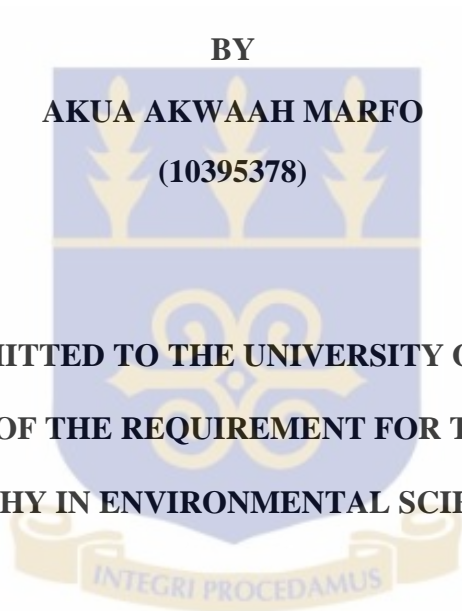


**ENVIRONMENTAL EFFECTS OF SEWAGE POLLUTION
AND WASTEWATER EFFLUENT QUALITY ASSESSMENT:
A CASE STUDY OF TEMA METROPOLIS, GHANA**

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**THIS THESIS IS SUBMITTED TO THE UNIVERSITY OF GHANA, LEGON IN
PARTIAL FULFILMENT OF THE REQUIREMENT FOR THE AWARD OF MASTER
OF PHILOSOPHY IN ENVIRONMENTAL SCIENCE DEGREE**



JULY, 2014

DECLARATION

I testify that this research work was carried out entirely by me in the Environmental Science Programme, Faculty of Science, University of Ghana. This thesis has never been presented, either in parts or in whole, for the award of a degree in this university or any other institution. All cited works and assistance have been fully acknowledged.

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Date

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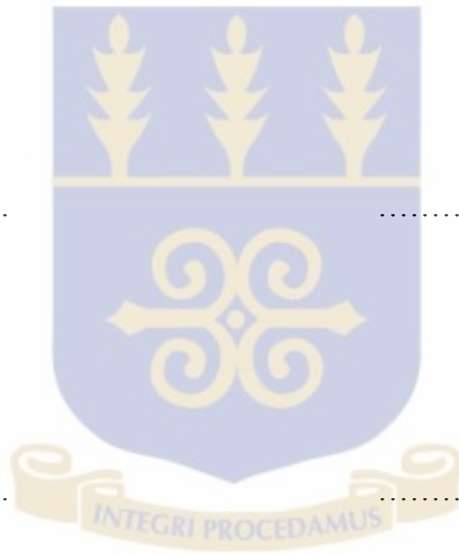
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Date



DEDICATION

This project work is dedicated to my husband Mr. Karikari Marfo and our daughters, Nana Akosua Agyeiwaa Marfo and Adwoa Boama Marfo for their patience and Support throughout my education.



ACKNOWLEDGEMENT

I wish to express my sincere and profound gratitude to the almighty God for his divine protection and guidance throughout my life, education, and career and during the entire study

My greatest appreciation also goes to my supervisors, Dr. Ted Yemoh Annang(Principal Supervisor) and Dr. Daniel Nukpezah, (Co-supervisor) Senior Research Fellow and Research fellows respectively at the Institute of Environment and Sanitation Studies and Mr. Richard Amfo-Otu, Research Fellow at the Department of Environmental Studies, Presbyterian university College, Ghana for their constructive criticism, guidance, corrections and significant contributions they made during the entire execution of the thesis.

I wish also to express my heartfelt gratitude to Mr. Emmanuel Ansah of the Ecological Laboratory (ECOLAB), University of Ghana, Legon and Mr. Amposah Mohammed for their immense contribution during field data collection and laboratory analysis.

I also wish to thank the entire staff of the Tema Metropolitan Assembly for their cooperation and assistance during the entire study period.

Finally, my thanks goes to my colleagues at IESS M.Phil.Class 2014, University of Ghana especially Mr. Bright Frimpong and all my friends and families for their prayers, encouragement and inspiration.

God bless you all.

ABSTRACT

The environmental effects of sewage pollution and wastewater effluent quality management in the Tema Metropolis, Ghana was assessed over a three month period. Effluent samples were collected from main manholes comprising raw wastewater from domestic, central business area (CBA), industrial and the outfall point at sea, sakumono beach. The Physico-chemical and bacteriological analysis were determined using standard methods. The results of the Physico-chemical parameters values were; pH 7.3- 8.2; EC 1277 – 56828 $\mu\text{S}/\text{cm}$; TDS 613 – 28413 mg/l; BOD 3.8-53 mg/l; and the nutrients ranged from NO_3^- -N 1.5- 13.5 mg/l; NH_3 -N,0.2-3.8 mg/l; PO_4^{3-} 0.6-6.4 mg/l. The bacteriological analysis also recorded TC 6.6-5761 cfu/100ml: FC 0.6-139cfu/100ml and E.coli 0.3-34cfu/1m respectively. The level of compliance of effluent with the physico- chemical and bacteriological parameters were all below the Ghana Environmental Protection Agency(EPA) permissible standards for wastewater discharge at the outfall point at the sakumono beach. Although, the nutrient levels were not too high,yet may have the potential to cause eutrophication especially in the water bodies that sewage overflow into such as Chemu, Gao and Sakumono lagoon and deplete the oxygen levels which will affect the aquatic life. The results of the social survey analysis observed some challenges with respect to the management of wastewater in the Tema Metropolis. Eighty percent (80%) admitted environmental, social and public health effects such as water borne diseases such as malaria, typhoid, diarrhea, dysentery among others.To prevent or reduce environmental effects and health risk associated with wastewater and sewage pollution, adoption and utilization of decentralized wastewater technologies that are most economically useful and efficient for the tropics such as waste stabilization ponds to safeguard public health and prevent negative environmental effects.

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CHAPTER ONE

1.0 Introduction

Safe disposal of all human wastes is necessary to protect the health of the individual, the family, and the community, and also to prevent the occurrence of certain nuisances (Davies & Masten, 2004). Wastewater is water whose physical, chemical or biological properties have been changed as a result of the introduction of certain substances which render it unsafe for some purposes such as drinking. The day to day activities of man are mainly water dependent and therefore generation and discharge of 'waste' into water bodies is a common phenomenon. Some of the waste substances include body wastes (faeces and urine), hair shampoo, hair, food scraps, fat, laundry powder, fabric conditioners, toilet paper, chemicals, detergent, household cleaners, dirt and micro-organisms (germs) which can make people ill and damage the environment (Modi, 2011).

Water pollution is the biggest menace of urbanization, industrialization and modern agricultural practices. It leads to alteration in physical, chemical and biochemical properties of water bodies as well as that of the environment. It directly or indirectly affects the life processes of flora and fauna of the water body, surrounded by chemical toxicants (Kumari *et al*, 2006; Indira & Sivaji, 2006; Krishnan *et al*, 2007). It is known that much of water supplied ends up as wastewater which makes its treatment very important. Wastewater treatment is the process and technology that is used to remove most of the contaminants that are found in wastewater to ensure a sound environment and good public health, economic, social and political soundness (Metcalf & Eddy, 1991).

The lack of wastewater management and adequate infrastructure creates major health issues which escalate the poverty level by causing disease, death and environmental deterioration, especially in developing countries such as Ghana (WHO & UNICEF, 2010). The planned nature of the city of Tema created a pure and a healthy environment devoid of pollution- effective sewerage system and good drainage system being contributory factors-in the early 1950s.As part of the overall development of Tema, a water-borne sewerage system was laid in the Tema Township. The system comprised pumping stations, invert siphons, gravity sewers, detention basins and submarine outfall designed and built to convey sewage into the sea.

According to Masten & Davis, (2004) to be able to protect the environment and health of people from sewage pollution, human waste must be disposed of so that: they will not contaminate drinking water supply; they will not give rise to public health hazards by being accessible to insects, rodents, or other possible disease carriers that may come into contact with food or drinking water; they will not give rise to public health hazard by being accessible to children; they will not cause violation of laws and regulations governing water pollution or sewage pollution; they will not pollute or contaminate the waters of any bathing beach, shellfish-breeding ground, or stream used for public or domestic water supply purposes or for recreational purposes; and they will not give rise to a nuisance due to odor or unsightly appearance.

1.1 Background of the Study

Wastewater is used water, comprising of substances such as human waste, food scraps, oils, soaps, chemicals, domestic wastes. Businesses and industries also contribute their share of used water/wastewaters in addition to storm runoff burdened with harmful substances via run off from roads, parking lots and rooftops and this can harm our fresh water systems. Even though, nature

has an amazing ability to cope with certain amounts of contaminants, there is a necessity to treat the billion gallons of wastewater and sewage generated daily by homes, industries, and business establishments before releasing it back to the environment. (Kumar *et.al*, 2010).

In sub-Sahara Africa, almost two thirds of the population (64%) lack adequate access to excreta disposal facilities (World Bank, 2002). In global terms, the continent contains 13% of the world's population without access to improved sanitation, with only Asia having a lower access. Nonetheless, in many African countries, no access to improved sanitation means no access to any sanitation facility at all, with sanitation coverage varying from 84% in urban areas to 45% in rural areas (WHO, 2002). Sanitation includes solid waste disposal, wastewater disposal, wastewater reuse, human excreta disposal, and drainage of rainwater. However, the management of municipal wastewater and human excreta in peri-urban and rural areas by means of improved and sustainable sanitation remains a mirage. Improved sanitation refers to excreta disposal facilities that can effectively prevent human, animal and insect contact with excreta (Ayisah, 2012).

Ghana has one of the highest sanitation coverage in West Africa with 58% compared to 34, 32, 38, and 26%, respectively for Togo, Benin, Nigeria and Liberia (WHO, 2002).

Accra and Kumasi are partly sewerred with only Tema and Akosombo being the only towns with a state of the art central sewerage system. Wastewater treatment is hardly ever accorded any resources. Service delivery is also not keeping pace with population growth and demand (Keraita & Dreschel, 2004).

There are conventional and non- conventional methods of wastewater treatment and the choice of a particular method should be based on factors such as characteristics of wastewater whether it

from a municipality or industry (chemical, textile, pharmaceutical etc.), technical expertise for operation and maintenance, cost implications, power requirements among others.

