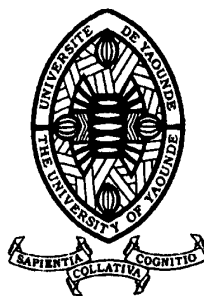


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UNIVERSITY OF YAOUNDE I
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DEPARTMENT OF CHEMISTRY

PHYSICO-CHEMICAL ANALYSIS OF THE NKOLFOULOU LANDFILL EFFLUENT AND TREATMENT USING A PILOT REED BED FILTER SYSTEM.

A DISSERTATION SUBMITTED IN PARTIAL FULFIMENT OF THE
REQUIREMENTS FOR THE AWARD OF A POSTGRADUATE DIPLOMA
(DIPES II) IN CHEMISTRY/PHYSICS

Par :

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CERTIFICATION

I, **Prof Charles FON ABI** hereby certify that this dissertation titled “ **PHYSICO-CHEMICAL ANALYSIS OF THE NKOLFOULOU LANDFILL EFFLUENT AND TREATMENT USING A PILOT REED BED FILTER SYSTEM**” is the original work of **MAIMUNA IYA YAYA** carried out in the Inorganic chemistry Laboratory of the Ecole Normale Supérieure, University of Yaounde I, Yaounde.

Yaounde, the

Charles FON ABI

Associate Professor

E.N.S. Yaounde.



DEDICATION

This work is dedicated to the:

HAMZA'S FAMILY

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ABSTRACT

In this study, some physico-chemical properties of leachate and water around the water bodies of Nkolfoulou landfill were analyzed in order to ascertain the level of pollution. The properties determined were pH, conductivity, cations (potassium, magnesium, calcium) and anions (chloride, nitrate, phosphate and sulphate ions). The pH and conductivity were measured in-situ while the cations and anions were measured in the laboratory using Ion Chromatography. The leachate samples were collected from three specific points of the active dumpsite. The water samples were collected from five specific points around the water bodies. In a pilot-scale reed bed filtration system constructed to treat the leachate from the landfill, samples were also collected from the inlet and outlet streams to see its efficiency.

The results obtained for water samples revealed a lower level of cations and anions compared to the WHO limit for drinking water quality except for K^+ at the up-stream river (42.55 mg/L) and down-stream river (31.96 mg/L) compared to 10 mg/L. This is because these points are closer to the landfill. At the active dumpsite, the level of cation and anions of K^+ and Cl^- in Z3A (1550.93, 534.6) mg/L, Z3E (1836.41, 581.05) mg/L, basin1 (4385.75, 136487) mg/L and NO_3^- , (PO_3^{3-} 278.18, 234.8, 324.22) mg/L respectively turn to be high at these points. In the treatment system, the level of Mg^{2+} (1539) mg/L, Ca^{2+} (46.50) mg/L and SO_4^{2-} (77.20 mg/L) turn to increase in the outlet stream compared to the inlet stream. This increase is due to the contributions of these ions from gravel and sand present in the reed bed system. This implies that the system is not able to treat these ions. However the level of K^+ , NO_3^- and Cl^- reduces implying that these ions are treated. Though the level of these cations and anion turn to increase, the system still serves as an efficient one for the treatment of the leachate since all the values lie below the Standard limit of WHO for drinking water except for K^+ 576.91 mg/L. Phosphate ion turn to be absent in all the points since it acts as a sedimentation agent in the treatment of drinking water and control algae in raw and public water supply.

Key words: Landfill leachate, reed bed filter, treatment

RÉSUMÉ

Dans cette étude, quelques propriétés physico-chimiques des lixiviats et eaux environnantes de la décharge de Nkolfoulou ont été analysées afin d'établir le niveau de la pollution. Les paramètres qui ont été déterminés sont: le pH, la conductivité, la quantité des cations (potassium, magnésium, calcium) et des anions (chlorure, nitrate, phosphate et sulfate). Le pH et la conductivité ont été déterminés in-situ tandis que les cations et les anions ont été mesurés dans le laboratoire en utilisant la chromatographie d'ions. Les échantillons de lixiviats ont été prélevés sur trois points spécifiques de la décharge. Les échantillons d'eau ont été prélevés dans cinq points spécifiques des eaux environnantes. Dans le système de traitement de filtres plantés de roseaux, les échantillons ont été prélevés à l'entrée du filtre 1, à la sortie du filtre 1 et à la sortie du filtre 2 pour tester son efficacité.

Les résultats obtenus pour des échantillons d'eau ont révélé des teneurs en cations et anions faible par rapport à la limite imposée par l'OMS pour la qualité d'eau potable excepté le K^+ (42,55 mg/L) au niveau du ruisseau en amont et (31,96 mg/L) au niveau du ruisseau en aval qui sont supérieur à la norme qui est de 10 mg/L. Ceci dû au fait que ces points sont plus près des casier de pompage du lixiviat . A l'intérieur de la décharge la teneur en, cation et anions (K^+ et Cl^-) dans Z3A (1550,93; 534,6) mg/L, Z3E (1836,41; 581,05) mg/L, basin1(4385,7; 1364,87)mg/L et les ions nitrates , phosphates et sulfates ont des teneurs respective (278,18; 234,8; 324,22) mg/L qui sont élevées. Dans le système de traitement, les teneurs en Mg^{2+} (15,39) mg/L, Ca^{2+} (46.50 mg/L) et Sulfate (77,20 mg/L) sont élevées à la sortie du filtre 2 par rapport à l'entrée du système. Ceci est dû au fait que le système possède le gravier et le sable qui sont source de production de ces ions. Bien que la teneur de ces cations et anions augment dans le système de traitement, il demeure toujours efficace au traitement des lixiviats puisque toutes les valeurs se trouvent en-dessous de la limite imposée par l'OMS pour l'eau potable excepté K^+ 576.91 mg/L. Les ions phosphate sont absents dans tous les points puisqu'ils agissent comme agent de sédimentation dans le traitement des algues d'eau potable et de commande dans l'approvisionnement en eau de puit et de source.

Mots clés : Décharge, Lixiviat, filtre planté, traitement.

LIST OF ABBREVIATIONS

CSW	: Wastes storage Centre
TOC	: Total organic carbon
YUC	: Yaounde Urban council
BOD	: Biological Oxygen Demand
COD	: Chemical Oxygen Demand
HYSACAM	: Hygiene and Sanitation Company of Cameroon
MINEPDED	:Ministry of Environmental Protection of Nature and Sustainable Development
VFA	: Volatile Fatty Acid
HMW	: High Molecular Weight
MSW	: Municipal Solid Waste
SBR	: Sequencing Batch Reactor
USR	: Up-stream river
DSR	: Down-stream river
USP	: Up-stream point
DSP	: Down-stream point
MP	: Meeting point
Z3A	: Zone 3A
WHO	: World Health Organisation
CW	: Constructed wetlands
UK	: United Kingdom
Mg/L	: Milgram per liter

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GENERAL INTRODUCTION

According to the 2005 report of the Limbe Urban Council, waste management, which they referred to it as the systematic control of generation, collection, storage, transport, source of separation processing, treatment ,recovery, and disposal of waste Globalization has raised some problems that have called for the attention of the developing world, including Cameroon. One of such concern is its impact on urbanization and the implications attributed to it. For Cameroon this has just helped to increase the already urban problems and challenges that go with it; in which waste management is the main challenge.

Waste management constitutes one of the most crucial land environmental health problems facing the Yaounde urban city council. Prominent on the list of these problems is environmental pollution. Among the various types of pollution, water contamination comes second after air contamination in terms of effects (Fomenky, 2003). Water contamination is a local, regional and global problem related to how we use the land. Water contamination is of concern when solid is placed near surface or ground waters, and when unhindered flow occurs from solid waste to the surface or ground waters. Where leachate enters surface waters, visual observations and sample analysis are used to verify its impact on water quality. Movement of leachate into surface formations is most often detected with monitoring river or, if the situation is serious, when a drinking water supply river is contaminated.

Leachate from a landfill constitutes a source of nuisance that comes to add to the already existing number of problems of contamination of the site. Organic matter, principal component of the effluent, must be given great attention in the measure where it is difficult to prevent the propagation and diffusion of these pollutants into the soil and groundwater. In various parts of the world, researchers have carried out studies on the types of pollutants found in the leachate and these are outline as follows: VFA, hydrocarbons, plastic matter, aromatic compounds, heavy metals, inorganic matter and cellulose (Ekani, 2015).

In Cameroon, this study had already been carried out by (Found, 2006), although the quality of leachate is evolutionary. It is with this regard that the landfill of Nkolfoulou is the subject of our study.

In this work, we are going to characterize the inorganic macro-pollutants present in the leachate of the landfill of Nkolfoulou, environment of water and in the treatment system.

Although landfills are an indispensable part of everyday living, they may present long-term threats to groundwater and also surface waters that are hydrologically connected. There is an increasing belief among solid waste experts that unless further steps are taken to detoxify landfilled materials, today's society will be placing a burden on upcoming generations to address future landfill impacts. Much of the concern revolves around leachate, the watery solution that results after water passes through a landfill. The nuisance of this leachate is as a result of organic, mineral and pathogenic substances. These elements can contaminate either the neighbouring landfill water by streaming or groundwater by infiltration.

The sanitary problem caused by the landfill of Nkolfoulou (Guy Djombe.; 2003), coupled with the demand to meet up with International Standards have motivated the residency of HYSACAM as a major operator, to assist in the preservation of the environment. These have forced researches on the different components encountered in the leachate in order to use better treatment techniques as well as adapt control of effluent.

In effect, since 2006, the HYSACAM enterprise had not yet published the actual pollutants found in the leachate. Knowing the level of leachate evolve as a function of waste composition, it is important to verify the variation of its previous composition in order to put in place the corresponding treatment system.

This work is aimed at determining the level of pollutants evolving from the landfill in the receptor medium which are the surrounding of the water bodies, active dumpsite of the landfill and from the treatment site.

In this work, the objectives are as follows:

Carry out a physico-chemical analysis on

- ❖ water around the water bodies from the Nkolfoulou landfill in order to determine the level of anionic (NO_3^- , SO_4^{2-} , Cl^- , PO_4^{3-}) and cations (K^+ , Ca^{2+} , Mg^{2+}) pollutants present in them,
- ❖ Leachate samples at the various active dumpsite of the Nkolfoulou landfill, inlet and outlet streams of the treatment system in order to determine the level of these anionic and cationic pollutants present,

And finally, compare the values obtained with International Norms.

This work is divided into three parts as follows:

Part 1: General Introduction gives the justification, problem, objectives and the research methodology of this work.

Part 2: include;

- ❖ Chapter 1 gives discusses literature review and definition of terms related to the work.
- ❖ Chapter 2(sample and method of analysis) presents the material, reactants, procedure for the determination of the presence of anions and cations in the samples.
- ❖ Chapter 3(results and discussion) presents the different results obtained and their interpretations. And finally

Part 3: (general conclusion, pedagogic interest and perspectives) which gives a summary of the work, recommendations and pedagogic interest.



CHAPTER I: LITERATURE REVIEW

1.1 GENERAL INFORMATION

Within a landfill, a complex sequence of physically, chemically, and biologically mediated events occurs. As a consequence of these processes, refuse is degraded or transformed. As water percolates through the landfill, contaminants are leached from the solid waste. Mechanisms of contaminant removal include leaching of inherently soluble materials, leaching of soluble biodegradation products of complex organic molecules, leaching of soluble products of chemical reactions, and washout of fines and colloids. The characteristics of the leachate produced are highly variable, depending on the composition of the solid waste, precipitation rates, site hydrology, compaction, cover design, waste age, sampling procedures, interaction of leachate with the environment, landfill design and operation.

1.2 SOLID WASTE LANDFILL

Solid waste landfill, which is used for the safe disposal of solid waste generated in huge amount on daily basis, is the necessity of modern society. It helps in minimizing the issues related to public health and safety as well as adverse environment impact. Landfill referred to as the site at which refuse is buried under layers of earth, generally contain a highly heterogeneous mixture of materials, which include both a very high organic component as well as soluble mineral substances. Some of the organic substances decompose naturally in the landfill body. Landfilling remains the dominant waste disposal method in most Asian and developing countries (Carra and Cassu, 1990) like Cameroon. All landfills produce leachate by the action of 'leaching' when rain water percolates through permeable waste heap. Therefore streams and other forms of water bodies can be contaminated due to the vertical and lateral migration of leachate (Jaffar et al., 2009), especially if there are no geomembrane liners.

The functioning of a landfill can be assimilated by a bio-physico-chemical reactor that gives rise to reactions and complex evolution that result in the physical, chemical and biological transformation of wastes.

With regard to the hydrological and geological conditions of the site, nature of waste stored, mode of control, each waste has its uniqueness. Thus, it is not possible to determine with precision a mode of evaluation that can be applied to all the centres.

However, some phenomena are common in the majority of the sites and therefore can be quantified in order to characterize the storage installation, in particular, as concerns hydraulic, physico-chemical, biological and geological aspects. Biodegradable matter in the waste put in place an object of biological actions of aerobic then anaerobic bacteria.

In the absence of any disposition, water that flows through the masses of waste produces leachate by changing chemical substances to biological substances. The physical and chemical transformations lead to partial destruction of matter and also make certain substances soluble or transformed to gases.

1.3. LEACHATE FROM A LANDFILL

1.3.1. Definition

Landfill leachate can be defined as liquid effluent percolating through or drains from a dump or organized trash collection site (Foo et al., 2009). The physical appearance of leachate when it emerges from a typical landfill site is a strongly odoured black-, yellow- or orange-coloured cloudy liquid. The smell is acidic and offensive and may be very pervasive because of hydrogen-, nitrogen- and sulfur-rich organic species such as mercaptans. The formation of this leachate is due to the contributions from runoff of rainwater, physical, chemical and biochemical reactions as well as the level of humidity (Ahmed and Lad, 2012).



Figure 1: Black-yellow or orange-coloured cloudy liquid of leachate.

1.3.2. Source

In the developing world, municipal solid wastes tend to have a very high content of putrescible materials compared to a typical developed city in the western world (Klinck *et al.*, 1995). Ultimately, it is the waste composition that influences the chemistry of the leachate

generated. Waste density is between two and five times higher compared to industrialized countries and moisture content is well in excess of 30 %, that is, any infiltration produces leachate. Indeed, Blight *et al.* (1989) and Blight *et al.* (1992) have shown that even in water deficient areas there is a potential to generate leachate because of the high organic matter contents.

Some leachate exists on its own, usually as a result of natural decomposition while liquids and chemicals that have been discarded also contribute.

The largest source of leachate in most places is rainwater, though, when rain hits collected trash, it tends to pool up. If this runoff is not properly managed, there stands a risk of it mixing with the groundwater near the site. This can have direct consequences for local communities, particularly in cases where the landfill leachate is toxic or contains harmful chemicals, and can potentially also impact the ecosystems of rivers, streams, and oceans.

