UNIVERSITY OF CAPE COAST

THE EFFECT OF LEACHATE FROM SOLID WASTE DISPOSAL SITES ON THE CAPE COAST MUNICIPAL ENVIRONMENT

BY

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DECLARATION

CANDIDATE'S DECLARATION

I hereby declare that this thesis is the result of my own original research and that no part of it has been presented for another degree in this University or elsewhere.

CANDIDATE: ....

DATE: 18-07-2001

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SUPERVISORS' DECLARATION

We hereby declare that the preparations and presentation of the thesis were supervised in accordance with the guidelines on supervision of thesis laid down by the University of Cape Coast.

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DEDICATION

DEDICATED TO MY MUM, MADAME ELIZABETH ESI AMOAKOAH, MY SISTER MRS. BEATRICE AWUSI, MY DEAR WIFE MARY AND KWEKU MY SON.

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ABSTRACT

As a developing country, Ghana is faced with the problem of management of her solid waste. Disposal of solid waste in open dumps and swampy areas in a bid to reclaim the land is the most common method used. This research was carried out at the Cape Coast Municipality to investigate the effect of disposed solid waste on the environment. The methodologies are purposive sampling for the solid waste evaluation, titrimetric and spectrophotometric for the analysis of the leachate from the solid waste. The refuse evaluation showed that about 1420 tonnes/month of solid waste is generated in the Cape Coast Municipality and out of this, about 976·25 tonnes /month is effectively being collected. The composition evaluation of the waste also gave screening < 20mm 26%, vegetable putrescible – 59%, paper – 3%, wood – 4%, plastics – 2%, metal – 1%, glass and others – 3%. Then also, the leachate analysis gave pH – (6.8 – 10.5), temperature – (19.9 – 29)°C, conductivity – (10,000 – 199,900)µs/cm, total iron – (1.2 – 720) ppm, sulphate – (13 – 21,600) ppm, phosphate – (2 – 1,423) ppm, dissolved organic matter – (65.0 – 3,655) ppm, nitrite – (0.7 – 97.3) ppm, nitrate – (2.0 – 736) ppm, ammonium – (13 – 1,140) ppm, chloride – (6.0 – 1,520) ppm and the bacterial count was uncountable. The analysis showed that about 72.0% of the total refuse generated in the Municipality is effectively being collected and the remaining 28% find their way into gutters, ravines and water bodies. Then also, apart from chloride and pH, all the other parameters determined for the leachate analysis had concentration levels higher than internationally accepted levels for solid waste disposal. With this, there is therefore the need for effective solid waste management in the Municipality to avert any epidemic.

CHAPTER ONE

INTRODUCTION AND LITERATURE REVIEW

1.1 0 ENVIRONMENT IN CRISIS

There has been heated debate about what has been the cause of environmental crisis and many different (and at times conflicting) arguments have been made about what might be the most important root cause. There are certainly a number of important factors which together, help to account for the observed changes. Some of the factors include;

- Advancement in technology (particularly since the industrial revolution). This has given people a better ability to use the environment and its resources for ends.
- The rapid increases in human population in recent times.
- A significant rise in human exploitation of natural resources, particularly over the last century.
- The emergence of free market economies which play a central role in decision-making about production, consumption, use of resources, and treatment of waste.
- Attitudes towards the environment.
- The short-term time horizon over which individuals, companies and countries prefer short-term profit maximization has generally been taken more seriously than long-term sustainable use of the environment.

Whilst in recent years there have been great advances in scientific application and public understanding of the relevance and seriousness of the environmental crisis, the root causes remains largely unresolved. This is perhaps inevitable, given the many different factors involved and the variety of disciplines (including History, Social

Science, Economics, Psychology, Theology and others) that have taken part in the debate [1].

1.1.1 New dimensions to the crisis

Many people ask "Is the situation really as critical as some scientists say?" There are problems, but have they really reached a crisis? The optimists say "There have been many environmental scare stories before but we are still here – so who is kidding who?" However, such arguments overlook several important aspects of today's crisis making it quite different from the past situations.

1.1.2 Global problems:

For the first time ever, mankind has the power to change the environment on a global scale. Many of today's pressing problems are affecting the whole world in one way or the other. For example, if the hole in the atmosphere's ozone layer continues to grow, then people around the world will suffer from excessive amounts of damaging ultraviolet radiation. If felling of tropical rainforests continues, we will all be affected by the resultant climate changes. Many environmental problems especially those affecting air and water cross national frontiers. The nuclear fallout from Chernobyl spread across Europe within a week [2] and the acid rain exported in countries (like Britain) is quickly imported elsewhere (like the Scandinavia) [3]. Such an uncontrollable movement poses a serious political as well as scientific problem.

1.1.3 Thresholds:

Many scientists are worried that we are now stretching our ecological systems to their breaking point (critical thresholds beyond which irreversible changes can occur). This makes the present situation more serious and more critical than ever before, and it means that the options available to generations that follow (including our own children) will depend largely on what remedial actions we adopt today. The planet earth has a finite ability to absorb our waste and renew its resources, and to knowingly approach those natural limit is to deliberately play Russian roulette with our environmental life-support system [4].

1.1.4 Uncertainty:

Another causes for concern is the growing awareness that we simply don't know how much of our actions are affecting the environment and people's health. There are many uncertainties in linking observed effects with possible or suspected causes. Examples include the widespread controversy and anxiety surrounding the suspected links between Leukemia and radiation pollution and uncertainties over whether BSE in cattle ('mad cow disease') can be transmitted to people. New risks are being created everyday, through the development of new technologies (such as genetic engineering) and the careless use of existing ones (such as the 1984 explosion at the Bhopal pesticide factory) [4].

The debate on climate change, which is flawed with many uncertainties [5], shows just how difficult it is to make reliable forecast or predictions the state the environmental systems are likely to be and how these changes are likely to affect national economies over the next 100 years or so. Inevitably, a major change in climate will have wide-ranging implications, particularly on agriculture, transport, energy and insurance sectors of the economy [6]. Whilst some sectors such as agriculture and transport can adapt quite quickly to environmental changes, others such as the energy and construction industries cannot and they require significant advanced warning and long-term investments.

1.1.5 Concerns Raised

Environmentalism is really a social movement, which individuals are free to join if they wish. (Environmentalism is a collective term to describe ways in which people express their concern about the state and the future of the environment). It is founded on a number of concerns, including:

- The welfare of deprived groups of people (particularly in developing countries), both the practical and ethical implications of the so-called North-South divide (between the developed and the developing countries of the world) [7].
- The wider issues of equity and justice. Since the early 1970s two important streams of social activism (environmental concern and civil rights) have grown alongside each other and in the 1990s they appear to have converged in what is now called the environmental justice movement [8].
- The sense of personal responsibility to leave a worthwhile environmental heritage for future generations. This trend has promoted public environmentalism through, for example, green consumerism, passive membership of environmental groups, and domestic recycling [9].

1.2.0 SOLID WASTE PROBLEM

Solid wastes are man's unwanted materials that cannot flow directly into streams or rise immediately into the air. They are non-liquid, non-gaseous residues of our manufacturing, construction, cooking, recreation, agriculture and other activities that use and then discard materials. Among them are outdated newspapers, glass bottles, metal cans, paper cups, plastic bottles, abandoned automobiles, demolition rubble, mine tailing, dead animals, denatured sewage sludge and the garbage from our dining tables. These are produced wherever man is found- in farms, mines, stores, offices, factories, homes, hospitals, streets and even the primitive encampments of traditional nomads' [10]. Environmental pollution has become a part of our everyday life. In many parts of the world, significant levels of contamination have been reached and if left unchecked would threaten not only our health and comfort but also our very existence [11]. The problem has to do with the generation, collection and the disposal of solid waste. An inscription on a sign post near outer limit of ancient Rome warns that: "take your refuse further or you would be fined". However, with large populations and modern industrialised society, we can no longer "take our refuse further" but have to cope with it in our midst and without "fouling our own nest" [11].

Historians assured us that it is a very old problem too, dating back to the days when people began to live in communities. We are prophetically told, "Archaeologist would be out of business if civilisation after civilisation had not been buried in its own garbage!"[11]. As far back as the year 2500 BC, attention was being given to sewage and refuse disposal in towns of Assyria and Babylon.

The collection, handling and disposal of solid wastes in large cities have been a problem, which is causing worldwide concern. As municipal service, it has become increasingly more costly and more difficult to administer. Major weaknesses under present conditions in Ghana and for that matter, Cape Coast are the fragmentation of disposal operations, the lack of adequate funds, and a general failure in planning on a long-term basis. Disposal of solid waste in open dumps is the most common solid waste disposal methods used in the Cape Coast municipality and much of the uncollected refuse is deposited in ravines, swamps and gutters. These have led to many flooding in recent years in Ghana with its associated numerous water-borne diseases.

1.2.1 Relationship between solid waste and public health hazard

Solid wastes that are mishandled can harbour disease-carrying agents, become air and water pollutants, and pose serious safety hazard both for the general public and for professionals engaged in waste collection and processing. Food waste represent about 60% by wet weight of all the solid waste collected by the municipal assembly, this is a serious problem since they offer an attractive food source for insect and rodents which can set up house keeping in the remaining 40% of the wastes.

The public health service of the United States has identified twenty-two human diseases that can be associated with solid wastes. Examples include typhoid fever, cholera, dysentery, various diarrhoeas, anthrax, tuberculosis, trachoma, plague, murine, leptospirosis, rabies, rickettsial pox, malaria, yellow fever, dengue, encephalitis filariasis, and trichinosis among others. Trichinosis a parasitic infection of humans transmitted by pork was especially prevalent in the United States until laws began prohibiting the feeding of unsterilised garbage to hogs.

Yet, like the linkage between smoking and lung cancer, the relationship between health and refuse site are often difficult to communicate convincingly to the public or to a hard-pressed city council trying to save every last pesewa of the sanitation department's budget.

When mismanaged, solid waste will also contribute to other forms of pollution that constitute health hazards. Rainwater falling on a garbage dump will wash salts and organic materials into nearby streams or into ground water, a process known as leaching. Leaching from solid wastes as mine tailings can be particularly dangerous if copper arsenic and similar toxic elements are present.

The most substantial evidence incriminating solid wastes, as health hazards are the health records of sanitation workers that experience a disproportionating rate of occupational diseases and injuries. A study of the Department of Sanitation in New York City found that muscle and tendon diseases (particularly in the back), cardiovascular disease, arthritis, skin diseases and hernias could be considered common occupational ailments [10,12,13].

1.3 .0 NATURE OF SOLID WASTES

Household, municipal and commercial solid wastes are of constantly changing nature. The changing nature in the composition and characteristics of solid wastes has been largely brought about by the growth in packaging, plastic and container industries and new marketing techniques based on the economic philosophy of, "buy, use and discard". The composition, the physical and chemical characteristics of refuse must be known to local authorities if they are to select the most economical collection procedures; to design and operate an efficient central incineration plant; to plan ahead for suitable sanitary landfill sites, or to design a composite site or a central grinding plant [11].

1.4 .0 ESTIMATION OF REFUSE IN CAPE COAST

There is no particular reliable data on waste generation in the Cape Coast municipality, only small quantities of refuse are more or less regularly collected and available records are not reliable. Most of the refuse is dumped as little heaps scattered all over in the municipality, making any direct evaluation very difficult. There are few available refuse containers put at certain places (old dumpsite) within the city. However, due to the inadequacy of these containers refuse heaps have developed at the various container sites.

1.5 .0 PREVIOUS WORK

Work done on refuse evaluation in Sekondi-Takoradi, Tema and Accra which have similar climatic conditions (dry equatorial climate) and demographic patterns (population of high proportion of middle and low income groups) could not be different from that of the Cape Coast municipality. Those of Sekondi-Takoradi and Tema are reproduced below for comparison.

Table 1.0: Average composition of refuse at Tema [14]

TYPE OF MATERIAL	% BY WET WEIGHT	% WATER CONTENT	% BY DRY WEIGHT
Screening <20mm	35	20	45
Vegetable putrescible	48	55	36
Paper	5	35	5
Wood	5	30	5
Plastics	2	6	3
Cloth, Textile and leather	2	35	2
Metals	1	6	2
Glass	-	-	-
Others	2	15	2
Total	100	38.4	100

Average wet density 0.5g/m^3

Table 1.1 Average composition of refuse at Sekondi-Takoradi [15]

TYPE OF MATERIAL	% BY WET WEIGHT	% WATER CONTENT	% BY DRY WEIGHT
Screening <20	30	25	39
Vegetable putrescible	52	60	38
Wood	6	30	4
Paper	5	40	5
Plastic	2	6	4
Clothes, Textiles and leather	2	40	2
Metals	1	6	2
Glass	-	-	-
Others	2	60	3
Total	100	36.4	100

Average wet density = 0.5g/m^3

Both works have also shown that due to the topography of the various sites water run off is likely to converge to these disposal site and hence it will be necessary to evaluate the risk of leachate reaching both underground and surface waters. Now, if the said risk is found to be high a peripheral drain upstream the landfill site may be deemed necessary. [14,15]

1.5.1 Observation From Previous Study

Earlier work done at Sekondi-Takoradi and Tema show that:

1. The putrescible/compostible component is made up of mainly vegetables, foodstuff remains, kenkey peels and Screening showed that putrescible matter represented about 85% of the total wet weight of the refuse.
2. Due to the presence of waste material from fruits, vegetables and foodstuffs, the initial water content was high.
3. The wet density was high: 0.5Kg/m^3. This was attributed to high water content.
4. Large quantities of non-putrescible materials are recycled at source. There was a total absence of glass, indicating the life-styles of the community. Here it would be inferred that, all the glass and glassy materials are recycled or put to other uses.

   The work also showed that estimation of the accuracy of the solid waste production and collection figures depends mainly on the accuracy of population figures [14,15].

1.6 .0 RESEARCH PROBLEMS

Regular surveys and evaluation of municipal refuse on a systematic and continuous basis over a period of time are necessary and can be of considerable assistance. This is normally done in certain urban areas in Ghana, but such basic information is completely lacking for the Cape Coast Municipality.

The composition, and the physical and chemical characteristics of refuse must be known to local authorities if they are to select the most economical collection vehicles; to design and operate an efficient central incineration plant; to plan ahead for suitable landfill site or to design a compost site. Also the silting and drainage of tips of land fill sites is a matter which requires to be closely watched in the future as there is evidence of pollution of water causes situated close to landfill sites. There is the need for the waters of streams and bore holes adjacent to sanitary landfill sites to be regularly monitored to determine whether pollutants are entering those waters. All these are lacking in the Cape Coast municipality.

1.7.0 IMPORTANCE OF THE STUDY

Disposal of solid wastes in open dumps is the most solid waste disposal method used in the Cape Coast municipality. Much of the uncollected refuse is deposited into ravines, swamps and gutters, and this poses public health problem by encouraging the growth of populations of flies which can transmit typhoid fever, cholera, dysentery etc. Again they are non-aesthetic to site and thus reduction in the quality of life of a particular environment. Looking at the position of Cape Coast in the socio-economic development in Ghana's vision 2020, with reference to Eco-tourism, the study would produce a document on the evaluation, collection and safe disposal of solid waste in the Cape Coast Municipality in order to promote tourism. Also in the event of persistent drought coupled with inflow of foreigners as tourists, people are compelled to use water from any source irrespective of its quality. Therefore, any attempt to monitor pollutional levels of water courses must be encouraged. This is the focus of this research. The study will be in two parts and these are evaluation of the quantities of solid waste and comprehensive laboratory analysis of the leachate from the disposal sites.

1.8.0 LABORATORY ANALYSIS OF THE LEACHATE COLLECTED FROM THE SOLID WASTE DISPOSAL SITES

Considering the persistent drought coupled with the continual increase in population, agricultural and industrial activities, the level of demand for freshwater has increased considerably. These and other factors have compelled many people to use water from any sources irrespective of the quality. This has brought about the accompanying hardship on most rural communities with regard to diseases. e.g. rural folks have to battle against diseases like cholera and other water-borne diseases as dysentery, bilharzia etc. as shown on page 31.

There is therefore the need to bring to the notice of the public the issue of environmental pollution, especially cases on the handling of solid waste, since most rural communities depend one way or the other on boreholes as the most wholesome source of water, and any attempt to pollute the water basins with solid waste could be detrimental.

A more significant problem in the developing countries is the effect of salt in underground water – mainly the chlorides and sulphates. These chemical substances make underground water unpalatable and so people are led to use surface water, which is more likely to be bacteriologically polluted. These salts tend to make the water undrinkable before they reach seriously harmful concentrations. For instance, there are some communities in North Africa and Iran that regularly drink water containing as much as 3000 mg/L of chlorides and 1500 mg/L of sulphates. Such high dosages would make the water quite unpalatable and would have a laxative effect on those who are not used to them.

More recently, evidence has linked a high intake of sodium, usually as sodium chloride, with high blood pressure. But drinking water usually contribute only a small amount of the total intake of salt in the diet, and the problem only arises when the water is so salty that it tastes bad. Moreover, it has been shown that people who rate the taste of their drinking water as bad consume considerably less than those assessing the taste as good [16].

Nitrate concentrations over 45 mg/L in drinking water are potentially hazardous to health in two ways. The nitrates in the body are reduced to nitrite and can cause a serious blood condition in infants known as infantile cyanosis (methaemoglobinaemia), particularly if the diet is not rich in vitamin C. It has also been suggested that very high nitrate concentrations, such as those found in some community water supplies in Colombia and Chile, may be implicated in the causation of gastric cancer [17].

High concentrations of nitrates in underground water may result from thick deposits of guano from certain volcanic rocks, or from prolonged heavy use of organic or artificial fertilisers. Nitrates are also a final product of the oxidation of organic compounds and are therefore associated with organic pollution. Surface or underground waters, which receive organic pollution from sewerage discharges or on-site sanitation systems, may show high nitrate levels. A rising nitrate level in underground water is a warning sign of continuing pollution. Boiling the water is likely to increase the nitrate content further. [17]

Solid wastes release pollutants from their effluents (leachate) at their disposal sites and this leachate are most likely to contaminate both surface and underground water. This concern has necessitated this present study.

1.8.1 Leachate

A leachate is the liquid that seeps from wastes deposited in landfills and dumpsites. It contains a variety of toxic materials including biological or pathogenic bacteria, inorganic materials like ammonia, toxic metals, and organic compounds like chlorinated hydrocarbon solvents and other toxic materials deposited in the waste. Leachate will usually have a very high Biochemical Oxygen Demand (BOD) and when they run into aquatic systems, can damage aquatic ecosystems and pollute underground water. The composition of leachate changes as the tip ages, depending on the chemical and biochemical reactions, which have occurred. Leachates can be treated although it is not currently practised in most developing countries including Ghana despite some notable successes elsewhere. Modern landfills in Germany and US do include leachate treatment facilities. Leachate generation can be controlled by restricting the amount of rainwater entering the tip and by lining the site. Many older landfills in Britain, containing domestic and industrial wastes, have leaks and as a result, their leachate may threaten groundwater sources. Dealing with such sites will be extremely expensive – if, indeed, they can be dealt with at all [18].

1.8.2 Parameters Investigated

The quality parameters studied in this work include:

i) The pH
ii) Nitrite-Nitrogen NO_2^-
iii) Nitrate-Nitrogen NO_3^-
iv) Ammonium-Nitrogen NH_4^+
v) Sulphate-Sulphur SO_4^{2-}
vi) Chloride
vii) Total Iron
viii) Dissolved organic matter
ix) Conductivity
x) Temperature
xi) Bacterial count
xii) Phosphate-phosphorous PO_4^{3-}

A more detailed consideration of these parameters follows:

1.8.2.1 The pH

pH which is a water quality parameter is defined as: $pH = -\log_{10}[H^+]$ where $[H^+]$ is the concentration of hydrated hydrogen ions in solution in mol/dm^3. Natural waters usually do not exceed the pH range from 3-10, and in most cases remain between pH = 6 and 9.

The pH of natural water is extremely important because it determines the solubility and chemical forms of most substances in water; for example, hydroxides of many metals are insoluble at higher pH's and less metal ion is available in the water unless hydroxo-complexes are formed. Acidity or alkalinity are both inhibitory and destructive to bacteria, that is bacteria can only survive in either neutral, mild acid, or mild alkaline conditions. For example, the bacteria *Escherichia coli* (*E. coli*) is active within the pH range of 6-7 and in any artificial media, growth will sieze at pH below or above pH 9 [19]. Also a period of six (6) hours at pH of about 10-12 is sufficient to destroy all *E. coli* and most other bacteria in water.

1.8.2.2 Dissolved Organic Matter(DOM)

The sources of DOM is largely effluents from solid waste disposal site, dairies, slaughterhouses, tanneries, pulp mill residues, domestic sewerage etc.

DOM deprives aquatic life of dissolved oxygen. The dissolved organic matter uses up dissolved oxygen in the water; they are oxidised by dissolved oxygen present in the water usually depleting the available oxygen in the water more rapidly. Also, a number of organic compounds are suspected carcinogens, and there is apparently a significant relationship between their presence and total cancer mortality [20].

1.8.2.3 Tetraoxosulphate (IV) SO_4^{2-}

Sources of sulphate results from the oxidation of sulphide ores, gypsum, industrial wastes and decomposition of solid waste.

It is commonly present in less than 1000ppm except in streams and wells influenced by acid mine drainage, and as much as 20,000 ppm in some brines.

Sulphate combines with calcium to form an adherent heat retarding scale. More than 250ppm are objectionable in water in some industries. Water containing about 500ppm tastes bitter. High concentration of sulphates produces a laxative effect. [21]

1.8.2.4 Total Iron (Fe)

Sources of iron are, weathering of igneous rocks, amphibole, ferrous sulphide (FeS) iron pyrites, well casting, storage tanks, cast iron objects, and sewage.

Generally, less than 0.5ppm is present in fully aerated water. Groundwater having pH less than 8.0 may contain 10ppm of iron.

The iron is usually in the +2 oxidation state but a concentration of more than 0.01ppm is readily oxidised to the +3 oxidation state on exposure to air. Here, it precipitates as $Fe_2O_3.xH_2O$. The precipitation is pH dependent. Iron oxides cause turbidity and impart objectionable taste and colour to water. More than 0.2ppm is objectionable for most industrial uses because of its effect on food and drink [22].

1.8.2.5 Dioxonitrate [III] NO_2^-

It is present in the atmosphere, in legumes plant debris, animal excrement, and nitrogenous fertilisers in soils and in (domestic) sewage.

In surface waters, which are not subjected to pollution, nitrite may be as much as 0.1ppm but it is commonly absent.

The cause of "cyanosis" [blue water babies] in babies is due to the conversion of haemoglobin to methaemoglobin by nitrates (produced bacterial reduction of nitrate to nitrite) [20,21]. This renders the haemoglobin [20,21] incapable of transporting oxygen so that the characteristic blue colour and associated symptoms develop. Nitrites also react with amines and amides to form carcinogenic nitrosamines.

1.8.2.6 Trioxonitrate (V) NO_3^-

This is present in the atmosphere, legumes, plant debris, animal excrement, and nitrogenous fertilisers, in soils and in sewerage.

In surface waters, not subjected to pollution, the concentration of nitrate may be as high as 5ppm, but is commonly less than 1ppm.

Water containing large amounts of nitrate for example 100ppm is bitter and may cause physiological distress. Water from wells containing more than 45 ppm has been reported to cause methaemoglobin in infants. The presence of nitrate in well water can cause "cyanosis" (blue water babies) in babies [20,21].

1.8.2.7 Chloride Cl^-

Chlorides come from weathering of igneous rocks, sedimentary rocks, marine evaporates and rock salts.

Its concentration is less than 10ppm in humid regions: about 19300 ppm in seawater and as much as 200,000ppm in brines.

A concentration in excess of 100ppm imparts a salty taste. Food processing industries require less than 250ppm. Textile processing, paper manufacturing and synthetic rubber manufacturing industries require less than 100ppm [21].

1.8.2.8 Conductivity

Electrical conductivity is a measure of dissolved salts in water. Dissolved solids or salts are obtained from pollutants that get into water column from the surrounding environment. The dissolved salts in water have a marked effect on the bacterial survival in water. An increase in the dissolved salts content, though different salts have different mobilities, results in an increase in the bacterial survival range. Thus, a measure of electrical conductivity of environmental water sample will give an indication of the extent of pollution of the water with respect to bacteria. The acceptable electrical conductivity of Ghana Environmental Protection Agency (GEPA) of usable water should be less than 750µs/cm.

1.8.2.9 Phosphate

This result from the breakdown of phosphates from inorganic fertiliser, soaps and detergent and effluents from food processing plants and sewage.

Phosphate (PO_4^{3-}) as an inorganic fertiliser displaces Arsenic in the soil as a free ion, which dissolves in water bodies. Arsenic is very toxic and could result in death of human beings. It could also cause eutrophication and algal blooms [18].

1.8.2.10 Ammonium $NH^{+}_{4} - N$

Ammonium ion could be present in water from such sources as: Artificial fertilisers, dissolution of ammonia gas in water, decomposition of refuse soil plant debris and domestic sewerage [17].

Ammonia is particularly toxic to fish and aids eutrophication. When bacteria act on ammonium/ammonia it is converted to Nitrates and therefore have all the effects of both nitrites and nitrates as stated in 18.2.5 and 18.2.6 respectively above.

1.8.2.11 Temperature

Temperature is defined as the degree of hotness or coldness of a body. The temperature of water medium has a marked effect on the biochemical and bacteria with respect to their growth and multiplication, which are measures of pollution. It has been stated that a general increase in temperature increases the biological processes of bacteria and that increased colony count of bacteria are observed [23]. Freezing on the other hand, though does not kill bacteria, suspends their activity. Thus bacteria can tolerate temperature fluctuation from freezing limits to about 40°C. This shows that water with temperature below 40°C can be a good medium for bacterial activity and consequently cause pollution. The GEPA tolerable temperature range is ±3°C of the ambient value.