In most developing countries like Ghana, low-cost, low-technology methods such as waste stabilization ponds have been successful whilst conventional methods like trickling filters and activated sludge systems have broken down. (Ayisah, 2010). Effluent which meets set discharge standards can be appropriately used for aquaculture and also irrigation. Though there are a few challenges in waste water management, they can be surmounted if attention and the necessary financial support is given to it.

Shuval *et.al.*,(1986) reported that waste stabilization ponds are the most suitable wastewater treatment option that could eventually be useful in agriculture. Waste stabilization ponds have proved to be a low-cost, sustainable method of wastewater treatment, particularly suited to the socioeconomic and climatic conditions prevailing in many developing countries. No input of external energy or disinfectants is needed (WHO, 2006).

This research work is therefore conceived to investigate the presence or otherwise the concentrations of some physical, chemical and bacteriological parameters in sewage effluent in the Tema Metropolis. This will help to ascertain whether they are within the acceptable standard of Ghana EPA for discharge into water bodies and or recommend appropriate measures accordingly.

1.2 Problem Statement and Justification

The Tema metropolis is served by a central sewerage system which covers approximately 60% of the active built up area with three (3) pumping stations as well as on-site septage treatment

facilities and treatment plant. The Tema Metropolitan Assembly sewage system was constructed in the early 1960's for the collection, and transport of human excreta and grey water within Tema Municipality. The management of the system was under the control of Tema Development Corporation until 1998 when it was transferred to Tema Municipal Assembly (T.M.A).

In 1998, a new treatment facility was constructed but this has been shut down since 2002. This has led to a condition where raw sewage is pumped through a by-pass into the sea without treatment due to high cost of operation and maintenance with accumulated bills. This situation is very alarming and has great potential to create environmental pollution and health hazard to the citizenry.

The increase in population size without a corresponding increase in the capacity of the sewer system has overloaded the system and inadequate maintenance have led to deterioration of the system with discharge of sewage into drains and water courses.

Also most of the pitch fiber sewers which out-lived their economic life span collapsed thus spilling untreated sewage into the open environment. The sub-marine outfall situated at Paradise Beach had been damaged by a wrecked ship, sewage was by-passed into water bodies, including the Gao, Sakumo and Chemu lagoons.

Some main problems associated with the reticulation system include undersize sewers which appear to have exceeded its design capacity and therefore experiencing overloads in most areas, especially during the peak periods. Also sizeable number of pitch fiber sewers in some communities which have exceeded their useful life span thus compounding an already bad

situation and have therefore collapsed thus resulting into frequent blockage of sewers and spillage of sewage into open drains and homes (Salifu, 2008).

Another challenge on the management of the system is that, some manholes are below ground level thus allowing storm water, solid waste and grit tree access into the sewers. Manhole covers made of steel has been stolen by scrap dealers promoting dumping of solids into the chambers and has contributed to the siltation in the sewers by the gross abuse by residents.

In practice around 95 per cent of the sewers suffer from sand depositions. Approximately 40 per cent of these pipes suffer a loss of cross-sectional area greater than 50 per cent. Thus at least half of the original flow capacity has been lost in these pipes; and consequently the so called “self-cleansing velocity” or “minimum tractive force” is not achieved and further deposition occurs. (Biney, 1995)

While the above act is suggestive of a declining sewage effluent quality, limited study has been done to ascertain this. Hence the present study fills this research void while further exploring the sewage quality management and its possible environmental and health risks.

1.3 Research Questions

1. What is the quality of effluent discharged into the environment?
2. How does the quality of influent affect the effluents?
3. What are the risks associated with sewage pollution?
4. How does the community perceive sewage pollution to their health?
5. What challenges are associated with the management of the system?

1.4 Main Objective

The main objective of the research is to assess the quality of the central sewage and residence perception on the management, environmental and health risks associated with sewage pollution.

1.5 Specific Objectives

1. To assess the quality of sewage effluent released into the environment.
2. To investigate some environmental and health risks associated with sewage pollution.
3. To assess community perception of health hazards associated with the sewage.
4. To investigate challenges on wastewater management and its effects.

1.6 Significance of the Study

The research is necessary to provide information and data on physico-chemical and bacteriological quality of wastewater effluent in the Tema Metropolis. This will also have positive repercussions for planning efforts and decision making in relation to wastewater and sewage pollution in the metropolis.

1.7 Limitations

As a result of time constraint and limited available resources, the social data was focused on some selected communities under social survey.

CHAPTER TWO

LITERATURE REVIEW

2.1 Introduction

The cities of Ghana are no exception to the poor wastewater treatment coverage. It has been shown that out of the 44 wastewater treatment plants in Ghana, only 20 % are working, most of them below design standard (IWMI, 2012). Thus raw wastewater is discharged into the urban sphere with severe consequences on the environment and human health. Generally, the poor coverage of wastewater treatment facilities is attributed to a number of factors, including but not limited to lack of funds, ignorance of low-cost wastewater treatment processes and economic benefits of treated wastewater re-use, together with the tendency among decision-makers to accept the status quo: the continued discharge of untreated wastewater into the environment (Mara, 2003).

2.2 Sewage and Sanitation

Increasing percentage of urban population does not always mean increasing level of urban development. For example, Ghosh& Maji (2011) argues that more urban population means that they consume vast amount of resources and generate more waste and garbage which is not totally managed by urban local governing body due to less equipment, shortage of manpower and low circulation of existing facility in drainage, sewage, public sanitation and solid waste management.

The process of rapid urbanization generates serious challenges to towns and cities, which are struggling to provide and maintain the already inadequate level of urban services and healthy environment. Coupled with the vast consumption of resources is the production of massive amounts of waste, much of which re-enters the environment as pollutant.

2.2.1 Sewerage System

Globally, sewerage system is currently designed based on a 'separate system' whereby used water is collected separately in a network of underground sewers that lead to a treatment plant whereas stormwater and surface runoff are collected in open drains and channeled to rivers and reservoirs. This reduces the amount of pollution that gets into the waterways and helps ensure that the quality of the water harnessed from the catchments is of good quality (Onn, 2005).

According to Rangwala *et.al*, (2011) an overflow of sewage can cause or has the potential to cause environmental effects such as polluting water bodies, breeding ground of insects and rodents. The conditions of the receiving environment will dictate the degree of risk of such effect. The scale of the spill depends on the volume and duration of the overflow and receiving environment characteristics.

2.3 Wastewater Management

The urban population growth, changing lifestyles and industrialization are among the factors that contribute to the generation of high volume of wastewater. This wastewater contains several contaminants notably from anthropogenic sources, it's therefore requires treatment before discharge into the environment or re-use for other purposes such as irrigation, aquaculture, urban greening among others. Since wastewater treatment is relatively an expensive process, many of

the underdeveloped and developing nations of Africa and Asia have not been able to treat their wastewater to appropriate levels.(Mekela et al, 2010).

Water plays an important role in the development of any activity in the world. A good management of water and wastewater resources uplifts any country or region status a higher in the aspects of health and economy. For the future decades the cost of investment will be implemented in treatment of wastewater by choosing low cost sewage treatment technology.

There is a great importance, and the need for wastewater treatment in the fact that untreated wastewater led into a natural water body constitute a great hazard for the environment and a health risk for human and animal life. The environmental risk is mainly due to overloading of physical and chemical components associated with human activity into an aquifer, while the health risk is mainly the result of pathogenic contamination (Kvernberg, 2012).

Looker (1998), recommends that ecological wastewater treatment closed-loop treatment system must be used when compared with the present day linear disposal system. Rose (1999), states that the development of ecological wastewater management helps to attain high environmental quality, high yields in food and fiber, low consumption, good quality, high efficiency production and full utilization of wastes.

The conventional centralized system flushes pathogenic bacteria out of the residential area using large amounts of water. This often combines the domestic wastewater with rainwater and cause the flow of large volumes of pathogenic wastewater (Volkman, 2003). On the other hand, decentralized wastewater treatment systems is a technical, effective, efficient and affordable approach for rural and urban households in developing countries (Seshadri, 1999).

The use of on-site treatment systems is quite extensive in Ghanaian communities. Individual and community/residential based septic tanks are the most preferred. Septic tanks only partially treat sewage, and the effluent is still rich in organic material. The septic tank has to be emptied from time to time and the disposal of the septic sludge causes severe public health and environmental particularly in urban areas. Major wastewater treatment methods found in Ghana includes stabilization ponds, trickling filters and activated sludge plants.

According to a recent survey conducted by Kvernberg, (2012) there are 46 wastewater treatment plants in Ghana. More than half of all treatment plants in Ghana are in the Greater Accra region, mainly in the capital city of Accra and port city of Tema. Brong Ahafo and Upper West regions have no treatment plants at all. The stabilization pond method is the most extensively used with almost all faecal sludge and large-capacity sewage treatment plants using the method. Most trickling filters and activated sludge plants recorded have a low capacity and belong to private enterprises like larger hotels.

Only about 10% of the treatment plants are operational (Obuobie *et al.*, 2006) and it is not clear if these plants meet the EPA effluent quality guidelines. This can be attributed to the fact that the conventional methods are energy dependent and also when the mechanical parts become faulty, the part has to be imported making it too expensive to maintain. Low-cost, low technology methods are however manageable.

2.3.1 Wastewater generation

Urbanization ratio and changing lifestyles, wastewater generated in the urban areas is large and continues to grow over time. As cities are the centers of political and economic power, their water needs usually receive a higher priority, but are subject to physical and economic scarcity constraints. Increases in urban water supply ensure increased wastewater generation. The depleted fraction of domestic and residential water use is typically only 15-25% and the remainder returns to wastewater (Scott et al., 2004).

2.3.2 Wastewater collection and transport

The purpose of a sewage collection system is to remove wastewater from points of origin to a treatment facility or place of disposal. The collection system consists of the sewers (pipes and conduits) and plumbing appertencesnecessary to convey sewage from the point(s) of origin to the treatment system or place of disposal. It is necessary that the collection system be designed so that the sewage will reach the treatment system as soon as possible after entering the sewer. If the length of time in the sewers is too long, the sewage will be anaerobic when it reaches the treatment facilities(Masten & Davis, 2004).