1.3.3. Generation

The precipitation that falls into a landfill, coupled with any disposed liquid waste, results in the extraction of the water-soluble compounds and particulate matter of the waste, and the subsequent formation of leachate. The creation of leachate, sometimes deemed "garbage soup," presents a major threat to the current and future quality of groundwater (Lee et al., 1991). Waste contains about 70 percent of water thus, it's usually true that some liquid exists already, or will over time. Some garbage, particularly food products, will lose moisture as it breaks down. Chemical waste is also fairly common, be it from discarded batteries, electronics, or household cleaners. As the trash is allowed to sit and pile up, liquids tend to drain off and get mixed up with each other. This is the primary source of leachate. But the most common source of leachate is rainwater filtering down through the landfill and aiding bacteria in the process of decomposition. When organic matter breaks down or decomposes, it needs oxygen; when water hits it, things tend to go a lot faster. Unless a dump is covered, rainfall is all but inevitable. Leachate can also be produced from land that was contaminated by chemicals or toxic materials used in industrial activities such as factories, mines or storage sites. It is also associated with stockpiled coal and with waste materials from metal ore mining and other rock extraction processes, especially those in which sulfide containing materials are exposed to air producing sulfuric acid, often with elevated metal concentrations.

1.3.4. Leachate composition

The decomposition products from the waste are susceptible to dissolution by infiltrating water percolating through the waste. This leads to the production of leachate that can enter both surface water and groundwater. The composition of leachate is not only very diverse but also variable with time and environment (Pronost and Matejka., 2000). Leachate generally contains a variety of pollutants that can contaminate groundwater. Christensen et al. (1994) have identified the following principal groups:

- Dissolved or suspended organic matter from biomass, generally expressed in COD (VFA, humic and fulvic substances);
- Organic micro-pollutants (hydrocarbons, aromatic substances...);
- Major mineral compounds in form of ions (Ca^{2+} , Mg^{2+} , Na^+ , K^+ , NH_4^+ , Fe^{2+} , HCO_3^- , Cl^- , SO_4^{2-} ...) and other compounds like borates, sulfides... (**Xu et al., 2006**);
- Cationic heavy metals mostly complexed with mineral ligands (HCO_3^- , SO_4^{2-} , Cl^-) or organic (macromolecules of humic and fulvic type).

This residue of leachate is also rich in Mg^{2+} , organic C, and, in some situations, hazardous organic pollutants like pesticides and pharmaceuticals products (Mangimbulude et al., 2009; Sang et al., 2010). On the other hand, leachate can contain pathogenic micro-organisms (Sillet., et al., 2001). Leachate composition is also closely dependent on the type and quantity of waste (Øygaard et al., 2011; Silva-Filho et al., 2006). Long-term variations depend strongly on climate, waste type and the degree of waste decomposition (Bozkurt et al., 2000; Kulikowska and Klimiuk, 2008).

More than 200 families of organic compounds have been identified during a number of studies of characterizing landfill leachate.

1.3.5 Types of leachate

In addition to the type of waste involved (industrial, municipal), leachate characteristics are determined by the siting, the design and the mode of operation of the landfill, and also depend on its evolution through time.

Organic and inorganic contaminants of landfill leachate are released from the waste due to successive biological, chemical and physical processes. Several studies deal with the biological decomposition of solid waste. Classing the landfill to a bioreactor makes it possible to relate the leachate composition to the activity of micro-organisms. Basically, three phases of

decomposition are distinguished for domestic landfills occurring within twenty years (Lo et al., 1996).

In the first stage following waste deposit, initial aerobic phase rapidly consumes the confined oxygen and water infiltration enhances acetogenic fermentation producing leachate characterised by high BOD, COD and ammoniacal nitrogen contents. Volatile fatty acids (VFA) are the main components of the organic matter release, besides the lower pH solubilized metals. Gradually, the methanogenic phase of decomposition starts and consumes the simple organic compounds resulting from acetogenic process to produce biogas. In that stage, the leachate composition represents the dynamic equilibrium between the two microbiological mechanisms with lower BOD and COD values while the ammonia concentration remains high. Dissolved inorganic materials are continuously released. With landfill ageing, waste stabilization takes place. As the volatile fatty acids leachate content decreases parallel to the BOD/COD ratio, the leachate organic matter is made up of high molecular weight humic and fulvic-like material (HMW).

Though leachate Composition may vary widely within these stages three types of leachates can be defined according to landfill age (Milot, 1986) (Table 1).

Table 1: Leachates classification:

Leachate type	Young	Intermediate	Stabilized
Landfill age year	<5	5-10	>10
pH	<6.5	7	>7.5
COD g/L	>20	3-15	<2
BOD/COD	>0.3	0.1-0.3	<0.1
TOC/COD	0.3	-	0.4
Organic matter	70 - 90 % VFA	20 - 30 % VFA	HMW
Metals g/L	2	<2	<2
Nitrogen	100 - 2000 mg/L TN		

1.4 EVOLUTION PHASES OF LEACHATE

The European Legislation defines leachate as any liquid that filters by percolation from waste placed in a landfill and flows from the landfill. More commonly, leachate comes from water that percolates through wastes by changing bacteriologically and chemically minerals and organic substances. The physical appearance of leachate when it emerges from a typical landfill site is a strongly odoured black-, yellow- or orange-coloured cloudy liquid. The smell is acidic and offensive and may be very pervasive because of hydrogen-, nitrogen- and sulfur-rich organic species such as mercaptans. Some leachate exists on its own, usually as a result of natural decomposition, liquids and chemicals that have been discarded also contribute.

The understanding of the origin of leachate does not only involve the nature of waste buried and mode of exploitation of the centre of storage but also the study of the interaction between wastes and water. The mechanisms of the origin of leachates are very complex; they are biological and physico-chemical in nature (Kulikowska et al., 2008).

The physico-chemical mechanism: It has to do with the variation of pH of buffer, salt and partial oxydoreduction of solutions percolating through the leachate. These solutions put in place chemical mechanisms of solubility, complexation, oxydoreduction, absorption, neutralization and material transfer.

The biological process: Aerobic and anaerobic biological processes play a dominant role in the origin of leachate. In effect, the waste buried serves as substrate for heterotrophic macro-organisms (bacteria, fungi) responsible for the degradation of fermentable organic fraction. The effect of the microbiological activity can be multiple either directly or indirectly and begins the secondary physico-chemical phenomenon.

1.5 PROCESSES OF LEACHATE GENERATION

Leachate quality varies throughout the operational life of a landfill and long after its closure. There are three broad and overlapping phases of waste decomposition, in which chemical and biological processes give rise to both landfill gas and leachate during and beyond the active life of the site (Robinson, 1996):

Phase 1: Oxygen present in the waste is rapidly consumed by aerobic decomposition. This phase typically lasts less than one month and is normally relatively unimportant in terms of leachate quality. This phase is exothermic and high temperatures may be produced. This speeds up the later phases if some of this heat is retained.

Phase 2: Anaerobic and facultative microorganisms hydrolyse cellulose and other putrescible materials such as complex carbohydrates, fats and proteins to soluble organic compounds. These hydrolysis products are then fermented during acidogenesis to various intermediates such as volatile fatty acids and alcohols. Finally, these intermediates are converted during acetogenesis to acetic acid, carbon dioxide and hydrogen. The high content of putrescible material in the waste may sustain acidogenic conditions for quite some time and provide a rich feed stock for methanogens subsequently.

Leachate from this acidic phase typically contains a high concentration of free fatty acids. It therefore has low pH of 5 or 6, and will dissolve other components of the waste, such as the alkaline earths and heavy metals, which can be mobilised in the leachate, possibly as fatty acid complexes (see for example Christensen *et al.* (1994). The leachate also contains high concentrations of ammoniacal nitrogen and has both a high organic carbon concentration and a biochemical oxygen demand (BOD).

Phase 3: Conditions become more anaerobic as waste degradation proceeds and methanogenic bacteria gradually become established. These start to consume the simple organic compounds, producing a mixture of carbon dioxide and methane that is released as landfill gas. The carbon dioxide tends to dissolve producing the very high bicarbonate concentrations typical of Phase 3 leachates. The rate at which this phase becomes established is controlled by a number of factors, including the content of readily putrescible waste.

Since the majority of the organic compounds are high molecular weight humic and fulvic acids, the leachates are characterised by relatively low BOD values. Ammoniacal nitrogen continues to be released by areas of the waste where phase 2 is continuing and generally remains at high concentrations in the leachate. Falling redox potential immobilises many metals as sulphides in the waste (Pohland *et al.* 1993; Belevi and Baccini, 1992).

1.6 FACTORS AFFECTING LEACHATE QUALITY

Leachate quality is highly variable. The variation in leachate quality can be attributed to many interacting factors such as the composition and depth of waste, the availability of moisture and oxygen, landfill design and operation, and waste age.

1.6.1 Waste Composition

Municipal waste has great variation in composition and characteristics. The waste composition of refuse determines the extent of biological activity within the landfill (Chen and Bowerman, 1974). Rubbish, food and garden wastes, and crop and animal residues contribute to the organic material in leachate (Pohland and Harper, 1985). Inorganic constituents in leachate are often derived from ash wastes and construction and demolition debris (Pohland and Harper, 1985). Chen and Bowerman (1974) found that increased quantities of paper in solid waste resulted in a decreased rate of waste decomposition. Lignin, the primary component of paper, is resistant to anaerobic decomposition which is the primary means of degradation in landfills.

1.6.2. Depth of Waste

Greater concentrations of constituents are found in leachates from deeper landfills under similar conditions of precipitation and percolation (Qasim and Chiang, 1994). Deeper fills require more water to reach saturation, require a longer time for decomposition, and distribute the leached material over a longer period of time (Qasim and Chiang, 1994; Lu et al., 1985). Water entering the fill will travel down through the waste. As the water percolates through the landfill, it contacts the refuse and leaches chemicals from the waste. Deep landfills offer greater contact time.

1.6.3. Moisture Availability

Water is the most significant factor influencing waste stabilization and leachate quality. Moisture addition has been demonstrated repeatedly to have a stimulating effect on methanogenesis (Barlaz et al., 1990), although some researchers indicate that it is the movement of moisture through the waste as much as it is water addition that is important (Klink and Ham, 1982). Moisture within the landfill serves as a reactant in the hydrolysis reactions, transports nutrients and enzymes, dissolves metabolites, provides pH buffering, dilutes inhibitory

compounds, exposes surface area to microbial attack, and controls microbial cell swelling (Noble and Arnold, 1991).

1.6.4. Temperature

Landfill temperature, a largely uncontrollable factor influencing leachate quality, has been shown to fluctuate with seasonal ambient temperature variations (Lu et al., 1985). Temperature affects bacterial growth and chemical reactions within the landfill. Each microorganism possesses an optimum growth temperature, and any deviation from that temperature will decrease growth due to enzyme deactivation and cell wall rupture. Solubility of many salts (e.g. $\text{Ca}_3(\text{PO}_4)_2$ and NaCl) increases with temperature. However, a number of compounds in leachate, such as CaCO_3 and CaSO_4 , show a decrease in solubility with increasing temperature (Lu et al., 1985).

1.7 TARGETED POLLUTANTS

The targeted pollutants are inorganic macro-components which are made of common cations and anions.

1.7.1. Cations

POTASSIUM

Potassium is one of the alkali metals. The alkali metals are the elements that make up Group 1 (IA) of the periodic table. It is represented by the chemical symbol K (atomic number 19, atomic mass 39.0983).

Potassium is so active that it never occurs free in nature. It always occurs in compounds, combined with other elements. It was first prepared in pure form in 1807 by English chemist Sir Humphry Davy (1778-1829). The chemistry of potassium is almost entirely that of the potassium ion, K^+ . Most potassium (95 %) goes into fertilizers and the rest goes mainly into making potassium hydroxide (KOH), by the electrolysis of potassium chloride solution, and then converting this to potassium carbonate (K_2CO_3). Potassium carbonate goes into glass manufacture, especially the glass used to make televisions, while potassium hydroxide is used to make liquid soaps and detergents. A little potassium chloride goes into pharmaceuticals, medical drips and saline injections.

Other potassium salts are used in baking, photography and tanning leather, and to make iodize salts. In all cases it is the negative anion, not the potassium, which is the key to their use.

Potassium is essential to both plant and animal life. It is one of the three primary nutrients, or macronutrients, required by plants. Plants require relatively large amounts of potassium in order to grow and remain healthy.

Environmental effects

Together with nitrogen and phosphorous, potassium is one of the essential macro-minerals for plant survival. Its presence is of great importance for soil health, plant growth and animal nutrition. Its primary function in the plant is its role in the maintenance of osmotic pressure and cell size, thereby influencing photosynthesis and energy production as well as stomatal opening and carbon dioxide supply, plant turgor and translocation of nutrients. As such, the element is required in relatively large proportions by the growing plant.

The consequences of low potassium levels are apparent in a variety of symptoms: restricted growth, reduced flowering, lower yields and lower quality produce.

MAGNESIUM

Magnesium is the second element in Group 2 (IIA) of the periodic table. The elements in Group 2 are known as the alkaline earth elements. It is represented by the symbol Mg with atomic number 12 and atomic mass of 24.305. Compounds of magnesium have been used by humans for centuries. Yet, the element itself was not isolated until 1808. The long delay occurred because magnesium forms very stable compounds. That means that such compounds do not break down very easily. Magnesium is the seventh most abundant element in the Earth's crust. It also occurs in large amounts dissolved in ocean waters. Although most cameras now use electronic flashes, magnesium metal is often contained in cameras that use flash bulbs. A thin strip of magnesium metal is inside the bulb. A common use of magnesium metal is in fireworks.

Environmental impact

Magnesium is essential for good health in both plants and animals. It forms part of the chlorophyll molecule found in all green plants. Chlorophyll is the molecule in green plants that controls the conversion of carbon dioxide and water to carbohydrates, such as starch and sugar. Plants that do not get enough magnesium cannot make enough chlorophyll. Their leaves develop yellowish blotches as a result. Magnesium is found in many enzymes in both plants and animals.

An enzyme is a catalyst in a living organism. It speeds up the rate at which certain changes take place in the body. A lack of magnesium can occur, however. For example, alcoholics and children in poor countries sometimes develop a magnesium deficiency. In such cases, magnesium deficiency may cause a person to become easily upset or overly aggressive. On the other hand, it is also possible to be exposed to too much magnesium. For example, inhaling magnesium powder can produce irritation of the throat and eyes, resulting in a fever. In large doses, magnesium can cause damage to muscles and nerves. It can eventually result in loss of feeling and paralysis (inability to move parts of the body). Such conditions are rare. They are likely to occur only among people who have to work with magnesium metal on a regular basis.

CALCIUM

Calcium is one of the alkaline earth metals. The alkaline earth metals make up Group 2 (IIA) of the periodic table. The alkaline earth metals are more chemically active than most metals. It is represented by the symbol Ca with atomic number 20 and atomic mass 40.08. Calcium compounds are common and abundant in the Earth's crust. Humans have used calcium compounds for hundreds of years in construction, sculpture, and roads. Calcium metal was not prepared in a pure form until 1808 when English chemist Humphry Davy (1778-1829) passed an electric current through molten (melted) calcium chloride. Metallic calcium has relatively few uses. However, calcium compounds are well known and widely used. They include chalk, gypsum, limestone, marble, and plaster of paris. Calcium sulfate has been used for the control of algae in raw and public water supplies (Mcguire et al., 1984)

Environmental impact

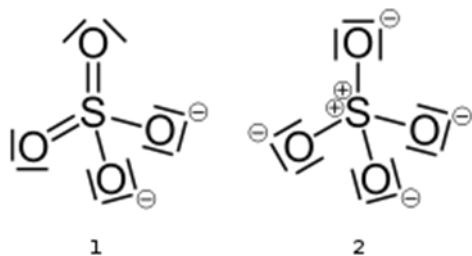
Calcium compounds used in the control of algae can stimulate the growth of plankton and aquatic plants which provide food for fish. This may cause an increase in the fish population and improve the overall water quality. However, if an excess of it enters the waterway, algae, and aquatic plants will grow wildly, choke up the waterway and use up large amounts of oxygen. This condition is known as eutrophication. 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. Calcium is not toxic to people or animals. About 99 percent of the calcium in a person's body is found in bones and teeth. Milk is a good source of calcium.

