection, extraction, analysis, and their functions

-**Canoe**: Used by the fisherman to detect the position of the fish.

-**Catchnet**: To trap the fish.

-**knife**: To slice the fleshy parts of the fish.

-**Electronic balance**: To measure the mass of the fish and sediment samples.

-**Electric oven**: To dry the fish for 3days at a temperature of 55^0c.

-**Indian bamboo**: To collect sediment sample.

-**Ion chromatogram**: To analyze water samples.

-**Hexane and dichloromethane**: Used as solvents for extraction of fish or sediment sample.

-**Aqueous Na$_2$SO$_4$**: Added to the powdered fish or sediment sample in order to ease extraction.

-**Soxhlet apparatus**: Used to carryout fish and sediment extraction.

-**RotavaporHeindolf**: To separate used solventfrom extract of fish or sediment.

-**HPLC and Gas Chromatography**: Method used to analyse fish and sediment samples.

II.2. METHODS

II.2.1. Collection of water samples

Water samples were collected on the 21st March 2016 in plastic bottles at four different points: the North (N), south(S), West (W) and East (E) (see figure 2), by deeping them in the lake and avoiding floating material. The stoppers of the sample containers were closed properly to prevent outside contamination. The containers were labeled describing the name of the water body and date of collection of water sample.These points were chosen because two of the points are the major inlets of wastes into the lake (North and East points), one is the outlet (south) and the fourth point (West) is characterized by enough floura.So, easy to detect ions which their presence in water can directly or indirectly affect plants. The temperature of the water was found by deeping a thermometer into it and allowing it for sometime. It was read when it showed a stable reading, as shown in table 10.The pH was measured using a pH meter (see table 10).This was done by

dipping it into the water.Figure 2 presents the chosen points for the collection of water samples while figure 3 shows a sketch map of the lake indicating the points of collection of water samples

A) North point (inlet 1) B) East point (inlet 2)

C) West Point D) South point (outlet)
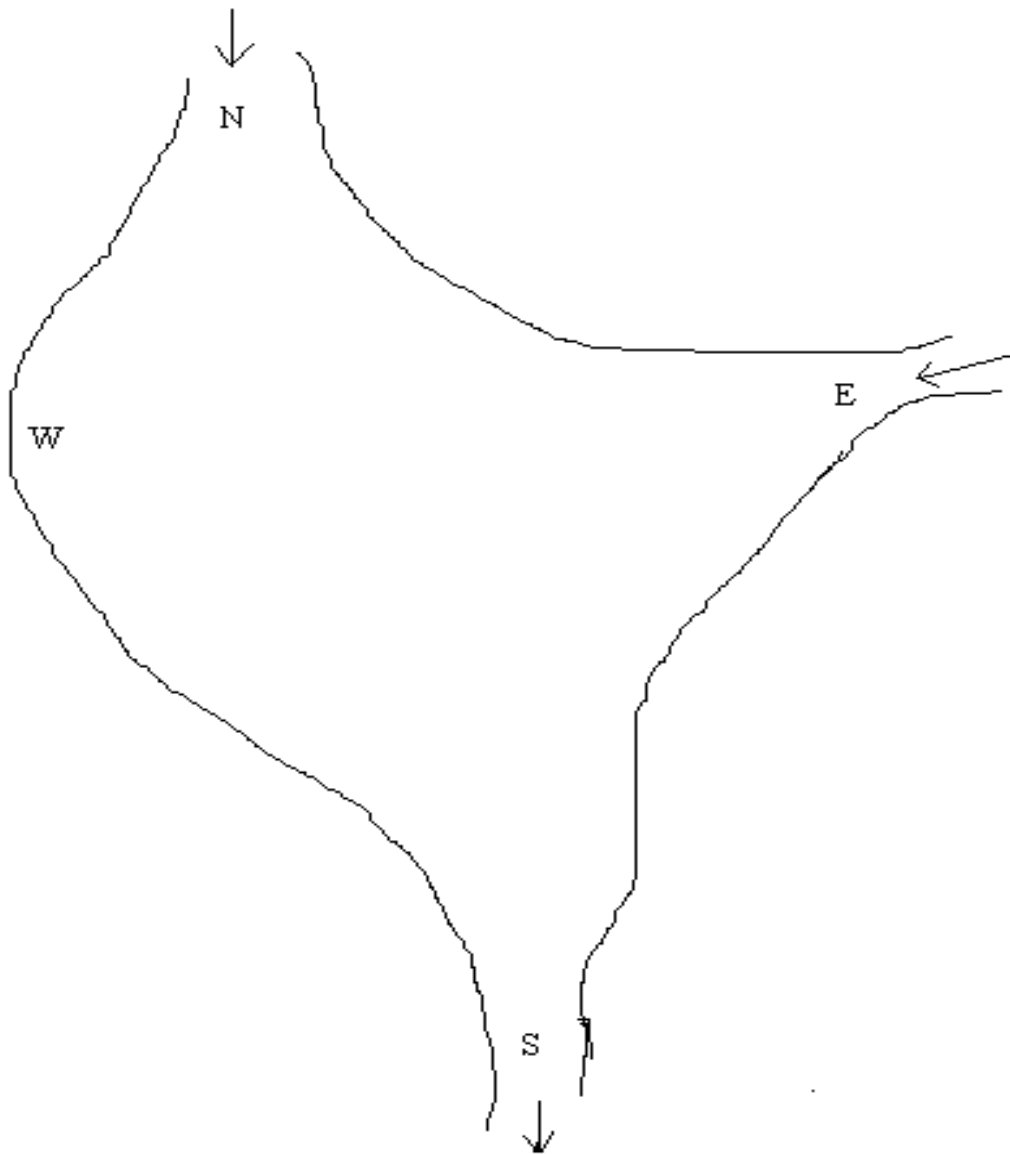
Figure 2 : Presentation of points of collection of water samples.