1.8.2.12 Bacteriological Studies

Bacteria are micro-organisms, which are practically ubiquitous on the earth's surface. Thus, bacteria are found in the atmosphere, in soils and water bodies. Though most ill-health situations may be attributed to the consumption of water polluted with inorganic salts, the majority of ill health is however caused by the presence of pathogenic bacterial [19]. These disease-causing bacteria are from excremental source, which find their way into water bodies. One other area where bacteria enter our water environment is the leachate that flow to water bodies from a solid waste disposal site. There are very high levels of bacteria activity at solid waste disposal site as a result of biological decomposition of organic matter in wastes and wastewater under aerobic conditions. These bacteria are pathogenic in nature. Examples are Typhoid bacteria, *Vibro cholerae*, *E. coli* etc.

It is very rare that natural water is devoid of bacteria. Bacteria are added to water through the interaction of water with the soil, vegetation life and waste matter on the earth's surface.

Though water may be seen as a major sink for bacteria, the bacteria population varies widely in different water bodies, different areas of the same water body and even at the same place of a specific water body at different times. These are due to the fact that some bacteria continue to live and multiply while others at unsuitable conditions succumb and there may be diverse new additions [19,22].

1.9.0 ENVIRONMENTAL CONCERNS

Environmental concerns over the concentration of the various nutrients in aquatic systems is centred on two issues: eutrophication of water bodies and the spread of both old and new kinds of diseases as a result of the consumption of water containing higher levels of these nutrients.

1.9.1 Eutrophication

This term translated literally means 'good eating'. When used in reference to natural water bodies, it refers to the phenomenon of increase in mineral nutrients resulting from the inflow of sewage into natural water bodies [23].

The impact of organic effluent on rivers has been well-documented [24-29]. Organic pollutants stimulate microbial activity and are gradually removed by the activities of micro-organisms. The increased microbial activities rapidly deoxygenate the water down stream from the discharges, resulting in an oxygen sag curve. The extent of deoxygenation depends on such factors as the dilution of the effluent on entering the river and the amount of biologically oxidisable material present in it. Large discharges or inputs from numerous sources may result in permanent eutrophication of a water system. Initially the effect may be minor (small increase in biomass production), however as the process continues the whole ecology of the water system is disrupted; changes occur in phytoplakton species composition which become increasingly dominated by rapid growing "bloom" of species including toxic blue-green algae. With increased production, the turbidity of the water increases reducing light penetration causing the loss of submerged macrophytes. These plants are very important components of fresh water ecosystems. They provide microhabitats for invertebrates and fishes. With their loss, the invertebrates become impoverished and the composition of the fish community changes. Eutrophic water bodies because of their high nutrient levels are prone to massive phytoplankton (usually blue-green and dinoflagellate algae) blooms particularly as the temperature and light intensity increases and the water body becomes stratified. Algae biomass increase rapidly until it is limited by the available nutrients, normally phosphorus and nitrogen. Rapid growth is followed by mortality, often causing a green scum of decomposing algae to form algal biomass, which reduces the oxygen content of the water severely causing substantial fish kills.

They as well reduce the recreational use of the water and bring about unacceptable odours in the water especially when they rot on the beaches. The water supply from such water bodies has unpleasant taste and odours. Bloom species are frequently toxic to both human biota and farm animals' [11].

1.9.2 Water Quality

Water is a vital ingredient in our everyday life. It is therefore important that we understand more about the causes of water contamination and methods of purifying polluted rivers and lakes. The importance of water quality with regard to human welfare and the production of food supplies have become widely recognised in recent years, and to some extent, the importance of water quality in the maintenance of a healthy and desirable aquatic population has also gained appreciation. Most waters contain substances such as nutrient elements, heavy metals and metal compounds which, when present in excessive amounts are regarded as potential contaminants.

These potential contaminants may endanger the health of both human and aquatic organisms. They are often present in a dissolved state and large quantities may also be found in the bottom sediments. They are also found attached to suspended matter in water by which they can be transported.

Aquatic ecosystems are sustained by the availability of the dissolved forms of a number of nutrient element, the most important of which include carbon, nitrogen and phosphorous. The presence of suspended material is one component in the cycling of these nutrients. Toxic substances are present in a variety of natural and man-made forms.

At the United Nations water conference in Mar del Plata in 1977 [30], the extent and complexity of the problem of water development was discussed in detail. The Mar del Plata Action included a community water supply and sanitation scheme with the goal of providing clean water and adequate sanitation for the whole population by the year 2000. The period from 1981 to 1991 was declared the international Drinking Water Supply and Sanitation Decade, and the World Health Organisation was designated to promote and co-ordinate the activities during the period [30].

However, the year 2000 is here with us and the big question is have we been able to realise this objective?

In the event of persistent drought coupled with continual increase in population, increase in agricultural and industrial activities, the level of demand for water has increased considerably. Investigation carried in Brimsu Water Works at Brimsu hinted that the water treatment station is to double the present supply of water to Cape Coast and its environments. These and other factors have compelled many people to use water from other sources irrespective of the quality. This has also brought about the accompanying hardship on most rural communities as they have to battle against cholera and other related water borne diseases as dysentery, diarrhoea, cholera and bilharzia.

Also, there has been a steady increase in nitrate levels in portable water sources as a result of the increased levels of leachate from solid waste as well as from inorganic nitrogen fertilisers, which leach nitrate into ground waters [31]. The nitrate itself does not pose a health threat as such, however nitrate is readily reduced to nitrite NO_2^-, by the enzyme nitrate reductase which is widely distributed in both plant and micro-organisms [32]. Nitrite poses two distinct environmental health problem; being potentially carcinogenic and also causing methaemoglobinaemia, (the blue-baby syndrome). Young babies during the first year of their life are susceptible to mathaemoglobinaemia due to the persistence of foetal haemoglobin and because their stomachs are not sufficiently acidic to inhibit the microbial conversion of nitrate to nitrite. Foetal haemoglobin has a much higher affinity for NO_2^- ligands than normal haemoglobin. Nitrite formed in the stomach readily passes into the bloodstream where it reacts with oxyhaemoglobin oxidising the ferrous iron to ferric form. The conversion of oxyhaemoglobin to methaemoglobin reduces the oxygen-carrying capacity of the blood. Fatality results from “chemical suffocation”.

One major problem of environmental pollution of particular concern to the world today is that of water pollution and the need for water conservation. Leachate from solid waste disposal sites is one of the main sources of this problem. The World Health Organisation (WHO) warns that " No environmental health problem has a greater significance than the disposal of man's liquid and solid waste". [11]

1.9.3 Water Filters

In an attempt to remove undesirable materials from drinking water, many people are turning to water filters. Manufacturers and suppliers, some of whose publicity materials have been less than honest, have encouraged this trend.

It is possible to remove all but very small traces of pesticides, lead, nitrates, aluminium, chlorine and solvents from water but to do so requires the expenditure of millions of cedis- and is probably not necessary anyway. Much smaller reductions in the concentrations of these materials can be achieved less expensively by just keeping our environment clean and keeping to proper attitudinal waste disposal methods.

Some types of filters – such as certain on-line devices fitted to the water supply – may actually increase the health risk from drinking water by allowing bacteria to breed, and water companies can advise on the suitability of a particular devices.

It must be remembered that a jug of water left standing for a long period in a warm place will tend to grow bacteria, particularly if residue has been removed [18].

1.9.4 Plastics

Plastics are not generally poisonous in the environment although when they burn they give off toxic fumes. They may cause a hazard to wild life, however they obviously constitute a visually offensive litter problem in many places. Plastics harm wildlife when animals accidentally swallow them or become trapped inside plastic containers.

Plastics usually have long-life in the environment, i.e. not easily biodegradable, a factor which may aggravate many problems they may cause. In order to alleviate this problem, a range of degradable plastics has been produced. Some rely solely on the action of bacteria, called bacteria-biodegradable plastics – while others (photodegradable types) depend on the action of sunlight triggering a chemical breakdown process which is then followed by biodegradation.

Degradable plastics can certainly help with litter problem and in some other specialised circumstances. The plastic yokes that hold beer cans together have caused problems in harbours by jamming the engines of boat [18]. However, the vast majority of plastics come from non-renewable fossil fuel sources and it makes more sense to control their use and recycle them whenever possible than to accelerate their breakdown. Environmental groups such as Friends of the Earth generally take a dim view of degradable plastics and would prefer to see plastics used only for purposes where their properties of durability and resistance to degradation are essential [18].

1.10.0 ATTITUDES ABOUT THE ENVIRONMENT.

Attitudes and perceptions towards waste, the rating of waste disposal issues in peoples minds and in the scheme of official development plans have not been adequately considered in the literature as the general concern has been on the design of waste management technologies and the means to reach people with these technologies [33]. While it is important to acquire the technology essential to clean up a city many of these technologies are expensive for developing economy and end up serving only the rich nations [34]

The environment has been defined as a composite set of behavioural settings in which individuals within a community act with diverse consequences [35]. Agbola [36] further observed that the 'cause of many developing nations' environmental problems could be found by the way the imbibed behavioural patterns and acquired values are superimposed on the environment'. The imbibed behavioural patterns are cultural in origin, derived from the socialising process in families and communities. The relationship between humans and the environment is thus a function of culture, the level of society's technological development, the level of education, poverty (wealth) and the perceived magnitude of existing environmental problems. The last issue is particularly dependent on the individuals level of environmental awareness and preparations [37].

The universal nature of the influence of culture on behaviour and policy is demonstrated by Wall's [38] study of pollution control strategies in the United State of America and the United Kingdom, that study showed how different cultural values influence the adoption of strategy: the Americans preferring the command and control approach whiles the British relying upon persuasion and co-operation. The question is, does Ghana know where it stands on these cultural values? In the towns and cities of Ghana today waste disposal is a serious problem. An estimated 89 percent of the population of Accra (the national capital and largest city) have no home garbage collection and 48 percent share toilet facilities with more than 10 other households. [39] In the other urban centres, Ghana living standard surveys [40] estimate that only about 11 percent of the residents have access to flush toilet facilities. Over 96 percent of the solid waste produced in these centres are dumped [40]. Consequently 70 percent of health care cost in Ghana have been linked to environmental health problems [41].

Cape Coast is a medium size municipality with a 1995 population of about 63000. It was once the national capital of the then Gold Coast (now Ghana) and was a vibrant town with a surf port and several large commercial establishments [42]. The economic decline of Cape Coast, which started, with the removal of the seat of Government to Accra in 1877 has continued to this time. Cape Coast declined from being the third largest town in Ghana in 1960 to sixth in 1970 and the ninth in 1984 [43]. The population growth rate of the town was 1.8 percent between 1970 and 1984, far lower than both the national urban growth rate and the general population growth rate. The low population growth rate of the town results from out-migration of active labour as a result of the poor economic base of Cape Coast and cannot be attributed to fertility decline. This creates a high dependency ratio, which in the face of few opportunities for employment entrenches poverty [42,43]. Admittedly, this issue has grave consequences for environmental sanitation.

Cape Coast was described as having serious sanitation problems even during the colonial era and colonial office records reveal that one factor contributing to the decision to move the seat of government to Accra was Accra's reputation as the healthiest spot on the Gold Coast at the time [44]. Attempts at improving sanitary conditions in Cape Coast during the colonial period were thwarted by the wilful violation of the laws of health on the part of the natives, perpetual complaints of lack of funds on the part of the colonial authorities and the placing of sanitation low on the priority list of development programmes' [44]. This very issue is still on going and needed to be addressed properly.

The Cape Coast municipal authority (CCMA) has been grappling with this issue of creating a clean environment in recent years given the municipality's position in tourism development programme of Ghana [43]. However, sanitation practices of the inhabitants and the waste management practices of the CCMA itself are damaging the quality of this environment thereby bringing numerous diseases to the inhabitants. Top ten causes of morbidity in Cape Coast Municipal area are shown in Table 1.2.below.

Table 1.2. Top Ten Causes of Morbidity in Cape Coast municipal area [43].

Number	Disease	Reported cases		Percentage OPD Cases	
		1994	1995	1994	1995
1	Malaria	22,816	35,001	39.1	52.3
2	URI	6,142	5,490	10.5	8.2
3	Skin disease	4,388	4,039	7.5	6.0
4	Gynaecological disorders	2,276	2022	3.9	3.0
5	Diarrhoea	1,737	1,560	3.0	2.3
6	Intestinal worms	1,136	1,411	1.9	2.1
7	Hypertension/Heart disease	1,452	1,392	2.5	2.1
8	Accidents	1,667	1,333	2.9	2.0
9	UTI	1,177	1,155	2.0	1.7
10	Acute eye infection	1,111	894	1.9	1.3
Total of top ten diseases		43,902	54,297	75.2	81.1
Total OPD new cases		58,384	6,692		

Source: Annual report (1995) Cape Coast Municipal Health Administration (page 24)

OPD- Out Patient Department

URI- Upper Respiratory Tract Infections

UTI- Urinary Tract Infection.

Note that skin infections, intestinal worms, diarrhoea, acute eye infections and URI are hygiene or environmental pollutional related diseases.

1.11.0 WHAT IS THE WAY FORWARD

Presently, all the refuse collected in the Cape Coast municipality is dumped in a swampy area at Nkanfoa near Third Ridge in Cape Coast. Due to the topography of the landscape run-offs from rainfall converge on this area and the effect of these on the environment is likely to be devastating since this final disposal site is not a planned disposal site, as no proper environmental impact assessments have been made. The result is that the area is filled with garbage and scattered pools of water.

Since leachate discharge from these solid waste disposal sites pollute water bodies, it is likely that these may have aided the spread of many diseases in the Cape Coast municipality, particularly the spread of cholera.

At present it is obvious that, with the present rate of population growth the rate of solid waste generation would be on the increase in the near future in the Cape Coast municipality. Effective action is therefore needed to ensure adequate and efficient disposal of solid waste in the municipality, and also to ensure adequate maintenance of the quality of the total environment and the conservation of the vital reserves of our consumable resources.

To quote President Nixon " This task is ours together. It summons our energy, our ingenuity and our conscience in a cause as fundamental as life itself" [11].

1.12.0 STATEMENT OF THE PROBLEM

Disposal of solid waste in open dumps is the most common solid waste disposal method used in Cape Coast and for that matter Ghana as a whole. Regular surveys and evaluation of municipal refuse on a systematic basis is simply not available in the Cape Coast municipality and also in most cities of Ghana. Even in places where these evaluations have been done, no attempt has been made to undertake leachate analysis to see how the effluent from these disposal sites are affecting the environment.

The disposal system in practice in the Cape Coast municipal area cannot be classified as an incinerator or a sanitary landfill. As a result, it has made solid waste management in the municipality very uncoordinated. This has also made it very difficult to deal with other problems associated with refuse disposal. Then also, the siting of solid waste disposal sites have been done without any proper impact assessment and this further aggravates the environmental pollution problem in the Cape Coast municipal area.

Looking at the position of Cape Coast in the socio-economic development in Ghana's vision 2020, with reference to eco-tourism, the study would attempt to produce a document on the evaluation, collection and the safe disposal of solid waste in the Cape Coast municipality in order to promote the quality of life in the municipality.

1.13.0 OBJECTIVES OF THE STUDY

The principal objective of this research is to generate comprehensive data on the composition of solid waste of the Cape Coast municipality and the physical and the chemical characteristic of the solid waste and how they affect the environment. This will serve as guideline for policy making and implementation of waste management plans and augment the efforts of Ghana Environmental Protection Agency (GEPA) in setting up standards for solid waste management in Ghana. The specific objectives of this study are as follows:

1. To estimate the amount of solid waste being generated in the Cape Coast municipality.
2. To determine the effects of leachate from the final disposal site on the environment.

3. To suggest or determine other alternatives or improve on the existing methods of solid waste disposal in the municipality.
4. To analyse the chemical components of the leachate and quality of its bacterial content.

CHAPTER TWO

EXPERIMENTAL METHODS

2.0 RESEARCH METHODOLOGIES

2.1.1 Methodology for solid waste evaluation

There are various generally accepted standardised methods for sampling and analysis of municipal refuse. However, purposive sampling technique was used to select sites throughout the municipality for the study. Quantities of refuse were then obtained by simple extrapolation of the sample data on the weighted basis for each of the socio-economic strata [45]. In this study, the total quantities of refuse generated by the population of the sampled areas (units, consisting of several blocks selected based on specific qualities at Abura, Cape Coast, Apewosika, Esuekyir, Pedu Estate and the University of Cape Coast each totalling twenty households) was collected by special crew on a routine basis throughout the period. The distribution of households in the research area is shown in Table 2.0.

TABLE 2.0 DISTRIBUTION OF SAMPLED HOUSEHOLDS BY TYPE OF DWELLING.

Sub	Type of household			
	Flats	Compound Houses	Shanty houses	Self contained
Abura	5	5	5	5
Cape Coast	5	5	5	5
Apewosika	5	5	5	5
Esuekyir	5	5	5	5
Pedu Estate	5	5	5	5
U.C.C.	2	2	—	9

N= 120

In selecting the households, cognisance was taken of their nearness to the refuse containers as well as to (heaps) dump. Then also, the social backgrounds of the households were considered. In Abura, five households were flats, five compound households, five shanty households and five self contain households. This was followed for Cape Coast, Esuekyir, Apewosika and Pedu Estate as well. At the University of Cape Coast, the distribution was not followed as done for the others. Nine self contain households, two flats, two compound households and each of the seven halls of residence were specifically selected. The reason being that, the lecturer villages do not have shanty households as found in other areas. The refuse samples were then manually sorted into those containing;

a) Screening less than 20mm that is, the samples are first sieved using 20mm mesh and those that goes through the sieve are referred to as screening less than 20mm.

b) Paper, wood, leaves.

c) Garbage.

d) Non-compostible.

For the first three components (a, b and c), analyses were done for their moisture contents and ash residue. The result (average) was then reported in percentage.

2.1.2 Solid waste estimation method

There were no existing data on waste production in the Cape Coast municipality. Refuse is more or less collected regularly by the use of containers however, available records are not usable. Most of the refuse is dumped in placed containers with little heaps scattered all around these containers. The inadequacy of the containers has also given rise to little heaps of refuse scattered all over in the municipality. Waste from both the wood processing and the palm kernel oil industries were not collected. This therefore makes the refuse evaluation very difficult.

However, surveys were therefore carried out in various areas to evaluate the present waste generation and to make projections. Quantities of domestic and commercial sources of refuse were obtained by field checkers, questionnaires and personal enquiries. Evaluation of refuse with those of the municipal authority was done by evaluating the number of tips (containers) picked-up in the day. Each container has a capacity of about 15m^3. This was then followed by field checks to evaluate the portions not collected from open dumps. Refuse from the University of Cape Coast was also evaluated by field surveys and direct evaluation. In all, the university had one hundred and twenty dustbins on its campus. Each of these dustbins weighed about 15kg on the average when full. The evaluation of refuse from the drains, Apewosika and Esuekyir were also done by field surveys in a similar way. The survey covered a period between May and August 1999.

2.2 EXPERIMENTAL METHODS FOR LEACHATE ANALYSIS

Leachate (effluent) from the four solid waste disposal sites, Esuekyir (EK), Adisadel palm kernel oil production site (OIL), Ankaful Junction(AJ) and then the Nkanfoa main disposal site(MS) all within the Cape Coast municipality were collected after rainfall event between March and June 1999 for analyses. The methods used to determine the various parameters were:

a) The pH of the leachate was determined using MK11 C series analogue pH meter.

b) The total iron concentration of the leachate was determined using an Atomic Absorption Spectrophotometer– AAS 6104 S Shimadzu.

c) The sulphate concentration of the leachate was determined using a Turbidimeter.

d) The phosphate content of the leachate was determined using a spectrophotometer – Jenway PC01.

e) The ammonium content of the leachate was also determined using a spectrophotometer– Jenway PC 01.

f) The chloride content of the leachate was determined using an IM-40S TOA ION METER (Ion selective electrode method).

g) The nitrate content of the leachate was also determined using a spectrophotometer– Jenway PC 01.

h) The nitrite content of the leachate was also determined using a spectrophotometer– Jenway PC 01.

i) Electrical conductivity of the leachate was determined using a TOA CM–40V Electrical conductivity meter.

j) Dissolved Organic Matter – Walkeley Black Method was used.

k) Temperature – the laboratory thermometer was used in the temperature determination.

2.2.1 Reagents: Their Preparation And Standardisation

Double distilled water was used in the preparation of all solutions. All the chemicals used were of the analytical grade supplied by BDH of UK and Shimadzu, Japan. All reagents that are ought to be standardised were done by using standard methods before their use.

1) Peptone water was prepared by dissolving 15.0g of the peptone water media in 1.000L double distilled water and autoclaved at 121^{0}C for 15 minutes.
2) The agar media was prepared by dissolving 35.0g of the MacConkey broth media in 1000L double distilled water. 70.0g of MacConkey broth was dissolved in 1.000L of double distilled water for the double strength analysis. They were autoclaved at 121^{0}C for 15munites.
3) For the plate count, 17.5g of agar was dissolved in 1000mL double distilled water by heating to boil. It was also autoclaved at 121^{0}C for 15 minutes.
4) NH_4^+ - N standard solution (1000ppm) supplied by Shimadzu Japan (on sale)
5) Ionic strength Adjuster, 1SA-NH supplied by Shimadzu Japan (on sale).
6) 40% Sodium Hydroxide (NaOH) was prepared by dissolving 40.0g Sodium Hydroxide pellets in 100mL of double distilled water.

7) 5M Sodium Hydroxide solution was prepared by using 500mL of the solution in (6) above into 1000 mL volumetric flask and made to the mark with double distilled water.

8) 0.166M Potassium dichromate was prepared by dissolving 32.868g of Potassium dichromate in 1000mL double distilled water.

9) Concentrated tetraoxosulphate (VI) acid (to which 5mL 0.1M silver sulphate has been added to 100 mL concentrated sulphuric acid).

10) Concentrated tetraoxosulphate (VI) acid

11) Diphenylamine indicator was prepared by dissolving 1.0g Diphenylamine in 100 mL ethanol

12) 0.4M Ferrous Ammonium Sulphate ($0.4M Fe(NH_4)_2(SO_4)_2 \cdot 6H_2O$. was prepared by dissolving 488.14g of the salt in 1000mL of double distilled water.

13) 0.001M Sodium Tetraoxosulphate (VI) standard solution was prepared by dissolving 0.1479g Sodium sulphate (VI), which has been dried at 105^{0}C in 1000mL double distilled water. This is equivalent to (0.100mg/mL)

14) Acid salt reagent was prepared by dissolving 240.0g of Sodium Chloride (NaCl) in 600 mL double distilled water containing 10mL of concentrated Hydrochloric acid and diluted to 1000mL.

15) 4M Sodium Hydroxide solution was prepared by dissolving 160.0g Sodium Hydroxide pellets in 1000mL of double distilled water.

16) 5% Salicylic acid was prepared by dissolving 5.0g Salicylic acid in 95mL of concentrated tetraoxosulphate (VI) acid. (This solution was used 24 hours after preparation and was stable for 7 days).

17) Standard trioxonitrate (V) solution (NO_3^-) was prepared by dissolving 7.223g of dry $NaNO_3$ in 1000mL of double distilled water to make 0.085M.

18) Dilute tetraoxosulphate (VI) acid – 5.0M was prepared by measuring 70mL (H_2SO_4) tetraoxosulphate (VI) acid diluted to 500mL with double distilled water.

19) Potassium antimonyl tartrate solution was prepared by dissolving 1.3715g $K(SbO)C_4H_4O_6.0.5H_2O$, in 400mL double distilled water and then diluted to 500mL. It was store in dark glass bottle at 4°C.

20) Ammonium molybdate solution was prepared by dissolving 20g of $(NH_4)Mo_7O_{24}.4H_2O$ in 500mL double distilled water and stored in a plastic bottle at 4°C.

21) Ascorbic acid solution: For a 0.1M solution, 1.76g of Ascorbic acid was dissolved in 100mL double distilled water. The solution was stable for 1 week at 4°C.

22) Combined reagent: Ammonium molybdate and Ascorbic acid solutions (20-21 above) was warmed to room temperature and with mixing the following were added in the order given: 50mL, 5M H_2SO_4, 5mL potassium antimonyltartrate solution, 15mL ammonium molybdate solution, and 30mL ascorbic acid solution. The solution was shaken and made to stand for few minutes before proceeding. This was done to avoid the formation of turbid solution. The solution was stable for 1 week at 4°C.

23) Hydrolysing acid solution: slowly, 310mL H_2SO_4 was added to 600mL double distilled water, cooled and diluted to 1L.

24) 50mg /L Phosphorous standard solution was prepared by dissolving 0.2197g KH_2PO_4, which has been dried at 105^{0}C in 1.0L of double distilled water.

25) Phenol nitroprusside was prepared by dissolving 5g of phenol and 25mg of sodium nitroprusside in 500mL of double distilled water and labelled as Reagent A

26) Alkaline hypochlorite was prepared by dissolving 2.5g of NaOH and adding to 2.4 mL of sodium hypochlorite and diluted to 500mL with double distilled water. This was also labelled as Reagent B.

27) Standard chloride solution: Sodium Chloride standard 1000ppm(NaCl) solution Shimadzu, Japan (on sale).

28) Ionic strength adjuster (ISA); ISA – CL^- supplied by Shimadzu, Japan (on sale)

29) Iron standard solution supplied by Shimadzu, Japan (on sale)

2.3.0 SAMPLE COLLECTION AND ANALYSIS

In all, four (4) samples were collected at each point on every sampled date from Esuekyir (EK), Adisadel palm kernel oil production site (OIL), Ankaful Junction(AJ) and then, the Nkanfoa main disposal site(MS) all within the Cape Coast municipality. The Leachate were collected and stored in large dark Pyrex reagent bottles of 1litre capacity which were made of borosilcate glass. This was done by dipping the Pyrex bottle into the Leachate to ensure that the bottles are completely filled and stoppered under water in such a manner so as to prevent air from entering. The analysis was carried out within 24 hours of sample collection.