Domestic wastewaters are collected in underground pipes which are called “sewers”. The flow in sewers is normally by gravity, with pumped mains only being used when unavoidable. The design of conventional sewerage (the sewer system used in industrialized countries and in the central areas of many cities in developing countries) is described in several texts (Metcalf & Eddy, 1991).

Collection systems are normally divided into three main categories. Separate systems are divided into two types. Sanitary systems consist of domestic wastewater and possibly industrial

wastewater and infiltration/inflow. Separate systems that only consist of storm water collection are named Storm collecting systems. There are also combined systems, where all the different types of wastewater are collected and led to a Waste Water Treatment Plant (Metcalf & Eddy 2004).

Except for force mains, sewers are laid to permit gravity flow of their contents. Unlike water in a water distribution system, the contents of a sewer do not flow under pressure. Usually the slope is such that a flow rate of 0.03 meter (m) per second or more is maintained when the line is flowing half full to full (Hodgson, 2000).

This is a self-cleansing velocity and prevents solids from settling in the sewer pipes. To the maximum extent practical, sewers are laid in straight lines. Corners and sharp bends slow the flow rate, permit clogging, and make line cleaning difficult.

Pumping is necessary where the slope of the sewer does not produce the required minimum velocity of 0.03 m or where sewage must be lifted to a higher elevation. Sewage can be pumped from pumping stations through pressure lines (force mains) regardless of their slope, or it can be raised to a higher elevation at pumping stations (lift stations), so that gravity flow will again produce the required velocity.(Rangwala *et al*, 2011).

Most cities in the developing world are only partially sewered, resulting in substantial volumes of wastewater (including toilet wastes) finding their way into surface water networks within cities. On an average only 28% of the population in the developing world in large cities is actually sewered, whereas more than 90% of the population is sewered in developed countries (WHO & UNICEF 2000).

2.3.3 Wastewater treatment

Wastewater or sewage treatment is one such alternative, wherein many processes are designed and operated in order to mimic the natural treatment processes to reduce pollutant load to a level that nature can handle. In this regard, special attention is necessary to assess the environmental impacts of existing wastewater treatment facilities (Jamrah, 1999).

According to Amoatey & Bani, (2011) wastewater treatment is very necessary for the following reasons:

It is more vital for the reduction of biodegradable organic substances in the environment: organic substances such as carbon, nitrogen, phosphorus, sulphur in organic matter needs to be broken down by oxidation into gases which is either released or remains in solution; Reduction of nutrient concentration in the environment: nutrients such as nitrogen and phosphorous from wastewater in the environment enrich water bodies or render it eutrophic leading to the growth of algae and other aquatic plants. These plants deplete oxygen in water bodies and this hampers aquatic life; Elimination of pathogens: organisms that cause disease in plants, animals and humans are called pathogens. They are also known as micro-organisms because they are very small to be seen with the naked eye. Examples of micro-organisms include bacteria (e.g. *vibrio cholerae*), viruses (e.g. enterovirus, hepatitis A & E virus), fungi (e.g. *candida albicans*), protozoa (e.g. *gentamoeba hystolitica*, *giardia lamblia*) and helminthes (e.g. *schistosoma mansoni*, *asaris lumbricoides*). These micro-organisms are excreted in large quantities in faeces of infected animals and humans (Awuah & Amankwaa-Kuffuor, 2002).

The sewage network is used to bring wastewater to the treatment plant. It can then be treated to primary, secondary or tertiary levels before it is discharged for further use or returned to a

natural water body. Wastewater treatment is an expensive process, both in terms of the land required and the energy consumed. The percentage of total sewerage wastewater that actually undergoes treatment to secondary level is 35% in Asia. Almost no sewerage is treated in Africa and more than 65% is treated in developed countries (WHO & UNICEF, 2000).

Wastewater from industries and sewage spillages from burst pipes around the country are released into streams and rivers which finally discharge into dams around the cities of Zimbabwe. With the prevailing hard economic situation in the country, most of the trade waste effluents are released into the environment untreated or partially treated. Industrialists have adopted the use of substandard treatment methods that partially treat and in some instances, forego the effluent treatment process (WHO& UNICEF, 2000).

These are low-cost, low-technology, less sophisticated in operation and maintenance biological treatment systems for municipal wastewater. Although these systems are land intensive by comparison with the conventional high-rate biological processes, they are often more effective in removing pathogens and do so reliably and continuously if system is properly designed and not overloaded (FAO, 2006). Some of the non-conventional methods include stabilization ponds, constructed wetlands, oxidation ditch, and soil aquifer treatment.

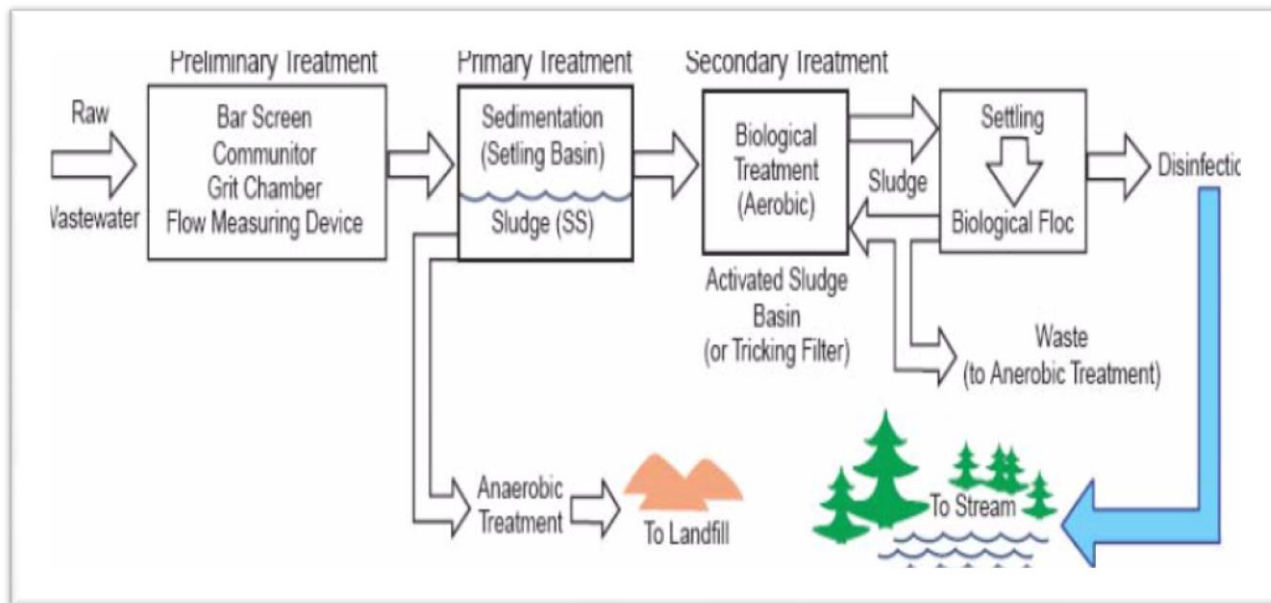


Fig 2. 1: Schematic diagram of a typical wastewater treatment plant

Source: Ayisah, 2010

According to Kvernberg, (2012), the most widely used treatment options in the country, Ghana include waste stabilization ponds, trickling filters and activated sludge processes. Since many of these treatment plants are broken down or working sub-optimally, large quantities of wastewater is discharged directly into the recipient, causing a negative impact on the environment.

Wastewater reclamation and reuse may play an important role in the development of strategies for the utilization of water resources. Reclaimed wastewaters may be reused in various applications, most commonly for irrigation of agricultural and urban areas, in industrial plants (as cooling water), as well as for enrichment of groundwater bodies. Thus, wastewater reuse may strengthen water savings generating supplementary water sources, which are especially important in areas with limited rainfalls (Petalaet *al.*, 2005).

Waste stabilization pond technology is the most cost-effective wastewater treatment for the removal of pathogenic microorganisms. The treatment is achieved through natural disinfection mechanisms. It is particularly well suited for tropical and subtropical countries because the intensity of the sunlight and temperature are key factors for the efficiency of the removal processes (Mara *et al.*, 1992).

In Ghana so far, stabilization ponds have worked very well due to the convenient climatic conditions. It usually flows under gravity from one pond to the other and mostly does not require any pumping. It is less energy dependent thus plant activities cannot be interrupted due to power cuts. Its disadvantages however include odour problems and it requires a large area of land to function properly.

Industrial wastewater treatment in general, the type of plant to be installed depends on the characteristics of the wastewater produced from that industry. The basic principle according to Kamala & Kanth Rao (1989) however is waste prevention by good housekeeping practices that will ultimately result in volume reduction and strength reduction. Industrial wastewater is treated the same way as domestic or municipal sewage-preliminary, primary, secondary and advanced treatment levels. There could however be peculiarities with different industrial depending on their major contaminant e.g. heavy metals, dye, etc. Industrial wastewater in Ghana is generated from breweries, distilleries, textile, chemical & pharmaceuticals and institutions and hotels which are mainly situated in urban centers (Amoatey & Banai, 2011).

2.3.4 Wastewater discharge, use and recycling

Water is a scarce and finite resource which is often taken for granted. In the last half of the 20th century, population has increased resulting in pressure on the already scarce water resources. Urbanization has also changed the agrarian nature of many areas. Population increase means more food has to be cultivated for the growing population and agriculture as we know is by far the largest user of available water which means that economic growth is placing new demands on available water supplies. The temporal and spatial distribution of water is also a major challenge with groundwater resources being overdrawn (National Academy, 2005). It is for these reasons that recycling and reuse of sewage is crucial for sustainability of this scarce resource. In most developing countries, wastewater receives little or no treatment and is discharged into a river or lake from which farmers divert it into the fields to grow different crops (Amoatey & Biney, 2011). In many of the developed countries, wastewater is being recycled in a number of sectors other than agriculture for various reasons, but only after suitable treatment and guidelines are in place for recycling whereas in Ghana raw sewage has been used for watering of vegetables and fruits in the cities for commercial consumption (Awuah, 2010).

Wastewater reuse becomes possible when it is physically, chemically and biologically treated by an appropriate wastewater treatment technology. The waste stabilization pond (WSP) is advocated as system one of the most efficient and economical technology to remove pathogens and fecal bio-indicators from wastewater (Hill & Sobesky 1998; Hodgson 2000; Kourra *et al.* 2002; Madera *et al.* 2002).