The body uses calcium in a compound known as hydroxyapatite ($\text{Ca}_{10}(\text{PO}_4)_6(\text{OH})_2$) to make bones and teeth hard and resistant to wear.

1.7.2. Anions

SULFATES

The sulfate or sulphate ion is a polyatomic anion with the formula 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 state. 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



Sulfates occur naturally in minerals including barite (BaSO_4), epsomite ($\text{MgSO}_4 \cdot 7\text{H}_2\text{O}$) and gypsum ($\text{CaSO}_4 \cdot 2\text{H}_2\text{O}$) (Greenwood and Earnshaw, 1984). These dissolved minerals contribute to the mineral content of much drinking water. Addition of calcium and magnesium sulfate to water was found to improve the taste (Zoeteman, 1980).

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, wood pulp, metal and plating industries. Aluminium sulfate (alum) is used as a sedimentation agent in the treatment of drinking water. Calcium sulfate has been used for the control of algae in raw and public water supplies (Mcguire et al., 1984).

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).

PHOSPHATE

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.

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.

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.

NITRATES/ NITRITES

Nitrate and nitrite 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. The nitrite ion contains nitrogen in a relatively unstable oxidation state.

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 meats. 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.

Nitrate can reach both surface water and ground water as a consequence of agricultural activity (including excess application of inorganic nitrogenous fertilizers and manures) from wastewater treatment and from oxidation of nitrogenous waste products in human and animal excreta, including septic tanks. Nitrite can also be formed chemically in distribution pipes by *Nitrosomonas* bacteria during stagnation of nitrate –containing and oxygen-poor drinking water in galvanized steel pipes.

The nitrate concentration in surface water is normally low but can reach 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 aquifers (Young and Morgan-jones, 1980).

CHLORIDES

Chlorides are widely distributed in nature as salts of sodium (NaCl), potassium (KCl) and calcium (CaCl₂). The taste threshold of the chloride anion in water is dependent on the associated cation. Taste thresholds for sodium chloride and calcium chloride in water are in the range 200-300 mg/L (Zoeteman, 1980). 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 chloride is 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).

Chlorides toxicity has not been observed in humans except in the special case of impaired sodium chloride metabolism, example in congestive heart failure (Wesson, 1969). Healthy individuals can tolerate the intake of large quantities of chloride provided that there is a concomitant intake of fresh water (Ottawa, 1978). As concerns water, chloride increases the electrical conductivity of water and thus increases its corrosiveness. In metal pipes, chloride reacts with metal ions to form soluble salts (Brooker Mp, 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 Mp, 1984).

Environmental impact

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. Leachate treatment before release into the environment is a necessity in many countries, because of significant concentrations of pollutants (Christensen et al., 2001), and because its toxicity must not endanger the quality of surface water and/or groundwater (Council Directive 1999/31/EC). The governments of most countries and localities require that landfill sites be equipped to collect, store, and treat leachate. In most cases this means that dumps have impermeable layers on the sides and at the bottom made of hard plastic or other non-corrosive material. Drainpipes and runoff filtration systems are also common, though these are often expensive and require regular monitoring in order to be effective.

1.8 IMPACT OF LEACHATE ON THE ENVIRONMENT AND HUMANS

As waste is continuously deposited on a landfill, it undergoes degradation processes linked to biological reactions and physico-chemical complexes. Leachate is produced as a result of infiltration of water and also biogas made of organic and mineral substances which create pollution mainly organics and metals with the natural biodegradation of wastes enclosed with anthropic compounds that release a number of toxic substances to the natural environment (Guy Djombe, 2013).

In a landfill site, there are basically three types of pollutants:

❖ **MICROBIOLOGICAL POLLUTION:** This is another form of pollution which is due to the presence of human and animal wastes resulting from leachate which enter water. It 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).

- ❖ **ORGANIC POLLUTION:** It is considered as the alteration of the quality of water due to the presence of pollutants of organic origin in leachate. These organic pollutants results from wastes coming from food and animal industries. The first consequence of this pollution is the increase in the BOD of the water by aquatic organisms which depend on oxygen for survival (Nsangou, 2005)
- ❖ **CHEMICAL POLLUTION:** Chemical pollution results from the presence of chemical substances in water. Water bodies are extremely vulnerable to toxic substances such as heavy metals (Iron, Lead, nitrates, nitrites, phosphates, chlorides), acids, solvents, PCBs, DDTs, dioxins. These substances not only cause instant death but they can accumulate along the food chain provoking mutations and sterility in some animals. And leading in a manner, to the destruction of the natural environment (Kargong, 2000).

1.9. LEACHATE TREATMENT

The most important characteristics of leachate which could influence treatment are: high concentration of organic and inorganic substances, irregular production depending on the amount of rainfall, variations in the biodegradable fraction of organic substance depending on the age of landfill (Cossu et al., 1995).

These leachate characteristics impose operational difficulties on treatment processes not normally found when treating wastewater of high strength and volume. Different treatment strategies are therefore required to match a treatment to the changing leachate volumes and strengths during the filling phase and aftercare of a landfill (Cossu et al., 1995). In an effort to control the pollution caused by landfill leachate, many treatment processes have been studied, such as leachate recirculation, biological methods and physiochemical methods (Zahrani, 2006).

Leachate recirculation is a process to enhance stabilisation of active landfills and in-situ treatment of problematic Leachate. Pohland & Kim (1999) have documented the benefits of increasing landfill moisture content and liquid movement through the fill; these benefits are associated with increasing gas utilisation opportunities, reduced leachate treatment requirements, avoidance of long-term monitoring and liability, and potential for landfill mining.

Biological methods include aerobic and anaerobic processes. Leachate from landfill may contain substances which are able to limit biological treatment efficiency, such as: metals, carbon

compounds, ammonia, chloride and sulphide. However, the sensitivity of biological treatment processes in the presence of toxic compounds is reduced by several factors. Aerobic and anaerobic treatment processes used with landfill leachate are: aerated lagoons, activated sludge plants, trickling filters, rotating biological contractors, anaerobic lagoons, anaerobic digesters and anaerobic filters.

Physiochemical treatment processes have been tested by many researchers, which have studied different treatment with sanitary landfill leachate such as: flocculation-precipitation, elimination of heavy metals and suspended solids, chemical oxidation to eliminate cyanide, phenol and other organic pollutants, active carbon to adsorption of some organic compounds or to nitrogen reduction and stripping with vapour to remove ammonia. One of the new developments of leachate treatment is the separation process with membrane, as: nanofiltration, microfiltration and ultrafiltration and reverse osmosis.

The most common method of handling collected leachate is **on-site treatment**. When treating leachate on-site, the leachate is pumped from the sump into the treatment tanks. The leachate may then be mixed with chemical reagents to modify the pH and to coagulate and settle solids and to reduce the concentration of hazardous matter.

Traditional treatment involves a modified form of activated sludge to substantially reduce the dissolved organic content. Nutrient imbalance can cause difficulties in maintaining an effective biological treatment stage. The treated liquor is rarely of sufficient quality to be released to the environment and may be tankered or piped to a local sewage treatment facility; the decision depends on the age of the landfill and on the limit of water quality that must be achieved after treatment. With high conductivity, leachate is hard to treat with biological treatment or chemical treatment.

Also, **passive treatment** of landfill leachate is an attractive option for landfill operators due to low operation and maintenance costs, as well as the flexibility that allows the biological consortia in the passive treatment systems to evolve in response to variations in leachate concentrations (Mehmood et al., 2009). Traditionally, the use of passive treatment systems has been limited to small systems due to limited oxygen transfer efficiency that can be overcome by operating at low loading rates, thereby increasing system size requirements.

Another simple and affordable way to treat landfill leachates is their collection and purification in **lagooning systems** by accumulation of the pollutants in the vegetation and at the

bottom of the basins. During sedimentation, incorporation of trace metals into the solid phase is mainly controlled by three mechanisms: (i) precipitation of metal-bearing calcite, (ii) binding to Fe oxyhydroxides and (iii) bonding to organic matter (Øygaard et al., 2008). This process is strongly influenced by seasonal variations in plant growth as well as by the concentration and mobility of trace metals in the surrounding water and sediment (Galletti et al., 2010).

Treatment of wastewater (to discharge criteria) can also be carried out using natural, or conventional steel-and-concrete treatment technologies (Haberl et al., 1995); each technology has its own advantages and disadvantages. **Conventional technologies** (such as membrane bioreactors) require significant input of fossil fuel energies, while **natural technologies** (e.g. constructed wetlands) primarily depend on naturally occurring energies such as wind, solar radiation, and biomass storage (Kadlec and Knight, 1996).

Constructed wetlands, as typical natural and environmental friendly systems (Cooper, 2009), use rooted water tolerant plants and gravel or soil media to provide treatment of wastewater (Kadlec and Knight, 1996). As a green treatment technology, constructed wetlands have the unique advantage of producing higher effluent quality without the input of fossil energy thereby reducing operation costs (Lee et al., 2010; Bruch et al., 2011).

Constructed wetlands are engineered wetlands that have saturated or unsaturated substrates, emergent/floating/submergent vegetation, and a large variety of microbial communities that are purposely built for water pollution control. Constructed wetlands and reed beds are designed and man-made systems which attempt to simulate treatment that has been observed to take place when polluted water passes through natural wetlands. In the UK, these systems tend to be called “reed beds” or “reed bed treatment systems” (RBTS), but internationally they are usually called constructed wetlands (CW). Systems are able to treat wastewaters by degrading organic matter (BOD and COD) and oxidizing ammoniacal-N, removing suspended solids, and to a lesser extent reducing concentrations of nitrate and macro-organic matter. Treatment mechanisms are complex and involve bacteria oxidation, filtration, nitrification and chemical precipitation.

A variety of basic constructed wetland designs have been used and performance varies significantly from one design type to another. The two basic design types are:

- Horizontal flow, and
- Vertical flow.

Horizontal flow reed beds / constructed wetlands

The majority of all of the constructed wetlands that have been built are used for sewage treatment on subsurface, horizontal flow systems (e.g. Cooper and Green, 1994). Such systems typically comprise lined beds, containing depths of gravel between 0.6-0.9 metres, with a horizontal top surface, and are longer than they are wide.

Wastewaters are introduced along one of the shorter edges of the bed, and discharged from the bed at the far end, generally via buried pipework. Liquid level in the bed is adjusted by a simple overview mechanism outside the bed – usually this will be maintained at or close to the gravel surface, but the horizontal surface of the bed allows intermittent flooding to be effected, for control of weeds (e.g. nettles) as necessary. Figure 1 below shows a typical arrangement for a horizontal-flow reed bed treatment system.

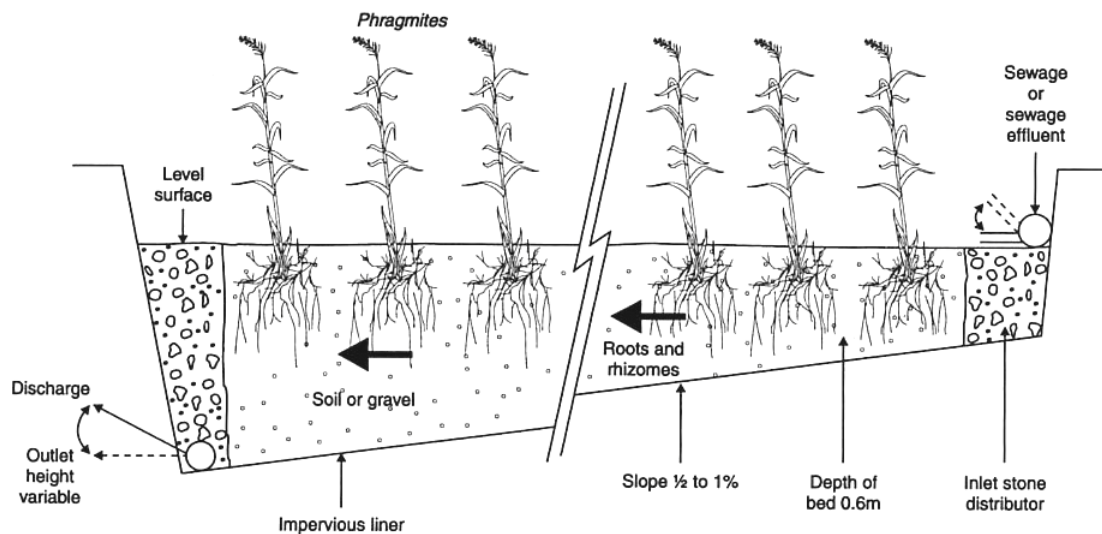


Figure 2: Typical arrangement for a horizontal-flow reed bed treatment system (after Cooper et al., 1996)

Subsurface flow wetlands mostly employ gravel as the main media to support the growth of plants; wastewater flows vertically or horizontally through the substrate where it comes into contact with microorganisms, living on the surfaces of plant roots and substrate (Cooper et al., 1996; Kadlec and Knight, 1996), allowing pollutant removal from the bulk liquid.

Vertical flow reed beds / constructed wetlands

They also comprise a flat bed of uniform depth, typically 0.5 to 0.6m, with reeds growing at similar planting densities. Vertical-flow reed bed systems differ from horizontal-flow systems in two fundamental ways (see Figure 2). The main differences are:

(i) The bottom half of the bed generally comprises much larger stones, typically to 30mm smooth washed gravel size or larger, on top of which lies smaller diameter pea gravel (<6 mm), and a surface depth of 80-100 mm of sharp sand, into which the reeds are planted.

(ii) The bed is fed with wastewater or leachate intermittently, as a large batch, which initially floods the surface of the bed, and then gradually percolates downward through it, to the coarser stone drainage network in the base. The bed is then completely drained, allowing air to refill it, and the next slug dose of liquid traps this air – leading to much improved oxygen transfer.

Vertical-flow systems were originally developed to address concerns about the limited ability of early horizontal-flow systems to nitrify ammoniacal-N – probably as a result of the limited ability of the reed rhizomes to transfer oxygen, which had generally been greatly overestimated (Cooper et. al. 1996). Vertical-flow systems have been shown to greatly increase oxygen transfer rates, acting more as a crude biological filter, but are much less good at solids removal than horizontal-flow systems – often they will be followed by a horizontal-flow reed bed system for polishing.

Many vertical-flow systems comprise several beds in series or in parallel – some parallel beds being sequentially fed in rotation for 1 or 2 days, then being rested for several days. Reeds growing in the bed provide limited oxygen transfer, having the primary purpose of assisting in maintenance of the required hydraulic conductivity within the bed.