2.3.1 pH Determination [46, 47]

The pH of the leachate was determined on a calibrated pH meter MK11 C series Analogue pH meter. The pH meter was calibrated against a buffer of pH 4 and pH 9.

The buffer tablets of pH 4 and pH 9 were dissolved separately in 100 ml double distilled water. Portions of these solutions were used to calibrate the pH meter at room temperature. The electrode of the pH meter was first dipped into a buffer solution of pH 4 and the buffer control adjusted until the digital reading settled at pH 4 for about 20 minutes. The electrode was removed from the pH 4 solution, washed well with double distilled water and again dipped into a buffer solution of pH 9. The slope control of the pH meter was also adjusted until the reading settled at pH 9 for about 20 minutes. This process was repeated to ensure effective calibration.

2.3.2 Dissolved Organic Matter [48,49,50]

10mL of water sample was accurately measured into a 250mL beaker (conical flask). 10.0mL of 0.166M Potassium dichromate was added to the flask and swirled for complete mixing. Immediately, 5.0mL of concentrated tetraoxosulphate (VI) acid (to which has been added 0.1M silver nitrate in the ratio 1mL silver solution : 20mL sulphate solution) were added. The silver sulphate suppressed any chloride present.

The mixture was shaken and allowed to stand for 30minutes to cool. The contents of the flask were diluted, to 150mL with double distilled water and 10.0mL concentrated tetraoxosulphate (V) acid was added followed by 3 drops of diphenylamine solution. The solution was then titrated with 0.4M $(NH_4)_2SO_4.FeSO_4.6H_2O$ until the colour changed from violet to a clear green colour. A blank titration was carried out simultaneously following the same procedure.

Calculation

The percentage of dissolved carbon is given by

$$\% C = 10(1-T/S) \times 0.003 \times 100F$$

Where 10 = the volume of $K_2Cr_2O_7$ added

T = Sample titre value (Volume used)

W = Sample weight used (g)

S= Blank titre value

0.003 is derived from the fact that 1.0mL $K_2Cr_2O_7$ is equivalent to 3.0mL carbon. F = Correction factor derived from the fact that 77% of organic carbon is recovered by the method. i.e. f = 100/77 = 1.33 The percentage dissolved organic matter may be calculated by multiplying the percentage organic carbon by 1.724, which is derived from the assumption that 58% of organic matter is carbon[48,49,50].

2.3.3 Total Coliform Count [51]

Well-sterilised and tightly corked sample tubes were used for sample collections(Four samples were collected at each point). The sample bottles were open under water and allowed to be filled with water and then re-corked. The filled bottles were immediately transferred into an ice chest containing ice block to keep the temperature below 0°C. This was to suppress any microbial activities so as not to exhaust the available oxygen in the sample tube leading to the death of the bacteria before reaching the laboratory. The samples were treated in an environment of a very high temperature of about 60°C in order not to contaminate the sample with environmental bacteria in the atmosphere.

The water samples were diluted into different well-sterilised container. The dilutions were made to 1:10, 1: 100, 1:1000, 1: 10,000 and 1: 100,000 with peptone water. Three (3) 10mL portions of each dilution was pipetted into three (3) MacConkey broth solution containing the Delham tubes 1ml of the 1:10 and 1: 100 samples were pipetted into the double strength solution and the 1:1000, 1:10,000, 1: 100,000 dilutions were also pipetted into the single strength solution. The solution were corked tightly and turned upside down three (3) times in order for the Delham tubes to be filled with the solution. Thus, nine (9) solutions were obtained for each sample collected. Therefore for the four (4) sampling points and hence, thirty-six (36) solutions were obtained.

The solutions were incubated at 37°C in an incubator for twenty-four (24) hours. After the 24hour period, the solutions were taken out of the incubator and the presence of coliform examined. The presence of coliform changes the violet colour of the solution to yellow due to the production of acids like acetic or succinic acid and the production of gas (either Carbon dioxide or Hydrogen) on the tip of the delham tube.

The most probable number (MPN) of coliform bacteria was determined comparing the number of tubes which showed positive to a chart, multiplied by the dilution factor and then the average of all the positive tubes for a particular sample taken.

2.3.4 Total Bacteria Count (Plate Count(PC)) [51]

Collection, preservation and the subsequent environmental conditions under which the samples were treated followed the same procedure as in section 2.2.3.

The samples were diluted in different containers to 1:100, 1: 10,000 and 1:100,000 in dilution water (peptone water). Three (3) 1mL portions of each diluted samples were transferred into well cleaned and sterilised petri-dishes and covered. Thus, nine (9) petri-dishes for each sample at different dilutions and totalling thirty-six (36) in all were sterilised for the plate count. The plate count agar media were warmed to melt, cooled to about 25-30°C and about 15mL each media added to the sample in the petri-dish. The samples were swirled gently in the petri-dish for the water to distribute itself in the agar media without splashing. The petri-dishes were covered and left for sometime to solidify. They were then labelled accordingly and incubated at 37°C for twenty-four (24) hours.

After the 24-hour period, the petri-dishes were brought out and the number of bacteria colonies counted using the colony counter. The number of colonies counted were then multiplied by the dilution factor and the average number of bacteria growth colonies obtained from the 9-petri dishes were taken.

2.3.5 Conductivity [52]

The TOA CM-40V electrical conductivity meter was used. The conductivity meter was calibrated using Potassium chloride (KCl). 0.75g KCl (Analar grade from BDH) was dissolved in 1000 ml of double distilled water to prepare 0.01M KCl solution.

The electrode of the conductivity meter was rinsed with portions of the 0.01M KCl solution and then dipped into the solution. The slope control was adjusted until it read 1,412 μs/cm at room temperature. The electrode of the conductivity meter was then dipped into the leachate and the value recorded.

2.3.6 Temperature

The laboratory thermometer was dipped into the leachate (water sample) to about 10cm below the surface and the reading taken after attaining a stable temperature in °C at the site.

2.3.7 Phosphate PO_4^{3-} [53]

Phosphorous standard (page 40 number 24) 10mL was diluted to 1.0L to give a concentration of 0.50mg/L. About 0.0, 1.0, 3.0, 5.0, 10.0, 20.0, 30.0, 40.0 and 50mL of the working standard were pipetted into a 50.0mL volumetric flasks and made to the mark to give 0.0, 0.01, 0.03, 0.05, 0.10, 0.20, 0.30, 0.40, 0.50 mg/L respectively.

To 50.0mL sample, 1.0mL hydrolysing acid, 0.4g NH_4^+persulfate was added and boiled gently on a preheated hot plate for 30-40 minutes until the volume became 10mL. The sample was not allowed to evaporate to dryness [alternatively, the solution was autoclaved for 30minutes at 121°C]. It was allowed to cool and few drops of phenolphthalein added. The solution was adjusted to pink with 1M NaOH solution, and then to colourless with a drop of hydrolysing acid solution. The solution was allowed to cool, and diluted to 50.0mL.

About 8.0mL of combined reagent were added and mixed thoroughly. The solution was allowed to stand for 30.0minutes to allow the colour to develop. The blank sample and working phosphate standards were treated the same and their absorbances measured at 880nm obtain the calibration curve and the subsequent extrapolation for sample concentration.

Calculation

PO_4^{3-}-P(mgL^{-1}) = Xmg × 1000/aliquot mL [53]

X = amount of PO_4^{3-} obtained from the calibration curve.

2.3.8 Chloride Cl⁻ [54]

About 0.1 and 10mL of the standard chloride solution were pipetted and made to 10mL to give 10 and 1000 ppm respectively. 1.0mL of the ISA-Cl Adjuster (buffer name) was added to 10mL portion of the standard chloride solution to make 10ppm standard chloride solution.

The samples were treated the same i.e. one volume of the ISA –Cl Adjuster was added to 10mL volume of the sample solution to be measured. The solutions were stirred using a magnetic stirrer at a constant speed. The Chloride- Cl electrode and the reference electrode were dipped into each sample solution and the concentrations read directly on the read-out.

Calculation

Cl^- - Cl (mgL^{-1}) = Xmg × 1000/aliquot [54]

X = amount of Cl^- obtained on the calibration curve.

2.3.9 Ammonium NH_4^+ [55]

The Indophenol-Blue Colorimetric method was used in determining the ammonium concentration in the leachates. Standard preparation: 0.3820g of NH_4Cl salt was dissolved in a minimum amount of double distilled water and diluted to 1.0Litre. This solution contains 0.1mg of nitrogen per $1.0cm^3$ in the form of ammonia. A $10.0cm^3$ aliquot of the 0.1mg solution was diluted to $1000cm^3$. The latter solution contains 0.001mg of ammonium-nitrogen. Working standards were prepared by taking 0,2,4,6,8 and $10cm^3$ of the $0.001mg/cm^3$ solution to represent 0,2,4,6,8 and $10mg/cm^3$ respectively. These solutions were diluted with double distilled water to $10cm^3$ in labelled beakers.

5.0mL of reagent A [5g of phenol and 25mg of Sodium nitroprusside were dissolved in 500mL of double distilled water] phenol nitroprusside was added to 10.0mL of both the samples, blank and the standards.

5.0mL of reagent B Alkaline hydrochloride [2.5g of NaOH was added to 2.4 mL of Sodium hypochlorite and diluted to the 500ml mark with double distilled water] was added to the standards, blank and the samples. The solutions were swirled to mix thoroughly and allowed to stand till the blue colour developed. The absorbance of the blue colour that developed was measured at 625nm.

Calculation

NH_4^+ - N (mg/L) = X (mg) × 1000/mL of sample [55]

X = amount of NH_4^+ obtained from the calibration curve.

2.3.10 Nitrite-Nitrogen NO_2^- [56,57,58,59]

The Greiss-Ilosvay method was used in determining the Nitrate-nitrogen concentration in the leachate. This was a modification of Greiss's method by Ilosvay [55]. The method is free from interference and is very sensitive to about 0.01mg/L Nitrite-nitrogen and has a reproducibility of ±2.0% possible at normal concentrations. However, the reagents used in this method are carcinogenic which demands a lot of care when handling them.

About 0.0mL – 5.0mL operating standards were pipetted into 50mL volumetric flasks to give a range of standards containing up to 5.0mg nitrite-nitrogen. Accurately 10.0mL of the water sample and the blank were pipetted into 50 mL volumetric flask, the standards, sample blank, and the samples were treated in the same manner.

The content was diluted to 45mL to give a pH of between 0.5 – 7.5. About 1.0mL sulphanilic acid solution was added and allowed to stand for 35 minutes. The pH of the solution was maintained at 1.4. 1.0mL amine solution (α-naphthylamine hydrochloride solution) was added. Exactly 1.0mL 2M NaOAc (Sodium acetate) was added and the absorbance of the reddish-purple colour measured at 520nm after 10-30 minutes.

Calculation:

NO_2^--N(mg/L) = X(mg) × 1000/mL of sample taken

X (mg/L) is the amount obtained from the calibration curve.

2.3.11. Sulphate SO_4^{2-} [46,47]

Turbidimetric method was used to determine sulphate using the turbidimeter. A series of sulphate standards at 0.50mg intervals in the range 0.50mg – 3.00mg in $50cm^3$ volume, were prepared with double distilled water. 50mL of each sample was pipetted into 100mL beaker. The standard, the blank and the sample solutions were treated exactly the same throughout the experiment. 10mL acid-salt reagent were added to the standards, blank and the sample and each mixed thoroughly.

To each solution 0.30g of $BaCl_2.2H_2O$ was added and stirred well for one minute and allowed to stand for 5 minutes. The solution was again stirred for one more minute and its turbidity measured at 520 nm with a turbidimeter.

Calculation

$$SO_4^{2-}(mg/L) = X(mg) \times 1000mL/\ ml\ of\ sample\ taken \qquad [46,47]$$

2.3.12 Nitrate – Nitrogen [60]

(i) In this method dried $NaNO_3$ was used for the preparation of the standard. About 10.0g $NaNO_3$ was dried at 105°C in a drying oven for 2 hours and then cooled in a dessicator.

(ii) A 7.223g of the oven dried $NaNO_3$ was then dissolved in double distilled water and the volume made up to the 1000mL mark in a volumetric flask.

(iii) About 25mL of the solution (ii) was measured and diluted to 500mL to give a stock solution of 50 µg/mL nitrate solution.

(iv) Into 50mL volumetric flask were pipetted, 0, 2, 4, 6, 8 and 10mL of the standard NO_3^- - N solution diluted with double distilled water and labelled. These were working standards and contain 0, 2, 4, 6, 8 and 10μg/mL NO_3^- - N.

Procedure

a) Into suitably labelled test tubes 0.5mL each of standard, sample blank and the sample were pipetted and

b) 1.0mL of salicylic acid solution was added to each test tube and then mixed thoroughly immediately the acid was added and allowed to stand for 30minutes to cool.

c) To each of the test tubes10.0mL of the 4M Sodium Hydroxide solution was added, mixed well, and left to stand for one hour for the full colour to develop. (The colour is stable for 12 hours only).

d) The absorbances for the standards, the sample blank and the samples were read at 410nm using a spectrophotometer .

Calculation

NO_3^- - N (μg/L) = Xmg × 1000/ Millitres of sample taken

Xmg = amount of NO_3^- - N obtained from the calibration curve.

2.3.13 Total Iron [61]

About 0.1mL of the standard iron solution was pipetted and made to 10mL to give 10ppm of iron solution.

Into 10mL graduated flask 0,2,4,6,8 and 10mL of the standard iron solution were pipetted and diluted to 10mL mark with double distilled water and labelled. These were the working standard for iron and contains 0,2,4,6,8,and10ppm

Procedure

Into other 10.0mL graduated flask, 10mL each of all the samples were pipetted. 10mL blank was also pipetted into another 10.0mL graduated flask.

The iron concentration of the working standard, samples and blank were measured by the use of 6104S Shimadzu A.A.S. and the levels read either directly and also by the extrapolation of the calibration curve.

Total iron – Fe ppm = Xmg × 1000/ Millitres of sample taken

Xmg = amount of iron - Fe obtained from the calibration curve.

CHAPTER THREE

RESULTS AND DISCUSSIONS

3.1 SOLID WASTE ANALYSIS

3.1.1 Perceptions of waste disposal problem.

Respondent were asked, how they have been disposing of the refuse in their community, as whether they dispose of their waste into the containers provided by Cape Coast Municipal Authority (CCMA) or into open dumps instead. The respondent were also asked if they would accept privatisation of the refuse collection in the municipality. The results are shown in Table 3.1. Analysis of the responses showed that 72 percent of the total households sampled dispose of their solid waste into containers provided by the CCMA. This implies that the municipal authorities were some how able to collect about 72 percent of the refuse through skip loading. However, these 72 percent households are households very close to the sited containers. The analysis also showed that 28 percent of the respondent disposed their refuse into open dumps. These were areas where CCMA containers were either absent or placed very far away. When the question of privatisation came up, 66.6 percent strongly opposed the idea. However, 33.4 percent of the respondent accepted the idea. These 33.4 percent households were those of the upper class receiving relatively high income. The 66.6 percent, which opposed the privatisation, said they couldn't afford paying for their refuse collection. The results indicated that the respondents were aware of and sufficiently concerned about the waste disposal problem but they expect that this would improve with the availability of enough containers. The study also identified a problem, which in a way has contributed to dumping of refuse. The problem identified was that, in all the study area, children, some as young as five years were sent to dispose of refuse. Meaning that the distance where the containers were placed was very important in solid waste collection.

Table 3.1.A) RESPONDENTS VIEW ON SOLID WASTE DISPOSAL.

Sub-Sample	Disposal refuses into containers.	Disposal of refuse in open dumps.
Abura	15	5
Cape Coast	17	3
Apewosika	12	8
Esuekyir	7	13
Pedu Estate	16	4
U.C.C	20	—
Total	87	33
	72%	28%

Number in sample = 120 households. Source field survey 1999.

Table 3.1.B) RESPONDENTS VIEW ON SOLID WASTE PRIVATISATION.

Sub-Sample	Want waste collection **not** privatised	Want waste collection privatised
Abura	14	6
Cape Coast	5	15
Apewosika	18	2
Esuekyir	20	–
Pedu Estate	2	18
U.C.C	20	—
Total	79	41
	66.6%	33.4%

Number in sample = 120 households. Source field survey 1999.

3.1.2 Evaluation of waste quantities.

The 1999 portion of Table 3.2 represented the 1999 situation, indicating the quantities of solid waste being produced presently and the quantities being collected and the mode of collection. The 2010 portion is a projection from the 1999 quantities over the 11-year period. This was done based on the following assumption; population growth is linked directly with waste generation. All other units' rates remained the same. The projections were proposed once again on the fact that a total waste quantity is directly proportional to the forecast number of producers. Therefore the solid waste production would increase at the rate of 3.2 percent per anum. Population and solid waste computation and projections refer to Appendix II.

The estimated waste generation rates as well as the breakdown of daily and monthly quantities of waste generation in different sectors of Cape Coast municipality are given in Table 3.2 The accuracy of the waste production/collection figures in the table depends mainly on the accuracy of the population figures. As the geographical limit of the sector in 1984 population census are not well defined, the accuracy per sector may be low, and uncertainty levels in any sector may reach 11%. But for the whole urban area, the uncertainty level is assumed to be less than 5%, which is considered acceptable at this stage of investigation [14,15].

TABLE 3.2: CAPE COAST MUNICIPAL SANITATION SOLID WASTE PRODUCTION AND COLLECTION

SECTOR		1999					2010		
			REFUSE PRODUCTION		METHOD OF REFUSE COLLECTION			REFUSE PRODUCTION	
LOCATION	NO.	POPULA-TION	DAILY T/DAY	MONTHLY T/MTH	MONTHLY T/MTH	BY	POPULATION	DAILY T/DAY	MONTHLY T/MTH
RESDENTIAL									
ABURA	1	6,066	2.65	79.50	57.24	Municipality	8438.0	3.6304	18.915
CAPE COAST	2	74,394	33.375	1001.30	658	Municipality	103476	46.2482	1402.445
APEWOSIKA	3	1,840	0.795	23.85	16.31	Municipality	2559.0	1.158	33.175
ESUEKYIR	4	450	0.195	5.85	4.0	Municipality	626.0	0.27125	8.14
PEDU ESTATE	5	3,680	1.85	47.55	32.52	Municipality	5,119.0	2.2047	66.14
U.C.C.	6	3,480	1.8	54.0	93.75	U.C.C SANI.	48,41.0	2.20	66.000
TOTAL RESIDENTIAL		89,907	40.38	1211.2	861.8		125,058	56.1673	1685.04
IMPORTANT MARKETS									
KOTOKURABA	1		3.9	117	80.03	Municipal		5.4248	162.74
ABURA	2		0.62	30	20.52	Municipal		1.996	47.99
TOTAL MARKET			4.5	147	100.5			7.0244	210.73
TOTAL REFUSE			44.93	1358.4	962.35			63.1912	1895.53
INDUSTRIAL SECTOR									
WOOD WORK				50	5.5	-			75
INDUSTRIAL AREA				5	3.4	Industries			7.5
TOTAL INDUSTRIAL				55	8.9				81.5
TOTAL				1413	971.25				1478.075
DRAIN CLEANSING		TOTAL DRAIN							
ABURA	1	2KM		0.5		Municipal	8KM		1.5
CAPE COAST	2	10KM		3.5		Municipal	20KM		7.0
APEWOSIKA	3	2KM		0.5		Municipal	8KM		1.5
ESUEKYIR	4	1KM		0.5		Municipal	9KM		1.0
PEDU ESTATE	5	3KM		1.0		Municipal	4KM		3.0
U.C.C.	6	5KM		1.0		Municipal	10KM		2.0
TOTAL DRAIN CLEANSING		23KM		7.0	5		59KM		16
TOTAL SOLID WASTE				1420	976.25				1992

3.2.0 WASTE COLLECTION

3.2.1 Municipal Refuse Collection

The municipality collects about 72% of the present commercial and domestic refuse produced. Table 3. 1A.

More precisely, refuse collection was only from containers placed at certain vantage parts of the municipality. This meant that areas not covered by the sited containers were not catered for. Private refuse collectors have not been involved in refuse collection in the municipality yet.

3.2.2 Industrial waste

The industrial sector in Cape Coast was not well developed. The prominent industrial activities were the wood processing and the palm kernel oil industries, which generate the sawdust, and palm kernel cake, which was virtually not collected by any known means. This made direct estimation of quantities of waste very difficult. Ameen Sangari Industry, a soap manufacturing industry recycles its solid waste in generating heat source for their boilers.

3.2.3 Waste from Drain Cleaning

Individuals collect only a few of rubbish and silt that settle in drains on communal basis.

Prominent problems occur in areas where refuse dumps have been sited close to most drains. Adisadel, OLA and Bakaano areas have dumps sited close to drains and these drains have become choked with plastics due to the fact that the drains are not covered.

Garbage and sullage are continuously being thrown into the drains around the market areas causing frequent choking of the gutters with consequent production of bad odours. Unfortunately during cleaning of gutters, most of the rubbish and silt collected from the drains were deposited on the shoulder of the drainage systems and eventually get back after rainfall event.

3.2.4 Specific Refuse

3.2.4.1 Hospital and Clinic Refuse

Although the total volume of refuse produced by hospitals and Clinics represent only a minor portion of the Municipal refuse, special attention has to be paid to it, since some of it could be hazardous and may need to be specially handled.

Investigation carried out at the University of Cape Coast Hospital, the Central Regional Hospital, the Cape Coast district Hospital and the other clinics, showed that the solid wastes from the hospitals were approximately 0.7kg per bed in a day with the following composition:

0.5 kg/bed/day	household type refuse
0.2 kg/bed/day	specific waste (bandages, syringes, and gauze)

This gives at the present refuse production from all the hospitals and clinics (with about 500 beds total in daily use) in the municipality to about 10 tonnes of refuse every month. This type of refuse is composed of seven tones of household type refuse and three tones of infectious wastes.

The infectious wastes are not added to the household waste. The hospital authorities themselves treat them. The new and old central hospitals bury their infectious waste after chemical treatments.

3.2.4.2 Slaughter House Waste

The solid waste generated at the slaughterhouse was mainly; intestine, offal's, animal heads, carcasses, skin blood and bones. However, intestines, offal's, animal heads, carcasses and skin, are recuperated by the animal owners or sold directly. The blood and bones are buried to generate compost which farmers collect free of charge. This means that, almost all the waste produced at the slaughterhouse is somewhat recovered recycled.

3.2.4.3 Demolition waste

Demolition waste consists mainly of construction debris and scraps of abandoned vehicles. Up till now in the Cape Coast municipality, demolition waste does not represent any important volume of waste as they are generally recovered for other uses. These include old out of use cars, which are presently cannibalised by car-repairers but they seem to exceed their needs. However, alternative uses of this scrap metal have been found and they are being recycled. They are collected by agents for smelting for eventual manufacture of iron rod by the Wahome factory and Tema Steelworks.

3.2.4.4 The University of Cape Coast refuse.

The sanitary unit of the University is responsible for the collection of both solid and liquid wastes from the University campus. Solid waste collection is by the use of dustbins. In all, the study showed that the sanitary units collect one hundred and twenty dustbins daily. Each dustbin on the average weighed 15.0kg (fifteen kilograms) given a total of about 1.80 tones of solid waste a day. The solid waste consist mainly of food household type refuse representing about 35-52 percent; and the rest being packaging (cartons, cans) bottles, papers, textiles (also taking up 48 percent by volume).

3.3.0 WASTE COMPOSITION

Table 3.3 below represents the average composition of refuse samples taken from six different parts of the municipality for analysis to determine the solid waste composition within the Cape Coast municipal area.

Table 3.3 Average refuse composition in the Cape Coast Municipality.

COMPOSITION	% BY WET WEIGHT	% WATER CONTENT	% BY DRY WEIGHT
Screening less than 20mm	26	22	41
Organic waste	59	65	37
Paper	3	35	5
Wood	4	30	7
Plastic	2	6	3
Metal	1	6	2
Glass	1	-	-
Clothes/leather	1	35	2
Others	3	30	3
Total	100	34	100

Average wet density: 0.5kg/dm^3

The results are typical of those found in cities with similar climatic conditions (equatorial climate) and demographic patterns (having high population of middle and low-income groups. Putrescible/compostable component represents the waste that could be recycled by composting. These are kitchen waste, garden waste, vegetable and screening, which represent about 96 percent of the net wet weight. The screening portion represents the waste that goes through 20mm mesh (sieve), after sieving the waste. They can not be clearly identified so it is put under putrescible waste. The water content of the waste was high as a result of high organic matter content given it a wet density of 0.5kg/dm^3. However, most of the non-putrescible materials are recycled at source by scavengers. Particularly, the almost total absence of metals, bottles and leather was noted.

The dry proportion of screening <20mm found in Cape Coast municipality is higher than those found in Sekondi-Takoradi (39%) as shown on page 9. This is probably due to a higher sand and silt content in the sweepings in the Cape Coast municipality, as most of the roads are not properly tarred.

3.4.0 PRESENT CONDITIONS OF REFUSE COLLECTION

3.4.1 Refuse Collection by the Municipal Authority

Presently, all the refuse collected in the municipality is dumped in an almost swampy area near Nkamfoa, behind Third Ridge in Cape Coast. The area is popularly called "Sukanfu". However, residents usually sweep their premises and carry their refuse to near by containers where available (or open dump). The location of containers seems to have been chosen by initial agreement between the residents, in order to minimise inconvenience. There are a lot of small open dumps and heaps scattered every where in the municipality. The study also showed that these areas served as grounds where people eased themselves. These open dumps serve between 1000 – 2000 residents.

In all forty-five (45) containers were identified and these containers were not evenly placed and were also placed at old dumpsites. The collection service carried out by the Environmental Health Division of the municipal assembly mainly consists of regular removal of big containers (about $15m^3$) filled with refuse once a day. In this area, the assembly was quite efficient. About 90% of the containers-covered areas were catered for, however, for the areas not covered by the containers, refuse from homes were dumped anywhere convenient.