Effluents which meet discharge standards could be used for agricultural purposes such as aquaculture or for irrigation of farmlands. The challenge however is that if wastewater treatment plants are not managed and continuously monitored to ensure good effluent quality, reuse becomes risky. Irrigation with wastewater is both disposal and utilization and indeed is an effective form of wastewater disposal (as in slow-rate land treatment). However, some degree of treatment must normally be provided to raw municipal wastewater before it can be used for agricultural or landscape irrigation or for aquaculture.

In many industrialized countries, primary treatment is the minimum level of pre-application treatment required for wastewater irrigation. It may be considered sufficient treatment if the wastewater is used to irrigate crops that are not consumed by humans or to irrigate orchards, vineyards, and some processed food crops (FAO, 2006).

Nutrients in municipal wastewater and treated effluents are a particular advantage as supplemental fertilizers. Success in using treated wastewater for crop production will largely depend on adopting appropriate strategies aimed at optimizing crop yields and quality, maintaining soil productivity and safeguarding the environment. Several alternatives are available and a combination of these alternatives will offer an optimum solution for a given set of conditions. The user should have prior information on effluent supply and its quality. Wastewater effluent can be blended with conventional water or solely used. Heavy metal concentrations in streams used for irrigation in and around urban centers such as Accra and Kumasi have been sometimes found to be beyond recommended levels for irrigation purposes and should therefore may pose a health concern. (Amoatey & Bani, 2011).

2.4 Wastewater management and Environmental Quality

Pollution is one of the greatest abuses of our natural water resources. All foreign material added to a natural body of water is considered pollution. Overloading a natural body of water beyond its reserve or recuperative capacities with raw sewage, improperly treated sewage, or industrial wastes is a very serious matter. If the volume and velocity of the stream are not sufficient to handle the quantity of effluent being discharged great environmental damage can occur.

The objective of water quality management is to control the discharge of pollutants so that water quality is not degraded to an unacceptable extent below the natural background level (source of information). Sewage overflows exert physical, chemical and biological effects on the receiving environment. This may result in human health, environmental and aesthetic impacts, which can be both acute and cumulative. Such impacts are dependent on the characteristics of the discharge and receiving environment (Davis & Masten, 2004).

A receiving water body will up to a certain level be able to render harmless the contaminants of discharged wastewater through dilution. Nevertheless, when the quantities of pollutants exceed the recipient's critical level, they will possibly do harm to the receiving environment. The solution to this problem is through treatment of the raw wastewater from various sources to meet established environmental quality standards.

The poor operational state and inadequate maintenance of most of these municipalities' sewage treatment works, i.e. design weaknesses, overloaded capacity, faulty equipment and machinery,

has resulted in major pollution problem and impacts on the quality of water resources, with marine water quality standards consequently not meeting regulatory standards (Kvernberg,2012).

When a city lacks the basic infrastructure to support its community, health and environmental degradation occur including ground water contamination. Lack of sufficient wastewater management has negative ripple effect in many areas of community including human health.

Some pollutants, particularly oxygen-demanding waste and nutrients are so common and have such a profound effect on almost all types of rivers that they deserve special emphasis.

Estuaries could be called the cradle of many birds, fish and other life because the estuary often provides sanctuary to nesting and spawning animals. It is also ideal spot for tired resting birds on their long migration.

Domestic wastewater in Ghana is mostly discharge directly into drainage systems that empty into water bodies such as rivers, lagoons and streams (EPA, 2002).

In the report from IWMI, (2010) several possible reasons for the problems of the Ghanaian wastewater treatment plants are suggested. These can be divided into three main groups; technical issues, institutional issues and financial issues. The technical issues include damage and wear and tear on physical components of the plants, blocked sewer lines, power cuts and more. The institutional issues are related to inadequate operation and maintenance activities, lack of qualified personnel, lack of commitment of the authorities in charge and a general lack of motivation among workers. The financial issues deal with lack of funds to buy items for maintenance and repair works and poor remuneration of workers at the plants.

2.5 Wastewater Effluent Quality Parameters

The use of appropriately treated wastewater, which complies with the quality guidelines set by the Environment Protection Agency (EPA), in various sectors like agriculture, industry, recreation or households. (IWMI). Physiochemical and biological qualities of raw or treated sewage are important not only in the assessment of the degree of pollution but also in the choice of the best treatment technology needed.

2.6 Physico-chemical Qualities

2.6.1 Temperature

Wastewater temperatures normally range between 10°C and 20°C, in general, normally, the temperature of domestic and municipal sewage is slightly higher than the water supply because of heat added during the utilization of the water (Modi, 2011).

Temperature affects sewage in several ways; temperature affects the biological activity of bacterial present in sewage. An increase in temperature up to about 60°C in sewage effluent decreases the oxygen concentration, (Sincero, 2003).

The mean temperature values varies with the local air temperatures. In the United States the mean annual temperatures of wastewater varies from about 3 to 27°C, while temperatures for some countries in Africa and the Middle East has been reported as high as 30 to 35°C. The optimum temperature for biological treatment is in the range of 25 and 35 °C. For lower temperatures the microbial reactions will appear more slowly, and at very high temperatures, aerobic digestion and nitrification stop. Effluent water with higher temperatures than naturally

found in the recipient could also affect the conditions regarding aquatic life, as it can cause a change in the species of fish that can live there (Metcalf & Eddy 2004). Temperature is therefore very important parameter as it affects the rate of both chemical and biological treatment of wastewater (Drinan & Whitining, 2001).

The temperature of wastewater also affects receiving waters. Hot water, for example, which is a by-product of many manufacturing processes, can be a pollutant. When discharged in large quantities, it can raise the temperature of receiving streams locally and disrupt the natural balance of aquatic life. Wastewater temperatures, as high as 30 to 35°C have been reported for countries in Africa and Middle East (Tchobanoglous *et al.* 2003). Increased temperature, for example, could cause a change in the species of fish that could exist in the receiving water body (Okoh, 2010).

Another important example of the effects of temperature on water chemistry is its impact on oxygen. Warm water holds less oxygen than cool water, so it may be saturated with oxygen but still not contain enough for survival of aquatic invertebrates or certain fish. Some compounds are also more toxic to aquatic life at higher temperatures. According to Middlebrooks *et al.* (1988) high temperature is good for removing wastewater constituents like nitrogen through volatilization. Generally, high temperatures favor pathogen removal, however, in some instances, even increase in numbers of pathogens (Ahmed & Sorenson, 1995).

2.6.2 Total Dissolved Solids (TDS)

One cubic meter of wastewater weighs approximately 1,000,000g and will contain about 500g of solids. One-half of the solids dissolved such as sodium and soluble organic compounds. The

remaining 250g will be insoluble. The insoluble fraction consists of about 125g of material that will settle out of the liquid fraction in 30 min under quiescent conditions (these are called settleable solids). The remaining 125g will remain in suspension for a very long time (these are called suspended solids). The result is that wastewater is highly turbid (Davis & Masten, 2004).

2.6.3 Total Suspended Solids (TSS)

Total suspended solids gives an indication of the content of solid matter in the wastewater. In general, raw wastewater contains solids of variable types and sizes. Larger objects and coarse materials are normally removed in the first stage of the treatment process. The TSS derived from the total solids content (TS) cover all types of solids found in a wastewater flow. It is normally a mixture of floating matter, settleable matter, colloidal matter and matter in solution. Typically, 60 % of the suspended solids are settleable. The TSS values are widely used to determine treatment efficiency for conventional treatment processes and to assess the need for effluent filtration in the case of reuse applications (Metcalf & Eddy, 2004).

2.6.4 Hydrogen-ion concentrations (pH)

According to Belhaj et al. (2011), pH is a fundamental factor for water quality which mainly depends upon a variety of chemical factors such as dissolved gases, organic acids, humic actions and inorganic salts. The pH value of sewage indicates whether it is acidic or alkaline in nature. The pH value of fresh domestic sewage is slightly more than that of the water supply to the community. Thus fresh domestic sewage is alkaline in nature having pH value between 7.3 and 7.5, which is good for bacterial action.

However, as time passes the pH value of sewage tends to fall due to production of acids by bacterial action and the sewage tends to become acidic. Thus septic sewage is acidic in nature which is difficult to be treated efficiently. A high concentration of either an acid ($\text{pH} \leq 7$) or base ($\text{pH} \geq 7$) is an indicative of industrial sewage being mixed with domestic sewage. The determination of pH value of sewage is necessary because certain methods of sewage treatment for their efficient working require sewage of pH value in specific range. Since most microbial life occur within a narrow pH range (typically 6-9), the hydrogen-ion concentration is of great concern in relation to biological treatment. Influent water with exceptional high or low pH-values (typically industrial wastewater) can be hard to treat by biological means. (Kvernberg,2012).

2.6.5 Dissolved Oxygen (DO)

Dissolved oxygen represents the amount of oxygen in dissolved state in sewage. According to Rangwala et al. (2011) sewage has generally no dissolved oxygen which is contentious. Its presence in raw sewage indicates the sewage is fresh and its presence in the effluent treatment indicates that considerable oxidation has been accomplished by the sewage treatment methods.

2.6.6 Electrical Conductivity (EC)

Conductivity is the ability of water to conduct electrical current. This depends on the ionic strength of the water sample. Conductivity increases as the concentration of ions increases, since electrical current is transported by ions in solution. The determination of electrical conductivity provides a rapid and convenient way of estimating the concentrations of dissolved ions or

estimating the amount of total dissolved salts (TDS). Conductivity is also a good measure of salinity in water. The measurement detects chloride ions from the salt. Salinity affects the potential dissolved oxygen levels in water. The greater the salinity level, the lower the saturation point (Okoh, 2010). Salinity is the total amount in grams of inorganic materials dissolved in 1kg water when all the carbonate has been converted to oxide, all the bromide and iodine have been replaced by chlorine and all organic matter have been completely oxidized (Annang, 2000).