Figure 3 : A Sketch map of the lake indicating the location of points of collection of water samples.

II.2.2) Preservation of water samples

The water samples were preserved by cooling at 4^0c, with a maximum holding time of 6days for it to be analyzed. This was done to avoid the variation in concentration of the ions.

II.2.3) Analysis of ions from water samples by ion chromatography

The ions were analyzed using the ion chromatographic method.The devices used were the ICS-90 and ICS-1100 Dionex models at the Geological Research Laboratory in Nkolbisson,Yaounde,Cameroon. The series of cations and anions were measured separately. For each set, an eluent (an ion extraction liquid flowing in the liquid circuit of the device), a chromatographic column and a specific suppressor were used.

Once introduced with an autosampler, the water sample reached the column in which the different species in solution were retained by a resin, and then released following an order determined by their size andload.After the removal of the eluent conductivity by the suppressor,a very accurate detector measured the conductivity corresponding to each of the species present in solution. The area of successive peaks was integrated by the device and converted into concentrations, through a series of standards that has gone before samples. If the concentrations obtained for certain species were out of the calibration range, the sample was diluted or and again analyzed.

II.2.3.1. Ion chromatography

The IC analyzes consists of four stages:

Eluent Delivery

• Eluent, a liquid that helps to separate the sample ions, carries the sample through the ion chromatography system. The ICS-90 and the ICS-100 are an isocratic delivery system. This means that the eluent composition concentration remain constant throughout the run. For anion analysis, the eluent is a combination of carbonate-bicarbonate (Na_2CO_3-$NaHCO_3$) up to 20mM. For cations, the eluent is H_2SO_4 22mN.

• Liquid sample is injected into the eluent stream automatically (each chromatograph is equipped with an automated sampler).

• The pump forces the eluent and sample through a separator column chemically-inert tube packed with a polymeric resin.

Separation

• As the eluent and sample are pumped through the separator column, the sample ions are separated. The mode of separation is called ion exchange and it is based on the premise that different sample ions migrate through the IC column at different rates, depending upon their interactions with the ion exchange sites. It means that ions are separated based on their relative affinity to the correspondent analytic column.

Detection

• After the eluent and sample ions leave the column, they flow through a suppressor that selectively enhances detection of the sample ions while suppressing the conductivity of the eluent.

• A conductivity cell monitors and measures the electrical conductance of the sample ions as they emerge from the suppressor and produces a signal based on a chemical or physical property of the analyte.

Data Analysis

• The conductivity cell transmits the signal to a computer running chromatography software.

• The chromatography software analyzes the data by comparing the sample peaks in a chromatogram to those produced from a standard solution. The software identifies the ions based on retention time, and quantifies each analyte by integrating the peak area or peak height. The results are displayed as a chromatogram, with the concentrations of ionic analytes automatically determined and tabulated.