3.4.2.0 Markets Cleaning

3.4.2.1 Kotokuraba Market

The Kotokuraba market is swept daily. However, some garbage, plastics and other solid waste (sand) found themselves into the nearby drains with the view that rainwater would carry them away. There are three containers at Kotokuraba market into which the waste are put. These are collected daily by the municipal authority.

3.4.2.2 Abura Market

The scene here was not very encouraging – sweeping appeared not to be carried out regularly and the area looked very dirty. Again, there are two containers at the Abura market into which refuse are put. This market is still in the development stage, making refuse control very difficult. These containers are collected by the (CCMA) daily.

3.4.3 Waste from Drain Cleaning

Drains are sometimes cleaned and the rubbish and the silt heaped alongside the drain awaiting collection, at other time by the municipal truck. The system was not really efficient due to the lack of workers and equipment to properly carry out the task, even though the drains are not enough. There are equally not enough slabs to cover the few, available drains in the Cape Coast municipality to prevent people from dropping waste into them.

3.4.4 Refuse from Hospitals and Clinics

The general pictures of refuse collection and disposal in most of the hospitals and clinics are as follows:

The different types of refuse (household type dressing and bandages, syringes and drugs, anatomic waste) are primarily stored in dustbins and then carried to a disposal site on the premises. Here;

- dressing and bandages as well as human parts are burnt using electric incinerator.
- syringes and drips as well as some anatomic wastes are buried.
- household type refuse and some non-infectious wastes are disposed off through skip loading to the final disposal site by the CCMA.

- wet refuse are treated in the sewage system using oxidation tanks.

3.4.5 Refuse from slaughterhouse

Almost everything was recovered.

3.4.6 Industrial wastes

Either dumped on the premises or outside, awaiting removal by the municipal authority. The sawdust and the palm kernel oil waste are still not collected. This could have been used to feed poultry and pigs but in Cape Coast municipality pigs are not allowed to be reared.

3.5 REFUSE DISPOSAL

3.5.1 Present situation

3.5.1.1 Nkanfoa disposal site

Presently, most of the refuse collected by the municipal assembly is dumped at a site in a valley between the third Ridge and Nkanfoa village. The dumped solid wastes are scattered all over the area with pools of water scattered all over the place, which serves as breeding grounds for mosquitoes, houseflies and rodents. The area is neither a landfill nor a well-planned incinerator. However, the refuse is periodically set on fire, causing health hazard to the nearby inhabitants.

3.5.1.2 Other swampy areas

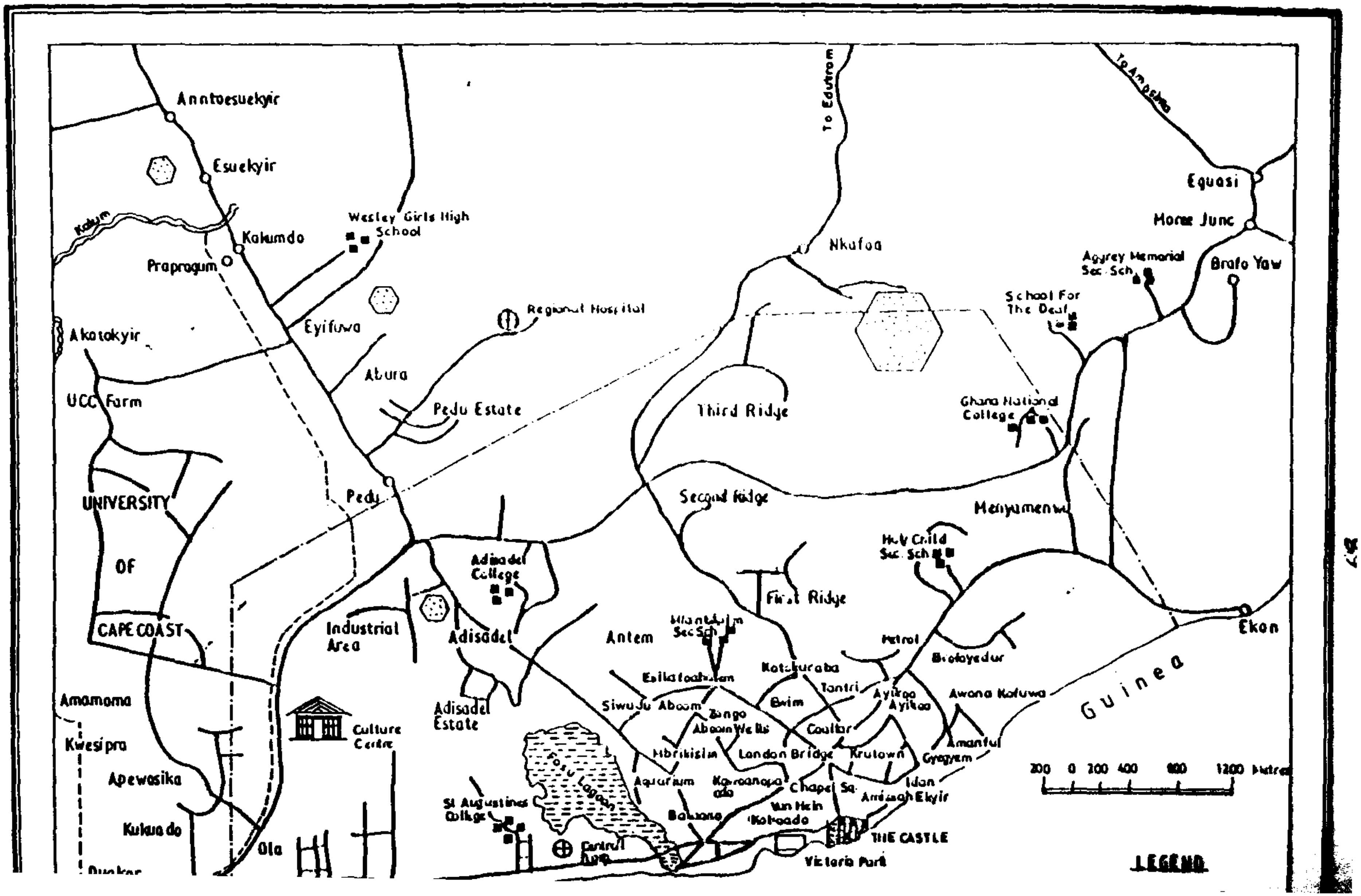
There are many swampy areas (wetlands) in the municipality, which are being used as final disposal site. One such area is at Esuekyire, near Ankaful junction. Due to the topography of the land, water run-off, converges in this area, resulting in a lot of leachate flow into the environment.

3.5.1.3 Comments on refuse disposal

The study showed that, the sitting of the final disposal site at Nkanfoa was environmentally unsound. Nkanfoa is very close to residential area (from figure 3.0 at page 68) it is clearly seen that, the site is very close to third ridge, Ghana National Collage, Nkanfoa itself and even the new regional hospital. The area is still under development with new and uncompleted structures seen all over the vicinity of the disposal site. The disposal site is also not protected from the effect of wind. The refuse is not covered regularly allowing wind to carry plastics, debris and smoke to the nearby-inhabited areas. There is also, a drain (run-off) which flows from the disposal site (which is a valley) into possible surface water(s) especially when it rains. No attempt has been made to restrict this run off, posing possible ground water contamination. It can also be said from the studies that, the whole refuse disposal operations of the municipal authority is environmentally unacceptable anywhere. The disposal site can not be defined. It is neither a land fill nor an incinerator. Burning is carried out at one time whiles compaction is sometimes done. The operational processes are very confusing. Then also the area is not very accessible by good roads or tracks all year round. The road is not tarred and therefore becomes cut-off during the raining season of the year. Also, because it was not properly constructed, leachate can not be collected for treatment and even the capacity of the site can not be precisely projected. There are no real controlled operations at the disposal site. There is no design for land and excavation fill-ins. Also, no procedures for tipping of the refuse at the disposal site, refuse are scattered all over the site.

Fig 3.0

SOLID WASTES DISPOSAL SITES IN THE CAPE COAST MUNICIPAL ASSEMBLY



3.6 LEACHATE ANALYSIS

Due to the topography of all the disposal sites, water run- offs converge; hence it was necessary to evaluate the risks posed by leachate entering the environment.

In order to show a clear picture of the leachates, four final disposal sites from the Cape Coast Municipality were chosen for analysis of the leachate. The results are tabulated in Tables 3.4.1-3.4.4

TABLE 3.4.1 AVERAGE RESULTS FROM FOUR SAMPLED POINT AT ESUEKYIR WITH ITS STATISTICAL DATA.

1999	pH	Teperature °C	Conductivity Us/cm	Fe ppm	SO_4^{2-} ppm	PO_4^{3-} ppm	DOM ppm	NO_3^- ppm	NO_2^- ppm	Cl^- ppm	NH_4^+ ppm	Plate Count
13-Mar	8.2	28	72000	2.34	446.9	21	209.7	13	0.7	111.2	401	30000
22-Mar	7.9	27.6	85000	10	4000	213.33	550	10	24	80	260.7	1000000
26-Mar	7.4	25.2	12200	52	980	195	299.08	144	3.36	140	434.4	18000
7-Apr	7.4	26.8	72000	22	720	48.33	224	720	16	108	114.8	10000
10-Apr	7.9	21.2	83100	16	1600	181	604.5	153.6	14	20	950	20000
20-Apr	8	24	34600	9.35	788.6	6.5	156.1	13	1.8	148.2	114.8	20000
11-May	6.8	28.3	11540	2.4	520	18.3	65.5	10.2	3.4	640	820	60000
22-May	7.4	27.9	11500	4.6	113.35	54	598.2	8.4	9.2	230	250	1000000
30-May	7.6	20.5	10330	14	1400	60	856	8	32	200	109	10000
31-May	7.3	20.9	56600	24	1148	35.5	2209.5	64	12	160	910	10000
8-Jun	7.8	28	14400	14.03	13	15	2015	32.4	2.7	98.3	289.6	30000
16-Jun	8.3	30	90800	9.2	20	2	1125.6	23	1.7	74.1	103.4	1000000
verall mean	7.68	25.7	46172.51	14.993	579.15	70.83	742.765	99.96	10.072	167.48	283.195	
D σ	0.43031	3.28855	33012.95	13.55	1083.65	78.191	710.9112	202.07	10	159.27	273	
ariance	0.18515	10.8146	1089900000	183.6025	1174295	6113.8167	505394.73	40831.877	100	25366.901	74529.546	

TABLE 3.4.2 AVERAGE RESULTS FROM FOUR SAMPLED POINT AT ANKAFUL JNCTION WITH ITS STATISTICAL DATA.

1999	pH	Teperature °C	Conductivity Us/cm	Fe ppm	SO_4^{2-} ppm	PO_4^{3-} ppm	DOM ppm	NO_3^- ppm	NO_2^- ppm	Cl^- ppm	NH_4^+ ppm	Plate Cou
13-Mar	6.9	28	18340	12.08	979.5	98.28	825	190.2	7.72	291.9	236.7	500
22-Mar	7.5	27.6	10200	44.4	2676	353.3	1376	2	1.2	104	157.8	300
26-Mar	6.8	27.6	14300	6	2120	150	299.08	72	3.36	340	78	100
7-Apr	8.1	27.5	46500	10	640	70	823	72	10	600	600	130
10-Apr	8	21.1	49000	26	24	16.4	1271.54	736	8	6	520	200
20-Apr	7.8	27.2	16200	7.27	1837.8	33.6	1024	251.3	25.61	417	35	900
11-May	7.6	28.4	10880	1.2	7600	9.6	150.3	20	1.05	1520	520	800
22-May	7.6	28.1	43600	6.4	387	12.6	498.5	32	6	470	50	100
30-May	8.4	20	17220	18	1800	10.2	678	20	48	400	650	140
31-May	6.8	21.2	24000	24	3600	26	1527.67	480	16	400	340	100
8-Jun	8.2	25.2	26700	12	829.5	9.97	1124	210	97.3	542	277.8	400
16-Jun	8.04	29	30200	9	20	11	938	200.2	87.2	627	627	600
verall mean	7.65	25.91	25595	14.696	1876.15	66.75	877.925	190.48	25.953	481.08	341.03	
D σ	0.556	3.241	13902.65	11.9008	2109.77	100.48	422.65	220	33.69	378.82	234.96	
ariance	0.30914	10.5041	193283648.5	141.629	4451129.48	100960.3	178632.1687	48400.4	1134.274	143503.82	55205.72698	

TABLE 3.4.3 AVERAGE RESULTS FROM FOUR SAMPLED POINT AT ADISADEL PALM KERNEL OIL PRODUCTION POINT WITH ITS STATISTICAL DATA.

1999	pH	Teperature °C	Conductivity Us/cm	Fe ppm	SO_4^{2-} ppm	PO_4^{3-} ppm	DOM ppm	NO_3^- ppm	NO_2^- ppm	Cl^- ppm	NH_4^+ ppm	Plate Count
13-Mar	8	19.2	1140	120	1200	195.8	251.25	203	10.7	440	62	1000000
22-Mar	7.8	26.4	11300	22	1840	363.3	826	16	10	440	342	40000
26-Mar	7.8	27.1	16300	6	400	365	179.45	1536	352	350	55	1000000
7-Apr	7.8	26.9	19900	6	1120	23.33	598	560	18	520	34	50000
10-Apr	8.4	21.1	12590	18	3200	31.82	458.89	72	10	100	13	40000
20-Apr	8.2	24.3	16200	5	1765.7	14.7	321.19	272.8	65.53	380	28	60000
11-May	7	28.5	13100	1.6	2020	28.6	150.3	42	15.5	1520	19	1000000
22-May	7.4	28	13220	18.8	723	69	398.8	42	21.5	217	480	80000
30-May	8	19.2	13340	120	1200	72	226.4	4	3.2	440	14	1000000
31-May	7	20.4	46300	60	2300	68	1438.29	70	10	120	120	7000
8-Jun	8.2	25	64800	17.42	2570.1	79.97	676.34	243	11.5	172	84	1000000
16-Jun	7.3	28.5	28700	21.42	4214	99.9	1342	232.4	15.3	416	847	>1000000
verall mean	7.74	24.55	224242	41.23	1879	117.62	408.91	274.4	45.27	426.25	174.83	
D σ	0.466	3.633	16637.7	47.17	1083.27	124.71	338.48	427.65	97.898	372.02	257.43	
ariance	0.2172	13.1987	276812725.2	2224.92	1173473.88	15552.333	114906.756	182882.72	9583.99	138398.13	86269.68	

TABLE 3.4.4 AVERAGE RESULTS FROM FOUR SAMPLED POINT AT THE MAIN DISPOSAL SITE AT NKANFOA WITH ITS STATISTICAL DATA.

1999	pH	Teperature °C	Conductivity Us/cm	Fe ppm	SO_4^{2-} ppm	PO_4^{3-} ppm	DOM ppm	NO_3^- ppm	NO_2^- ppm	Cl^- ppm	NH_4^+ ppm	Plate Cou
13-Mar	8.3	29	59600	140	4450	80	1076.2	298	40.3	567	46.69	10000
22-Mar	8.7	27.8	175800	200	1548	346.5	1926	4	16	700	60.7	20000
26-Mar	10.1	27.8	199900	2560	2400	443	1615.01	236.8	57.6	680	58.6	30000
7-Apr	7.9	27.4	132100	640	21600	70	972	720	64	1440	290	20000
10-Apr	10.5	21.1	89300	720	19200	108	2543.06	204	16	400	18	10000
20-Apr	9.2	28	34200	210	11858.5	324	1580.2	1520	67	860	43.9	10000
11-May	8.6	28.3	15340	200	12800	500	1703	420	81	1520	145	38000
22-May	8.7	27.9	17600	341	17551	1120	3655.38	400	10	1353	215	10000
30-May	9.5	20.3	145800	256	3200	890	1085	32	20	740	13	20000
31-May	8.4	22.1	139800	200	1400	1423	1730.11	1536	35.2	600	228	10000
8-Jun	8.6	26.1	52400	310	3064	69.3	1034	274	28	328	160.03	10000
16-Jun	8.12	28.5	69700	160	5366	72.6	1876.03	283.9	44.1	1424	667	10000
verall mean	8.89	26.19	90158.2	494.75	8703.125	453.867	1732.999	494.058	39.933	884.333	162.16	
D σ	0.794	3.132	64035.5	673.32	7490.05	457.644	760.779	516.8596	23.22156	431.3312	183.424	
ariance	0.63044	9.809424	4100543967	453354.4	56100833.9	209438.03	578784.6853	267143.85	539.2406	186046.6	33644.3638	

3.6.1 Relationship between solid waste component and some water quality parameters.

From Tables 3.4.1-3.4.4 the high levels of nitrites, sulphates, ammonium, phosphate and dissolved organic matter are a reflection of the solid waste composition as a result of high percentage of organic waste undergoing decomposition as shown in the figure 3.1 below [61].

The organic waste is basically made up of nitrogenous, carbonaceous and sulphurous compounds. Looking at the cycle of decomposition, ammonia, carbon dioxide and hydrogen sulphide are produced initially and further oxidation of these produces nitrate, carbon dioxide and sulphur.

The final product of decomposition are nitrate, carbon dioxide and sulphate, which end up in air, water and soil, thereby causing pollution into the environment. Figure 3.1 below summarises the above process.

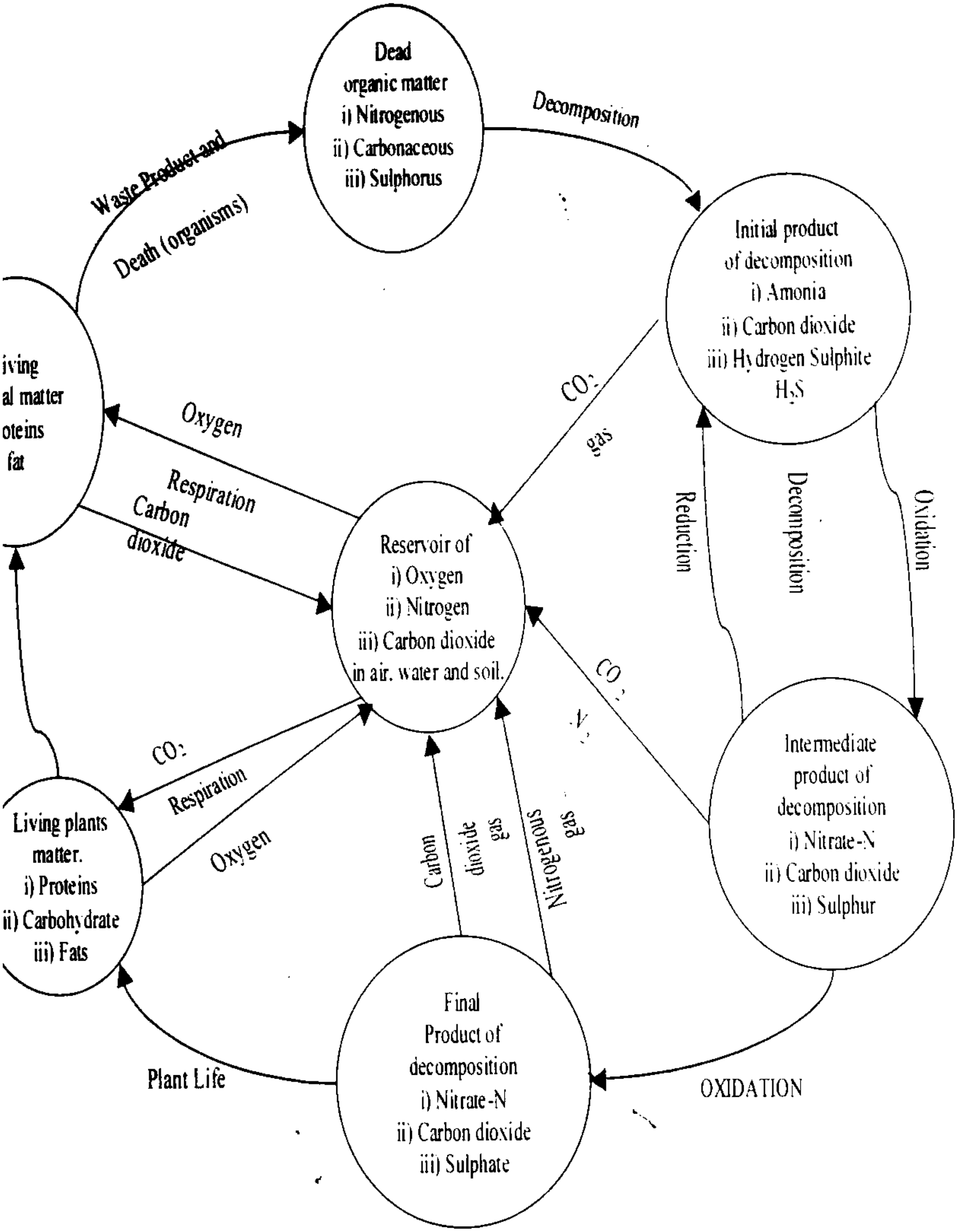


Figure 3.1: Relationship between Some Solid Waste Components and Some Water Quality Parameters [61].

3.6.2 Discussion of Leachate Analysis

For the sake of comparison, the maximum permissible concentration of the various parameters in leachate (as shown in Table 3.5) [63] were used as a guideline to determine the level of pollution with regards to solid waste disposal in the Cape Coast municipality. We believe therefore, that this situation might apply to other areas in Ghana since the solid waste disposal methods are similar, if not the same.

Table 3.5: Leachate limit for Class II Landfills [63] and the levels obtained.

Characteristics	Permissible levels allowed for class II landfills*	Levels obtained from the analysis
PH	5.5 – 13.0	6.8 – 10.5
Temperature	(28 – 34)°C ± 3°C	19.2 – 29.0°C
Specific conductivity	50,000 µs/cm	199,900µs/cm
Iron – Fe	30 mg/L	720 ppm
Sulphates – SO_4^{2-}	1000 ppm	21600ppm
Phosphate – PO_3^{2-}	60 ppm	1423ppm
Dissolved Organic Matter	100ppm	3655.4ppm
Nitrate – NO_3^-	100ppm	736ppm
Nitrite – NO_2^-	5.0 ppm	97.3 ppm
Ammonium – NH_4^+	200 ppm	1140ppm
Chloride – Cl^-	2000ppm	1520ppm
Coliform count	10,000	uncountable

**These are landfills that are permitted to accept waste with a higher percentage of organic material and a corresponding higher leachate production. Therefore, the design and operational requirement for class II landfills are more stringent* [63].

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Sulphates – SO_4^{2-}	1000 ppm	21600ppm
Phosphate – PO_3^{2-}	60 ppm	1423ppm
Dissolved Organic Matter	100ppm	3655.4ppm
Nitrate – NO_3^-	100ppm	736ppm
Nitrite – NO_2^-	5.0 ppm	97.3 ppm
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Chloride – Cl^-	2000ppm	1520ppm
Coliform count	10,000	uncountable

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In order to get a clear picture of the extent of pollution of leachate from solid waste disposal site on the environment, four final solid waste disposal sites from the Cape Coast municipality were chosen for this studies. They include the Esuekyir disposal site (EK), Ankaful junction site, Adisadel site and the main disposal at Nkanfoa.

3.6.2.1 Esuekyir disposal site (EK)

The area lies at the point where run-offs collect after each rainfall event. The solid waste dump was created there as a way to reclaim the land. The result showed that there was Leachate with high levels of nutrient going out of the disposal site.

The data from the analysis of this disposal site is given in Table 3.4.1. From the results, the pH of the leachate ranged between 6.80 and 8.33, the temperature between 20.5 and 30.0°C, the conductivity between 10330 and 90,800 µs/cm, the total iron between 2.34 and 52 ppm, the sulphate between 13.0 and 4000 ppm, the phosphate ranged between (2.0 and 213) ppm, the dissolved organic matter between 65.5 and 2209.54ppm, the nitrate – nitrogen between 8.01 and 736ppm, the nitrite- nitrogen between 0.7 and 32ppm, the ammonium –nitrogen between 109.0 and 1140 ppm and the plate count between 10, 000 and > 1000 000.

These levels as compared with waste characteristics and leachate limit for various types of landfills (Class II Landfill Table 3.5) are too high. The levels are too high for all the parameters analysed except for pH and chloride. However, there has been no attempt for pre-treatment before disposal into the environment.

Then also, the overall mean, the standard deviation and the analysis of the variance (ANOVA) between-sample variation were also computed. From this computation, the pH values at Esuekyir had insignificant variation between the samples. Meaning that the pH values did not differ greatly over the period. However, between-sample variations for the other parameters were very significant. This again means that between-sample variation were very great over the period [64,65].

3.6.2.2 Ankaful Junction disposal site (AJ)

This dumpsite is an old waste disposal site. Generally, the level of pollution recorded did not differ significantly from that of Esuekyir. The results are shown in Table 3.4.2. The levels were high, again the site also served as land reclamation site. The result from the site are as follows: The pH of the leachate ranged between 6.8 and 8.4, the temperature between 20.0 and 29 °C, the conductivity between 10200 and 49000 μs/cm, the total iron concentration between 20.0 and 8295.0 ppm, the phosphate between 150.3 and 1521.67 ppm, the nitrate-nitrogen between 2.0 and 736 ppm, and the nitrite-nitrogen between 1.2 and 97.5 ppm, the chloride between 6.0 and 1520.0ppm, the ammonium –nitrogen between 13 and 1140 ppm and the plate count between 10,000 and 90,000.

Again, compared with waste characteristics and leachate limit for various types of class II landfills as shown in Table 3.5, the levels measured are unacceptable except for pH and chloride. Once again, no attempt has been made to treat the (effluent) leachate from this site before getting to both surface and underground waters.

Then also, the overall mean, the standard deviation and the analysis of the variance (ANOVA) between-sample variation were also computed. From these computation the pH values at the Ankaful Junction had insignificant variation between the samples over the period. Meaning that the pH values did not differ greatly. However, between-sample variations for the other parameters were very significant. This again means that between-sample variation were very great over the period [64,65].