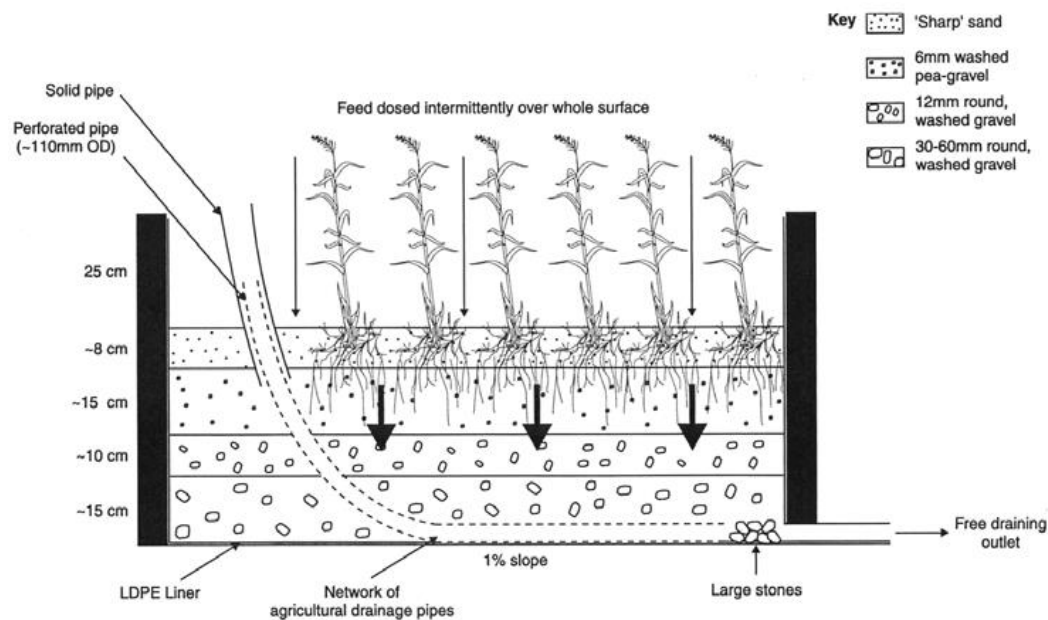


Figure 3: Typical arrangement of a vertical-flow reed bed system (after Cooper, 1996)

Different types of pollutants (such as: nitrogen, phosphorus, organics, solids, metals and coliforms) can be removed by employing constructed wetlands, through a complex interconnected system of plants, media, bulk water and biomass population (Fountoulakis et al., 2009).

Constructed wetlands have become popular across the world, because they are seen to have the following advantages:

- Relatively low capital and operating costs.
- Simplicity of operation (low requirement for operator supervision).
- Suitable treatment for low flows, previously untreated.
- Seen as a natural and therefore “green” process.
- They are attractive and provide wildlife habitat.
- As a polishing stage they can improve and enhance performance of initial treatment processes.

The treatment technology generally relies on processes similar to those used extensively in gravel “filter beds”, enhanced by the extensive rhizomatous root system of the reed plants (*Echinochba pyramida*) which can transfer limited quantities of oxygen into the surrounding media, stimulating bacterial communities. Other constituents of the effluent can be immobilized, or absorbed by the plants themselves. Although aerial growth of the reed plants (which can reach 2-3m high) dies down during the long-dry months, treatment has been demonstrated to continue

effectively. In situations where effluent from a previous treatment process, such as an SBR, may be warm (20-25 °C), the dead reed stems typically mat down on the gravel surface of the bed, providing heat insulation and maintaining adequate temperatures within the root zone of the reeds at all times.

In reality, the characteristics of landfill leachate can be better expressed in the following elements: BOD, COD, BOB/COD, pH, turbidity, metals, suspended solid, Nitrogen ammonia, heavy metals. These parameters give an outline of the quality of leachate and the need to design an operational unit for treatment. It is therefore necessary to carryout preliminary analysis before constructing a treatment unit.

The table 2 below gives an indication on the concentration of certain components of leachate obtained from some countries of the world.

Table 2: Composition of leachate from different garbage in some countries of the world.

Element	Garbage						0,01,2,3,4,5 standard values
	⁴ Mariannhi II (South Africa)	Canada	Greek	South Korea	China	Cameroon	
<i>pH</i>	8,1	5,8	6,2	7,3	7,8 – 9	7,5	5,5 – 9,5
<i>Alkalinity in CaCO₃</i>	6260						
<i>Conductivity</i>	1846						2500
<i>COD</i>	3816	13.800	70.900	24.400	50.000	2245	75 – 300
<i>BOD</i>	725	9.660	26.800	10.800	22.000	700	20 – 100
<i>BOD / COD</i>	0,19	0,7	0,38	0,44	0,44	0,31	
<i>TKN</i>		212	3.400	1.766	13.000	-	<30
<i>N-NH₄</i>	1232	42	3.100	1.682	13.000	-	2 – 15
<i>N-NO₃</i>	<0,1	-	-	-	-	13,6	250
<i>N-NO₂</i>	0,03	-	-	-	-	54,8	
<i>PO₄-P</i>	3,90	-	-	-	-	14,7	0,5 – 1
<i>SO₄</i>	150	-	-	-	-	24,8	250
<i>Na</i>	350	-	-	-	-	-	50
<i>Cl</i>	-	-	-	-	-	1644	250
<i>Mn</i>	0,78	-	-	-	-	0,435	
<i>Fe</i>	0,53	-	-	-	-	10,3	
<i>K⁺</i>	0,82	-	-	-	-	0,396	10
<i>Zn</i>	0,23	-	-	-	-	0,099	
<i>Mg²⁺</i>	0,01	-	-	-	-	-	50
<i>Ca²⁺</i>	0,12	-	-	-	-	-	75.5

⁰WHO., 2003; ⁰¹Novella et al., 2005; ²Renou et al., 2008 ; ³Zhang et al., 2010 ;

⁴Strachan & Mzizi, 2010 ⁵Yidong et al., 2012

2. THE LANDFILL OF NKOLFOULOU

2.1. DESCRIPTION OF SITE

The municipality of Soa is located at a score kilometer from Yaounde. It is in this municipality located North East of Yaounde that the YUC, in the 1980s, acquired a piece of land worth fifty hectares. The town of Soa had about 3200 inhabitants in 2001 (Bessala, 2003).

Since HYSACAM started work in the Nkolfoulou on the 1st September 1985, it has harnessed effective dialogue and communication among the inhabitants. The risk of pollution at the landfill, especially that of those who are around the area is very important. However, the population of this municipality have benefited from the construction of three springs thanks to HYSACAM.

A committee was set up for the follow- up of the activities of the landfill. At the Centre of this committee are the Mayor of Soa, the chiefs, some notables- representatives of the community. The committee meets once per semester at the Soa municipal council (hall) in order to verify the development of the activities. It is here that the semestral, systematic control of the deralization and debugging of the landfill is carried out.

Important discussions are made concerning the activities of the landfill by both the YUC and the inhabitants of Soa. The transparency of this committee enables HYSACAM and its partners to leave in harmony and this prevent any future problem between the parties (YUC and the inhabitants).

2.2. CLIMATIC FACTS

The city of Yaounde is found in the tropical zone and has an equatorial climate that is characterized by four alternating seasons (Kengne, 2008) namely; two dry seasons and two rainy seasons distributed as follows:

- ❖ A long dry season from mid-November to mid-March
- ❖ A short rainy season from mid-March to June
- ❖ A short dry season from July to August and
- ❖ A long rainy season from September to mid-November Daily temperature varies between 23 and 35 °C. It is represented in the bar chart below.

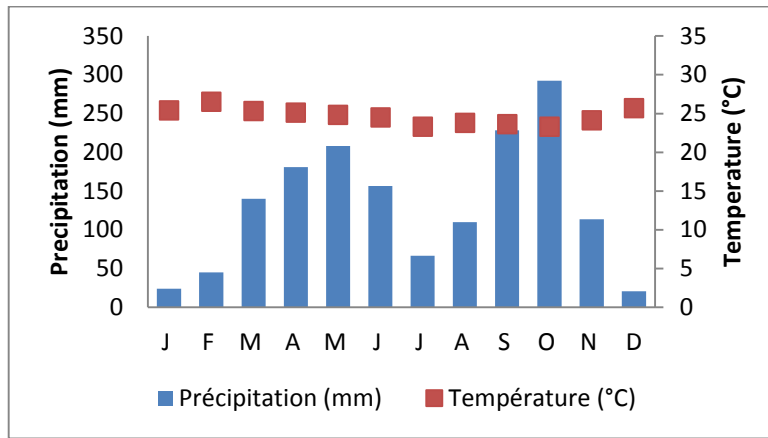


Figure 4: Repartition of monthly temperature and precipitation in the Yaounde city (source Nkolfoulou station and Military airport station of Mvan, 2010-2012) (Mboe, 2012).

The average annual temperature of Yaounde is about 24.5 °C. February is the hottest month with temperatures of about 25 °C. The average pluviometry is about 1500 mm/year. October has the highest rainfall with average of 273 mm whereas January with 14 mm is the most dried period of the year (Zahrani, 2006).

2.3. HYDROLOGY OF THE SITE

The Nfoulou river is located at the basin of the hillside of Nkolfoulou site and has a simple hydrographic network, composed of tributaries (Ebengui, Akoo, Voumudi) which are transformed into streams during period of heavy rains. Many accommodations and constructions had been realized in the Nfoulou basin such as CSG, the University of Yaounde II in Soa, roads and residential quarters. The Nfoulou river flows via Afamba which enters Sanaga.

It is a good receiver of discharged leachate of Nkolfoulou and waters of diverse origin (MINMEE, 2004).

2.4. TYPES OF WASTE DISCHARGED ON THE SITE

The idea of storing waste at the site started with HYSACAM since 1st September 1985. About 1200 tons out of 1800 tons produced by the Yaounde city are treated per day. After collection at the level of the household, the garbage is transported in metallic dustbin. At the level of municipal market, one or many dustbins are kept for disposal of the different types of garbage.

In Cameroon, the sensibilisation of selective sorting out is not wide-spread within the population, thus we can find all types of wastes in one dustbin. The dustbin is situated at precise places and is well-known by the population of the quarter. The truck loaders collect the dustbins and their content to the landfill. The content of the truck is represented in the table below.

Table 3: Composition of wastes entering the waste storage centre of Nkolfoulou (Zahrani, 2006).

	High standing	low standing	Homes	Market	Pre-urban
Wood	0.2	1.1	0.5	1.9	0.4
Rubber	0.0	0.0	1.8	1.2	0.0
Cartons	5.4	3.0	1.5	13.5	4.6
Papers	1.0	3.8	1.0	3.7	3.1
Danger	0.1	0.1	0.1	0.1	0.0
Gravels	2.0	0.4	1.1	0.3	0.8
Metals	1.5	0.9	1.2	1.7	1.0
Plastics	7.0	8.0	12.2	6.6	7.9
Textile	4.6	5.0	6.0	2.6	3.2
Glasses	1.5	1.0	1.2	0.6	1.4
Organic matter	62.2	70.4	65.7	63.7	66.5
Finish elements	5.5	6.3	7.7	4.1	11.1
Total	100	100	100	100	100

2.5. LEACHATE LEAVING THE SITE

The storage center of waste at Nkolfoulou until 2006 did not have any equipped system for drainage of leachate. The continual flow of the leachate at pressure provoked by increased in the

buried wastes had affected the pit and thus compartments and basins are put for retention of the leachate.

In 2006, Zahrani worked on the leachate in order to characterize it. Samples were collected from three points: E1 (inlet of the basin), E2 (outlet of the basin) and E3 (compartment used in 2004-2006). The results obtained are given on the table4 below.

Table 4: Analysis of leachates of Nkolfoulou (Zahrani, 2006)

Class	Parameters	E1	E2	E3
Global indicators	T (°C)	31	30.5	30
	pH	8	8.9	7.5
Organic charge (mg/L)	BOB ₅	420	500	700
	COD	722	1124	2245
Carbon	CT	1340	1154	1699
Anions (mg/L)	F ⁻	< 0.0005	< 0.0005	< 0.0005
	Cl ⁻	1313	1393	1644
	NO ₂ ⁻	111	25.4	13.6
	NO ₃ ⁻	238	177	54.8
	Br	< 0.0005	< 0.0005	< 0.0005
	SO ₄ ²⁻	436	72.1	24.8
	PO ₄ ³⁻	7.93	8.61	14.7
Heavy metals(mg/L)	Cd	<0.005	<0.005	<0.005
	Cr	0.151	0.133	0.12
	Cu	0.108	0.010	0.007
	Fe	3.12	1.37	10.3
	Hg	0.011	<0.002	<0.002
	Mn	0.146	0.104	0.435
	Ni	0.163	0.213	0.396
	Pb	0.019	<0.003	0.059
	Zn	0.113	0.035	0.099

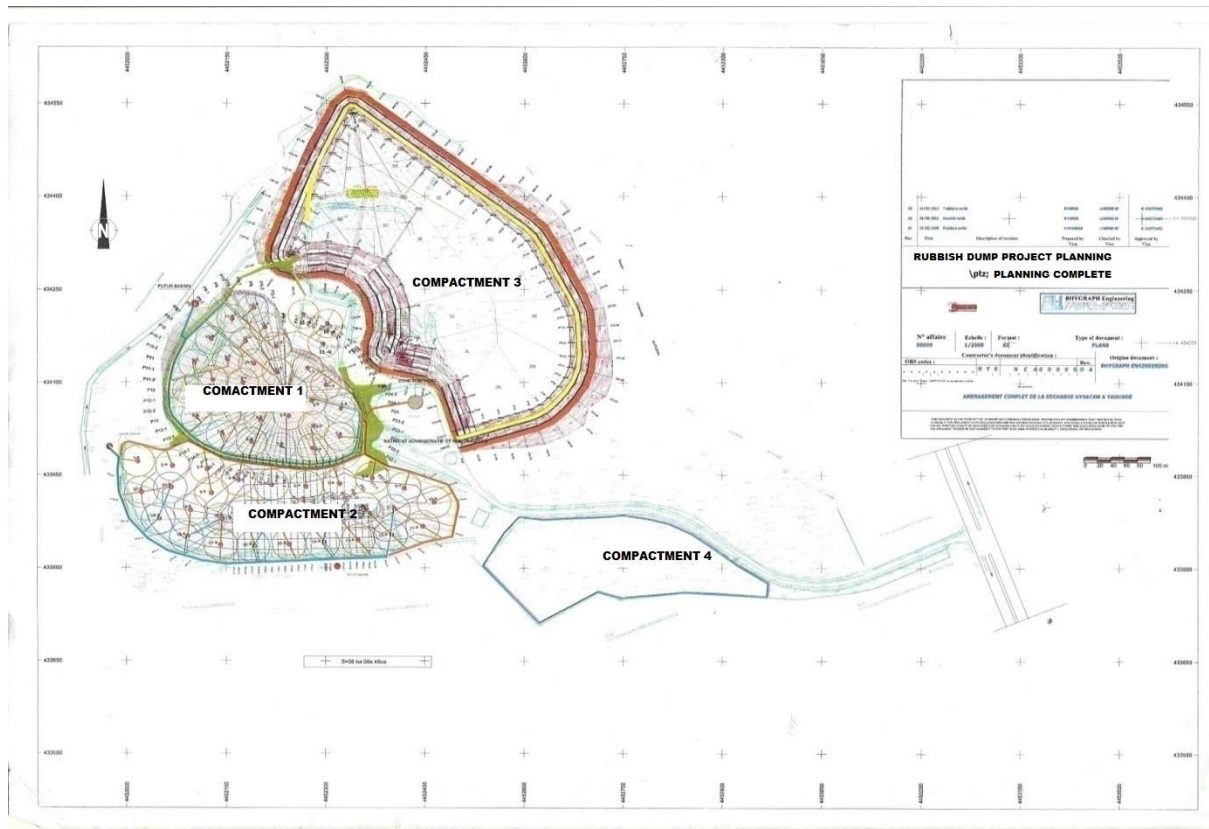


Figure 5: Presentation of the site of study (MINEPDED, 2012)

2.6. Presentation of the landfill site of Nkolfoulou

The interior of the WSC constitutes of an administrative block of area 90 m² and consists of a manager of the site and the leader of employees in one of the rooms while his employees are in the other. There is a hall for meetings and sanitarians. There is also a seesaw bridge that is used in measuring the weight of load entering as well as a parking lot. Also constructed are shelter for mechanics, cloakroom, a water supply system and a petroleum pumping station.