2.6.7 Turbidity

Turbidity is an expression of the optical property of water/wastewater that causes light to be scattered and absorbed rather than transmitted in straight lines through the sample. Turbidity is caused by suspended and colloidal particulate matter such as clay, silts, finely divided organic and inorganic matter, plankton and other microscopic organisms. It is another test used to indicate water quality of waste discharges and natural waters with respect to colloidal and residual suspended matter. It is measured in NTU (Nephelometric turbidity units) using a turbidity meter, however different readings can be obtained using different kinds of meters (Slaats et al., 2003; APHA/AWWA, 1998). As observed by WHO (2004) high levels of turbidity can protect microorganism from the effects of disinfection, stimulate the growth of bacteria and exerts a significant chlorine demand. In all processes in which disinfection is practiced, therefore, the turbidity must always be low, preferably below 1 NTU for effective disinfection. The recommended guideline is 5 NTU (WHO, 2004).

2.6.8 Nitrogen contents

The Nitrogen content of sewage is in the form of nitrogenous compounds presents in it. The principal nitrogenous compounds present in domestic sewage are proteins, amines, amino-acids and urea which are organic compounds, and ammonium salts which are inorganic compounds. The nitrogenous organic compound presents in sewage undergo decomposition or oxidation. Depending on the state of decomposition or oxidation of nitrogenous organic matter nitrogen appears in sewage in the forms of albuminoid nitrogen or albuminoid ammonia, ammonia nitrogen or free nitrogen, nitrites or nitrites nitrogen and nitrates or nitrate nitrogen.

Ammonia nitrogen or free ammonia results from the bacterial decomposition of the nitrogenous organic matter. It exists in sewage as either ammonium ion (NH_4^+) or ammonia (NH_3) depending on the pH value of the sewage. In aerobics environment bacteria can oxidize the ammonia to nitrites and nitrates and the relative amount of ammonia present in the wastewater is thus an indicator of the age of the wastewater.

Nitrites is a reduced form of nitrate that is form from decomposition of nitrogenous organic materials. Hence nitrites indicate the intermediate stage of conversion of nitrogenous organic matter of sewage into stale form. The presence of nitrites in sewage treatment shows that the treatment is incomplete and the sewage is still stale. Thus the presence of nitrites is an indicator of past pollution in the process of stabilization.

Nitrates are the final products of decomposition or nitrogenous organic matter present in sewage. As such the presence of nitrates indicates fully oxidized and the most stable form of nitrogenous organic matter contained in sewage thereby indicating the well oxidized and treated sewage. Increase in proportion of nitrates during the process of sewage treatment serves as a guide for

measuring the progress achieved in the sewage treatment. Nitrates may vary in concentration from 0 to 20 mg/l as nitrogen in sewage.

According to Kvernberg, (2012) nitrogen is an essential nutrient for the growth of microorganisms, plants and animals. Since it is an essential building block in the synthesis of protein, it is a necessity in biological treatment processes. The content of nitrogen in the effluent of wastewater cause an environmental concern, as it contributes to eutrophication. On the other hand, if reuse of the wastewater effluent for irrigation is desirable, the nitrogen content should be conserved as it makes an important nutrient for this purpose.

2.6.9 Total Phosphorus

Phosphorus is usually present as phosphate (PO_4^{3-}) in water medium. Phosphorus is found in wastewater in three principal forms: orthophosphate ion, polyphosphates or condensed phosphates and organic phosphate (Mahmut & Ayhan, 2003). Organically bound phosphorus originates from body and food waste but biological decomposition of these solids is finally converted to orthophosphates.

Polyphosphates are used in synthetic detergents, and used to contribute as much as one-half of the total phosphates in wastewater. Polyphosphates can be hydrolyzed to orthophosphates. Thus, the principal form of phosphorus in wastewater is assumed to be orthophosphates, although the other forms may exist. Orthophosphates consist of the negative ions PO_4^{3-} , HPO_4^{2-} , and H_2PO_4^- . These may form chemical combinations with cations (positively charged ions). According to Clark *et al.* (1997) and Sedlak, (1991) the phosphorus concentrations in secondary effluent stand usually within the range of 3-7 mg/L, which mostly consist of orthophosphate and about 1 mg/L

of organic phosphorus. Thus, it is necessary to reduce the concentration of phosphorus in secondary wastewater to prevent the algal bloom. Other sources of phosphorus aside human waste include animal wastes, industrial waste, soil erosion and fertilizers.

Phosphorus just like nitrogen is an essential nutrient for growth of biological life. Raw wastewater normally holds a large fraction of phosphorus, and as it makes a significant contribution to eutrophication when led untreated into a natural water body, it should be removed during treatment. Phosphorus is, just like nitrogen, of great interest in relation to reuse purposes, since it constitute a resource that can be utilized for irrigation means and help sustain food security (Hodgson, 2000).

2.6.10 Biological Oxygen Demand (BOD)

Oxidation of organic compound is carried out by microorganisms using the organic matter as food source; the oxygen consumed is known as biological oxygen demand (BOD) and it is one of the most commonly measured constituents of wastewater. Wastewater is composed of a variety of inorganic and organic substances. BOD measures the oxygen consumed by microorganisms as they decompose organic matter and includes any chemical oxidation of inorganic compounds. Effluents high in BOD can deplete oxygen in receiving waters, causing fish kills and ecosystem changes. The BOD test measures the amount of oxygen consumed during a specified period of time, usually 5 days at 20 °C and so is called BOD₅. By measuring the initial concentration of a sample and the concentration after five days of incubation at 20°C, the BOD₅ can be determined (Greenberg *et al.* 1992).

2.6.11 Chemical Oxygen Demand (COD)

COD is often measured as a rapid indicator of organic pollutant in water. It is attractive as the test yield results within two hours. It is normally measured in both municipal and industrial wastewater treatment plants and gives an indication of the efficiency of the treatment process. COD measures biodegradable and non-biodegradable organic matter of wastewaters. COD test is used to measure the oxygen equivalent of the organic material in wastewater that can be oxidized chemically using dichromate in acid solution (Masten& Davis, 2004).

2.7 Bacteriological Parameters

2.7.1 Total Coliforms and Faecal coliforms

Wastewater usually contains millions of microorganisms per milliliter. However many of these organisms are harmless. Few disease-causing microorganisms called pathogens invade some part of the host and either grow and multiply or produce toxin which interferes with normal body processes. They are divided into categories with the most common groups associated with water pollution being bacteria, viruses, protozoa, helminthes (intestinal worms) and algae. These can exist naturally or can occur as a result of contamination from human or animal waste. Contact with the contaminated water may lead to disease such as typhoid, cholera and gastrointestinal problems. (Keriata *et al.*2004).

Coliform tests are useful for determining whether wastewater has been adequately treated and whether water quality is suitable for drinking, recreation or reuse. Coliform are a family of

bacteria common in soils, plants and animals. Because they are very abundant in human wastes, coliform bacteria are much easier to locate and identify in wastewater than viruses and other pathogens that cause severe diseases. For this reason, coliform bacteria are used as indicator organisms for the presence of other, more serious pathogens. Coliforms are frequently monitored as total or faecal coliforms. (Modi, 2011)

Total coliform (TC) is defined as a large group of anaerobic, non-spore forming, rod-shaped bacteria that ferment lactose with gas formation within 48 hours at 35 °C (Chapra, 1997). Total coliform bacteria are a collection of relatively harmless microorganisms that live in large numbers in soils, plants and in intestines of warm-blooded (humans) and cold-blooded animals. Some pathogens enter the human body through the skin but more commonly they are ingested with drinking water. Faecal coliform (FC) is a subgroup of TC that comes from the intestines of warm-blooded animals. However, since they do not include soil organisms, they are preferable to TC as an indicator organism. World Health Organization Guidelines for Drinking Water Quality state that as an indicator organism faecal coliform *Escherichia coli* (*E-coli*) provides conclusive evidence of recent faecal pollution and should not be present in water meant for human consumption.

It is generally assumed that the higher the number of coliform organisms found in a 100 ml sample, the higher the risk for waterborne disease (http://en.wikipedia.org/wiki/Indicator_bacteria). They are measured by running the standard total coliform test at an elevated temperature (44 °C) (Chapra, 1997).

There are two commonly used methods for determining the presence and density of coliform bacteria. The membrane filter (MF) technique provides a direct count of colonies trapped and then cultured. The multiple tube fermentation method provides an estimate of the most probable number (MPN) per 100 milliliters from the number of test tubes in which gas bubbles form after incubation.

The environmental hazards are to a large extent related to eutrophication. Eutrophication occurs when a natural water body is overloaded with phosphorus and nitrogen, causing extensive algal growth. Decomposition of algae requires large amounts of oxygen. This gives less available oxygen in the water body, causing fish death (Kemira, 2003). Health hazards are associated with pathogenic microbial agents from wastewater that are not removed before the wastewater is discharged into the environment. The greater the quantity of pathogenic agents transmitted to the environment, the greater are the risk of disease outbreaks.

The maximum permitted discharge values of critical parameters in the wastewater are normally given by national regulations. The Environmental Protection Agency (EPA) of Ghana has given the guidelines for Ghana as shown in table 1. 1

Table 1. 1: EPA Ghana Guidelines for maximum permissible wastewater effluent discharge levels

Parameters	Units	EPA Guideline Value
Ph		6-9
Temperature	°C	< 3 °C above ambient
Colour	TCU	200
Turbidity	NTU	75
Electrical Conductivity	µs/cm	1500

TSS	mg/l	50
TDS	mg/l	1000
BOD5	mg/l	50
COD	mg/l	250
Ammonia	mg/l	1.0
Nitrate	mg/l	50
Total Phosphorus	mg/l	2.0
E. coli (cfu/100 ml)		10
Total Coliforms (cfu/100 ml)		400

Source: EPA GHANA, 2010.

2.8 Health Effects Associated with Wastewater pollution

Issues with drinking water negatively affecting one's health can be very common occurrence in most urban areas, especially the populace that do not have adequate waste water treatment and facility (Feliciano *et al.* 2004).

As sewer overflows may contain raw sewage, they can carry pathogens (disease causing organisms). These include bacteria, viruses, protozoa (parasitic organisms), helminthes (intestinal worms), and inhaled molds and fungi. Thermo tolerant coliforms and enterococci can be used as indicators of pathogen pollution. The diseases they may cause range in severity from mild gastroenteritis (causing stomach cramps and diarrhea) to potentially life-threatening ailments such as cholera, dysentery, infectious hepatitis, and severe gastroenteritis (Davis & Masten, 2002).