3.6.2.3 Adisadel Dump Site (OIL)

In many parts of the country, palm kernel oil production is very common. However, this process of oil extraction is always accompanied by the problem of disposing off the waste generated. After each operation, the waste is left at the scene of production and new one's added on every now and then. Unfortunately, these palm kernel oil-producing sites are close to drainage systems and leachate from their dumpsite enters directly unto these drains.

The data collected from this disposal site as shown in table 3.4.3, indicate the extent of leachate pollution. The pH ranged between 7.0 and 8.4, the temperature between 19.2 and 28.5 °C, the conductivity between 11,300 and 64,800 µs/cm, the total iron concentration between 1.6 an 60.0ppm, the sulphate concentration between 400 and 4214.0ppm, the dissolved organic matter between 150.3 and 1438.3ppm, the nitrate-nitrogen between 4.0 and 560.0ppm, the nitrite-nitrogen between 3.0 and 65.5ppm, the chloride levels between 100.0 and 1520ppm, the ammonium nitrogen between 13.0 and 480 ppm and the plate count between 40,000 and above10^6.

Except for pH and chloride, all the parameters measured recorded higher concentration levels when compared with values of waste characteristics and leachate limit for the various landfills (Class II) (Table 3.5).

Then also, the overall mean, the standard deviation and the analysis of the variance (ANOVA) between-sample variation were also computed. From these computation the pH values at the Adisadel dumpsite had insignificant variation between the samples over the period. Meaning that the pH values did not differ greatly. However, between-sample variation for the other parameters was very significant. This again means that between-sample variation were very great over the period [64,65].

3.6.2.4 The Main Disposal Site (MS) the Nkanfoa site

The Nkanfoa site is the main solid-waste disposal site of the Cape Coast municipal assembly. It is made up of a big dumpsite occupying an extensive area of about 500m^2 in a valley where run-offs converge after each rainfall event. This dumpsite is biggest in the municipality. The disposal site, supposedly a landfill site is indeed no where near the status of a properly managed landfill. Solid wastes are just dumped there anyhow, and after so much waste has gathered a bulldozer goes over it to reduce its volume. After a day or two, the wastes are burnt, (with the view to reduce the volume) even though it is not an incinerator. At the moment the whole area stinks and the non-biodegradable materials are scattered around with quantum of numerous flies and rodents hovering all over the place making life within the immediate environs unbearable.

The data collected from this disposal site as shown in table 3.4.4 indicate that this was the most polluted site of the four under investigation. This site takes about 90% of the total solid waste collected from the municipality hence its high pollution. The results shows that; the pH ranged between 7.9 and 10.5, the temperature between 20.3 and 29.0 °C, the conductivity between 234,200 and 199,900 µs/cm, the total iron concentration between 140.0 and 720 ppm, the sulphate concentration between 1400 and 21,600ppm, the phosphate concentration between 69.3 and 1423 ppm, the dissolved organic matter concentration between 972 and 3655.4 ppm, the nitrate-nitrogen concentration between 4.0 and 720 ppm, the nitrite-nitrogen concentration between 10.0 and 81.0ppm., the chloride concentration between 328 and 1520.0 ppm, the ammonium-nitrogen concentration between 13.0 and 667.0 ppm and the plate count values were far greater than 10×10^6.

The high levels of these parameters could be attributed partly to the improper burning of the waste, which results in the oxidation of most of the components. The use of the bulldozer in continuously turning the refuse over and over also enhances both aerobic and anaerobic decomposition of the refuse.

The problem here was that, once the disposal site was not well defined, there could be no proper scientific pollution impact assessment, and this poses a threat to both surface and underground waters. Again pH and chloride were within acceptable levels at the site.

Then also, the overall mean, the standard deviation and the analysis of the variance (ANOVA) between-sample variation were also computed. From these computation the pH values at the main disposal site had insignificant variation between the samples over the period. Meaning that the pH values did not differ greatly. However, between-sample variation for the other parameters was very significant. This again means that between-sample variation were very great over the period [64,65].

Table 3.6: **Rainfall figures and sampling dates (from March to June)**

Date	Amount of Rainfall (mm)	Sampling
13/03/99	1.6	Sampled
18/03/99	5.5	Not sampled
22/03/99	Trace	Sampled
26/03/99	Trace	Sampled
06/04/99	68.8	Not sampled
07/04/99	Nil	Sampled
10/04/99	Trace	Sampled
13/04/99	1.7	Not sampled
17/04/99	26.6	Not sampled
20/04/99	Nil	Sampled
10/05/99	2.1	Not sampled
11/05/99	Nil	Sampled
22/05/99	0.6	Sampled
30/05/99	62.4	Sampled
31/05/99	Trace	Sampled
06/06/99	16.3	Not sampled
08/06/99	Nil	Sampled
15/06/99	22.4	Not sampled
16/06/99	Nil	Sampled

Source: Geological Survey Department, Cape Coast, 1999.

There were no specific relationship between the rainfall volumes and the analyte concentration since there were other factors such as, the volume of solid waste added the previous day, when the Bulldozer went over the solid waste and the type of solid waste added at the time.

However, analyte concentrations were slightly higher when rainfall days were quite apart. This may be due to the fact that certain reaction had enough time to go to completion to allow for easy dissolution to be leached out. However, the sampling was done not necessarily the day of the rainfall but after a rainfall event as it appears in the table above.

3.7 VARIATION OF PARAMETERS WITH RAINFALL PATTERN

3.7.1 pH Values

There was no significant difference in the pH of all the sites studied (Tables 3.4.1-3.4.4). All of them ranged between 6.8 and 10.5, and were within waste characteristics and leachate limits for various types of landfills. This is shown in Fig. 3.2. However, the main landfill site at Nkanfoa recorded higher pH values than the other sites. This is a result of the fact that Nkanfoa site houses about 90% of the solid waste collected in the municipality. It was observed that when rainfall was heavy the pH reduced slightly, meaning that there was much dilution of the pollutant into the environment.

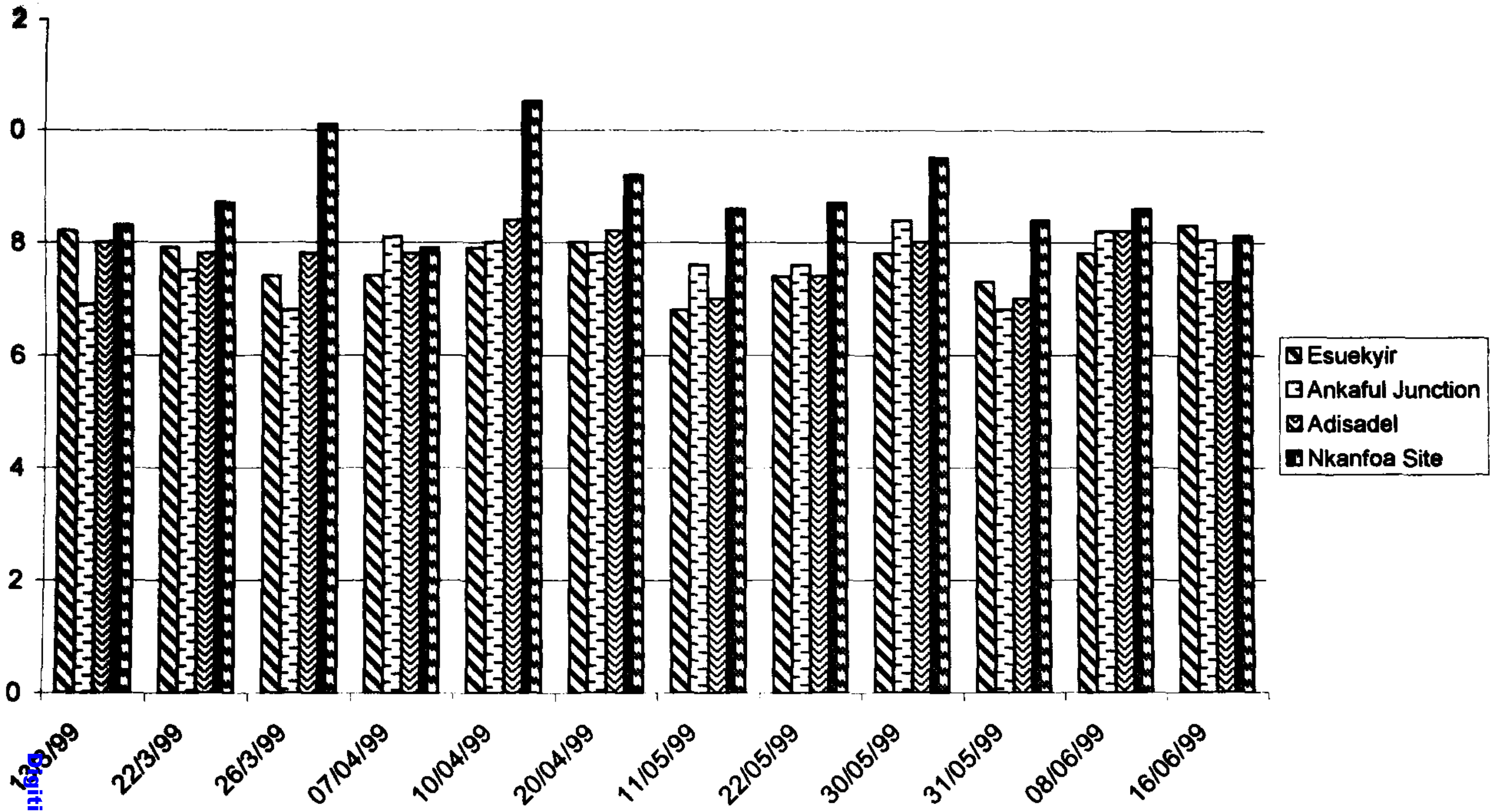

FIG. 3.2: pH VERSUS DATES OF COLLECTION

3.7.2 Conductivity

The conductivity values were higher than those of the waste characteristics and leachate limits for various types of landfills studied (Tables 3.4.1-3.4.4). The conductivity values ranged between (10,200 – 199,900µs/cm). The specific conductance at the Nkamfoa (main disposal site) was very high as shown in Fig.3.3 This is a result of the fact that Nkanfoa site houses about 90% of the solid waste collected in the municipality.

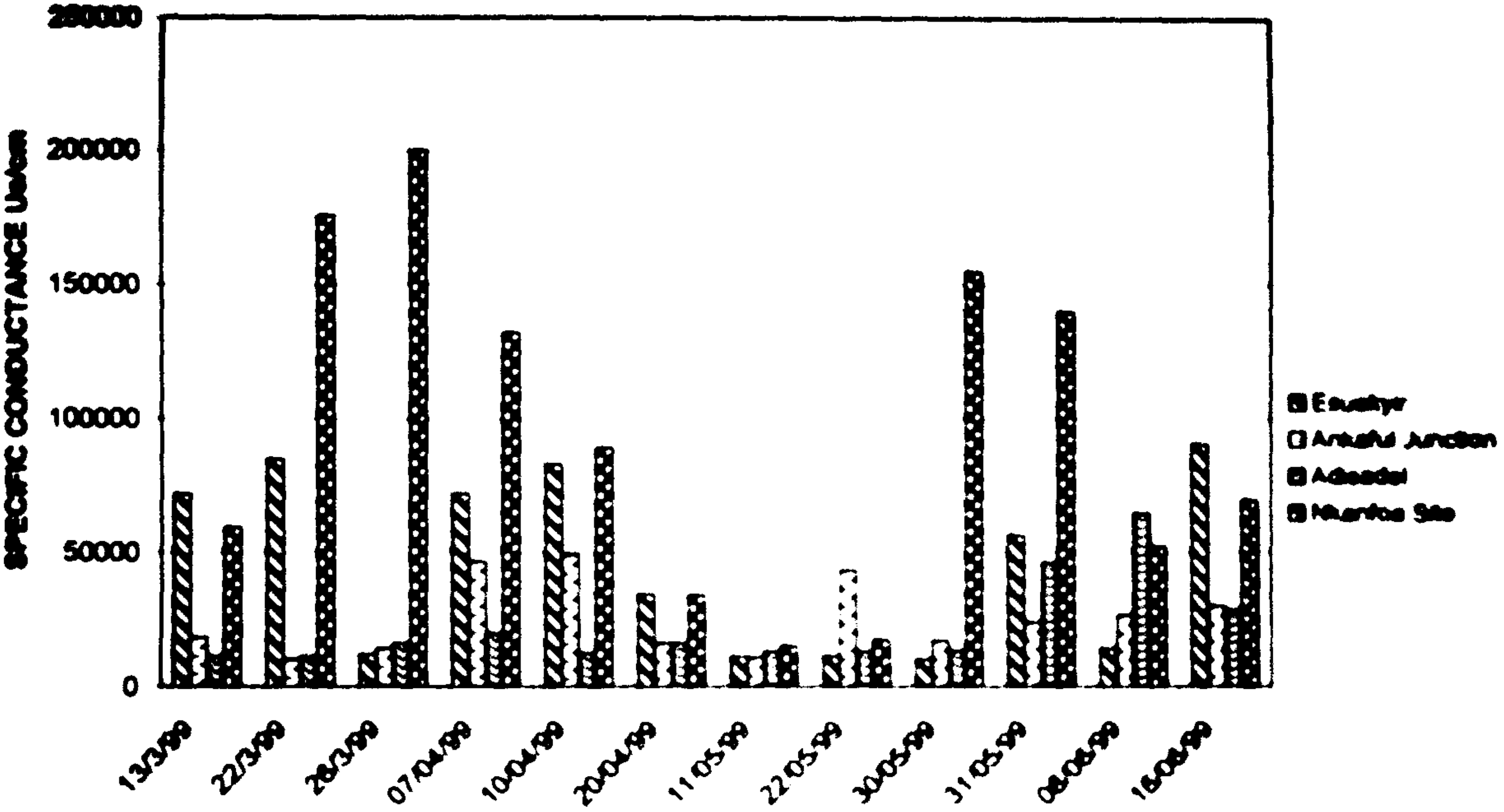

FIG. 3.3: GRAPH OF SPECIFIC CONDUCTANCE VERSUS DATES OF COLLECTION

3.7.3 Temperature

From the graph (Fig 3.4) of temperature versus days of collection, the temperature values were all less than 40°C, this allowed bacteria activities in all the studied area to pertain. Since all these temperature ranges fell below 40°C, the water environment serves as a good substrate environment for the growth, multiplication and survival of bacteria and therefore offers a good breeding site for bacteria related diseases. This is confirmed by the high plate count of coliforms found in the analyses (Tables 3.4.1-3.4.4). This shows that the leached wastewater contain high level of various types of pathogenic bacteria and when such leachate enter both ground and surface water they pose an increased high risk for water-borne diseases.

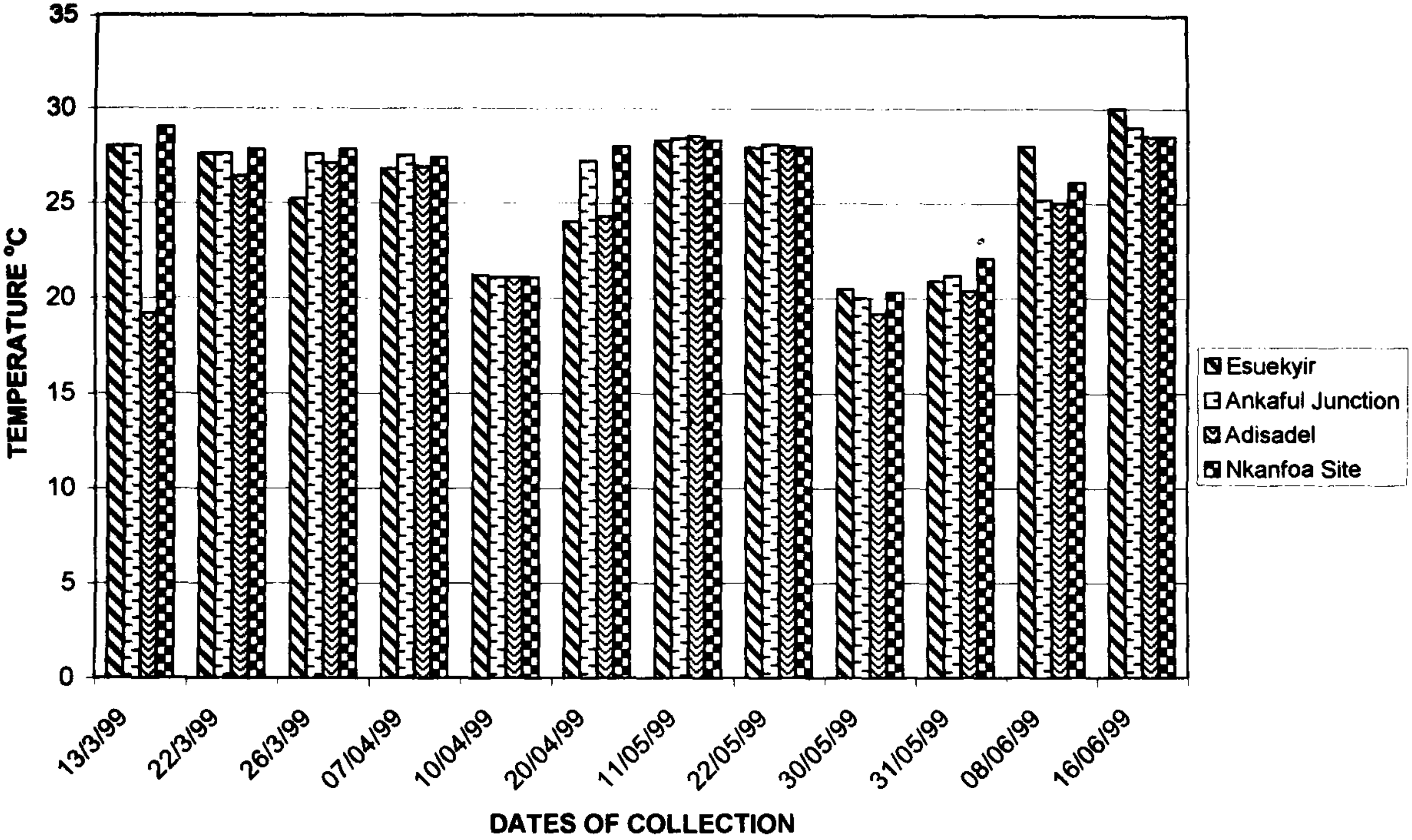

FIG. 3.4: GRAPH OF TEMPERATURE VERSUS DATES OF COLLECTION

3.7.4 Total Iron

The concentration of total iron generally decreased as the raining season advanced to the peak, due to much dilution by rainfall at the sites (Tables 3.4.1-3.4.4). From the graph (Fig 3.5) the peaks at the main disposal site (Nkanfoa site) were exceptionally higher than all other sites studied even though all the other sites showed high concentrations of iron. This is a result of the fact that Nkanfoa site houses about 90% of the solid waste collected in the municipality.

Then also, most of the refuse are first burnt before covered in the so-called landfills, thus allowing for the oxidation of the metal component of the refuse, and hastening the dissolution of the iron component. One other problem is that, the disposal system employed does not allow for sorting of the various components of the solid waste, at source, as being done elsewhere, in the developed countries. If sorted out properly, iron collection would boost the smelting industry since the steel industry now have equipment that uses scrap metals. Also, when refuse is collected together, the organic component aids the dissolution of the iron by forming soluble chelate compounds. This calls for the need to collect refuse in well-labelled bins. The rather high level at the Nkanfoa site in April may be due to the fact that, that day recorded the highest rainfall immediately after the dry season hence much would dissolved to be leached out.

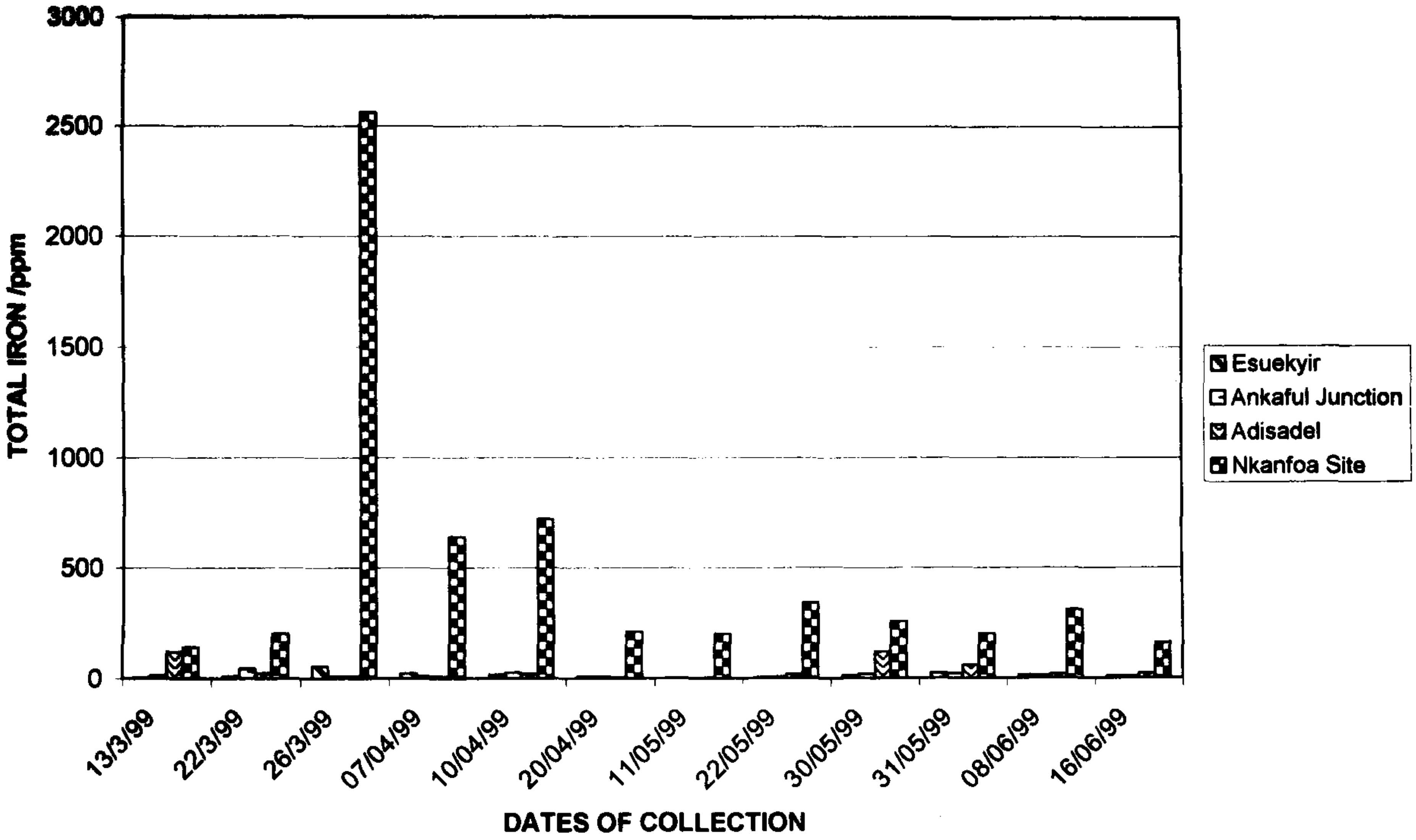

FIG. 3.5: GRAPH OF TOTAL IRON VERSUS DATES OF COLLECTION

3.7.5 Sulphate

It was observed From Fig.3.6, that the sulphate concentration generally decreased as the raining season advanced from March to June, due to much dilution by water at the various sites (Tables 3.4.1-3.4.4).

However, the concentrations at the main disposal site (MDS) were very high over 20,000ppm. This is a result of the fact that Nkanfoa site houses about 90% of the solid waste collected in the municipality. The levels were higher than the acceptable ones for waste characteristics and leachate limit for various landfills (Table 3.5) At this level, the sulphate could reach to both ground and surface waters through various run-offs and seepage mechanism. The increase in sulphate concentration could be attributed to both aerobic and anaerobic decomposition of the refuse.