. The sensitivity is 0.01 ppm.
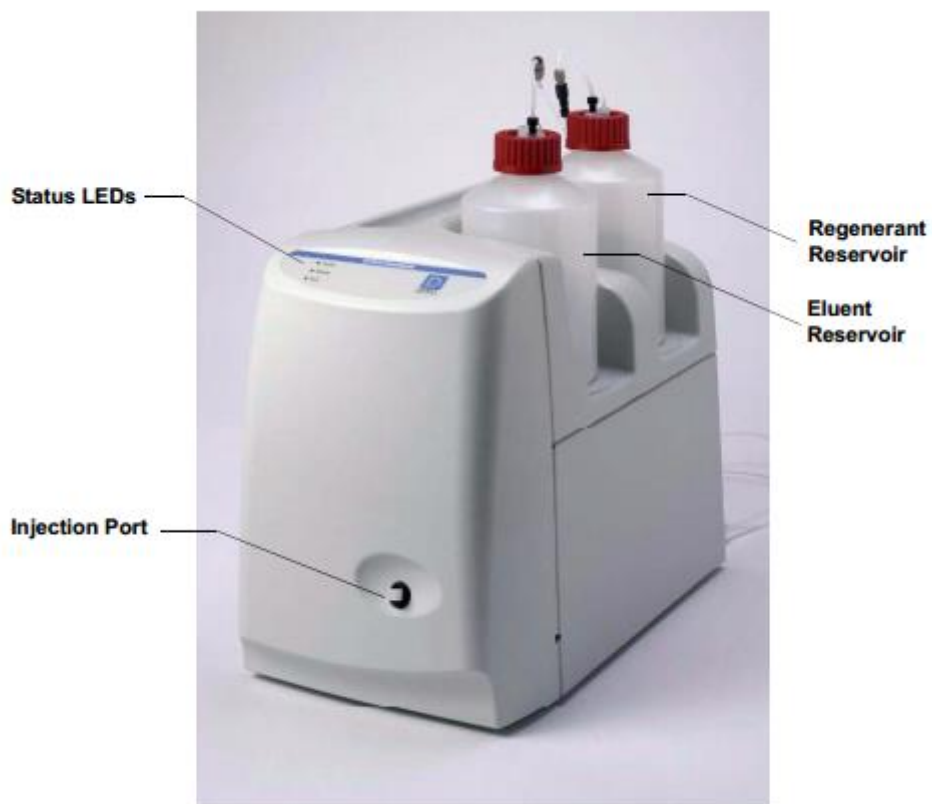
Figure 4 : Ion Chromatogram system-90.

II.2.4. Collection and preparation of fish and sediment samples

II.2.4.1. Collection of sample of fish

The fish sample (figure 5) was caught using a cast net by a fisherman on the 24th March 2016(4 Tilapia). He dipped the net into the lake and the fish on moving from one side of the net to another got stock in between the holes of the net.The net and fish were brought to the shore and the fish removed and put in a plastic bag.

Figure 5 : Fish sample of Oreochromis niloticus (Tilapia).

II.2.4.2. Collection of samples of sediments

The sediment samples were collected at the center of the lake with a specially designed Indian bamboo apparatus (see figure 6) of length 5m (i.e bamboo 3m and attached stick 2m).The Indian bamboo, at the bottom was split longitudinally into 5 plates up to about 60cm with holes pierced by its sides for water to run out as shown in figure 6. One of the plates was cut at about 50cm from the bottom at the other end such that it could be completely detached from the

apparatus in order to have access to sediment collected from the lake. The whole was rapped in Aluminum sheet and tied with black rubber allowing a hollow for the sediment to enter.

A fisherman standing inside a canoe on the lake dipped the bottom of the apparatus to the bottom of the lake, tilted it round and round many times, removed the sediment, put the bamboo and its content in the canoe and brought to the shore. The black rubber was untied and removed from the apparatus. The aluminum sheet was also removed. The detectable plate was removed giving access to the sediment (see figure 6) .The average height of column of sediment sample collected was 25cm.It was put in a plastic bag and taken to the laboratory.

Figure 6 : Indian Bamboo Apparatus used for sediment sample collection.

II.2.4.3. Preparation of fish and sediment samples for persistent organic pollutant analysis

Fish: The fish sample was washed and chopped into pieces. It wasnext dried in an electric oven at 55^0c overnight for 3 days. All the tilapia was pooled to form one sample. Afterdrying, the sample was ground to powder using a molinex grinder.

Sediments: The sediment sample was air dried for 5days, crushed using a mortar and pestle and sieved using an aluminum sieve to obtain particles of maximum diameter 150μm, which was put in a sampled bottle and labeled.