The evaluation of garbage is developed by spreading residues in the form of compost. A committee was thus developed to test the quality of the compost product. The storage elements described here are made of four compartments a tank for retention of leachate and a treatment plant; viz:

- Compartment exploited in 1998-2003: it has a surface area of 5.1 hectares, depth of about 6m covered with soil and growing plants
 - Compartment exploited in 2003-2004: it is covered with clay layer of 0.75 m thick.
- The leachate and runoff are drained via a canal

- Experimental compartment in 2004-2006: it had enabled studied how biogas products can be controlled by installation of a system that capture the gases
- New compartment in 2006- up till date: it occupies a volume of 7600 m³. It was dug for three years from 2002-2005 and receives all the garbage entering the site.
- A tank for retention of leachate: it is found just below the old compartment (of 1998-2003) and is made of three cascade basins. It was renovated in 2006 and is used for storage and treatment before discharging in the Nfoulou river. The first basin has a volume of 40 m³ while the others are 20m³ each (MIMEPDED, 2012). See annex 1
- A reed bed filtration system: (2015-till date) it is made of a reservoir(inlet 1, for storing leachate), two filter tanks(outlet 1 and 2, each contain reed plants for absorbing contaminants, then, gravel and sand for purification).see figure 7.



CHAPTER 2: EXPERIMENTAL PART

2.1. MATERIALS AND EXPERIMENTAL METHODS

2.1.1 General information

The aim of this section is to present the method of collection and preservation of samples, chemical products used as well as the techniques of sampling and analysis.

2.1.2. Materials

The materials and equipment used can be grouped under two headings namely: those that were used for collection and preservation of the water samples and those used for the preparation and analysis of the samples.

Material use for collection at the points of sampling include following:

- Clean plastic bottles
- Conductometer
- PH-meter
- Thermometer
- Pen and paper (for labeling)

2.1.3. Techniques of sampling

Three types of samples were collected, that is, from water around the water bodies, leachate from the active dumpsites (compartment, basin) and from the treatment system. The collection of the samples was done manually.

2.1.4 Points of Sampling

The sampling was carried out in the March, 2016 at 11 points in the landfill. To know if the leachates from the site cause pollution, samples were collected from different points of the landfill namely: from water around the water bodies; up-stream and down-stream which are two small streams closer to the landfill compared to the river and up-stream, down-stream points of the Nfolou river and also at the point where the river and the leachate meet. Samples were also collected from the active dumpsites of the landfill (Z3A and Z3E), basin (basin 1) and from the treatment system

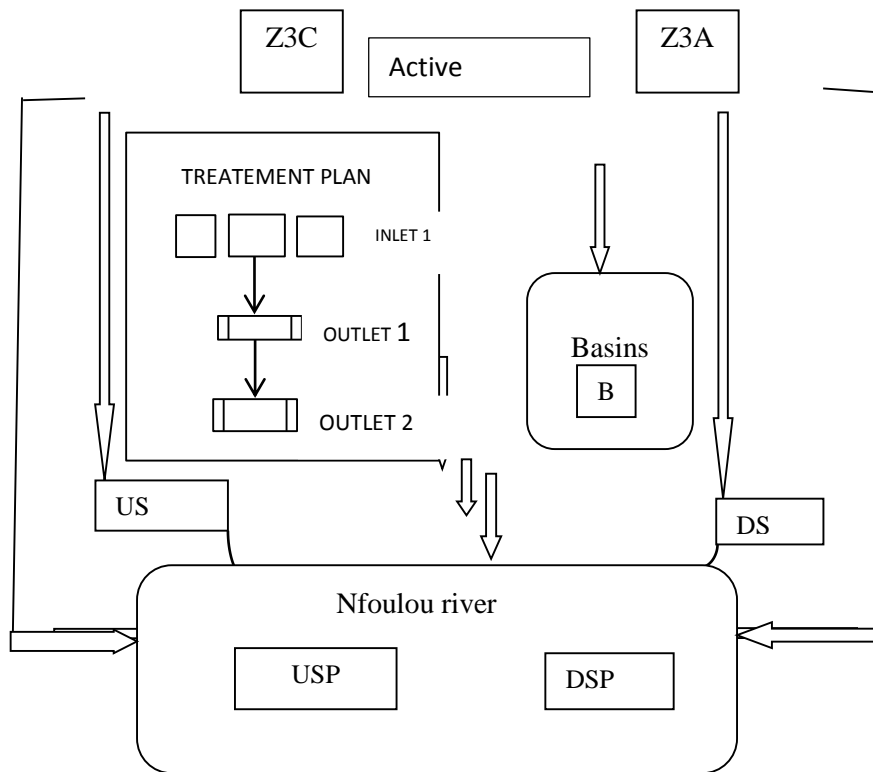


Figure 6: Points of collection and placing of sample from the site

Z: zone B: basin1 DS: down-stream river MP: meeting point
 US: up-stream river DSP: down-stream point USP: up-stream point

2.1.5. Methods of Treatment

The method employed in the treatment of the leachate is that of subsurface vertical flow reed bed filtration system. Two vertical reed beds were constructed each comprising a flat bed of uniform depth, typically, surface area of 1m² and 1m³ volume with growing reeds.

Inlet one acts a tank for storing the leachate before treatment. The leachate found in the tank is a mixture of leachate from basin 1 and water in a ratio of 100:150 L respectively. The sample is mixed in order to ease fluidity and better absorption by the reed.



Figure 7: Subsurface vertical-flow reed beds treatment system.

2.1.6 Methodology of sampling

In order to characterize the leachate and ground water from the landfill, the following were carried out:

- ❖ Measurements of pH and conductivity and collection of water at specific points of the three water bodies using plastic bottles.
- ❖ Measurement of pH and conductivity and collection of leachate samples from the active dumpsites (Z3A and Z3E) and treatment basin 1 in plastic bottles.

- ❖ Measurement of pH and conductivity and collection of leachate samples at the inlet and outlet streams of the two reed bed system setup to treat leachate in plastic bottles.
- ❖ Storage of all the samples in the refrigerator of the inorganic laboratory before analysis
- ❖ Analysis of the samples

2.1.7. Conservation and Storage

After collection, the samples were immediately taken to the laboratory for conservation. It was stored in the refrigerator at cold temperature about 4°C.

2.1.8. Analysis and physico-chemical parameters

The samples were then transferred to the laboratory for analysis. The analysis covered physical-chemical parameters of each sample type. The qualitative chemical analysis was carried out in the Laboratoire d'Analyse Geochemique des Eaux, Yaoundé.

The physio-chemical parameters analysed include: pH, Conductivity, Nitrate, Chloride, Sulphate, phosphate and major cations of Na⁺, K⁺, Mg²⁺ and Ca²⁺. The pH and Conductivity were determined in situ with portable conductivity and pH meters. All the results obtained were compared with the World Health Organization (WHO) standard for Drinking Water.

2.2. METHOD OF ANALYZING THE SAMPLE

2.2.1 General information

Here, we are going to say little about the chemical products and method use since the result obtained is from the laboratory of Analysis of the Geochemical of water in Yaounde. The method employed is ion chromatography where ion exchange method was preferred. Detail will be discussed in annex 1.

2.2.2 Ion chromatography: definition and principle

The method employed for analyzing the samples is ion chromatography. Ion chromatography is used for water chemistry analysis. Ion chromatographs are able to measure concentrations of major anions, such as fluoride, chloride, nitrate, nitrite, and sulfate, as well as major cations such as lithium, sodium, ammonium, potassium, calcium, and magnesium in the parts-per-billion (ppb) range. Ion chromatography which is a form of liquid chromatography measure the concentrations of ionic species by separating them based on their interaction with a

resin. Ionic species separate differently depending on species type and size. Sample solutions pass through a pressurized chromatographic column where ions are absorbed by column constituents. As an ion extraction liquid, known as eluent, runs through the column, the absorbed ions begin separating from the column. The retention time of different species determines the ionic concentrations in the sample.

CHAPTER 3: RESULTS AND DISCUSSION

3.1 GENERAL INFORMATION

In this section, emphasis will be laid on presentation and interpretation of results obtained on the characterization of the leachate and water from the landfill of Nkolfofoulou. The analysis made and the pollutants found are grouped on different tables. The study of these tables enables us to identify the level of pollutants at each point of the site and comparing with the standard value of WHO for drinking water.

3.2. PHYSICO-CHEMICAL PARAMETERS OF WATER AROUND THE WATER BODIES OF THE NKOLFOULOU LANDFILL.

From the up-stream river to the up-stream point, the concentration of K^+ turns to decrease while those of the other ions increased as the river flows. From the down-stream point to the down-stream river, the concentrations of K^+ and Cl^- decrease while that of Mg^{2+} , Ca^{2+} , NO_3^- and SO_4^{2-} turn to increase. The concentrations of these ions at the meeting point between the river and the leachate increase compared with those at the up-stream. PO_4^{3-} concentration appears to be zero. The table below gives the values of these parameters.

Table 5: Physico-chemical parameters of water around the water bodies of landfill.

Sample	pH	Conductivity $\mu S/cm$	Cation (mg/L)			Anion (mg/L)			
			K^+	Mg^{2+}	Ca^{2+}	Cl^-	NO_3^-	PO_4^{3-}	SO_4^{2-}
Up-stream river	7.4	260	42.55	3.14	8.74	14.46	6.59	0	2.15
Down-stream river	7.2	180	31.98	2.61	6.97	8.16	0.41	0	2.24
Up-stream point	7.3	239	6.67	3.22	18.14	5.52	2.52	0	5.12
Down-stream point	7.4	178	8.89	3.27	18.70	4.82	3.14	0	4.63
Meeting point	7.4	196	8.12	3.25	19.85	4.59	2.65	0	5.00

Conductivity measured in the water bodies of the landfill.

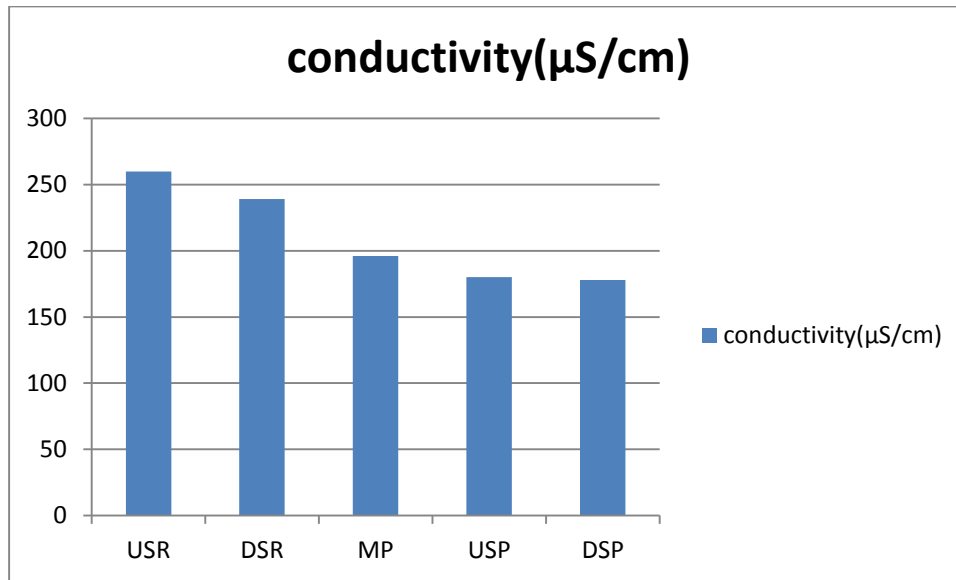


Figure 8: Conductivities of water samples from water bodies of the landfill.

From table 5 and figure 8, conductivity is seen to be highest at the up-stream river, 260 µS/L and lowest at the up-stream point, 178 µS/L. The conductivity of the down-stream river, meeting point and up-stream point are 239, 196 and 180 µS/L respectively. High conductivity tells us that there is high level of contaminants especially cations.

The levels of Potassium ion in the water bodies.

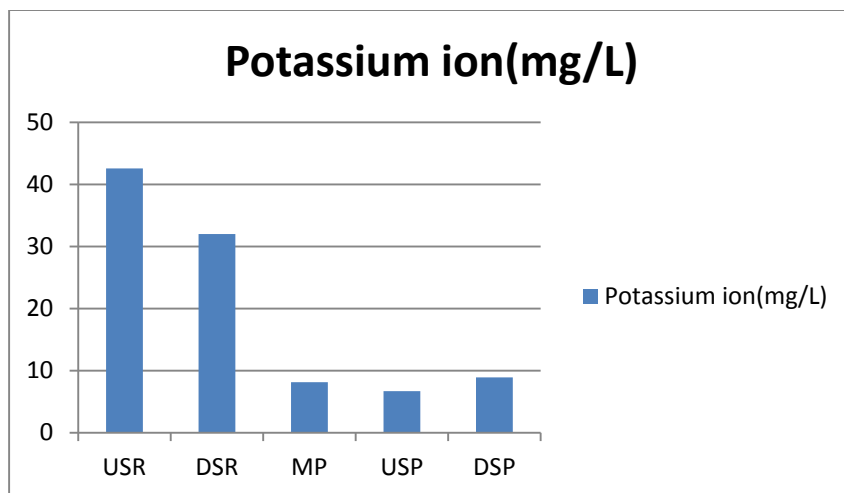


Figure 9: Potassium ion in the water bodies

Table 5 and figure 9 revealed highest concentration of k^+ in the USR (42.55 mg/L) and lowest at the USP (6.67 mg/L). The concentrations at the DSR, MP and DSP are 31.98, 8.12 and 8.89 mg/L respectively. At the USR and DSR, the values obtained are higher than the Standard Norms of WHO (10 mg/L). This is because these areas are closer to the landfill thus there is flow of leachate into the two rivers which lead to contamination of this ion.

The levels of Magnesium ion in the water bodies.

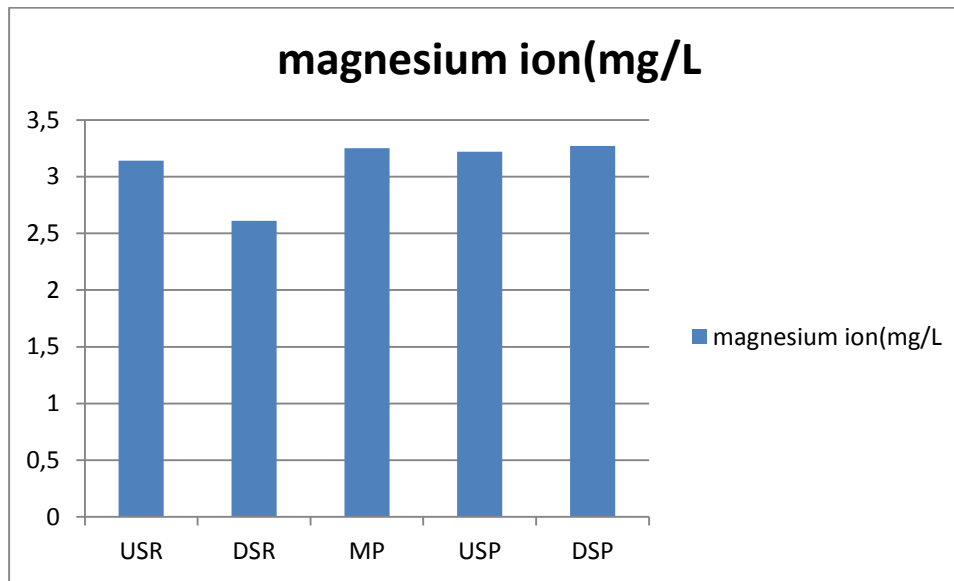


Figure 10: Magnesium ion in the water bodies.