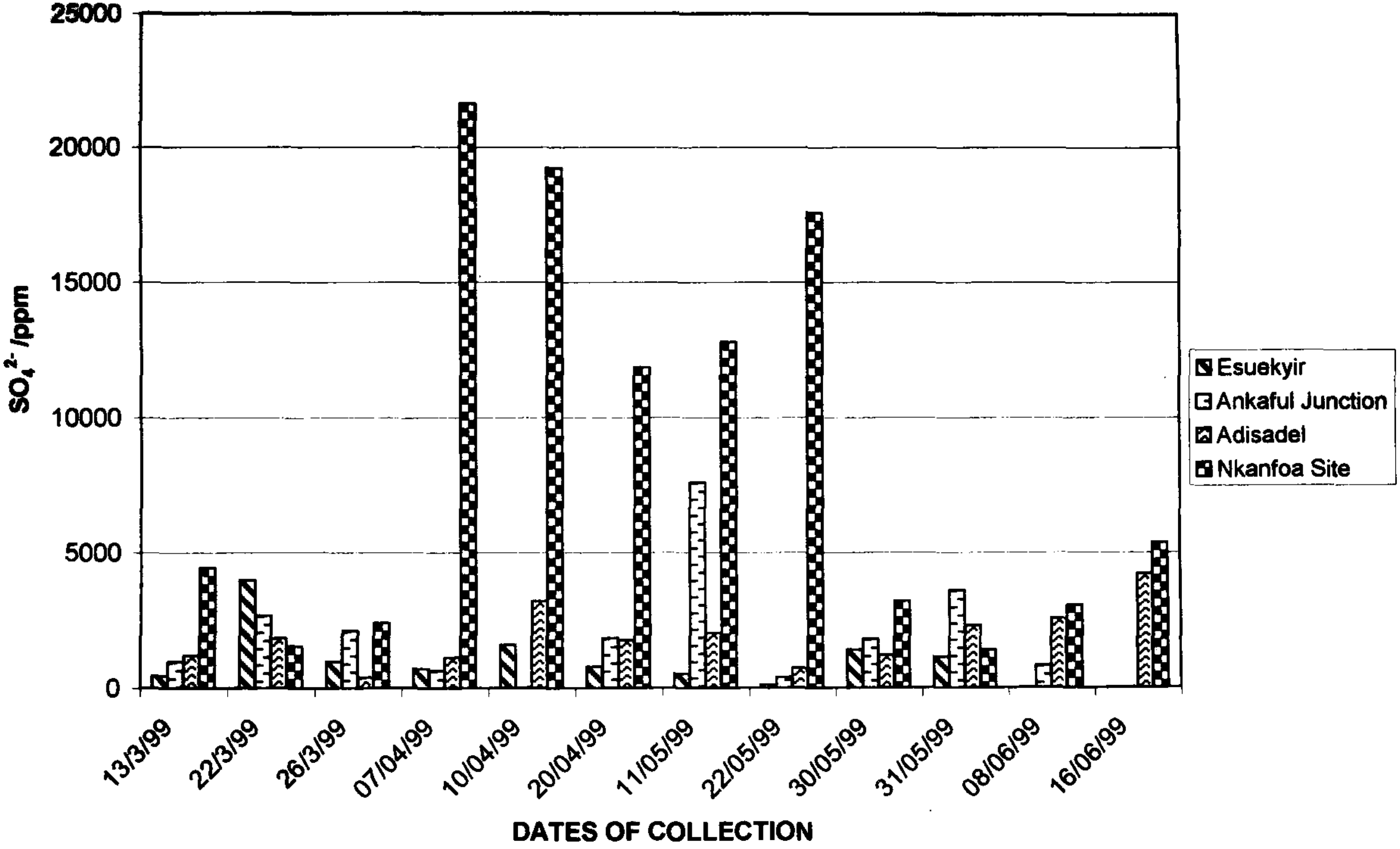

FIG. 3.6: GRAPH OF SO$_4^{2-}$ VERSUS DATES OF COLLECTION

3.7.6 Phosphate (PO_4^{3-})

The phosphate concentration generally increased over the period (Tables 3.4.1-3.4.4). Again, from the graph (Fig. 3.7), the concentration of phosphate at the main disposal site (MDS) was very high, over 1400ppm, which were far higher as compared with waste characteristics and leachate limit for various landfills (Table 3.5). This is a result of the fact that the Nkanfoa site houses about 90% of the solid waste collected in the municipality.

The rather high phosphate content is of much concern, since phosphates could be exchange for arsenic (very toxic substance) in the soil, which has a higher potential of polluting both surface and ground waters. This also can cause algal bloom that aids eutrophication, leading to the killing of aquatic ecosystems.

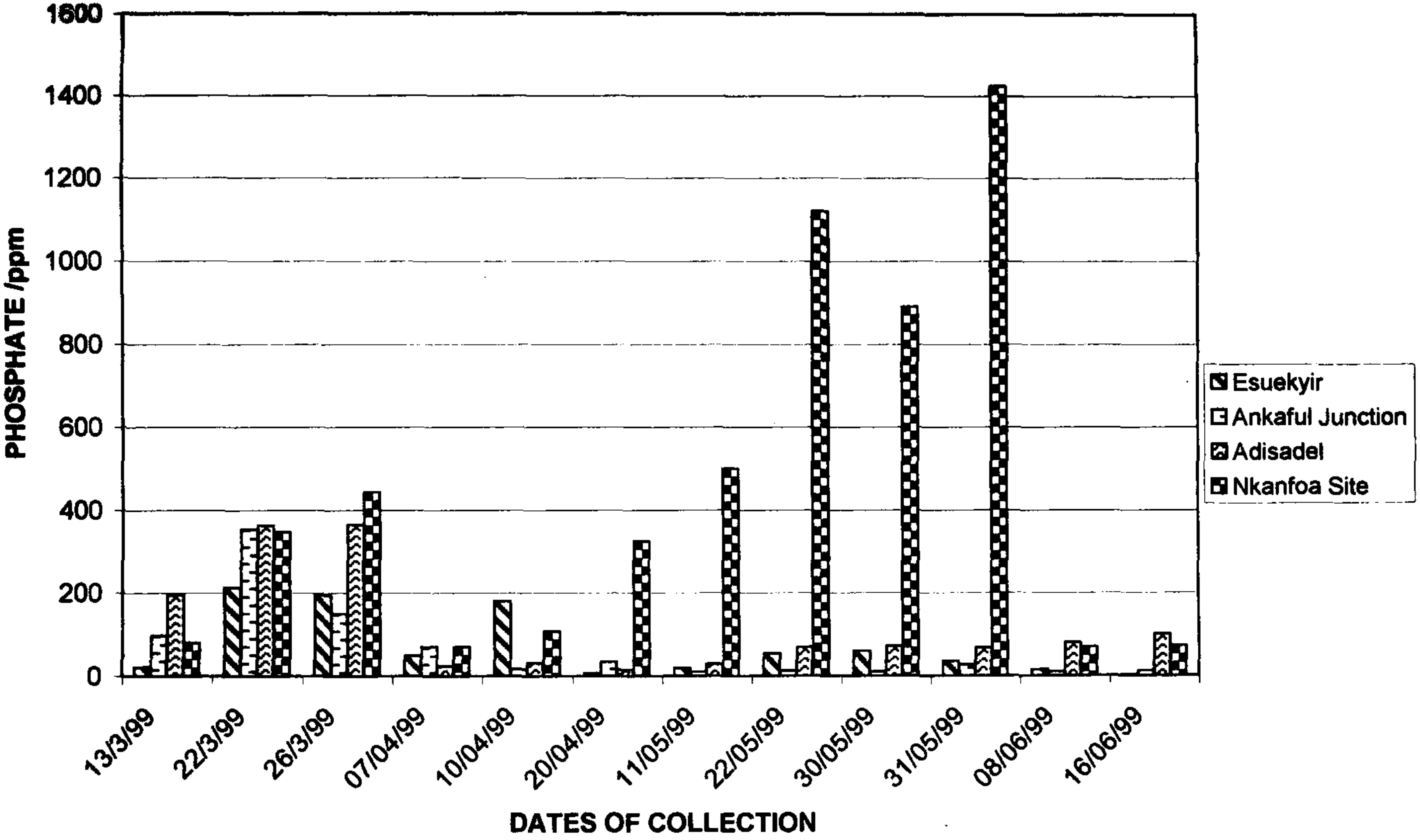

FIG. 3.7: GRAPH OF PHOSPHATE VERSUS DATES OF COLLECTION

3.7.7 Dissolved Organic Matter (DOM)

The levels of the Dissolved Organic Matter (DOM) were higher than that of waste characteristics and leachate limits for various landfills (Tables 3.4.1-3.4.4). The rather high level is due to the high proportion of organic (puttrescible) component of the refuse. About 85% by wet weight of the total refuse analyzed in this work were made up of organic materials. This organic component served as source of food for rodents and houseflies. As a result of the fact that, the waste were not covered on time, a great deal of houseflies were found all over the disposal vicinity. If immediate steps are not taken, the situation could be explosive. Table 3.4

The increase in the level of DOM at the disposal site after each rainfall event implied that, much of the decomposed organic matter were being washed gradually into the environment, both to surface and ground waters (Fig. 3.8). Again the Nkanfoa site recorded higher levels. This is a result of the fact that the Nkanfoa site houses about 90% of the solid waste collected in the municipality.

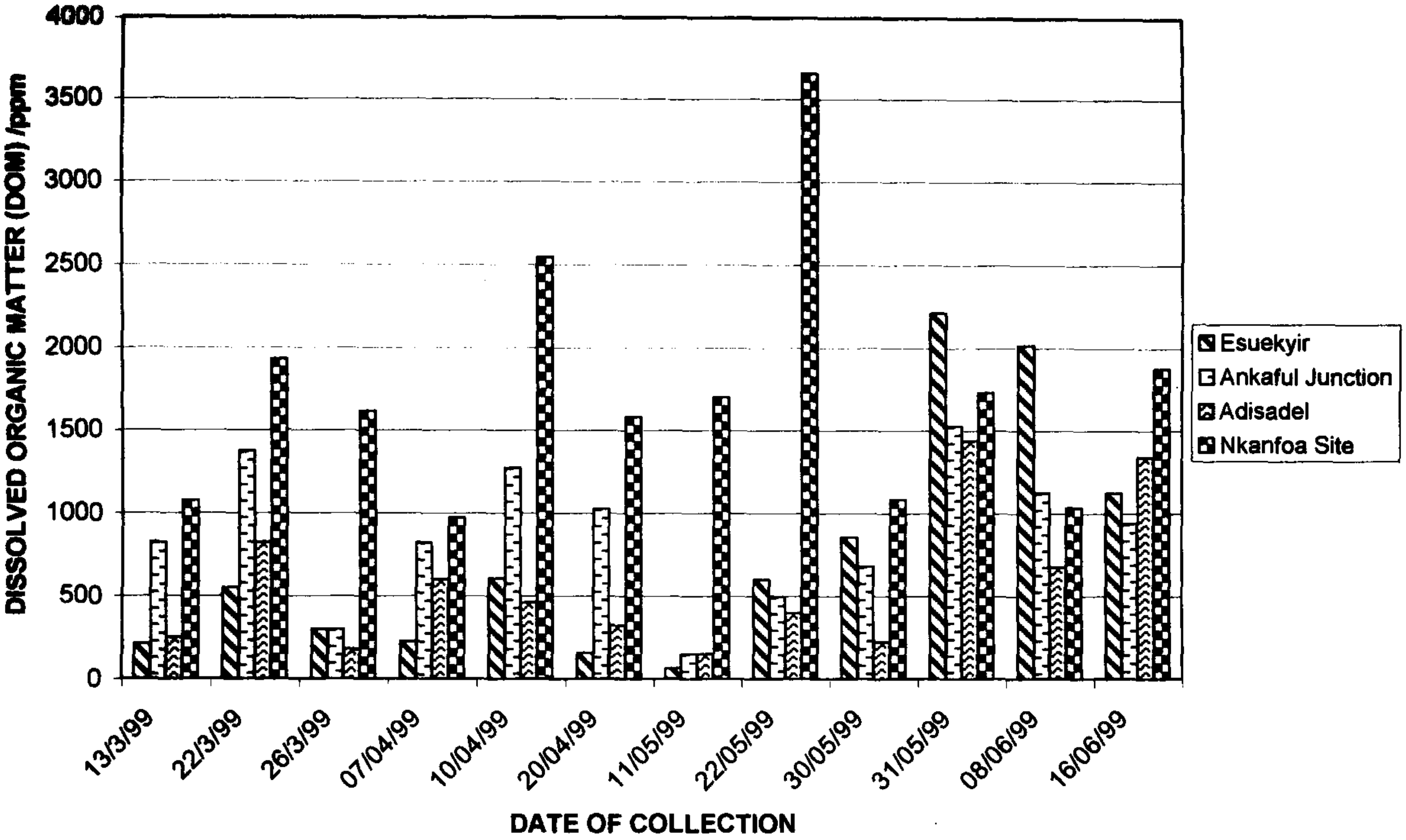

FIG. 3.8: GRAPH OF DOM VERSUS DATE OF COLLECTION

3.7.8 Nitrate – (NO_3^-)

The rather high levels of nitrate-nitrogen recorded were an indication of the decomposition processes of the refuse at the various dumpsites (Tables 3.4.1-3.4.4). From fig. 3.9, nitrate levels were as high as above 1500ppm. The high levels were found at the Ankaful Junction site and this might be due to the fact that the area in a way also served as a place of convenience. The microbial activities will therefore be on the increase hence an increase in both aerobic and anaerobic decomposition of the refuse as well as those from the atmosphere and other sources.

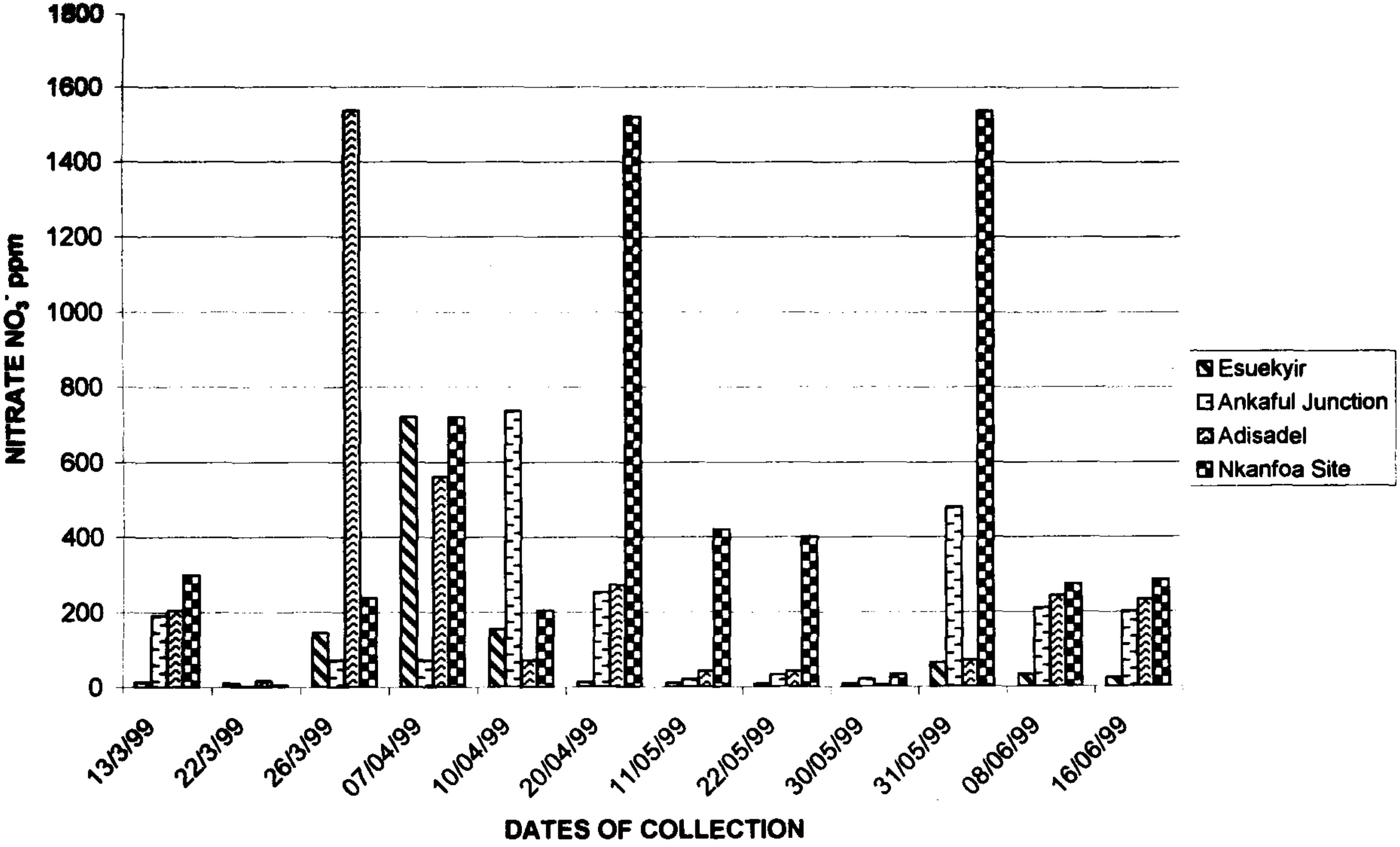

FIG. 3.9: GRAPH OF NITRATE VERSUS DATES OF COLLECTION

3.7.9 Nitrite – (NO$_2^-$)

From Fig. 3.10, the nitrate concentration with rainfall pattern did not show any clear pattern but with the main disposal site (MDS) there was a general increase in nitrite concentration as the raining season advanced from March to May.

The nitrite-nitrogen is usually an oxidation product of ammonia-nitrogen, specifically a reduction product of nitrate nitrogen.

$$\text{Ammonia} \rightleftarrows \text{Nitrite} \overset{\text{oxidation}}{\underset{\text{reduction}}{\rightleftarrows}} \text{Nitrate}$$

The presence of the nitrite therefore varies with their amount, the source and its relationship with other constituent of the solid waste, for example, the relative magnitude of ammonia and nitrate-nitrogen present. Since nitrite-nitrogen is rather rapidly and easily converted to nitrate, its presence in concentration greater than a few thousand of a milligram per litre is generally indicative of active (bacterial) biological process in wastes [66,67]. The high levels were found at the Ankaful Junction site and this might be due to the fact that the area in a way also served as a place of convenience. With this microbial activities will be on the increase hence the higher levels recorded.

Also the levels recorded in this analysis were much higher than that of waste characteristics and leachate limits for the various landfills (Tables 3.4.1-3.4.4). This implies that, these disposal sites under study were highly polluted. They would then produce adverse effect on the environment.

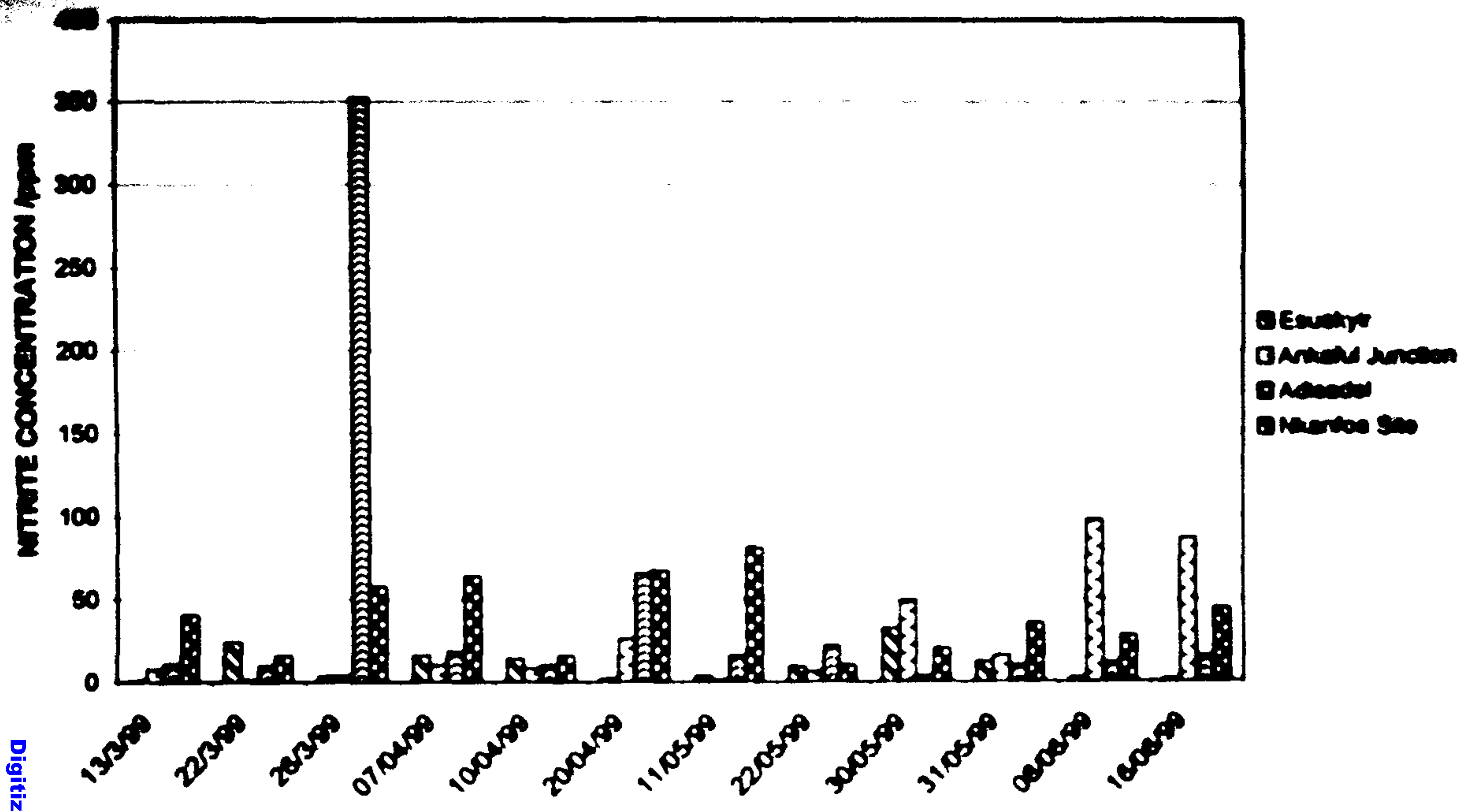

FIG. 3.10: GRAPH OF NITRITE CONCENTRATION VERSUS DATES OF COLLECTION

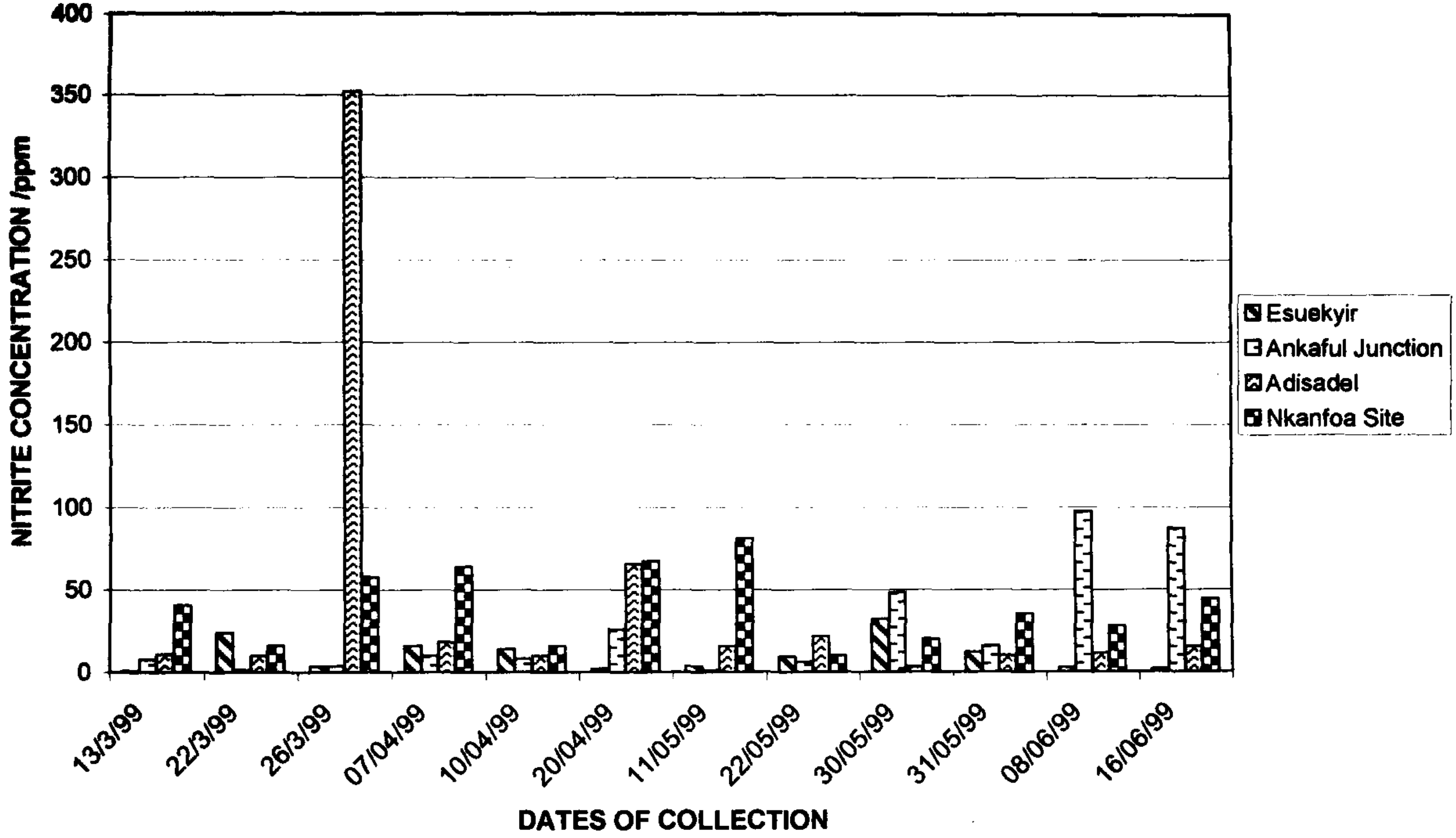

FIG. 3.10: GRAPH OF NITRITE CONCENTRATION VERSUS DATES OF COLLECTION

3.7.10 Ammonium (NH_4^+)

The graph of ammonium versus days of collection is shown on fig. 3.11. The levels were high over 1140ppm (Tables 3.4.1-3.4.4). These are higher than the waste characteristics and leachate limit for various types of landfills. Ammonia gas is released when organic matter containing proteins or some other nitrogenous compounds are decomposed by micro-organisms. The leachate from domestic solid waste dumps are often high in ammonia (especially when the organic waste is very fresh), and hence, must not be allowed to pollute streams. Ammonia gas is emitted in large quantities from intensive livestock farms. It is a contributor to acidification of lakes and rivers since it can be oxidised to nitric acid; this phenomenon appears to be a serious problem in the Netherlands where livestock husbandry is particularly intensive. This is one of the reasons why the Dutch government has placed restrictions on the expansion of such farm [18]. The high levels were found at the Ankaful Junction site and this might be due to the fact that the area in a way also served as a place of convenience. With this microbial activities will be on the increase hence the higher levels recorded.