II.2.5. Solvent extraction of organic pollutants from fish and sediment samples
A fixed mass (10-50g) of powdered sediment or fish sample was mixed together with a fixed mass of anhydrous sodium sulfate, a dehydrating agent. The sample was dehydrated in order to ease extraction. The mixture was put in a cylindrical filter paper where one end has been folded to prevent mixture from coming out and placed in a soxhlet (see Figure 7).With 200ml solvent, Dichloromethane or Hexane; extraction was done at different time intervals. The sample extracts were concentrated (removal of some of the solvent) to 15ml using a Rota vaporHeindolf.Each extract was put in 10ml and 5ml sample tube and labeled.This was done with the technical supervision of Pr. Deccaux Kapche.Table 9 shows the solvent used, mass of sample of fish or sediment used and mass of aqueous Na_2SO_4 used during the extraction
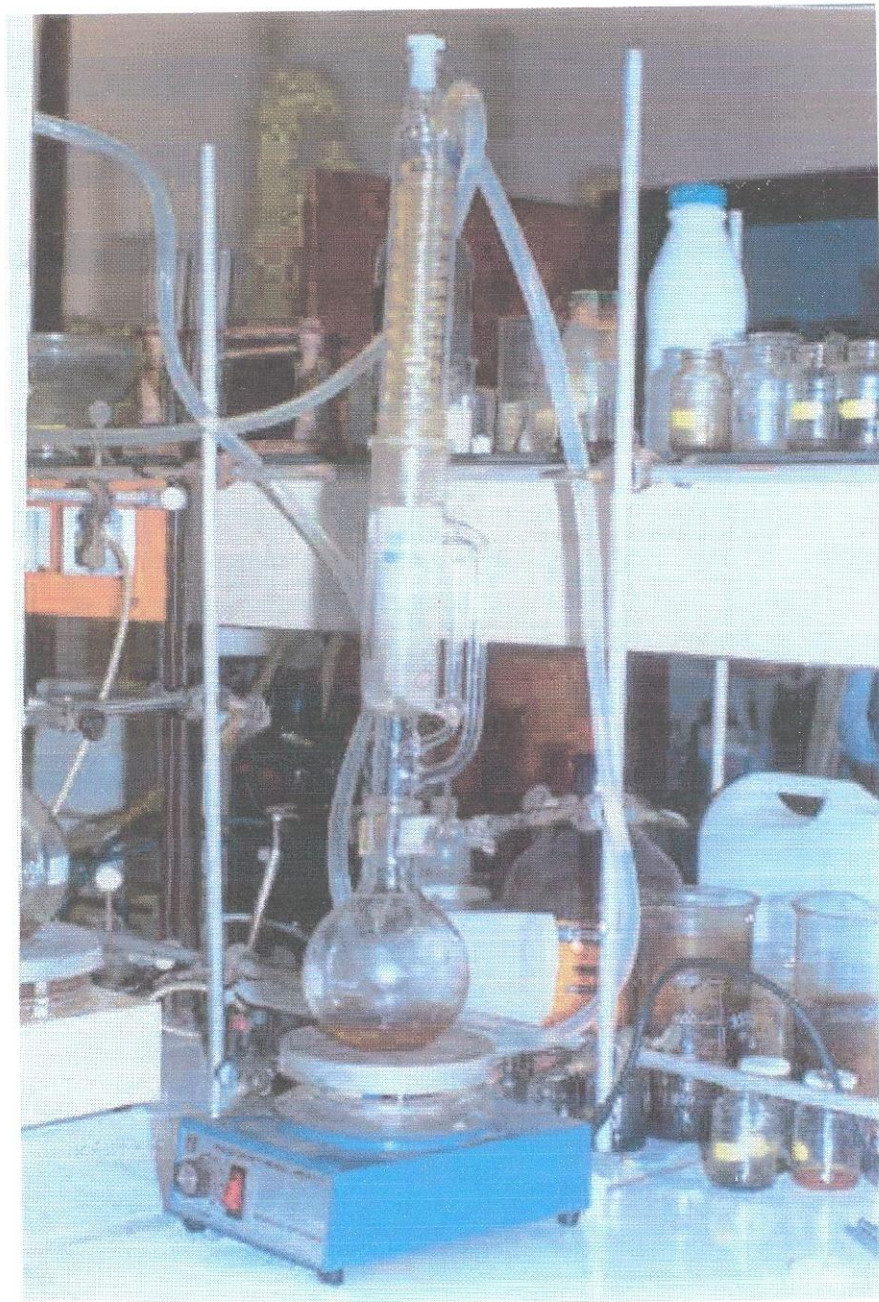
Figure 7 : Soxhlet apparatus used for solvent extraction.

Table 9 : Solvent, mass of sample and mass of Na_2SO_4 used during extraction.

Sample number	Identity	Solvent	Mass of sample(g)	Mass of Na_2SO_4(g)
1	Tilapia TD	CH_2Cl_2	12	12
2	Sediment SD	CH_2Cl_2	25	25
3	Sediment SH	Hexane	30	30

II.2.6. Analysis of Hexane and Dichloromethane extracts of fish and sediment

II.2.6.1. Qualitative Analysis

We were able to carryout extraction and observe the colours. The colours range from yellow, red brown to black indicating the presence of persistent organic pollutants in the fish and sediment samples.