From table 5 and figure 10, the values of magnesium ion lie between 2.61-3.14 mg/L which is far less than the Standard values 150 mg/L. This means that the water bodies have minor concentration of this ion, thus, contamination.

The levels of Calcium ion in the water bodies

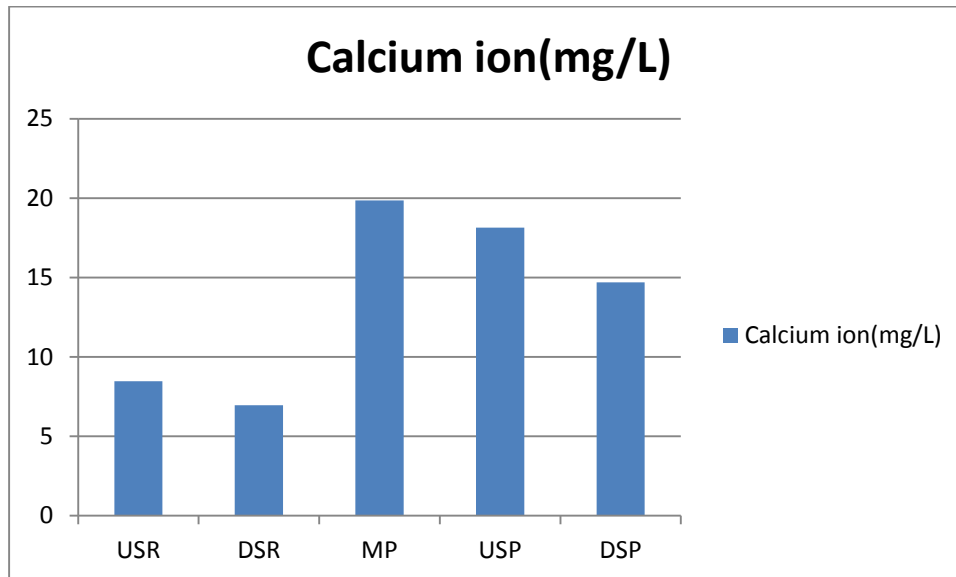


Figure 11: Calcium ion in the water bodies.

From table 4 and figure 11, the values ranged from 6.97-19.85 mg/L. These values are small compared to WHO Standard value 100 mg/L. This means the water bodies do not contain this ion in high concentration. The high value observed at the meeting point (MP) implies there is flow of leachate from the landfill into river Nfolou.

The levels of chloride ion in the water bodies.

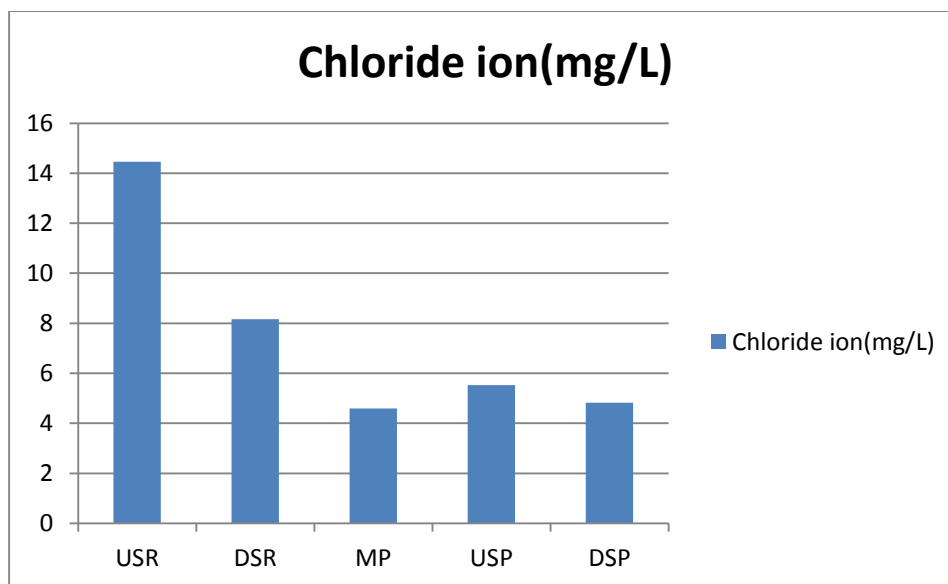


Figure 12: Chloride ion in water bodies.

The values shown by table 5 and figure 12 revealed higher level of chloride ion at the USP, 14.46 mg/L and lower level at DSR, 4.59 mg/L. the high value at the USP is due to the presence of weathered silicate rich rocks beneath the overburden and leaching from soil due to infiltration from the landfill. However, the values of this ion ranged from 4.59-14.46 mg/L which is quite small compared to that of WHO limit of 250 mg/L. This means that there is no contamination by this ion.

The levels of nitrate ions in the water bodies.

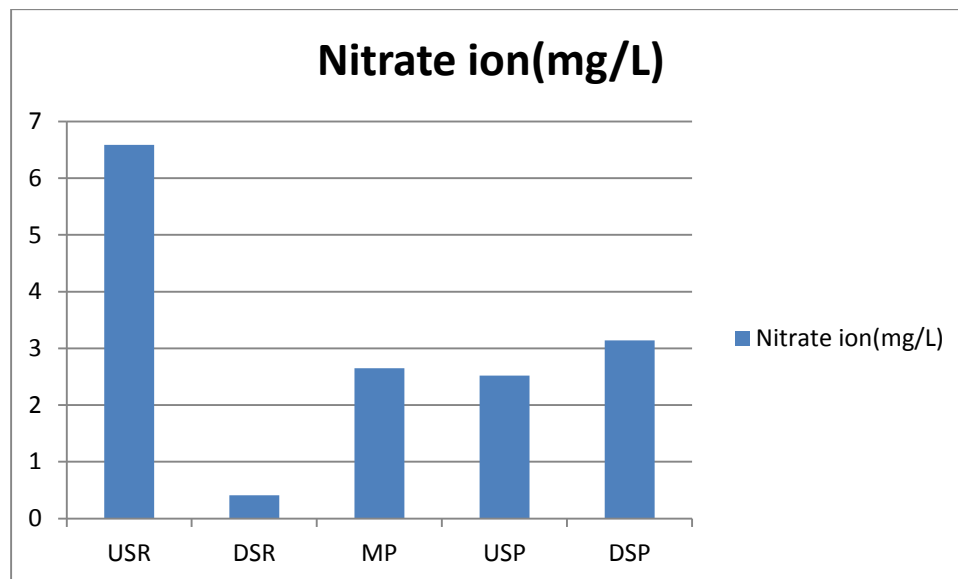


Figure 13: Nitrate ion in the water bodies.

From table 5 and figure 13, we have highest value at the USR, 6.59 mg/L and lowest value at the MP, 0.41 mg/L. The Nitrate values ranged from 0.4 to 6.59 mg/L. Unpolluted natural water usually contains only minute quantities of nitrate and hence all nitrate value for all samples lie below the limit prescribed by WHO. Nitrate can become a contaminant of water if its concentration exceeds 10 mg/L in drinking water and all the samples fall below this limit.

The levels of Sulphate ion in the water bodies.

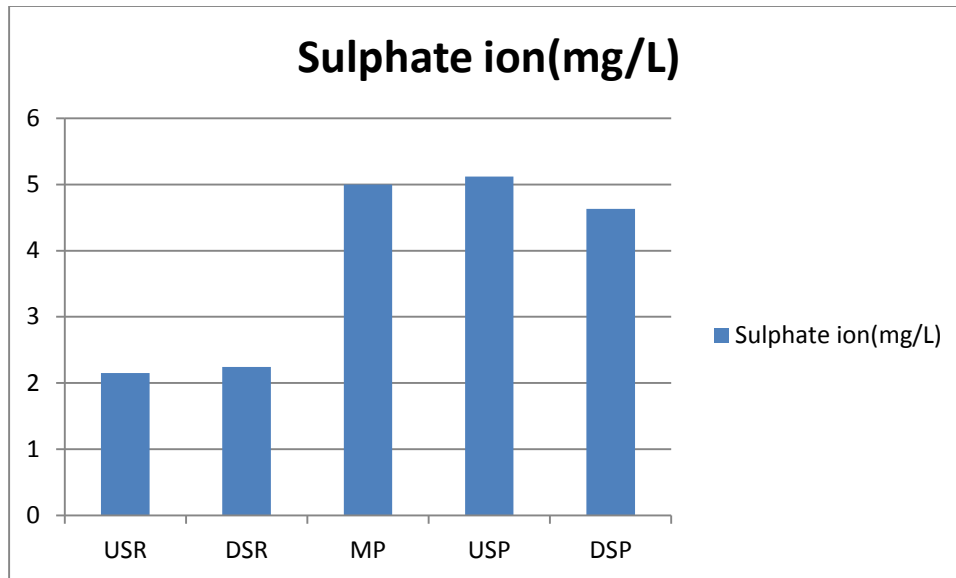


Figure 14: Sulphate ion in the water bodies

From table 5 and figure 14, highest level of sulphate ion was observed at the USP, 5.12 mg/L while the lowest value at the USP, 2.15 mg/L. The values of all the points lie between 2.15-5.12 mg/L which is small compared to the WHO limit of 250 mg/L. Though, sulphate values lie below 200 mg/L according to WHO limit, the low values are most probably due to the removal of the ions by the action of bacteria. This implies no contamination of the water bodies by the sulphate ion.

3.3. PHYSICO-CHEMICAL PARAMETERS OF THE ACTIVE DUMPSITE OF THE NKOLFOULOU LANDFILL.

In Z3A and Z3C, the concentrations of the cations and anions increased as the leachate flows along the site except for phosphate. High conductivity values are observed in the site.

Table 6: Physico-chemical parameters of the active dumpsites of the landfill

sample	pH	Conductivity μS/cm	Cation (mg/L)			Anion (mg/L)			
			K ⁺	Mg ²⁺	Ca ²⁺	Cl ⁻	NO ₃ ⁻	PO ₄ ³⁻	SO ₄ ²⁻
Z3A	8.0	19200	1550.93	23.80	65.16	534.67	274.18	0	324.22
Z3C	8.2	7040	1836.41	21.26	24.08	581.05	0	9.19	28.08
Basin 1	7.3	7470	4385.73	63.39	68.91	1364.87	14.28	0	18.45

Conductivities of the samples at the active dumpsite of the landfill.

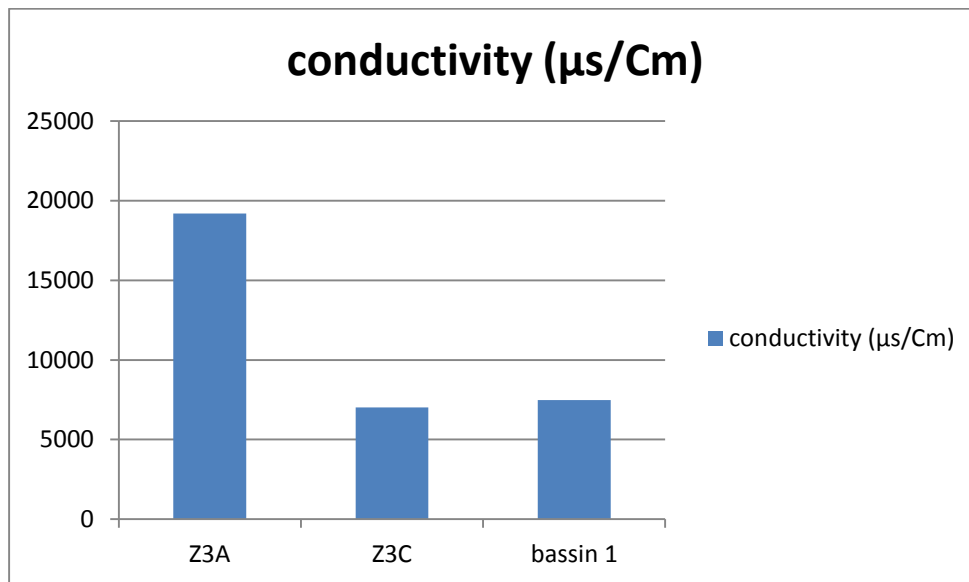


Figure 15: Conductivity at the active dumpsite of the landfill

High conductivity implies high concentration of ions. This implies that at Z3A 19200 μS/L, the concentrations of ions shall be higher.

The levels of potassium ion in the active dumpsite of the landfill.

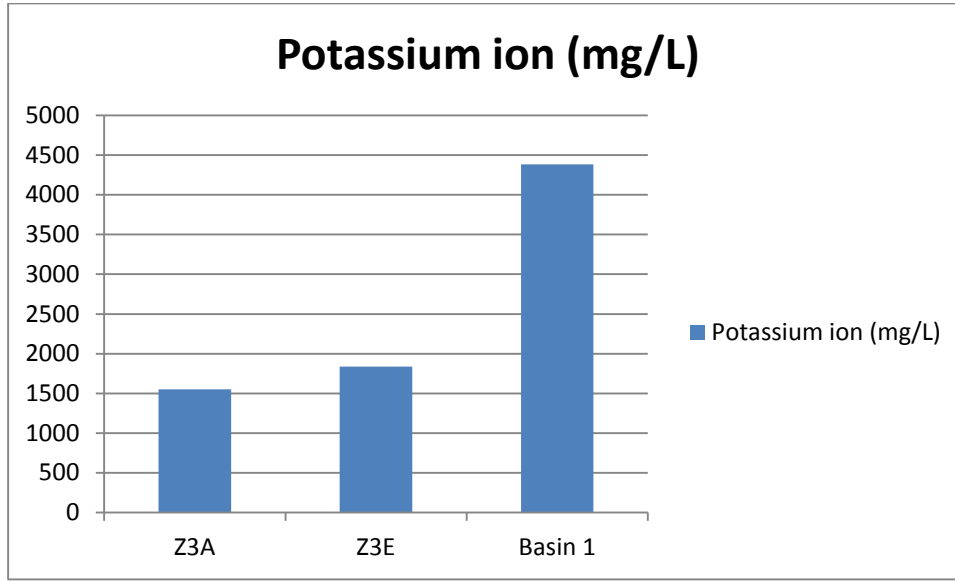


Figure 16: Potassium ion in the active dumpsite

Table 5 and figure 16 shows highest level of potassium ion in basin 1, 4385.73 mg/L and lowest at Z3E, 1836.41 mg/L. The high concentration in basin 1 is due to the fact that all the leachate samples of different concentrations at the active dumpsite are channeled to the basin, and there, they combined to give a high concentration.

The levels of magnesium ion in the active dumpsite of the landfill.