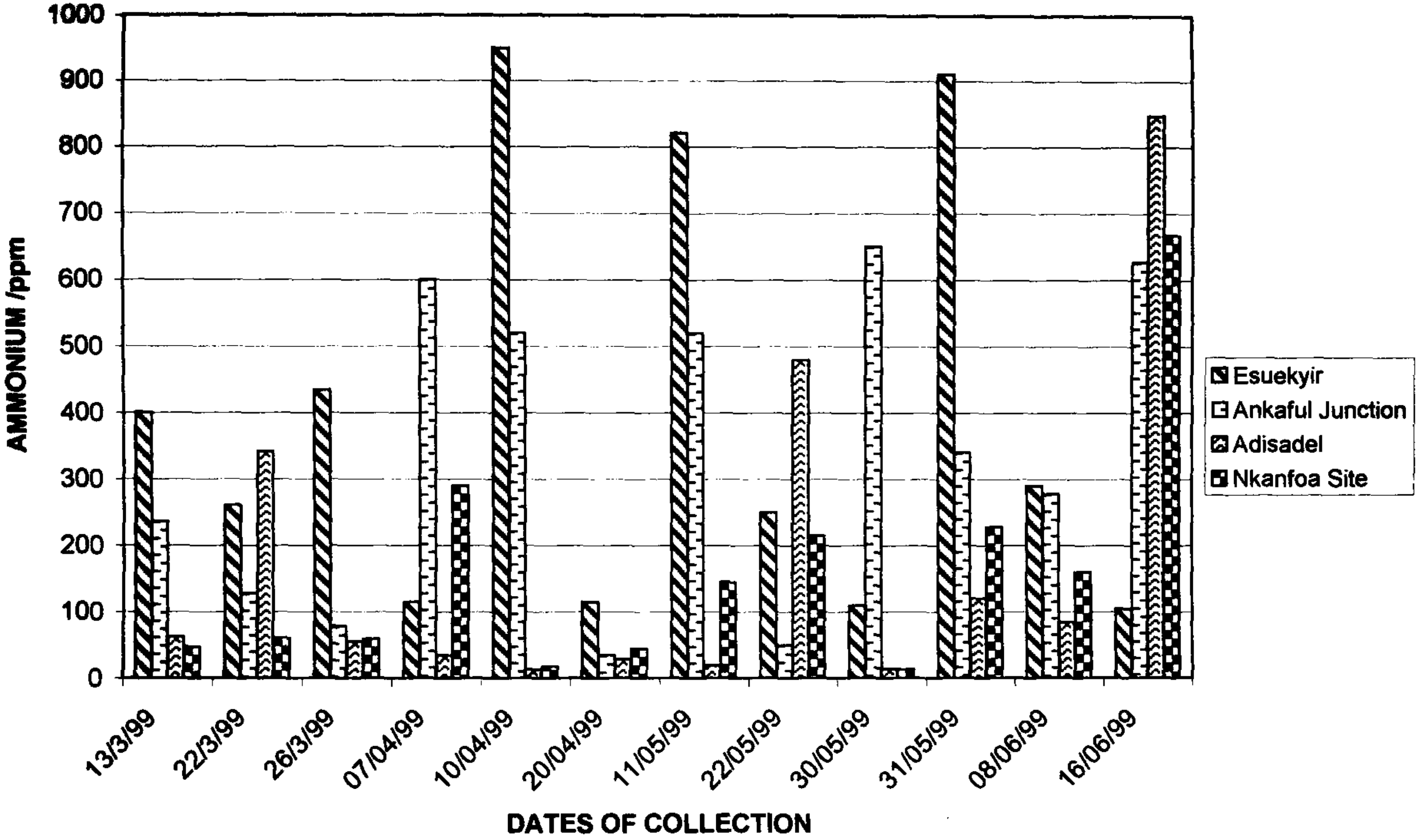

FIG. 3.11: GRAPH OF AMMONIUM VERSUS DATES OF COLLECTION

3.7.11 Chloride (Cl⁻)

The chloride concentrations were rather low as compared with the waste characteristics and leachate limits for various types of landfill. Their values were all less than 2000ppm (Tables 3.4.1-3. 4.4). The rather low levels of chloride suggest that the rate of leaching of chlorides from the dumpsite into the environment after each rainfall event is rather high. This evidence is shown in Table 3.5 as well as fig. 3.12.

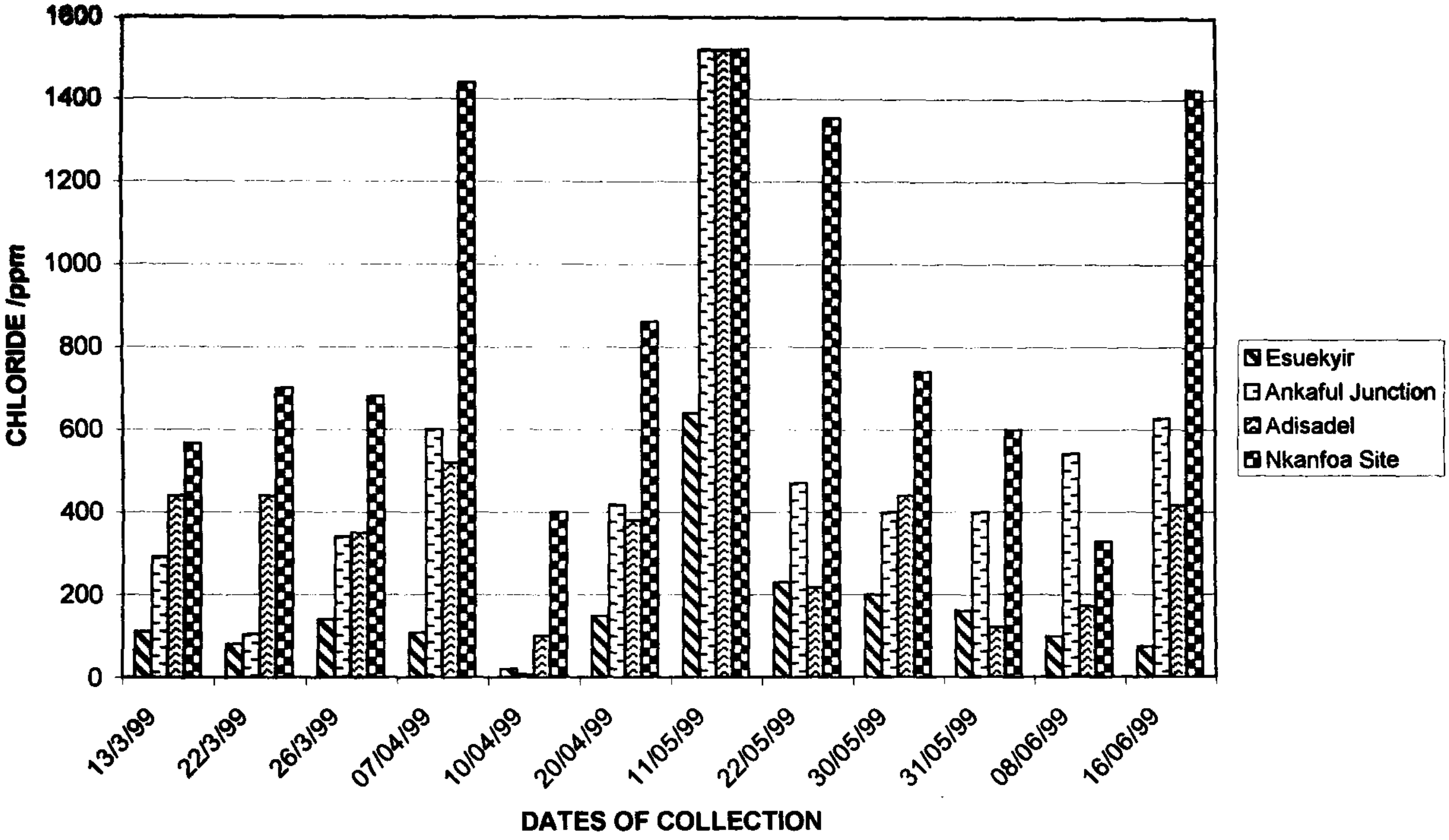

FIG. 3.12: GRAPH OF CHLORIDE VERSUS DATES OF COLLECTION

3.7.12 Total Bacteria Count

The results obtained for total bacteria count during the experiment ranged between 10,000 and 3.8 × 10^6. The high bacteria counts correspond to definite evidence to heavy bacteria and sewage pollution. The data from the main disposal site had high levels of bacteria count. Again the Nkanfoa site recorded higher levels. This is as a result of the fact that the Nkanfoa site houses about 90% of the solid waste collected in the municipality. This is shown in Tables 3.4.1-3.4.4 as well as fig. 3.13.

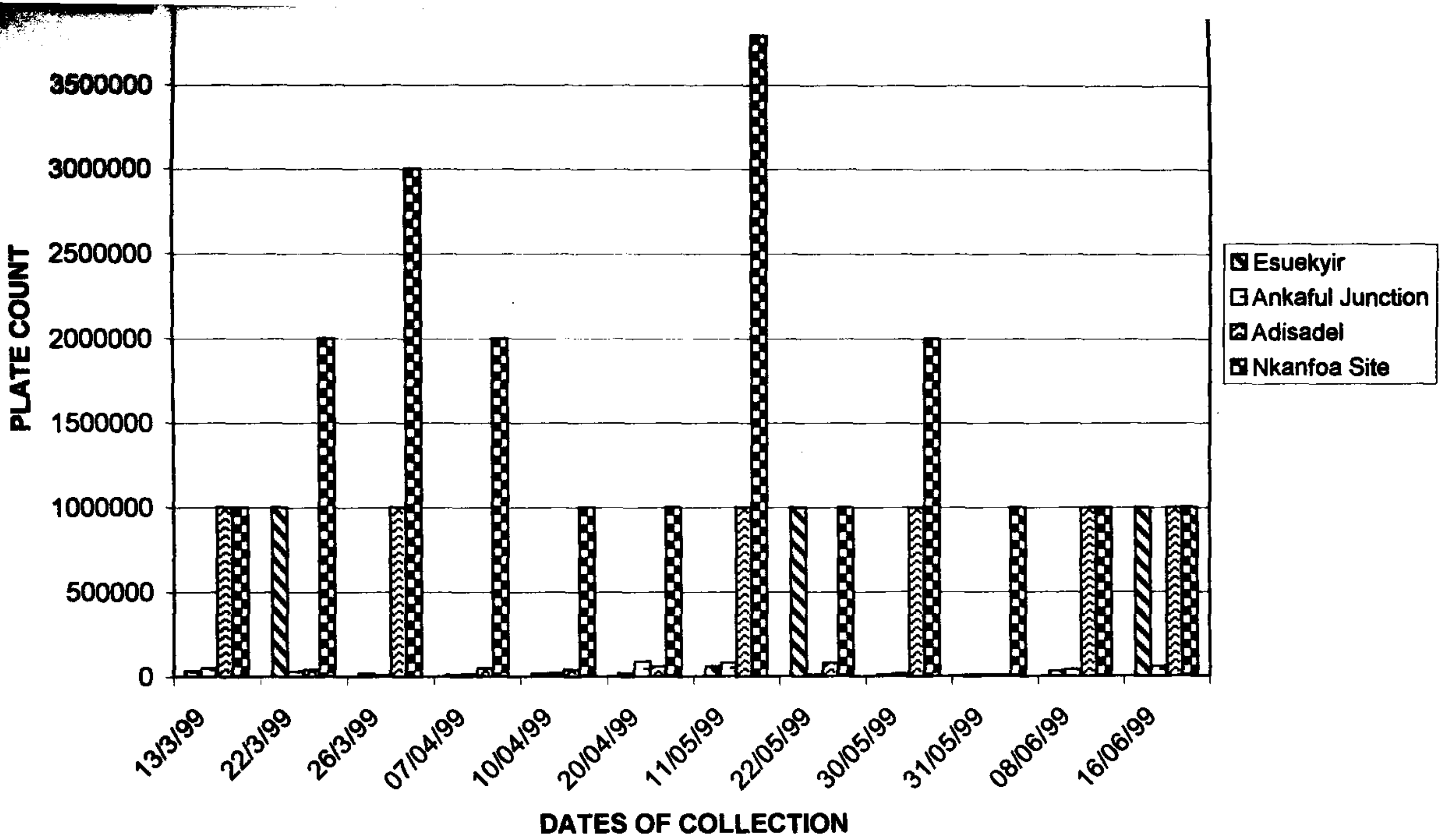

FIG. 3.13: GRAPH OF PLATE COUNT VERSUS DATES OF COLLECTION

CHAPTER FOUR

4.0 OBSERVATIONS RECOMMENDATIONS AND CONCLUSIONS

We are reminded constantly of various aspect of this rapidly growing problem of environmental pollution and have become more and more conscious of the importance of the environment in a world, which is being drastically changed by man. But the problem of environmental pollution is already with us and it is everyone's problem since it affects all of us.

4.1 PRESENT SOLID WASTE SITUATION IN THE CAPE COAST MUNICIPALITY

The study showed that out of the 2,847 tonnes/month of refuse generated in the municipality, about 2,031 tonnes/month that is about 72% of the solid waste produced is effectively collected. The study also revealed that, containers for collection of solid waste was either inadequate or improperly placed, and this has resulted in one way or the other in the;

i. creation of small open dumps in the municipality and indiscriminate burning of refuse in the city.

ii. waste from the saw-mills are not collected by the municipal assembly.

iii. wastes from palm-kennel oil production are also not catered for by the municipal assembly, hence, they are just left to rot by themselves.

iv. most potential wet lands are being used as solid waste disposal site and as result render them as wasteland.

v. concerning the beaches, it was found that the sea waves brought back dumped solid waste into the sea, making the beach not nice to see.

v. delay in picking up the filled containers sometimes allows for solid waste dumpsite to be created at the container site. The municipal assembly has no well-defined final refuse disposal site as is either an incinerator or sanitary landfill. This make solid waste management in the municipality very uncoordinated to deal with other problems associated with refuse disposal.

However, these problems might not be peculiar to the Cape Coast municipality alone. We therefore see it as a national problem. With other refuse evaluation done at other places in Ghana, leachate analyses were not done. This may be that, they do not see the need and relevance of leachate analysis.

4.2 HAZARDS OF REFUSE MISMANAGEMENT

The amount of domestic refuse collected varies widely, with factors such as the standard of living and eating habits of the inhabitants. Despite this, large volumes of refuse are produced and form an enormous public health and aesthetic problem in most cities of developing countries. Large dumps of refuse can be seen in many cities and these provide support for communities of people (street children), goats, rats and dogs who scavenge on them [68].

A variety of environmental hazards are associated with mishandling or mismanagement of refuse. Uncovered piles of rotting refuse will always encourage breeding of flies which play a role in the transmission of diseases. Piles of refuse will also contain mosquito-breeding sites where pools of rainwater formed in cans, discarded car tyres, etc. The mosquitos, *Aedes aegypti* will breed under these conditions and may transmit dengue, yellow fever and arboviral infections. Rats will also breed and live in and around refuse. They may promote or transmit a variety of diseases including plague, leptospirosis, flea-borne typhus, rat bite fever and *Salmonellosis* [69].

Of special interest from public health viewpoint is the control of seepage from tips. Over half the rain falling on a tip will probably be absorbed or evaporated. The remainder will flow out of the base and this leachate may contain a high concentration of bacteria (up to 10^8-coliforms/100 mL), BOD (up to 30000 mg/L), nitrogen, sulphides and chlorides. This leachate contains all the toxic or poisonous substances found already in the tip. The quantity of the leachate tends to reduce, as the tip ages. The danger to ground and surface water abstraction points depend completely on the local topography, geology and climate [70].

4.3 LEACHATE POLLUTIONS

"We believe all citizens have an inherent right to the enjoyment of pure and uncontaminated air, water and soil; that this right should be regarded as belonging to whole community; that no one should be allowed to trespass upon it by his carelessness or his avarice or even his ignorance." This was the resolution of, Massachusetts Board of Health [71]. Water represents one of the basic human needs, and in these days of widespread water pollution, we easily forget the simple joys of a clean environment. Do we sense a world that could be in the descriptive fragments written by early observers of rivers familiar to most of us. In 1524, Gioranni de Veraazano entered the Hidson River and was enchanted that "the trees exhaled the sweetest odors". Then in the nineteenth century, a resident of Albany could still describe the Hidson River as "clear as crystal and fresh as miul" [71].

We in Cape Coast and for that matter Ghana cannot boast of the water resources as being described here by Gioranni de Verrazano as we have virtually polluted almost all our water resources. It was observed from the leachate analysis that, effluents from refuse disposal site carry high concentrational levels of nutrients as well as toxic substances, as shown in table 3.1.1.

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It would be seen clearly that these solid waste disposal sites serve as "point sources"[1] to our water resources. The results also show, that final solid waste disposal sites are created without due attention given to leachate pollution. We have observed from this analysis that, apart from chloride concentrational levels, all the other eleven parameters studied had higher levels compared with waste characteristics and leachate limits for various types of landfills. There is no doubt that leachate pollution for both ground and surface water is inevitable if solid waste is not properly handled.

4.4 RECOMMENDATION

There are various solid waste disposal methods such as;

i. Composting
ii. Incineration (Thermal disposal)
iii. Sanitary landfills.
iv. Recycling

4.4.1 Composting

Composting can be considered with initial separation and biological decomposition of the organic constituent of solid waste under controlled conditions.

In doing this, properly labelled waste bins are placed in public places to ensure that domestic solid waste materials are collected in a grouped manner; in which case, bottles, paper and biological waste, metals, etc., are put into separate bins. However, due to our culture the cost in design, and the cost in the provision of separate bins, this method might not be applicable now but may be, some time later.

---

[1] "Point sources" has been defined as any pipe, ditch, channel, tuned vessel, feed lot, vehicle, or any thing else that could convey waste water.

4.4.2 Incineration

A sound incineration procedure can reduce the bulk volume by up to 90%. Thus, about 10% of the materials still have to be deposited in landfills. Problems associated with incinerators are concerned mostly with emissions of dioxin and furan. Waste incinerators and crematoria produce measurable quantities of dioxins – the former from chlorinated materials in the waste stream and the latter from plastic coffins. Fires involving electrical equipment containing PCBs cause the formation of dibenzofurans in particular.

Traces of dioxin and dibenzofurans are present nearly everywhere and they originate almost entirely from human activities. They bio-accumulate and are known to contaminate foodstuffs and both human and cow's milk. The importance of widespread dioxin contamination in health terms is uncertain, but it is known that toxic dioxin TCDD causes cancer, birth defects in laboratory studies and chlorocane, a painful unsightly skin disease [18].

Incinerators therefore, require sophisticated air pollutional control equipment. Capital expenditure notwithstanding other problems is high which is a major consideration in justifying the choice of the incineration method.

4.4.3 Sanitary Landfills

Landfills are advantageous (to developing countries) as the sole waste disposal method because the technology is rather simple. Furthermore, short-term operational considerations and the low associated cost, depending on the landfill's location, size and ages are also important.

Most developing countries have in a way adapted the landfill waste disposal method, however if these methods are not done properly the environment is put into greater danger. To protect the subsurface and the ground water, landfills are equipped with leachate collection system as shown in fig. 4.0 and fig. 4.2. With this system the leachate are pumped directly into a treatment facility. They are therefore treated before discharging into the environment.

The leachate is either pumped directly to a treatment facility or it is pumped by pressurized or non-pressurized lines, or transported by a tanker, to a municipal treatment plant. In any case, the leachate tanks and transfer lines outside of the landfill area should be buried below the soil to avoid settling and gas accumulation.

In-depth description of the operations of a class II landfill is given below. Class II landfills are used for the disposal of waste with higher organic content and a higher leaching rate. These landfills are subjected to higher regulatory standards. I believe that sanitary landfill seems the best option [63].

4.4.3.1 Composite Liner

The term composite liner refers to the layering of different lining materials that are in direct contact with each other. Composite liners are required for Class II landfills. Construction of these systems can be characterised as follows;

- at the base of the planned landfill and on top of the geological barrier, three thin clay layers with a combined minimal thickness of 0.75m are installed and compacted to attain a permeability (k) of $\leq 1 \times 10^{-10}$ m/S. (k = hydraulic conductivity in m/S velocity).
- the clay layer is covered with synthetic liner (preferred material; High Density polyethylene[HDPE]) with a minimum thickness of 2.5 mm. This synthetic liner

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- the clay layer is covered with synthetic liner (preferred material; High Density polyethylene[HDPE]) with a minimum thickness of 2.5 mm. This synthetic liner

is then covered and protected with a layer of fine sand or similar material. On top of that layer, a drainage layer made of gravel or crushed stones is applied ($k \leq 1x10^{-3}$ m/S), into which drainage pipes are laid for leachate collection.

- The final base layer consists of a topsoil layer 1.0 m in thickness. Figure 5.0 schematically illustrates a composite liner according to the technical guidance of municipal solid waste (TG MSW).

The TG MSW requires that during the operating phase of the landfill, each layer of waste must be covered with a surface liner. The lining system for Class II landfills are presented in Figure 4.0. After closure, the appropriate final cap has to be installed.

The final landfill cap should meet the following requirements;

- 0.5 m buffer layer.
- 0.3 gas channel (only when gas is generated) (e.g. gravel).
- 0.5 m impermeable layer ($k \leq 1x10^{-9}$ m/S) (e.g. clay).
- 2.5 mm synthetic liner (e.g. HDPE).
- 0.3 m drainage layer ($k \leq 1x10^{-3}$ m/S) including, if necessary, leachate collection systems with assess for monitoring and cleaning.
- 1.0 m loam, which should be planted in a manner to protect the cover from frost and root damage. Water and wind erosion should be prevented, and minimisation of infiltration should be a priority.

The final cover should have a top slope greater than 5% after the settling of the waste has subsided [63].

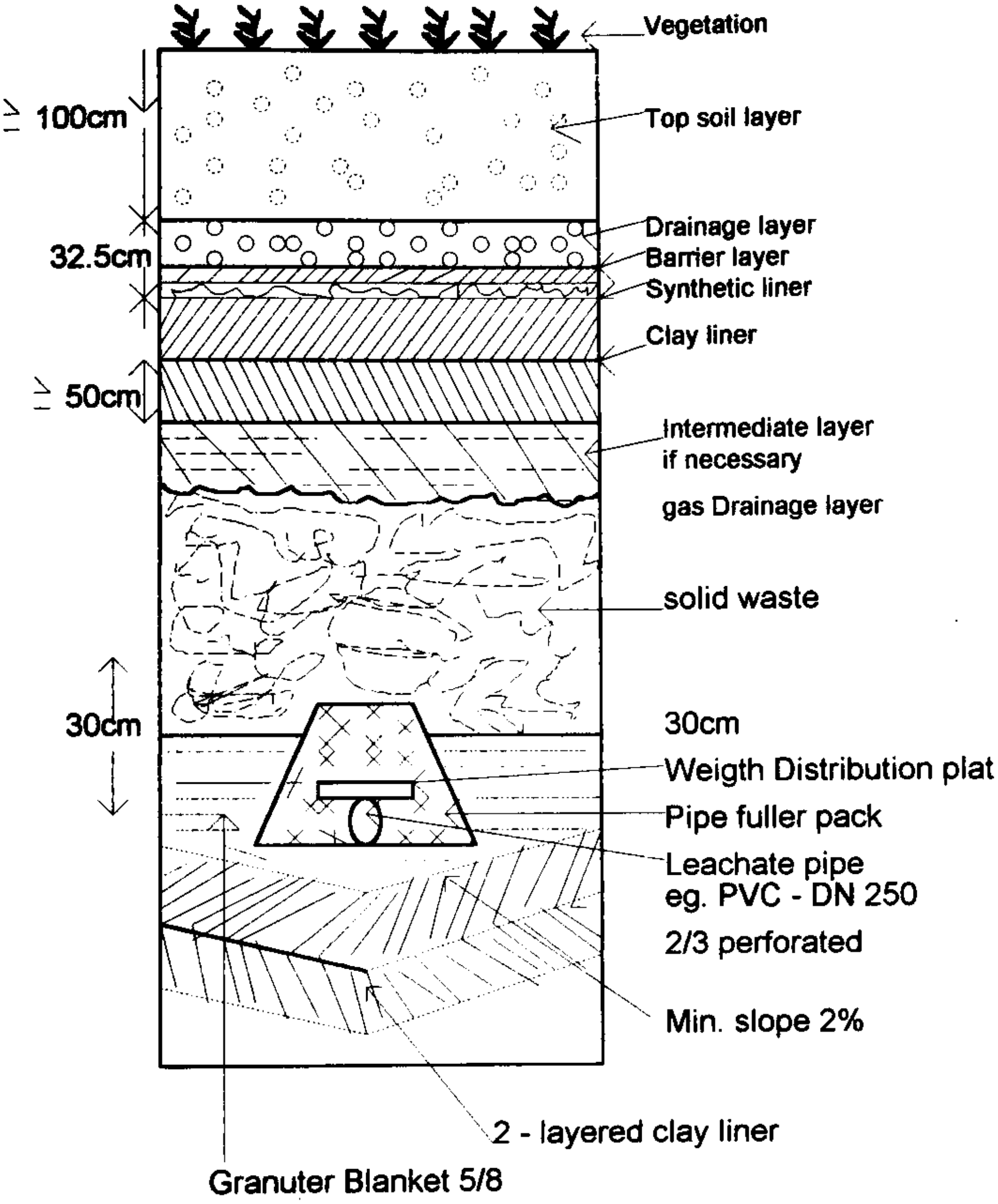

Fig. 4.0 Schematic of a composite liner according to municipal solid waste (MSW) guidance [63].