II.2.6.2. Quantitative Analysis

Extracts of fish and sediment were sent to France for analysis by HPLC followed by Gas chromatography.This was due to the lack of equipments for analysis to be done here in Cameroon

CHAPTER III

RESULTS AND DISCUSSION

Table 10 below shows the pH and temperatures at the different points of collection of water samples.

Table 10 : Points of collection of water samples, their respective pH and temperatures.

Points of collection of water sample	pH	Temperature(^{0}C)
North	7.5	28.2
South	7.8	28.4
West	7.6	28.0
East	7.3	28.5

III.1. Ionic concentration of lake water samples at different points

The determination of the anionic and cationic concentrations of water samples taken at different points of the lake using an ion chromatogram was done and the results obtained are presented in table 11 and 12 respectively.

Table 11 : Concentrations of the anions studied at different points of collection of water samples.

Point of water sample collection	F^- (mg/L)	Cl^- (mg/L)	NO_3^- (mg/L)	PO_4^{3-} (mg/L)	SO_4^{2-} (mg/L)
W_{north}(inlet 1)	0.17	13.83	0.51	0	1.95
W_{east}(inlet 2)	0.12	13.39	0.64	0	1.81
W_{west}	Traces	14.18	0.19	0	1.79
W_{south}	Traces	13.43	0	0	1.78

The fluoride ions are seen to have 0.17 mg/L at the inlet1 (north point) of the lake, 0 .12 mg/L at inlet 2 of the lake (east point) and appears as traces in the west point and at the outlet.This is largely due to the fact that fluoride is a constituent of bones and when it enters, it is used up by aquatic organisms for the growth of their bones causing it to appear as traces at the outlet (Barbier and al. 2010).

Chloride ion concentration is high at the inlet 1(13.83 mg/L), observes a decrease at the east point (13.39 mg/L) which corresponds to inlet 2, a sharp increase at the west point and finally decreases again at the outlet.This is because the chlorides may have reacted with metal ions in the lake to form soluble salts thus increasing the level of metals in the lake (Brooker 1984).

The nitrate ion ,observes an increase from inlet 1 to inlet 2(0.51 mg/L to 0.64 mg/L).This shows that wastes entering into the lake from the east point contain high amounts of nitrates.The amount at inlet 2 is very close to that at inlet 1 because there is a high deposition of human and animal wastes at these points.The concentration decreases at the west(0.19 mg/L).There are so many plants at this point,so the amount of nitratesare just those that occur naturally in plants as a main source of nutrients.The nitrate concentration becomes zero at the outlet.this can be explained by the fact that it accumulates in the lake and increases algal growth(Böhlke 2002).

Phosphates recorded a zero concentration at all points of collection of water samples.Phosphate readings are not expected to be high if the algae is already blooming, as the phosphate will already be in the algae and not the water (http:/www.epa.gov/1983).Equally, these water samples were collected in march which is the period in which the rainy season was just starting in Yaounde.Low

amount of fertilizer runoff are experienced which is a major factor that accounts for high phosphates in water.

The sulfate ion concentration is almost evenly distributed at all the chosen points of the lake giving an average concentration of1.8±0.1 mg/L,which is very high as compared to the value recommended by the American Environmental protection Agency.This indicates a high level of eutrophication leading to algal growth.This causes an increase in the BOD of the water leading to the death of many aquatic plants that depend on oxygen for survival.

Table 12 : Concentrations of the cations studied at different points of collection of water samples.

Point of water sample collection	Na^+ (mg/L)	NH_4^+ (mg/L)	K^+ (mg/L)	Mg^{2+} (mg/L)	Ca^{2+} (mg/L)
W_{north}(inlet 1)	28.65	6.46	11.78	3.38	21.66
W_{east}(inlet 2)	28.11	6.47	11.36	3.39	21.72
W_{west}	28.81	6.44	12.02	3.70	22.74
W_{south}	27.33	6.55	11.58	3.24	21.01

The sodium ion concentrations are on average the same at the inlet1,inlet 2 and west points.The outlet observed a drop in concentration up to 27.33 mg/L.Since sodium ions are responsible for pHadjustment,this is clearly seen in the pH values .This point records the highest pH value.

The ammonium ion is averagely the same at all points with an average concentration of 6.48±0.1 mg/L.This shows ahigh amount of nutrient in the

lake.Confering the work of Randal and Tsui 2002, concentrations greater than 0.2 mg/L become toxic, meaning high levels of eutrophication and increase in BOD and equally death of aquatic organisms that depend on oxygen for survival.Ammonium ions are also high in regions of high human habitation, confirming the idea of Ip and al. 2001.