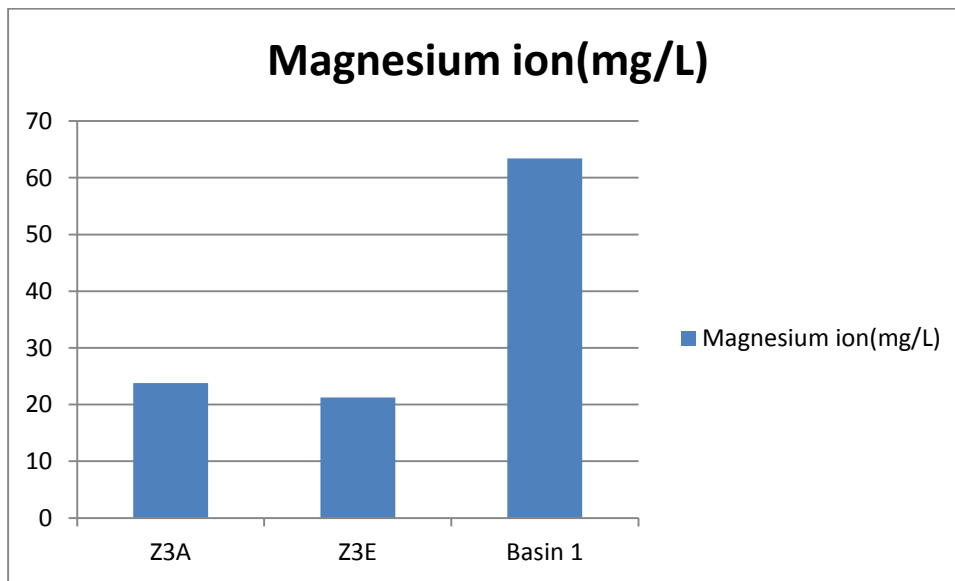


Figure 17: Magnesium ion in the active dumpsite of the landfill.

Table 5 and figure 17 show that highest level of magnesium lies in basin 1, 63.39 mg/L while lowest value lies in Z3E, 21.26 mg/L and 23.80 mg/L in Z3A. The high value observed is due to the fact that all the leachate are channeled in the basin and so it turn to have a higher concentration compared to the active dumpsite. Also, basin 1 is not covered such that rain water which is considered as hard water (contains magnesium) increase it concentration in the basin whereas the active dumpsite is closed.

The levels of Calcium ion in the active dumpsite of the landfill.

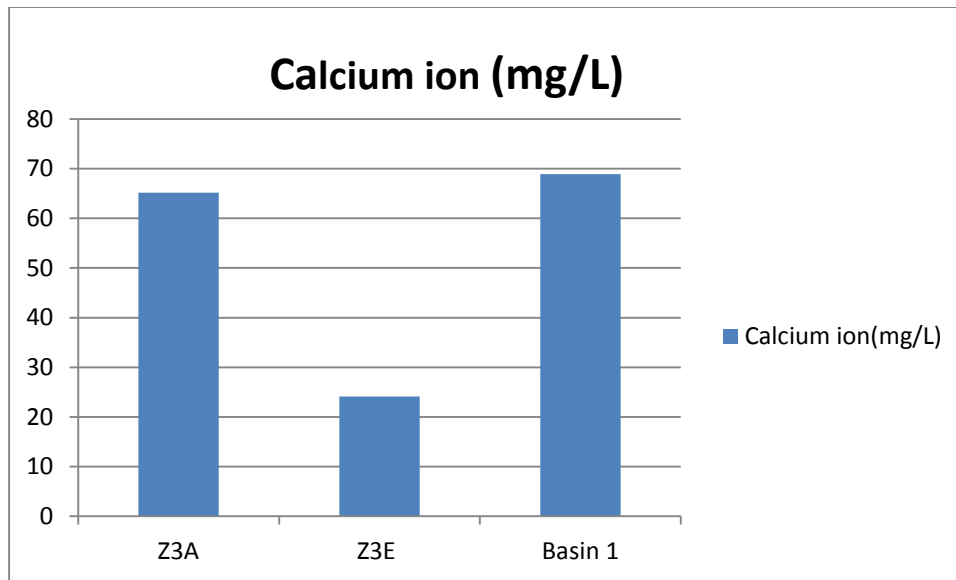


Figure 18: Calcium ion in the active dumpsite.

From table 5 and figure 17, the concentration of calcium decreased in the order basin1 (68.91 mg/L) followed by Z3A (65.16 mg/L) then Z3E (24.08 mg/L). It high concentration at the active dumpsite is because only the raw substances are present. In basin 1, hard water from rainfall also contribute to its highest concentration.

Levels of Chloride ion in the active dumpsite.

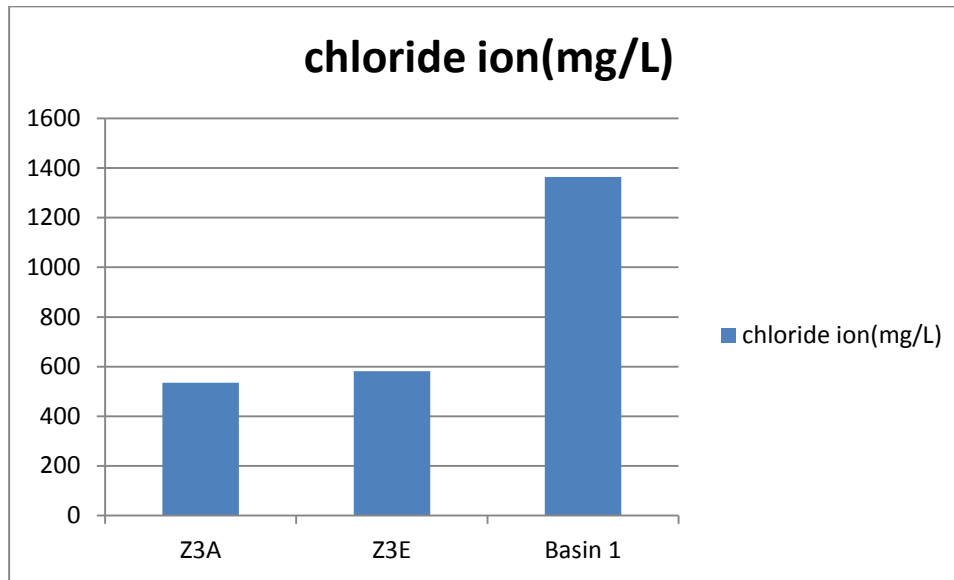


Figure 19: Chloride ion in the active dumpsite of the landfill.

Basin 1 (1364.87 mg/L) shows the highest concentration of chloride ions followed by Z3E (581.05 mg/L) and then Z3A (534.67 mg/L). All the leachates is channeled to the basin that is why the concentration is high.

Levels of Nitrate ion in the active dumpsite of the landfill.

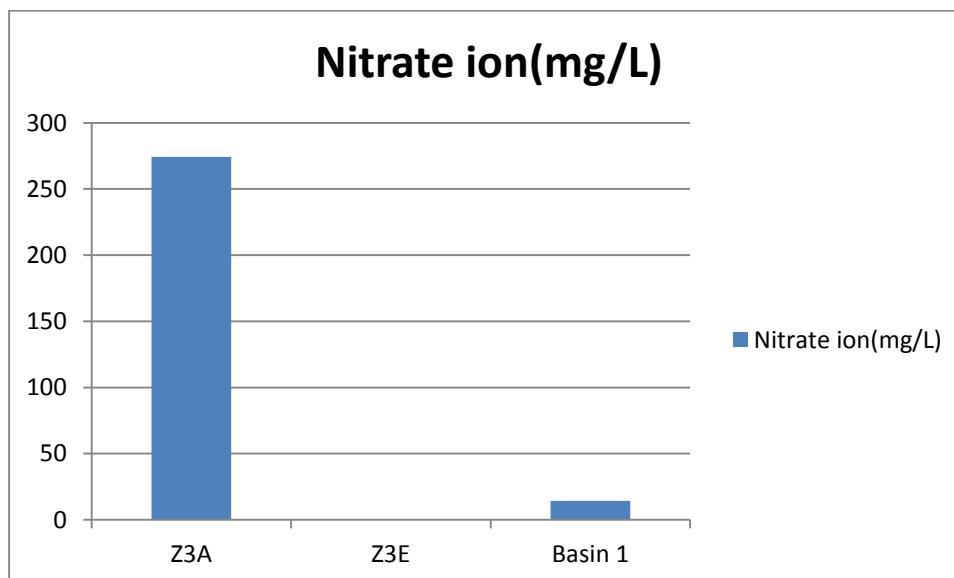


Figure 20: Nitrate ion in the active dumpsite.

From table 5 and figure 20, nitrate ion level turn to be high at Z3A (274.18 mg/L) and small at basin 1(14.28 mg/L) while at Z3E, no trace was observed. Concentration is high at Z3A since they are so many substances that contain nitrate compounds like sodium nitrate added to food for preservation.

The levels of Sulphate ion in the active dumpsite of the landfill.

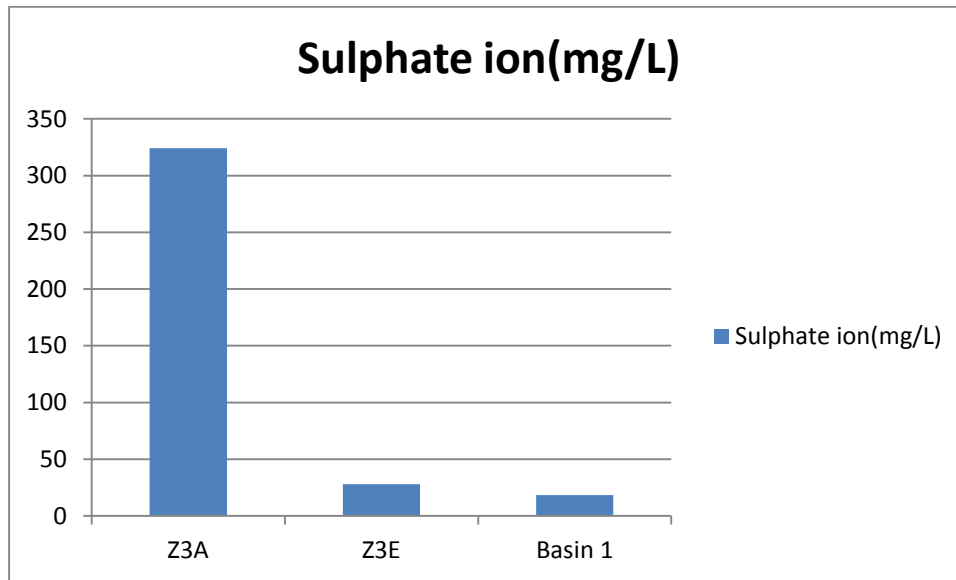


Figure 21: Sulphate ion in the active dumpsite.

From table 5 and figure 21, higher values are observed at Z3A (324.22 mg/L). Basin 1 and Z3E show very small concentrations of sulphate. Z3A gives a higher concentration in sulphate ion as it serves as the site for which waste is actively dumped.

3.3. PHYSICO-CHEMICAL PARAMETERS OF THE REED BED FILTER SYSTEM.

In the treatment system, the concentrations of the cations and ions decrease drastically for K^+ and Cl^- while that of Mg^{2+} , Ca^{2+} , NO_3^- , and SO_4^- turn to decrease as the leachate filters through the system. Here also there is the absence of PO_4^- . The conductivity is as well high

Table 7: Physico-chemical parameters at the reed bed treatment system at Nkolfoulou landfill.

sample	pH	Conductivity μS/cm	Cation (mg/L)			Anion (mg/L)			
			K ⁺	Mg ²⁺	Ca ²⁺	Cl ⁻	NO ₃ ⁻	PO ₄ ³⁻	SO ₄ ²⁻
Inlet 1	9.5	1670	417.37	6.79	8.95	123.05	10.15	0	17.53
Outlet 1 filtered	9.3	2170	353.98	8.80	22.48	102.21	3.40	0	23.79
Outlet 2 filtered	8.4	865	76.91	15.39	46.52	39.07	2.92	0	77.20

Conductivities of samples of the reed bed filter system.

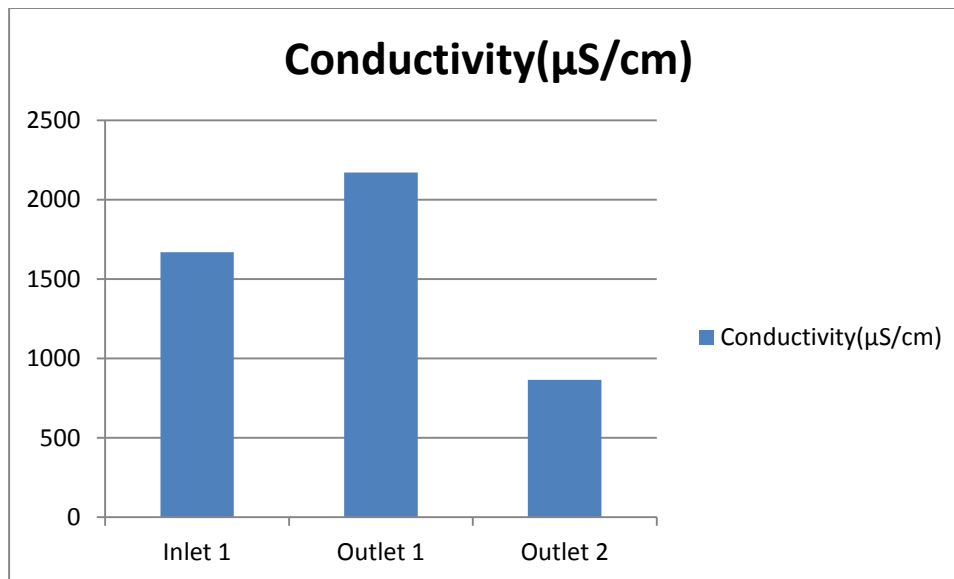


Figure 22: Conductivities at the filter system

The levels of potassium ion in the filtration system.

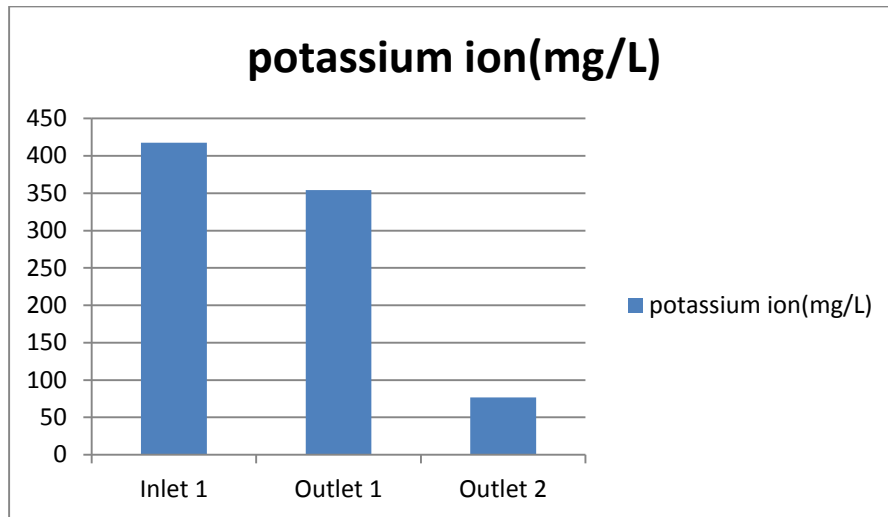


Figure 23: Potassium in the filtration system.