Human health impacts can be dependent on the duration of exposure to, and the levels of pollutants in the overflow. Humans can be exposed to pathogens through sewage overflows into drinking water sources, direct contact with overflows in public areas such as parks, streets, swimming or boating waters that has been contaminated with polluted water or raw sewage (Salifu, 2008).

2.9 Social survey on socio-economic impacts of wastewater pollution

The social structure of any project is an integral part in identifying what is needed to properly manage wastewater as it takes the customs and culture of the people into consideration. Overcrowding is detrimental to the sewage system and quality of its services because the increase in wastewater may reach beyond design capacity level of the system, however, due to social and cultural traits, households tend to overcrowd, therefore threatening the wastewater management systems and water quality.

A person's socio-economic status, cultural ties, and past experiences influence how they perceive environmental quality. In addition, familiarity with, or exposure to information about, environmental quality can interact with these personal attributes to affect overall perceptions. (Renn *et al.* 1992).

Because an individual's perception of environmental quality and risk may affect their behavior. To properly manage wastewater systems in the Tema metropolis, it is necessary to understand people's concept on the facility and the ways in which perceptions of risk and the environment influence these concept. Such an understanding of perceptions is required to accurately predict how people will use the facility in the future.

CHAPTER THREE

MATERIALS AND METHODS

3.1 Introduction

Research methodology for this project consist of books, scientific journals and articles, personal interview and internal research, involving a review of existing information contained in reports, studies and monitoring programs. Also collation of information contained in files, such as 'complaints about overflows, and face to face interview with staffs including the sewage manager and field staff.

Again, discussions were held with the local council, catchment management bodies, and relevant stakeholders including the Assembly Members, Environmental Health Unit, and Environmental Protection Agency, and community consultation through administration of questionnaires.

3.2 Study site

Tema Metropolitan area is a coastal district situated about 30 kilometers east of Accra, the capital city of Ghana. It shares boundaries on the North East with the Dagme West District (DWD), Southwest by Ledzekuku Krowor Municipal , Northwest by Adenta Municipal and the Ga East Municipal (GEMA) North by the Akuapim South District and the south by the Gulf of Guinea. The Ashaiman Municipal is in- lock district within the Tema Metropolitan Assembly. The Metropolis covers an area of 396km and lies within the coastal savannah zone.

The Greenwich meridian (i.e. Longitude 0) passes through the Metropolis, which meets the equator or latitude 0 in the Ghanaian waters in the Gulf of Guinea. The southern tip of the Metropolis lies on the latitude 541 north. The Metropolis proximity to the sea with its low lying

terrain which projects into the sea makes a natural endowment for harbor hence the construction of Tema harbor making the district “The Eastern Gateway of Ghana”. Tema came into focus in 1957 when the government decided to construct a port at the Metropolis natural harbor to serve as the main import entries into the country.

3.3 Physical Characteristics

3.3.1 Topography

The topography of Tema Metropolis is generally flat and forms part of the coastal plains, ranging from 0m (south) to 35 (north) above sea level. The terrain of the district barely rises up to 65m above sea level.

3.3.2 Soil

Soils in Tema Metropolis are composed of sand clay humus, gravel and stone. The sandy and humus nature of the soil support the cultivation of vegetable. Clay which supports bricks making also have adverse effect in support of building foundations. Sand winning and stones quarry provide employment opportunities for a section of the people in the Metropolis.

Although, Sand winning, is a legitimate economic activity which requires licensing from the Minerals Commission and environmental permit from the Environmental Protection Agency (EPA), its adverse effect are numerous, notable among them are agricultural lands that are taken over for winning and even areas where winning is long completed still has heaps on the top soil that takes a longer time before land is suitable for agricultural purposes again. Secondly, the land

is left with wide and sometimes very deep pits which collect water during rainfall which serves as a breeding ground for mosquitoes.

3.3.3 Climate

The metropolis lies in the coastal savannah zone of Ghana and therefore enjoys a dry equatorial climate. Mean annual rainfall ranges between 730mm to 790mm. The rainy season is usually from April to July (major rainy season) and from September to November (minor rainy season). The highest amount of rain is experienced in May, June, and early July. Temperatures are high all year round with significant daily and seasonal variations. The annual average temperature ranges between 25 °C and 30 °C in the major rainy season while in the minor season temperatures range between 34°C and 40 °C. Humidity varies from 60% -80% (or more) in the wet season to less than 30% in the dry season. Winds, generally of low velocity, blow over the area from the south during the day and evening and from the west in the night and early morning.

As a result of Tema being an industrial hub and the absence of reserve forest in the area, some areas were demarcated and reserved as greenbelt zones to control the micro climate of Tema (Climate condition in relatively small area). The number of industries and waste generated increases in the Metropolis without a corresponding increase in afforestation to absorb excess carbon dioxide generated by these factories, also areas that were reserved as green belts are encroached upon by people and developed as residential areas. These can lead to negative changes in weather condition and its associated effects such as loss of biodiversity and erratic rainfall pattern

3.3.4 Drainage Pattern

The streams in the Metropolis are seasonal. Most of these streams flow through depressions into the sea during rainy season. Notable among them is the Gynakorgyor (flows into the Gao Lagoon between Manhean and Kpone). Industrial liquid waste and water from the eastern part of Tema Manhean Township converge into a major drain ending up in the Chemu lagoon. These pollutants have destroyed the aquatic life of the lagoon.

3.3.5 Vegetation

The vegetation zones in the Metropolis comprise of the following: shrub land, grassland and few semi deciduous forests. The grassland in areas such as Appollonia, Gbetsile, Santeo, Katamansu etc. supports livestock farming.

3.3.6 Geology

The Metropolis is underlain by the Precambrian rocks of the Dahomeyan formation, metamorphic rocks mainly consisting of granite gneiss and schist probably derived from sedimentary layers. These rocky formations are weathered or decomposed at the surface with a thickness of the weathered component not exceeding 12m. This creates some employment in the form of stone quarrying. Geological resources such as salt deposits exist at Kpoi. (T.M.A Planning Unit, 2010)

3.3.7 Hydrology

The streams in the Metropolis are seasonal in nature, they do not flow throughout the year. A number of streams however flow through depressions into the sea during the rainy season. Notable among them are the Gynakorgyor (flow into the Gao Lagoon between Manhean and Kpone.). Water from the industrial area and the Eastern part of the township converge into a major drain ending up in the Chemu Lagoon located between the harbor area and Tema Manhean. These have contributed to the biological death of the Chemu lagoon. Chemicals washed from the industries pollute and destroy the aquatic life of lagoon. (T.M.A Planning Unit, 2010)

3.3.8 Population Size and Growth

According to the 2000 Ghana Population and Housing Census and Household Survey, the total population of the Metropolis was 298,432 with males and females forming 49% and 51% of the population respectively. With a growth rate of 2.6% the population as at the time GPRS II 2006 was prepared and estimated at 348,815 subsequently the current population size could be estimated at about 387,045 and expected to reach 418,444 by the end of 2013.

The Metropolitan population growth rate of 2.6% per annum is quite on the low side when compared with the regional and national figure of 4.4% and 2.7% respectively. (Ghana Statistical Service, 2000).

3.3.9 Land Use of Tema Metropolitan Area

The total land coverage of Tema Metropolitan Area is approximately 369 sq. km. Out of this about 45% has been planned, approved and developed. The major land uses that make up of the Metropolis are residential, industrial, commercial, agricultural and social accessible facilities.

Industrial land use is estimated approximately 7.5% of the total land area. It is the pulling factor of influx of people into the southern parts of the Metropolis and into the City of Tema seeking for employment thus creating slums and squatters zones. The industrial pollutions of sound, odour, dust and carbon are setbacks to the development of the Metropolis. The heavy trucks, articulators and trailers plying the roads in the Metropolis reduce the life span of the roads.

Commercial land use and activities in the Metropolis is estimated to be 4.1% of the total land area. Commercial activities are concentrated in the urban centers and along some major radial roads like the Spintex road, Akosombo road etc. The biggest commercial concentration is located at the Central Business District (CBD) of the city of Tema. The harbor, the main entry point for imported goods and services into the country, its magnetic factor couple with the industries have promoted these commercial activities in the Metropolis. On the other hand, the activities within the proposed Green Belt zones are destroying the intended purpose of such belts which were created to absorb the carbon dioxide produced by the industries and in return give out oxygen to the dwellers of the city.

Currently, the living area in the Metropolis is about 36% of the total land use of the land. The residential land use has shaped the settlement pattern of the Metropolis. The built up

environment is made up of well planned communities, peri-urban settlements and the industrial area. The well planned communities and the peri-urban areas form about 40% of the total land area with industrial and commercial areas forming 15%. With rapid population increase, the built up areas continue to increase and this has compounded the environmental and sanitation problems and challenges that face the metropolis. Figure 3.1 below shows the study area map with sample sites.