The K^+ ions had a drop from inlet 1 to inlet 2.Since K^+ mostly settles in sediments (http:www.lenntech/2014) ,as it enters with a high concentration,it moves down to the sediments and does not remain inside water samples since it is non-water soluble.It is low at inlet 2,due to low K^+ waste deposits at this point.From inlet 2 to west point,there is an increase.Potassium ions usually end in water through urine.The west point is characterized by the existence of a road where cars and pedestrans pass .So many inhabitants after eating and drinking end up urinating and it moves down into the lake through that point accounting for that increased concentration.Since this point flows directly to the outlet,we see that the difference in concentration between this west point and the outlet is about 0.4 mg/l.

The Mg^{2+} ion showed an almost the same concentration for inlet 1 and inlet 2, an increase at the west point (3.70 mg/L) and a drop at the outlet (3.24 mg/L).This is due to the fact that it is the main constituent of chlorophyll used by plants for photosynthesis.So, most plants in the lake benefit from the influx of magnesium.It is showing a very high value at the west due to high concentration of plants at this point.

The calcium ions presented an increase from inlet 1, inlet 2, west point, and a drop at the outlet (21.01 mg/L).This drop is due to the fact that as it enters the lake, some of it is used as a building stone of skeletons for most marine organisms.A very high concentration of calcium at the west point is suggesting that, there can be

a high amount of limestone or calcite or marble existing at this point, which are the main sources of the calcium ion.

III.2. Persistent Organic pollutant Analysis

III.2.1. Colour of fish and sediment samples
Table 13 shows the colours of samples of fish and sediment when wet ant when dry.

Table 13 : colours of wet and dry, fish and sediment samples.

Sample	Wet colour	Dry color
Tilapia	White	Brown
Sediment	Brown	Pale brown

The wet fish sample is white and when dry is brown.This could be indicative of the type of pollutant found in the fish sample.Sediments are expected wastes that enter the lake.they decay and become black and act as top sediments.After sometime, they move deeper to the bottom of the lake where they get mixed with soil, hence the bown color of the sediment when it is wet.

III.2.2. Colour of solvent extracts of the fish and sediment samples
  Table 14 shows the colours of the solvent extracts of fish and sediment samples together with the time of extraction for each sample.Figure8 shows the colours of the fish and sediment extracts.

Table 14 : Duration of extraction and colours of extracts of fish and sediment sample.

Sample No	Identity	solvent	Mass of sample(g)	Duration(hrs)	colour
1	TD Tilapia	CH_2Cl_2	12	6	Red brown
2	SD Sediment	CH_2Cl_2	25	5	Black
3	SH sediment	Hexane	30	10	Pale yellow

Figure 8 : Colours of solvent extracts of fish and sediment samples before evaporation.

Form table 14 and figure 8, it is found that the color of the extract depends on the sample, the solvent and the duration of extraction.They also range from yellow to black and were different from the colors of the dried samples.This difference could be attributed to the presence of pollutants in the sample whose colors were not visible in the dried samples.The darkest color, black was found in sample 2 which implies this sediment would have more pollutants than the others.

When hexane is used as solvent, it takes more hours to extract than when CH_2Cl_2 is used to do the same exercise i.e from the time taken to have a clear solution in the soxhlet, meaning all or almost all pollutants have been removed and from the colors of the extracts.CH_2Cl_2 is a better solvent for the extraction of organic pollutants than hexane.This is because, whereas hexane is non-polar and removes only non-polar substances,CH_2Cl_2 is moderately polar and removes both polar and non-polar substances.

PEDAGOGIC INTEREST

Our work whichwas based on <<EVALUATION OF THE LEVEL OF SOME IONIC POLLUTANTS IN WATER AND OF POPs IN FISH AND SEDIMENT IN THE YAOUNDE MUNICIPAL LAKE>>pulled us to do a lot of scientific research and make use of several application softwares like Word, Excel, Paint, Power point which is equally a similar way in the initiation to the New Information and Communication Technologies (ICTs)

   Pollution of the municipal lake is being taught in the Forms 1 and 2 classes, and is also covered in Form 5 as part of the G.C.E program.It permits us to better transmit knowledge on pollution related topics in the classroom and give viable advice, verifable effects to learners/students relative to pollution in general and water pollution in particular.