From table 5 and figure 23, the concentration values of the leachate decrease as it flows from one filter system to the other. K^+ has slower mobility with water flow (Leal et al., 2009) because of a greater tendency to interact with soil colloids. Though the concentration of K^+ decrease from inlet to outlet streams (417.37-76.91 mg/L), the value exceed the standard limit (10 mg/L) implying that the system supplies this ion. The main source of K^+ in water is weathering of potash silicate and clay minerals (Lee et al., 2010). The system is built with sand and gravel thus weathering of the sand and gravel also increase the level of the ion.

The levels of Magnesium ion in the filtration system.

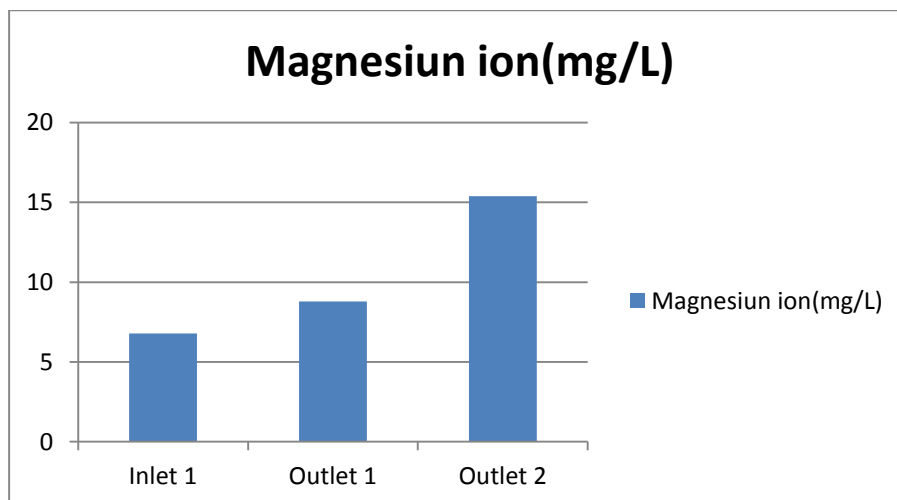


Figure 24: Magnesium ion in the filtration system.

The values of magnesium according to table 5 and figure 24 shows an increase from the inlet stream (6.79 mg/L) to the outlet stream (15.39 mg/L) as leachate filters through the reed bed filter. The increase in the concentration of this ion is due to the fact that it forms stable compounds that do not break down easily and so the reeds find it difficult to absorb it.

The levels of Calcium ion in the filtration system.

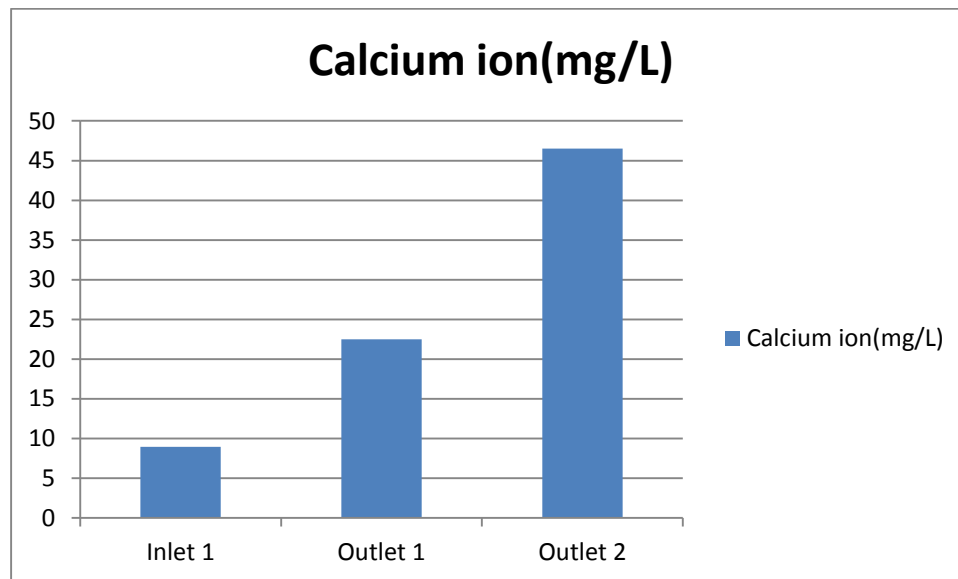


Figure 25: Calcium ion in the filtration system.

The values of calcium according to table 5 and figure 25 turn to increase from the inlet (8.95 mg/L) to the outlet (46.52 mg/L) as the leachate sample is allowed to flow through the filtration system. This increase is due to the presences of calcium in gravel and sand used in constructing the reed bed. Also, it combines with sulphate ions and so, forms stable compounds that passed out unabsorbed.

The levels of Chloride ion in the reed bed filter system.

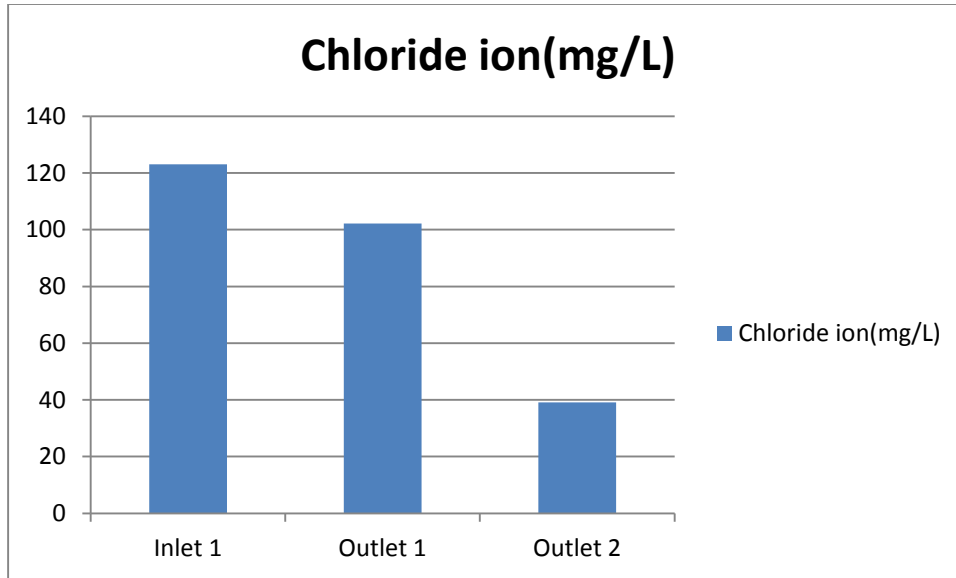


Figure 26: Chloride ion in the filtration system.

The level of chloride ion turns to decrease from the inlet (123.05 mg/L) to the outlet (39.07 mg/L) as the leachate flow through the filtration system as revealed by table 5 and figure 26. This decrease is because it combines with calcium and potassium to produced salt (Zoeteman, 1980). The levels of Nitrate ion in the reed bed filter plants system.

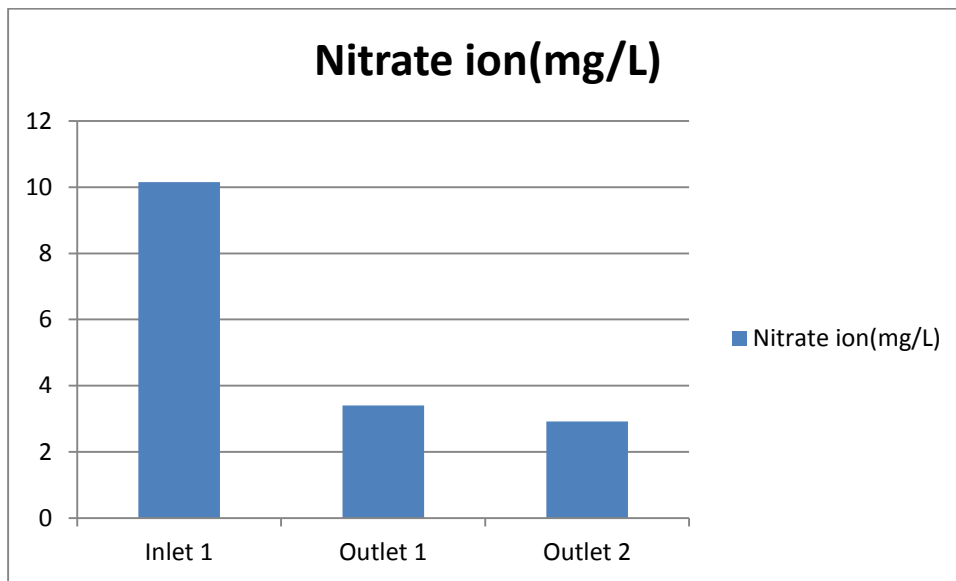


Figure 27: Nitrate ion in the filtration system.

From table 5 and figure 27, we observed a decrease in the level of nitrate from 10.15-2.92 mg/L as the leachate filters through the reed bed system. The decrease in the concentration of nitrate ion is caused by its consumption by micro-organisms found on the roots of the reed.

The levels of Sulphate ion in the reed bed filter plants system.

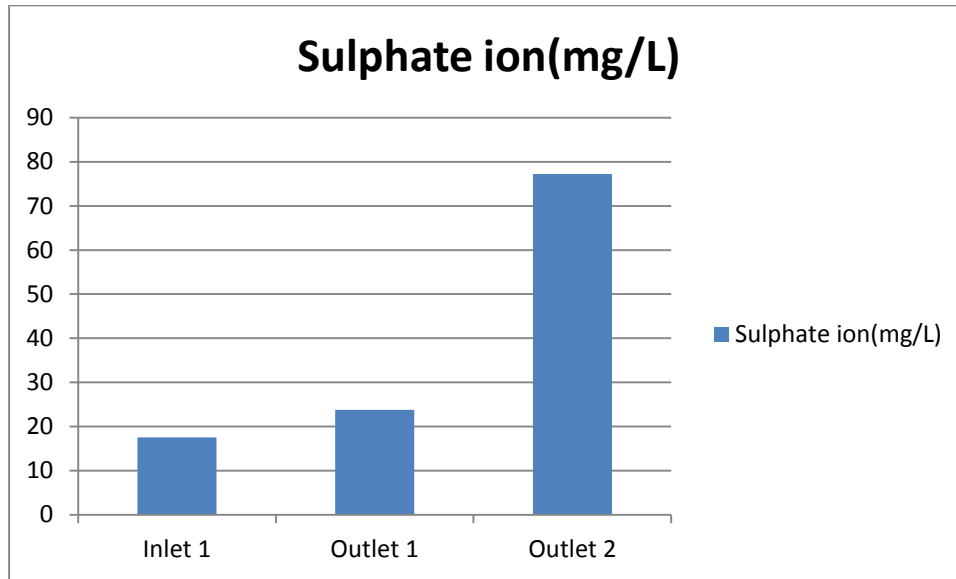


Figure 28: Sulphate ion in the filtration system.

The concentration of sulphate ion increased from 17.5 mg/L of the inlet stream to 77.20 mg/L of the outlet stream. The high value at the outlet stream is due to the fact that sulphate ions were not consumed by bacteria found on the root of the reed but instead they were produced. Also, they combine with calcium to produce stable compounds that are difficult to break so they pass out unfiltered.

The value of pH is an important parameter in wastewater quality and effluent discharge. It is often used to represent the aggressiveness of leachate and biochemical conditions in solid waste (Jaffar et al., 2009).

The physico-chemical analysis of the leachate obtained at the treatment system shows effectiveness in the reduction of the concentrations of the ions. That is, the values of all the concentrations lie below the standard limit except for k^+ . Apart from this cation, the system had succeeded in absorbing the cations and anions present and the values lie below the standard limit recommended by WHO. Therefore, discharging into the river will cause no contamination and will be suitable for drinking.

PEDAGOGIC INTEREST

This dissertation will permit me as a future teacher to:

- Assimilate certain laboratory techniques like preparation of solutions, simple filtration and understanding certain method so as to better explain the different ways of preparing solutions to students as well as exercising the experimental data during class and exam period.
- Know many analytical techniques
- Developed critical spirit, analyze, judge and syntheses after exploiting a document.
- Better understand the field of research and to define the relative beginning approach to a research.
- Master information tools which is considered as the major base at the time of typing subject and exercises.

GENERAL CONCLUSION AND PERSPECTIVES

The present study demonstrated that anion and cation concentrations throughout the stream reach are not always uniform due to heterogeneous distribution of ionic material caused by leachate flowing at different concentration into the river, as the case with the meeting point of the leachate and river, although stream water has been regarded as providing a uniform continuous body for the ionic materials. The low concentrations of the anionic material observed is because as the leachate from the site flow down into the river, a series of processes, including mechanical decomposition by invertebrates and chemical decomposition thereby reducing the concentration of the leachate before it reaches the river. The high concentration observed in the landfill site is because only raw concentration of the leachate is present. But nitrate ion concentration is zero at Z3C thus no contamination. Also the concentration of phosphate ion is zero in the entire sample except in Z3C in which the concentration is above the standard limit thus contamination of the zone. In the treatment system, there is fluctuation in variation of the ions. The concentration of potassium, chloride, nitrate and phosphate ions decrease drastically as the leachate filters. This is due to absorption of these ions by the roots of the reeds. Some cations Mg^{2+} (6.79-15.39 mg/L), Ca^{2+} (8.95-46.52 mg/L) and anion SO_4^{2-} (517.53-77.20 mg/L) concentration values increase from the inlet to the outlet streams. This increase is due to the presence of sand and gravel which are the sources of these cations while the anion act as sedimentation agent thus they passed out unabsorbed.

To ameliorate this work, we have to:

- Add a system or a chemical that will help reduced the concentration of potassium.
- Build a larger system to allow well distribution and adsorption by the filtered plants.
- Assign careful consideration to the quality of leachate and effluent from leachate treatment that the wetland can treat. Selection of plant species and support media may allow a range of leachate types to be treated.



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APPENDIX

APPENDIX 1: NKOLFOULOU LANDFILL



Figure 29: Presentation of the Nkolfoulou landfill

APPENDIX 2: METHOD OF ANALYSIS

Details about ion chromatography (IC) system

Major anions and cations analyzes

The IC analyzes consists of four stages:

1. 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 anions analyzes, the eluent is a combination of carbonate-bicarbonate ($\text{Na}_2\text{CO}_3\text{-NaHCO}_3$) 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.

2. 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.

3. 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.

4. 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 0.01ppm.

APPENDIX 3: WHO STANDARD FOR DRINKING WATER (Amit et al., 2015)

	Max. Permissible	WHO standard
pH	6.0-8.5	6.5-9.2
conductivity	300	-
BOD	5.0	6.0
COD	4.0	10.0
Boron	1.0	-
Calcium	100	100
Cadmium	0.01	0.01
Chromium	0.05	0.05
Ammonia	0.5	0.5
Copper	1.0	1.5
Iron	0.3	1.0
Lead	0.05	0.1
Chloride	250	250
cyanide	0.5	0.5
Magnesium	30	150
Nitrate-Nitrite	10	45
PAH	0.002	0.2
Pesticides	0.05	
Total Hardness (as CaCO ₃)	-	500
Total Dissolve Solids	-	500
Sulphate	-	250
phosphate	-	0.5-1
Potassium	-	10