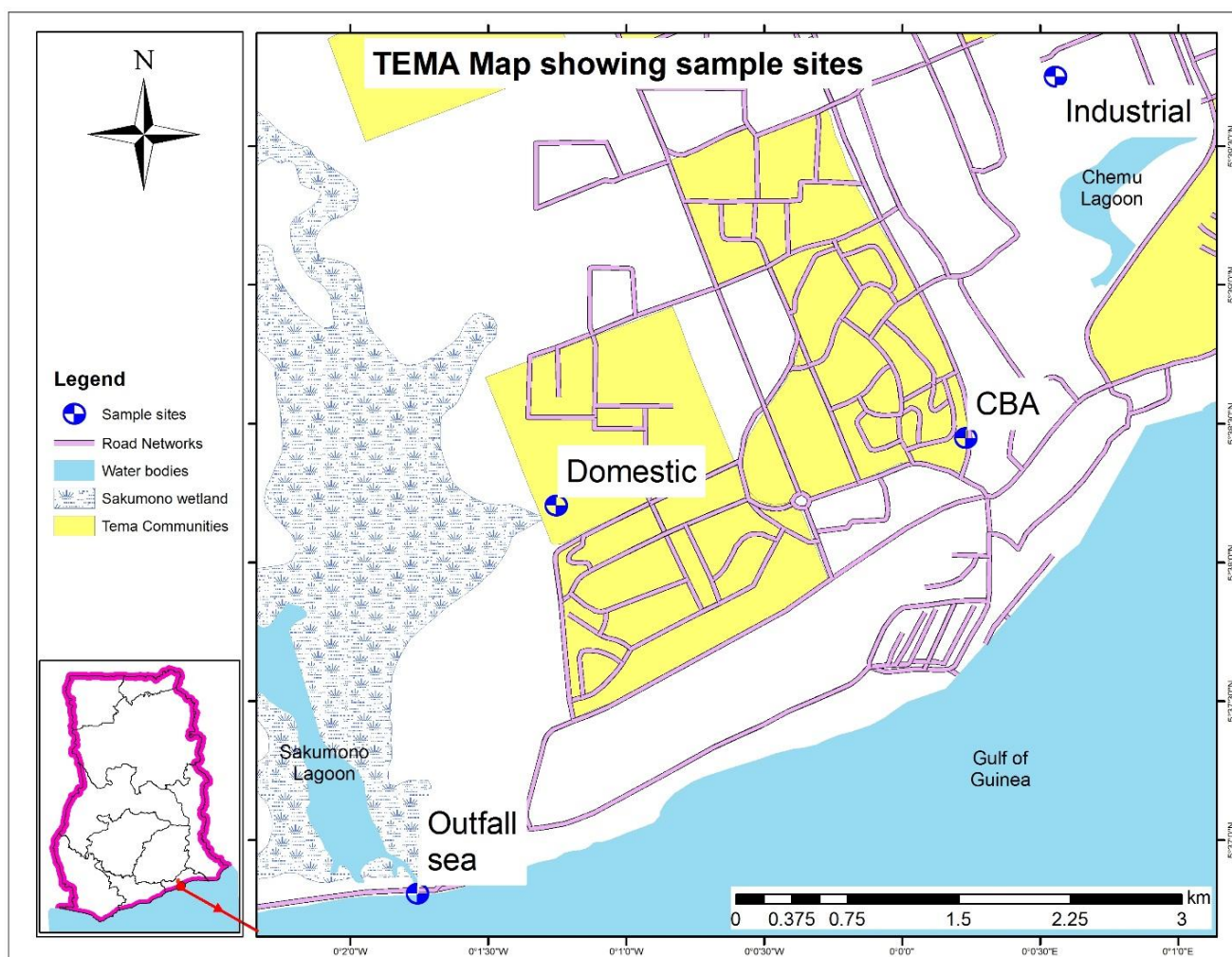


Fig 3. 1study area map showing sample sites

Source: Ghana survey department.

3.3.10 The Tema Sewerage System

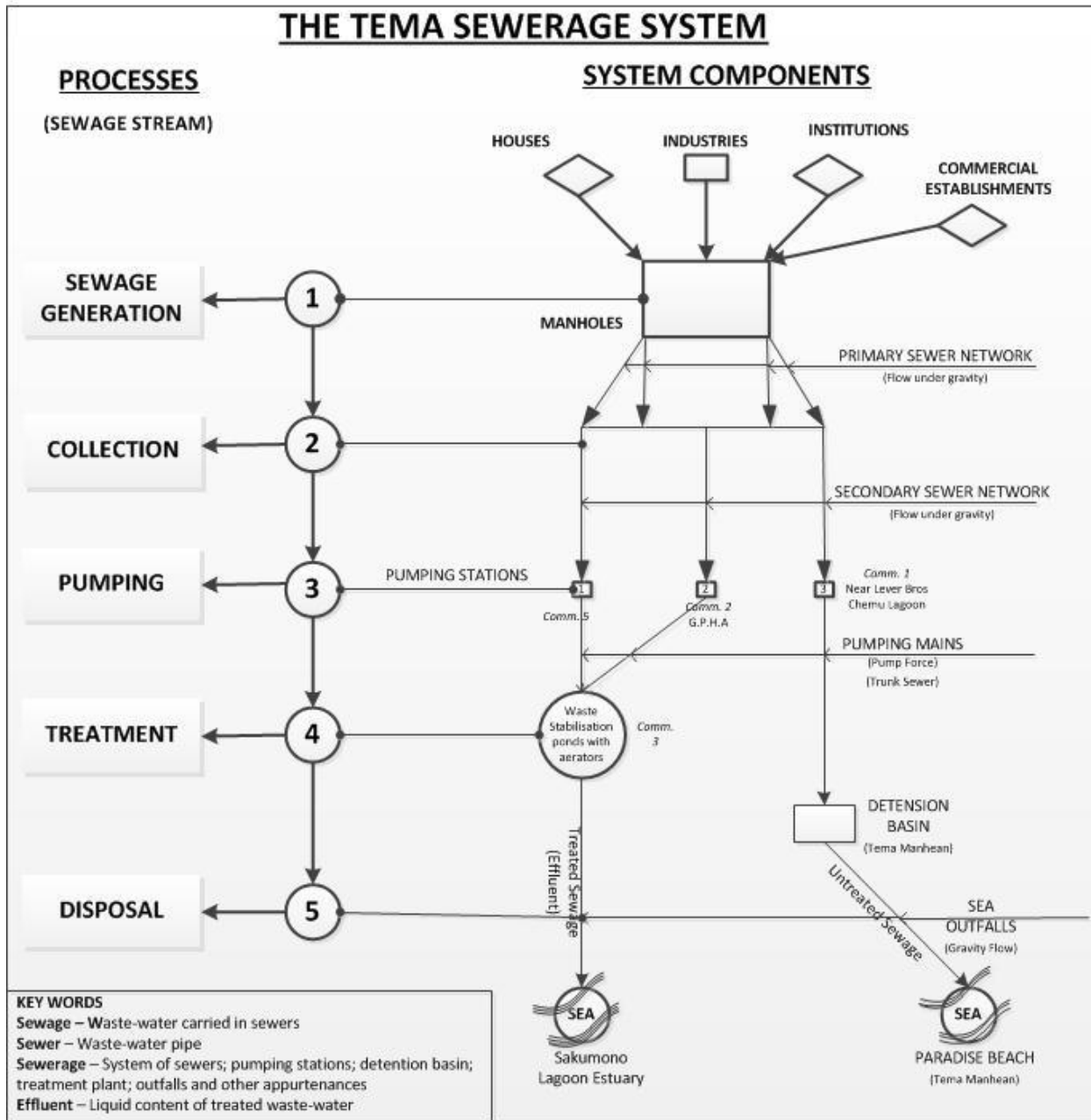


Fig 3.2: Schematic Diagram of Tema Central Sewerage System

Source: Author

The Tema sewerage system was constructed in 1963. The extracting Sanitary Sewer System covers twelve communities, the harbor and the industrial area. The whole area of the town is divided into three catchment basins by two ridges.

The three basins are: The *Southern basin* which covers parts of Communities 2, 3 and the Harbor; The *Western basin* covers Communities 5, 6, 7,8,9,10,11 and 12 and the *Eastern* one covers Community 1, part of Community 4 and 7 and the industrial area.

The system has 100mm diameter gravity house sewer, 150mm diameter sub-mains and 300mm diameter mains or truck sewers forming the sewer networks for the conveyance of the influent to the pumping stations and treatment plants.

The treatment plant has a designed capacity of 20000 cubic meters per day. This falls short of the current combined sewage flow of 24,426meter cube per day from PS1 and PS2.The designer of the treatment plant anticipated the necessity increase of the treatment capacity of the plant beyond 1996 and recommended, that due consideration be given to the creation for additional aeration lagoons (TMA, Waste management Department, 2013).

3.4. Research Design

To ascertain the physicochemical and microbiological quality of wastewater, a total of seventy four (74) effluent samples from mainlines manholes in the selected communities and the central business area, outfall drains at pumping stations (PS1, PS2 and PS3) and industrial area manhole and the sea outfall at the Sakumono beach was collected for analysis.

The fields studies at various sites were carried out during the month of February to April 2014. The sample points drain from community 1, 2,4,5,6, 8,9,11 and industrial main chambers. Coordinates of sampling stations were determined using Geographical Position Setelite (GPS) Garmin etrex 2.

3.4.1 Sampling Procedures

Strict measures were adhered in avoiding contamination of samples during sampling; handling and storage. Working conditions were carefully selected. At each sampling site, effluent sample was collected into a plastic bucket for in-situ measurements. Temperature, Conductivity, Turbidity, Total dissolved solids and pH were measured on site. Temperature, pH and conductivity Total dissolved solids were measured using water quality multimeter (HORIBA U-50 SERIES), Turbidity was measured using turbidimeter (Model HACH 2100P) NTU A two-liter polyethylene sampling container was filled with effluent at each site. The sampling containers with well-fitted stoppers were pre-treated by washing with distilled acetone to get rid of organic substances such as grease and fat residues. They were then washed with detergent and rinsed with de-ionized water and then soaked in 1.0 M nitric acid solution for 48 hours. The containers were finally rinsed several times with de-ionized water before used for taking and holding the effluents samples. Effluent samples that were not analyzed immediately were stored in a cold box and transported to the University of Ghana, Ecological lab.

3.4.2 Biochemical Oxygen Demand (BOD) and Dissolved Oxygen (DO) Sampling

Two bottles, one plain and the other dark (painted with bitumen to prevent possibility of photosynthetic production of oxygen) were used for sampling. The plain ones were used for

dissolved oxygen sampling and the dark bottles were used for BOD sampling. The bottles were filled with effluent to overflow in order to avoid any air bubbles from getting trapped in the bottles. The dissolved oxygen samples were fixed on site with 2 ml each of Winkler 1 (Manganous chloride) and Winkler 2 (alkaline-iodide-azide reagent). Samples, which were not analyzed within 2 hours of collection, were kept at or below 4 °C but brought to 20 °C before analysis in the laboratory.

3.5 Bacteriological Sampling

One effluent sample for bacteriological analysis was taken at each site. Glass bottles with a metal cap were used to collect the water samples. These bottles were sterilized before use and the mouths covered with aluminum foil to avoid contamination during sample collection. Upon collection, the samples were stored on ice to avoid multiplication of bacteria.

3.6 Laboratory Analysis

Analyses were carried out at Ecological laboratory of University of Ghana, Legon. Samples, which were not analyzed within 2 hours of collection, were kept at or below 4 °C but brought to 20 °C before analysis in the laboratory.