The method of presentation of this dissertation is identical to the elaboration,preparation,presentation and evaluation of secondary school teaching programs.It is necessary to better choose text books to use in secondary schools and those to keep in our individual libraries for better transmission of knowledge.The writing of this dissertation has instilled in us the spirit of research,a scientific reasoning spirit which manifest itself by acquisition of some scientific investigative skills ,scientific attitudes such as critical spirit,objectivity,observation of objects and phenomenon.

CONCLUSION AND RECOMMENDATION

From the theme of this work whose general objective was to evaluate the level of some anions and cations in water samples taken at different points of the lake and POPs in fish and sediment from the Yaounde municipal lake, we can say our objective of determining the concentration has been attained since we were able to obtain the concentration of the different ions at the targeted points using an ion chromatogram.

From the results in the preceeding chapter, we notice that anions like fluorides and nitrates observed an almost zero and zero concentration respectively at the outlet of the lake.This shows their accumulation and consumption in the lake.We equally noticed the highest inlet point for sulfate, nitrate, and ammonium ions being the East point (inlet 2).This point is telling us that the ions which accounts for negative effects in the Yaounde municipal lake mostly enter the lake through this point.

The sulfate ion had almost the same concentration at all points with an average of 1.8±0.1mg/L, far greater thanthe value recommended by the EPA showing high level of algal growth at all points of the lake.

The ammonium ion was almost the same at all points with an average concentration of 6.5±0.1 mg/l.This value is far greater than that recommended by EPA indicating high level of eutrophication in the lake.

Thus,in order to reduce the concentration of some of the ions which have a negative effect on aquatic life as well as humans who feed on some of the aquatic organisms, wastes should undergo serious treatment before being dumped into the

lake, especially wastes from the ''hotel de depute'' and the ministries in particular, and the East point in general. The East point should constantly be verified if any further research on ionic pollution has to be carried out on the lake.

To remedy this problem;

-Wastes should be well treated before emptying into the lake (especially at the East point).

-The government should ban the consumption of fish from this lake.It has been noticed that the ions which have negative effects on the fish we consume are having the same average concentration at all point.As such it becomes difficult to control from a targeted point

-Fishing in the lake should be stopped by the government by bringing forth a decree on the numerous dangers surrounding the fish caught.

-The car washing stations at or around the lake should be relocated.They contribute to the oil spillage which moves directly into the lake and increase the harmful mineral content in the lake.

For further research on this topic,we propose:

-Analysis of the other cations and anions.

-Analysis of all types of fish samples.

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APPENDIX

Calculation of averages of ion concentration of water samples taken at different points of the lake

   a) **Sodium ion(Na+)**

$$\text{Mean} = \frac{28.11 + 28.65 + 28.81 + 27.33}{4}$$
$$= 28.225$$

To calculate the standard deviation, σ

$$\sigma^2 = \frac{\sum(X_i - \bar{X})^2}{n-1} \qquad n=4, n-1=4-1=3$$

Table 15 : Mean Sodium ion concentration at all chosen points.

Na^+	W_E	W_N	W_W	W_S
X_i	28.11	28.65	28.81	27.33
$\bar{X}$	28.225	28.225	28.225	28.225
$X_i - \bar{X}$	-0.115	0.425	0.585	-0.895
$(X_i - \bar{X})^2$	0.013225	0.180625	0.342225	0.801025

$\sum(X_i - \bar{X})^2 = 1.3371$

$\sigma^2 = \frac{\sum(X_i - \bar{X})^2}{3} = 0.4457$

$$\sigma=\sqrt{\frac{\sum(X_i-\bar{X})^2}{3}}=0.66760767$$

Therefore average concentration of Na^+ in water=**28.2±0.7mg/L**

b) Ammonium ions(NH_4^+)

$$\sigma^2=\frac{\sum(X_i-\bar{X})^2}{n-1}$$ $\quad$ n=4,n-1=4-1=3

Table 16 : Mean ammonium ion concentration at all chosen points.

NH_4^+	W_E	W_N	W_W	W_S
X_i	6.47	6.46	6.44	6.55
$\bar{X}$	6.48	6.48	6.48	6.48
$X_i-\bar{X}$	-0.01	-0.02	-0.04	0.07
$(X_i-\bar{X})^2$	0.0001	0.0004	0.0016	0.0049

$\sum(X_i-\bar{X})^2=0.007$

$$\sigma^2=\frac{\sum(X_i-\bar{X})^2}{3}=0.00233333$$

$$\sigma=\sqrt{\frac{\sum(X_i-\bar{X})^2}{3}}=0.04830459$$

Therefore average concentration of ammonium ions=**6.5±0.1mg/L**

c) Potassium ion (K⁺)

$$\sigma^2 = \frac{\sum(X_i - \bar{X})^2}{n-1}$$

n=4,n-1=4-1=3

Table 17 : Mean potassium ion concentration at chosen points.