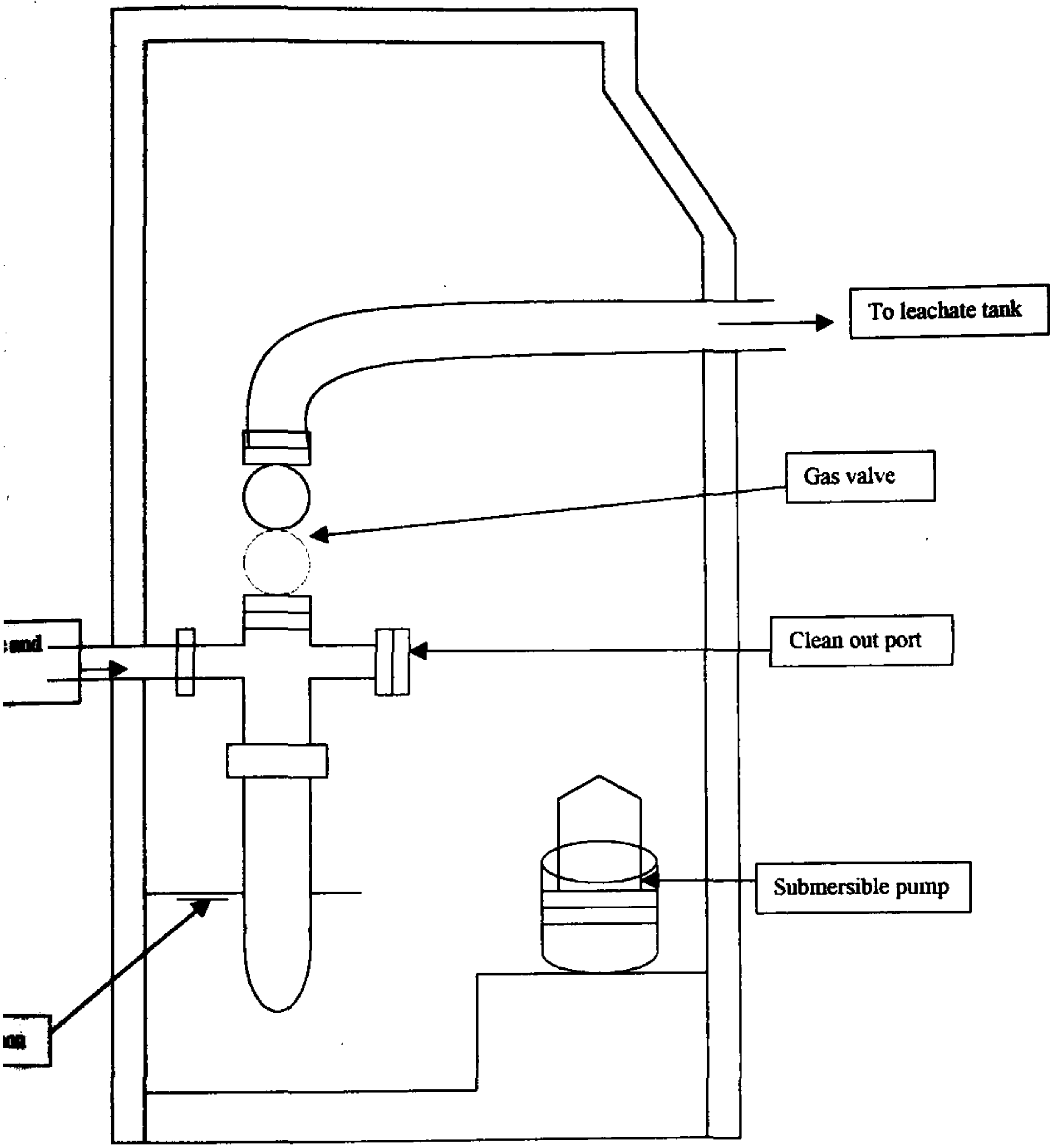

Fig.4.1. Leachate Collection Manhole with Submersible Pump [63]

The drainpipes are either directly placed on the liner or on a pipe bed when greater stability is needed.

For the proper maintenance of buried pipes, periodic cleaning of the drain pipe is necessary .To ensure the continued drainage of leachate in case a section of the pipe becomes clogged, a sum pit should be provided for the insertion of a submersible pump. This is shown in Fig. 4.1.

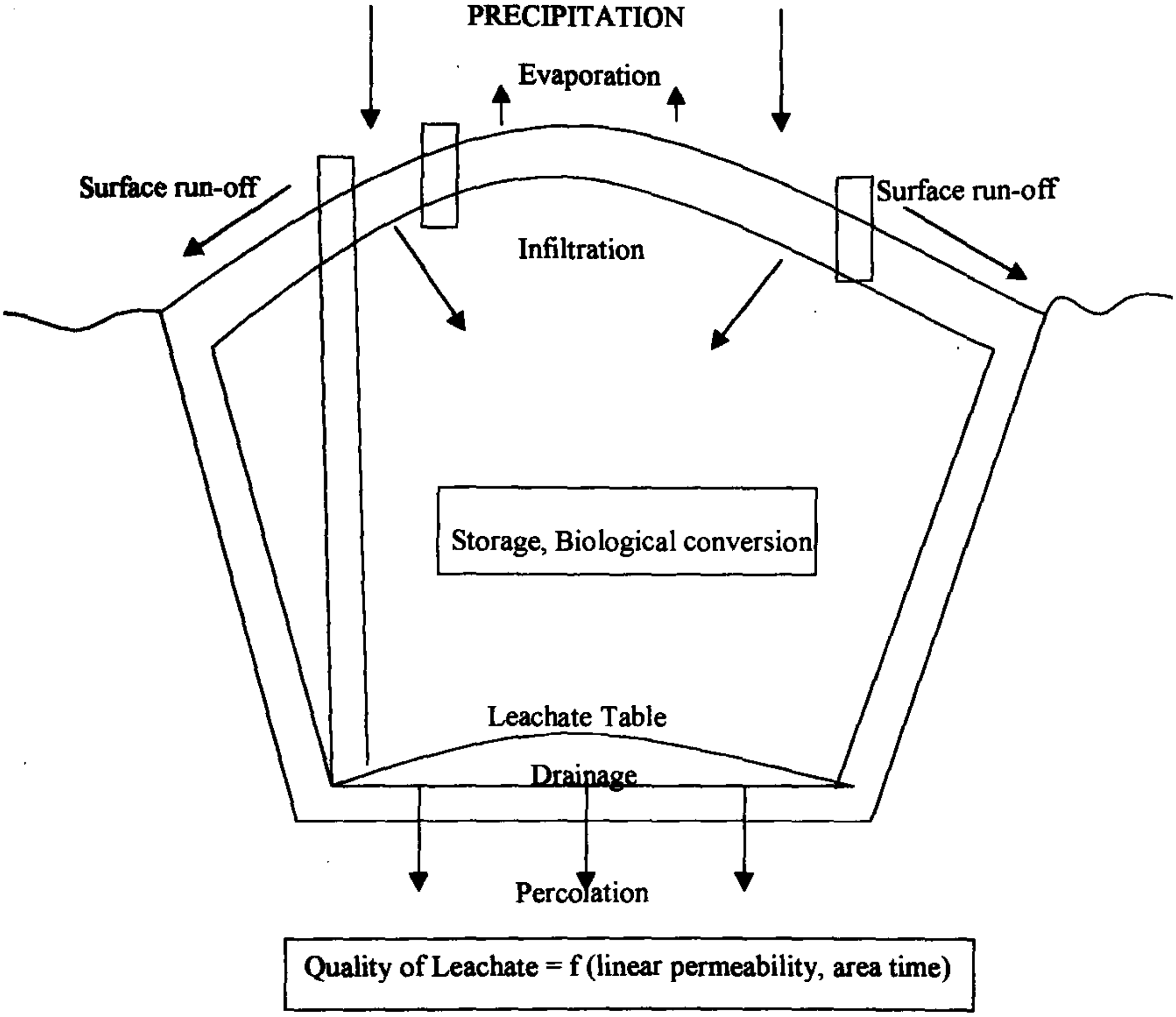

Fig. 4.2 schematic drawing of a landfill with cover [63]

Note; a final cover is the only mechanism that almost completely controls infiltration independent of site location, while simultaneously offering long-term cost advantages.

However, even an optimum vegetative cover by itself is unable to prevent percolation of excess precipitation [63].

4.5 LEACHATE TREATMENT METHODS

Nearly all wastewater treatment methods currently in use or any combination thereof, can be used for treating landfill leachate. Table 5.0 shows the most important methods currently employed.

Table 4.0 Overview of various processes of treating landfill leachate. [63]

NO	METHOD	COMMENTS	PROBLEMS
1.0	Physical methods		
1.1	Sedimentation	Low cost	suitable for insoluble compounds only
1.2	Evaporation	Preconcentrating constituent	costly corrosive only a partial solution, COD is removed but not destroyed
2.0	Physical/chemical methods		
2.1	Activated carbon Adsorption	Suitable for hydrophobic Compounds in wastewater	only provides partial treatment, regeneration of carbon necessary
2.2	Resin Adsorption	Suitable for chlorinated Hydrocarbons, other Hydrocarbons, aromatic	costly and only partial treatment
2.3	Membrane Process/Reverse Osmosis	Reverse osmosis, good retention	Concentrated solids may require additional treatment, membrane fouling possible
2.4	Ion Exchange	Only specialised ions Suitable	organic solid and colloids are disruptive to process
2.5	Flocculation and Precipitation (with Ca $(OH)_2$ + Fe salt, eg. $Al_2(SO_4)_3$	Often used, partial COD Elimination not Necessarily state-of-the-art anymore	Treatment/disposal of sludge's and salt necessary (35kg per m^3 of leachate)
3.0	Chemical methods		
3.1	Wet Oxidation with H_2O_2	No concentrating, Elimination, of residual COD and AOX	Not always appropriate for direct treatment, (salimization), high energy demand
3.2	Wet oxidation with ozone/uv treatment	No concentrating, Elimination of residual COD and AOX	Not always appropriate for direct treatment (salinization) high Energy demand
3.3	Wet oxidation with Ozone/fixed bed Catalyst	Fast reaction process	Lacking full scale Implementability
4.0	Biochemical methods		
4.1	Anaerobic Treatment	No energy needs for Oxygenation, no surplus Sludge	Retaining the Biomass, Sensitivity, not a total treatment
4.2	Anoxic Treatment	Denitrification	Prior nitrification necessary
4.3	Aerobic Treatment (COD/BOD Elimination)	Most common, most Cost effective method	Not effective for non Biodegradable materials, Regulatory limits difficult To achieve.
4.4	Nitrification	Oxidation of ammonia nitrogen from nitrite to nitrate	Sensitive method (inhibiting)

4.6 BIOLOGICAL METHOD

Since the 51st amendment to the German Wastewater Regulations (November 1989), wastewater containing primarily MSW leachate is subject to leachate treatment. The parameters to be considered for the treatment of leachate at wastewater treatment plants are presented in Table. 4.1.

Nearly all wastewater treatment method currently in use or any combination thereof, can be used for treating landfill leachate. Table.4.0. Shows the most important methods currently employed.

4.6.1 Biological Treatment

An extensive study of biological leachate treatment demonstrates that, this method is of particular value for the treatment of non-problematic MSW leachate. Aerobic biological treatment leads to an almost complete elimination of the biodegradable components if there is sufficient contact time between the biomass and the leachate. Multiple, aerated basins are recommended for aerobic treatment of MSW leachate and these are being used in several locations.

Anaerobic leachate treatment is possible only to a limited extent, since the leachate has already been subjected to anaerobic processes while in the landfill. If leachate is contaminated with particularly toxic substances, such as organochlorines, biological processes must never be used alone, since there is a potential for uncontrolled emission of contaminants into the air, water, and into the sewage sludge.

A unique approach of leachate treatment is the return of leachate to the landfill by spraying and/or allowing leachate to percolate back into the landfill surface, or by returning it directly into the landfill body. This method was sparked by the idea that evaporation might eliminate the necessity for leachate collection altogether, but there were several setbacks. Except for particularly dry years, leachate still had to be collected, even if in noticeably smaller quantities (mean of 0.3m3 per m2 of landfill per year). Often noxious odours also caused problems. Additionally, the pumping costs and personnel needs are significant. However, based on these experiences, suggestions for improving this approach have emerged. The landfill body has proven to be an effective fixed bed reactor for leachate recirculation. When the leachate circulates repeatedly, decomposition does take place, and in sufficiently thick landfills, an upper zone of acidification and a lower zone of methane generation have been observed. In such cases, or when recently generated leachate is sprayed on the surface of old landfills a relatively low final concentration of the leachate can be achieved. However, the generated leachate is still not suited for simple treatment at a sewage treatment plant. Because of the unpleasant odours from the acidic phase, it is suggested that, rather than spraying the leachate onto the landfill, instead, it should be thinly spread and allowed to seep into the landfill, or it could be directly injected. This does, however, reduce the benefits of evaporation [63].

Table. 4.1. Waste water requirement for MSW leachate treatment (current limit and proposed change [63]

Parameters	Current limit/ ppm	Proposed change/ ppm
Generally accepted standards (mg/L).		
BOD_5	20	
COD	200	200
TOC		70
NH_4 (ammonia)	50	10
Total Inorganic N		70
PO_4		3
Hydrocarbons		10^{2*}
State-of-the-Art Technology		
Total solids	20	
Cyanide, volatile		0.2^{3*}
Sulphide		1^{3*}
Nitrite		1^{3*}
GF(diluted)	2	2^{3*}
AOX	0.5	0.5
Mercury	0.05	0.05^{3*}
Cadmium	0.1	0.1^{3*}
Chromium	0.5	0.5^{3}
Chromium(VI)		0^{3}
Nickel	0.5	0.5^{3}
Lead	0.5	0.5^{3}
Copper	0.5	0.5^{3}
Zinc	2	2
Arsenic		0.1^{3*}

1. When indirectly added, reduced by 75% or 400mg/L.
2. This parameter does not apply to MSW.
3. Only to be included when expected in the wastewater.
4. GF (F high salt concentrations)= (sum of Cl^- +SO_4 (g/L)/8); when treated together after biological elimination test /elimination of ammonia effect)

4.7. IRONING OUT POLLUTANT

Contaminated groundwater from leaking landfill often moves in a plume toward a near by lake or a stream. Is there any effective way to remove contaminant as the water moves through the ground? One way that is relatively inexpensive and quite effective for removing chlorinated compounds is to place a pit containing scrap iron filings as a barrier.

in the path of the flow of the leachate. Recall that iron corrodes through a redox reaction in which dissolved oxygen is the oxidising agent and iron is the reducing agent.

Oxidising half-reaction $2(Fe \rightarrow Fe^{2+} + 2e^-)$

<u>Reduced half-reaction</u> $\underline{O_2 + 4H^+ + 4e^- \rightarrow 2H_2O}$

$$2Fe + O_2 + 4H^+ \rightarrow 2Fe^{2+} + 2H_2O(l)$$

In a reaction with a chlorinated compound, Fe atoms give electron to the chlorine atoms, converting them to chlorine Ions. In the reduction half-reaction, a chlorine-containing compound designated; RCL is converted to a hydrocarbon, RH.

Reduction half-reaction; $RCl + H^+ + 2e^- \rightarrow RH + Cl^-$

The overall reaction can be written as; $Fe + RCl + H^+ \rightarrow Fe^{2+} + RH + Cl^-$

The hydrocarbons formed are generally less toxic and more easily degraded by micro-organisms rather than the chlorine-containing compounds [72,73].

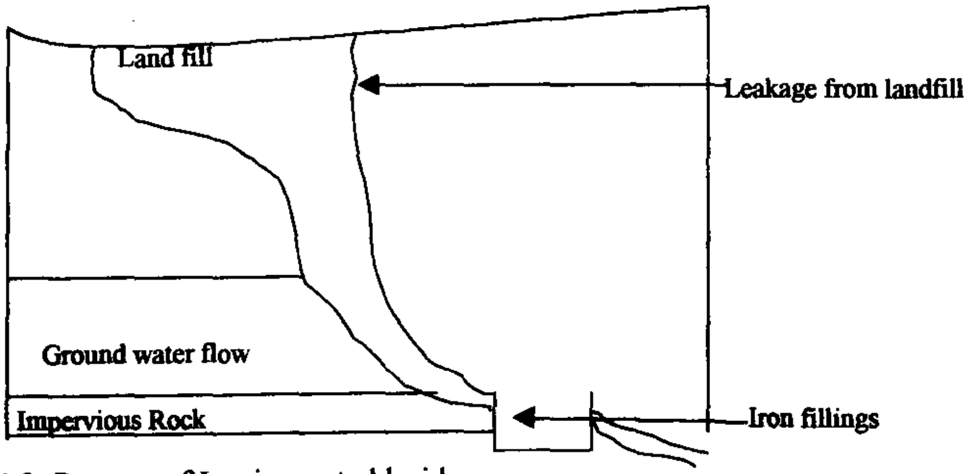

Fig. 4.3: Process of Ironing out chloride

From the foregoing discussion it is therefore recommend that the Cape Coast municipal assembly and for that matter Ghana should adopt the sanitary landfill as means of managing the solid wastes in the cape coast municipality.

4.8 CONCLUSION

The results of both the solid waste evaluation and the analysis of the leachate showed the pattern of pollution from the waste disposal sites. In all, the concentrational levels were above the standards as set out by waste characteristics and leachate limits for the various types of landfills. This however, shows the extent to which solid waste disposal is destroying the environment of the Cape Coast municipality.

4.9 OPEN DUMPS AND BURNING

Disposing of solid waste in open dumps and burning of such solid waste, is the most common solid waste disposal method found in the Cape Coast municipality, despite the provision of waste containers. Open dumps and burning of their content, which is a health hazard, is not an acceptable method of solid waste disposal and must henceforth, be discouraged. For example, vinyl chloride and polythene forms greater proportion of the solid waste in terms of volume as a result of the packaging industry. Now, vinyl chloride, more fully known as vinyl chloride monomer or VCM, is the building brick for the plastic PVC. It is a gas, which is heated under pressure to form the PVC. VCM was found to cause a rare form of liver cancer in workers making PVC. It was also found to migrate into food from some types of plastic wrappings. Non-PVC versions are now widely on sale.

The combustion (burning) of PVC results in the production of hydrogen chloride gas, a material that is toxic and corrosive. It is also thought to contribute to the formation of dioxins when domestic and plastic coffins are burned, but there is not simple relationship between the amount of PVC burned and the amount of dioxins produced [18].

Efforts should be made by everybody to keep to proper disposal methods. By using waste containers wherever available. Sometimes the solid waste is burnt right in the containers. This attitude must be stopped to ensure long-life of the containers.

4.10 WHAT NEEDS TO BE DONE

4.10.1 Solid Waste

At present it is obvious that, with the present rate of population growth coupled with poverty, and non-availability of properly constructed solid waste disposal sites, the rate of solid waste generation could be doubled in the near future in this municipality.

The increase in waste generation and its complex compositions threatens not only our health and comfort but also, our very existence. The success of any new disposal facility in the municipality (Ghana), will depend to a large extent on the improvement of the collection service under the municipal authorities. This necessitates the moderation of the vehicle fleet and storage facilities as well as better management of manpower.

From the above discussion, proper sanitary landfill seems to be the best option for solid waste disposal in the Cape Coast municipality. Proper landfilling today requires highly sophisticated technology and is no longer the easy solution considered to be some decades ago. Landfills should not be regarded once again as dumps, but rather as disposal sites designed and operated to minimise the pollution emissions to air, soil and water. Provisions should be made for surface water drains to limit leachate generation.

We recommend that for, waste avoidance, recycling and low and non-waste technologies should also be carefully investigated. We also recommended that programme to clean up the municipality must be participatory. Respondents are not confident that the authorities would be able to solve the waste disposal problems and they are also not prepared to pay for improved services. These attitudes would be changed with adequate information and involvement of the population by CCMA in waste management especially in recycling and community composting. A local-local dialogue in which the authorities confer continuously with community groups to improve the quality of the municipal environment is required. The world bank urban management project (UMP) as operates in Cape Coast does stress participation but the kind of dialogue that ensures change in behaviour in the part of the population derives from more active involvement of the people than currently obtains.

4.10.2 Water Bodies

Water pollution is a major source of human health problems. As much as 80% of all diseases and some 25 million deaths each year may be attributed to water contamination. It is known that more than 500 types of disease-causing (pathogenic) bacteria, viruses and parasites can travel from human waste through water [71].

Generally, sources of ground water pollution result from the widespread practice of on-site disposal of untreated domestic and industrial effluents to the ground, owing to the prohibitive cost of handling the disposal processes. Consequently, the possibility of an expansion waste disposal leachate into the ground is very real, especially in many cities in Ghana where many people are without any proper form of sanitation.

The natural soil profile can be effective in purifying human waste, including the elimination of faecal microbes, and also in the adsorption, breakdown and removal of many chemicals. However, in some cases, for example where thin soils are developed on aquifer outcrops, there is the risk of direct migration of pathogenic microbes, especially viruses to adjacent ground water sources. The inevitable result will be the transmission of water-borne disease [68].

With these, an effective action (e.g. legislature) should be in place for efficient disposal of solid waste in this municipality. This is to ensure adequate maintenance of the quality of the total environment, and the conservation of the vital reserve of our consumable resources.

4.11 SUMMING UP

It should be noted that with the present rate of industrialisation, population and city growth, and with public concern about the environment, we couldn't afford to neglect this growing problem of environmental pollution any longer without the occurring of serious consequence [11].

We are reminded in an article (Sydney morning Herald, 18th April, 1970) by professor O'Brien [11] of the plight of the Apollo 13 astronauts, hurrying back to earth before their reserved oxygen, water and power were completely exhausted. And so it is with spaceships. Earth - too may be running short of consumables and the time is near when we all should start checking and conserving our vital reserves before time runs out. If we should fail in this, the alternative would not be the 'triumphant failure' of Apollo 13! [11].

Mr. Wesley Gilbertson of the United States Department of Health Education and Welfare, summed up the situation of solid waste disposal problems in a very dramatic way in a paper which he presented in 1966[20], when he said, "A crisis tends to conjure up in our minds that thought of clear and personal danger and of perils that threaten our very existence, and in examining our solid waste management problem and population problem today, he thinks that the word crisis is not too awesome to apply. In these circumstance, therefore, because we do have crisis situation it will unquestionably be necessary that in order to come to grips with the problem, that the agencies of government at the municipal level must recognise that protecting the environment from the relentless accumulation of unmanaged solid waste will require a commitment of public resources, the equal of which has never been brought to bear on this problem and let us not mince words by what we mean by these resources we mean public funds and government action [74].

Finally, the municipal assembly should attempt privatising refuse collection in some carefully selected areas in the municipality on a trial basis to see if broadbase privatisation could be possible. They should also employ qualified personnel to see to the proper management of their solid waste disposal.

4.12 SUGGESTIONS FOR FURTHER WORK

For further studies, the research should in the initial state cover certain selected cities so as to obtain a comprehensive data on the state of the effect of solid waste generation, (volume) disposal and possible pollutional problem on our environment, especially on our water sources.

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APPENDIX 1

UNIVERSITY OF CAPE COAST
DEPARTMENT OF CHEMISTRY

STUDIES ON THE SOLID WASTE GENERATION, COLLECTION AND DISPOSAL IN THE CAPE COAST MUNICIPALITTY.

QUESTIONNAIRE FOR SCHOOLS, HOSPITALS AND INDUSTRIES.

1. What kind of solid waste do your institution produce?

....

2. What is the volume (mass) of the refuse do you produce in a day?

....

3. How is your refuse disposed off?

....

4. Are you able to disposed off all the refused generated properly?

....

5. What role does the municipal assembly/ authority play in the collection of your refuse?

....

6. Any identified problem(s) with the refuse collection?

....

7. Any comment..

....

....

....

....

....

UNIVERSITY OF CAPE COAST
DEPARTMENT OF CHEMISTRY

STUDIES ON SOLID WASTES GENERATION, COLLECTION AND DISPOSAL IN THE CAPE COAST MUNICIPALITY

MODULE: (A) From domestic and civic/commercial sources

(B) From market- by field surveys and direct evaluation

(C) From drains/ - by field check

(D) From industries- by enquiry and questionnaire.

CITY: Cape Coast
SUBURB:

Code if site [ ] [ ]

	D	M	Y
Date of study/interview	[II]	[II]	[II]

Time started [ ] [ ] [ ] [ ]

Time ended [ ] [ ] [ ] [ ]

Please Tick Against whichever is applicable in your Case AND ANSWER The question that follows.

MODULE: A

1. U.C. C.
2. ABORA/NSUAKYI
3. ADISADEL/OLA
4. MARKET AREA
5. RIDGE
6. BAKANO
7. OTHERS

B

MARKETS
(What one sells)

C

DRAINS IN THE PRINCIPAL STREET
(Location must be stated)

D

OPEN DUMPS
(Location must be stated)

E

INDUSTRIES
(Name given)

1. Number of people in the house/ area...

2. How many basket/kg of refuse you produce in a day.................................

3. How much or quantity of the refuse produce are collected............................

4. How is your refuse disposed off? I.e. into containers or in open dumps...

5. How are the drains kept?..

....

6. What is your impression about refuse collection in the municipality?

....

7. Do you envisage that refuse collection must be privatised?............................

8. What is the general composition of the waste?..

MUNICIPAL/ U.C.C. SANITATION DEPARTMENT ONLY

APPENDIX II

COMPUTATION OF POPULATION AND POPULATION DENSITY OF THE CAPE COAST MUNICIPALITY.

The exponential growth rate method was used to compute the present (1999) population of the district. The formula is denoted by:

$P_t = P_0 e^{rt}$ where

P_t = Population of the present year (1999)

P_0 = Population of the based year used (1984)

e = Natural logarthm

r = Growth Rate for Ghana (3%)

t = Time between the base period population and the present year population.

(1984 – 1999)

P_0 = 144,325

e = 2. 71828

r = 3% (0.03)

t = 15 year (1999 – 1984)

Substituting the figures in the formula:

$P_t = P_0 e^{rt}$

$= 144, 325 \times 2.71828^{0.03(15)}$

$= 144, 325 \times 2.71828^{0.45}$

= 144, 325 (1,433)

P_t = <u>206, 865</u>

<u>2* 1984 Population Census Report on Localities, C/R</u>

The most notable figures are the following:

TABLE 3.3: REFUSE BREAKDOWN.

	1999			2010	
	Waste production		Waste collection	Waste production	
	Kg/Cap/day	T/month	T/month	Kg/Cap/day	T/month
Residential & Market	0.43	1358.4	962.4	0.47	1895.75
Industrial		55	9.5		87.5
Drains		7.0	5.0		16