K^+	W_E	W_N	W_W	W_S
X_i	11.36	11.78	12.02	11.58
$\bar{X}$	11.685	11.685	11.685	11.685
$X_i - \bar{X}$	-0.325	0.095	0.335	-0.105
$(X_i - \bar{X})^2$	0.105625	0.009025	0.112225	0.011025

$\sum(X_i - \bar{X})^2 = 0.2379$

$\sigma^2 = \frac{\sum(X_i-\bar{X})^2}{3} = 0.0793$

$\sigma = \sqrt{\frac{\sum(X_i-\bar{X})^2}{3}} = 0.28160256$

Therefore average concentration of K⁺=**11.7±0.3mg/L**

d) Magnesium ions (Mg^{2+})

$$\sigma^2 = \frac{\sum (X_i - \bar{X})^2}{n-1}$$

n=4,n-1=4-1=3

Table 18 : Mean magnesium ion concentrations at all chosen points.

Mg^{2+}	W_E	W_N	W_W	W_S
X_i	3.39	3.38	3.70	3.24
$\bar{X}$	3.4275	3.4275	3.4275	3.4275
$X_i - \bar{X}$	-0.0375	-0.0475	0.2725	-0.1875
$(X_i - \bar{X})^2$	0.00140625	0.00225625	0.07425625	0.03515625

$\sum (X_i - \bar{X})^2$=0.113075

$\sigma^2 = \frac{\sum (X_i - \bar{X})^2}{3} = 0.03769167$

$\sigma = \sqrt{\frac{\sum (X_i - \bar{X})^2}{3}} = 0.19414342$

Therefore average concentration of magnesium ion (Mg^{2+})=**3.4±0.1mg/L**

e) Calcium ion (Ca^{2+})

$$\sigma^2 = \frac{\sum (X_i - \bar{X})^2}{n-1}$$

n=4, n-1=4-1=3

Table 19 : Mean calcium ion concentration at all chosen points.

Ca^{2+}	W_E	W_N	W_W	W_S
X_i	21.72	21.66	22.73	21.01
$\bar{X}$	21.78	21.78	21.78	21.78
$X_i - \bar{X}$	-0.06	-0.12	0.95	-0.77
$(X_i - \bar{X})^2$	0.0036	0.0144	0.9025	0.5929

$\sum (X_i - \bar{X})^2 = 1.5134$

$\sigma^2 = \frac{\sum (X_i - \bar{X})^2}{3} = 0.50446667$

$\sigma = \sqrt{\frac{\sum (X_i - \bar{X})^2}{3}} = 0.71025817$

Therefore average concentration of calcium ion=**21.8±0.7mg/L**

f) Chloride ion (Cl⁻)

$$\sigma^2 = \frac{\sum(X_i - \bar{X})^2}{n-1}$$

n=4,n-1=4-1=3

Table 20 : Mean chloride ion concentration at chosen points.

Cl⁻	W_E	W_N	W_W	W_S
	13.39	13.83	14.18	13.43
X_i				
	13.7075	13.7075	13.7075	13.7075
$\bar{X}$				
	-0.3175	0.1225	0.4725	-0.2775
$X_i - \bar{X}$				
	0.10080625	0.01500625	0.22325625	0.07700625
$(X_i - \bar{X})^2$				

$\sum(X_i - \bar{X})^2$=0.416075

$\sigma^2 = \frac{\sum(X_i - \bar{X})^2}{3}$=0.13869167

$\sigma = \sqrt{\frac{\sum(X_i - \bar{X})^2}{3}}$=0.3724133

Therefore average chloride ion concentration=**13.7±0.4mg/L**

g) Sulfate ion (SO_4^{2-})

$$\sigma^2 = \frac{\sum (X_i - \bar{X})^2}{n-1}$$

n=4,n-1=4-1=3

Table 21 : Mean sulfate ion concentration at chosen points.

SO_4^{2-}	W_E	W_N	W_W	W_S
X_i	1.81	1.95	1.79	1.78
$\bar{X}$	1.8325	1.8325	1.8325	1.8325
$X_i - \bar{X}$	-0.0225	0.1175	-0.0425	-0.0525
$(X_i - \bar{X})^2$	0.00050625	0.01380625	0.00180625	0.00275625

$\sum (X_i - \bar{X})^2$=0.018875

$\sigma^2 = \frac{\sum(X_i - \bar{X})^2}{3}$=0.00629167

$\sigma = \sqrt{\frac{\sum(X_i - \bar{X})^2}{3}}$=0.07932003

Therefore average sulfate ion concentration=**1.8±0.1mg/L**