3.6.1 Biological oxygen demand (BOD)

The 5-day BOD test was used. This method consists of filling with sample an airtight bottle of the specified size and incubating it at the specified temperature for 5 days. Dissolved oxygen was measured initially and after incubation, and the BOD was computed from the difference between

the initial and final DO. For this study all samples taken from the field for BOD analysis were diluted (The samples were diluted because BOD concentration in most waters exceeds the concentration of DO available in an air-saturated sample. Because the initial DO is determined immediately after the dilution is made, all oxygen uptake, including that occurring during the first 15 minutes, is included in the BOD measurement). The dilution water was prepared by 1 ml each of phosphate buffer, MgSO₄, CaCl₂, and FeCl₃ solutions /l of water.

$$\text{Calculation: BOD}_5 \text{ mg/l} = \frac{D_1 - D_2}{P}$$

Where;

D₁= DO of diluted sample immediately after preparation, mg/l

D₂= DO of diluted sample after 5 day incubation at 20 °C, mg/l

P=Decimal Volumetric fraction of sample used

(APHA, 1995).

3.6.2 Nitrate Nitrogen (NO₃⁻ -N) analysis

The method used for the Nitrate analysis was the Cadmium Reduction Method. The nitrate level in each sample was measured using Nitrate Powder Pillows in a direct reading Hach spectrophotometer Model DR. 2000. Twenty five (25) ml of the sample was measured into sample cell of the Spectrophotometer. One Nitraver 5 (Nitrate Reagent Powder Pillow) was added to the sample. The mixture was then shaken vigorously for 1 minute. Five minutes was allowed for the reaction. An orange color of the mixture indicates the presence of Nitrate. After five minutes, another cell was filled with 25ml of only the sample (blank). The blank sample

was placed in the spectrophotometer. Then the prepared sample was placed into the cell holder to determine the Nitrate concentration at 500nm in mg/l (HACH, 1996)

3.6.3 Phosphate (PO_4^{3-}) analysis

A 25ml of effluent sample (the prepared sample) was placed in the sample cell. Phos Ver 3 Phosphate Powder pillow was added to the cell content and swirled immediately to mix. A two-minute reaction period was allowed. A blue coloration of the mixture indicates the presence of phosphate. Another sample cell (the blank) was filled with 25ml of sample and placed into the cell holder. After reaction period the prepared sample was placed into the cell holder and the level of phosphorus was determined at 890 nm. The Spectrophotometer displayed the results in mg/l PO_4^{3-} (HACH, 1996).

3.6.4 Ammonia Nitrogen (NH_3-N)

Direct nesslerization and spectrophotometric determination at wave length of 425nm was used to determine Ammonium-nitrogen. 25 ml of the sample (the prepared sample) was measured using graduated cylinder. A second graduated cylinder was filled with the 25ml of demineralized water (blank). Three drops of Mineral Stabilizer was added to each of the cylinders. The solutions were inverted several times to mix. Three drops of Polyvinyl Alcohol Dispensing agent was added to each cylinder and inverted several times to mix to aid the color formation in the reaction of Nessler reagent with ammonia ions.

1.0 ml of Nessler Reagent was pipetted into each cylinder, Stopped and inverted several times to mix. A 1-minute reaction period was allowed during which each solution was poured into

respective blank and prepared cells. The blank was placed into the cell holder of the Spectrophotometer. The prepared sample was placed into the cell holder to determine the Nitrogen ammonia level at 425nm. A yellow color is formed proportional to the ammonia concentration. (HACH, 1996)

3.6.6 Total suspended solids analysis

The photometric (Non filterable residue) method was used. 500 ml of sample was blended at high speed for two minutes. This was poured into a 600ml beaker. The sample was stirred and 25 ml immediately poured into a sample cell. The stored programme number for suspended solids, 630, was entered. The wavelength was set to 810 nm. A sample cell was filled with 25 ml demineralized water (blank). This is placed into the cell holder. Next the sample was placed into the cell holder and the reading taken in mg/l suspended solids (HACH, 2010)

3.7 Analysis of Bacteriological parameters

The Total and faecal coliform present in water samples were determined using the Membrane Filter (MF) technique (HACH, 1996; WHO, 1997). Membrane filter with 0.45 μm was sterilized in a system and used to filter 100 ml of water mixed with 10 ml of the sampled water. The results obtained from the colony counting were then multiplied by 10 to obtain the actual count per 100 ml. The membrane filter was lifted from the system with a sterilized forceps and carefully placed on the sterile media in Petri dish. M-lauryl sulphate broth was used as growth medium for the incubation of coliforms in a Petri dish. Two milliliters of sterilized M-lauryl sulphate broth was poured on an absorptive pad placed in a Petri dish. The Petri dish was then covered and inverted

for incubation at 37 °C for Total coliform and 44 °C for faecal coliform. After 24 hours the Petri dishes were removed from the incubator and the colonies counted and recorded in coliform forming units per 100 ml (cfu/100ml).

3.8 Sampling design for Socio- economic survey

The data collection techniques that was used in this study involved a combination of purposive and incidental sampling technique. These techniques were considered based on the objectives of the study and the questions were structured accordingly using both pre-coded and open ended. In the cluster sampling, the households were divided into three clusters namely; Tema West cluster, Tema East cluster, Tema central cluster. The population was then identified and selected from each cluster using purposive sampling techniques based on social status of the community. In the stratified sampling the population was stratified, thus divided into groups such as youth groups, middle aged and elderly. This was to avoid bias in interviewing a population of a certain age groupings. In the incidental sampling technique, the samples were picked by accident where there was no prior decision. In this technique any person within the various strata was interviewed.

3.8.1 Administration of questionnaire

Questionnaire was the main research tool that was used to collect data on issues of sanitation, water supply and waste management. The opinions and comments of a total number of 70 respondents in the study area were sought using a structured questionnaire. The interviews were conducted in the sampling residential houses selected and other households within the

community. Information that were gathered include wastewater management, responsible agencies, challenges, causes, effects and mitigation measures in respect to sewage pollution.

In addition, 30 people from small businesses, commercial and public establishments such as small restaurants, central market, hospitals, etc. were interviewed to collect necessary data to identify management effects and impacts of sewage pollution on them and their opinion on solving it. Focused group discussions, and a number of key informant interviews were also held to gather relevant information. Three focused group discussions and key informant interviews were conducted to collect socio economic information and to triangulate the collected data.

3.9 Data Analysis

Raw data collected for Physico-chemical, bacteriological and socio-economic survey were subjected using Microsoft spreadsheet version 2007. Statistical Package for Social Science (SPSS) software version 20.0 was used to generate the means, maximum and minimum values for the various parameters and frequencies used in the data for both the social survey and the water quality. One-way Analysis of variance (ANOVA) was used to test for any significant difference between the various parameters and sample sites. Least significant difference (LSD) was used to compare the sample means. A correlation analysis was also carried out to establish the degree of relationship and similarities between the Physico-chemical and microbiological counts and the various sites; domestic, central business district, industrial and outfall points. Results were presented in the forms of tables, charts and thematic maps.

CHAPTER FOUR

RESULTS OF THE STUDY

4.1 Physico-Chemical Parameters

4.1.1 Temperature

The effluents have slight variations in temperature with average temperature of 30.3 °C during the sampling period. The mean temperature of effluents ranges from minimum value of 29.5°C at the industrial area to maximum mean value at domestic site with the average temperature of 31.2 °C. The results are showed in figure 4.1. Analysis of variance at 95% confidence level revealed a significant difference ($P < 0.05$) for temperature values between the various sample sites. However when the Least Significant Difference (LSD) was used to compare means, there were no significant difference between domestic, central business area and outfall but there were differences between domestic and industrial area effluent. (Appendix A1)

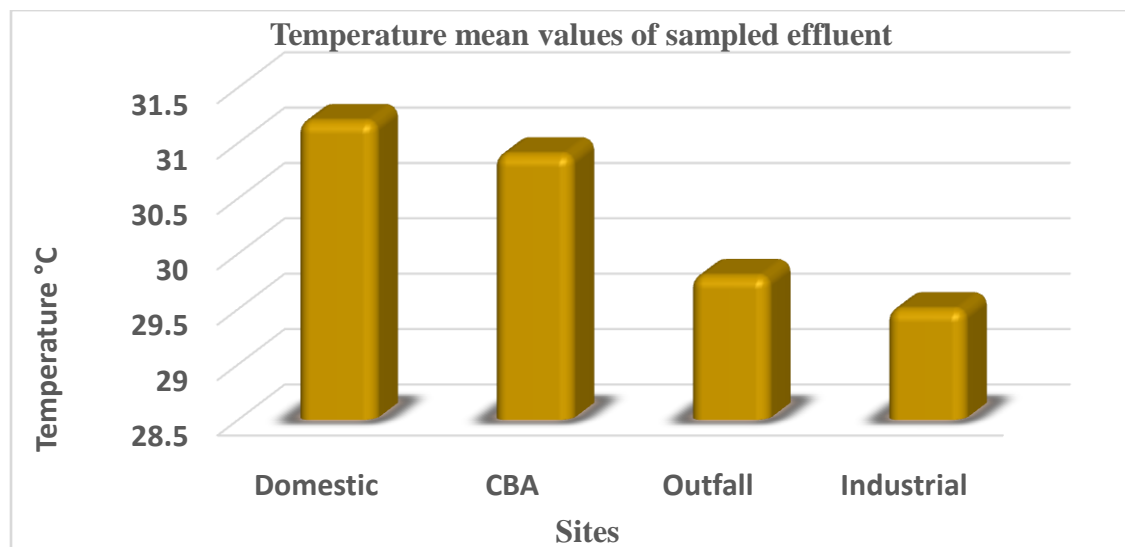


Fig 4.1: Mean variation in effluent temperature of sampled wastewater in Tema Metropolis

Source: Field Survey, 2014.

4.1.2 Hydrogen ions (pH)

During the study period, the effluent pH values ranged from a minimum of 7.3 (CBD) to a maximum of 8.2 (outfall). (Fig.4.2) Analysis of variance at 95% confidence interval did not show any statistically significant differences for pH in relation to sites over the study period ($P>0.05$).

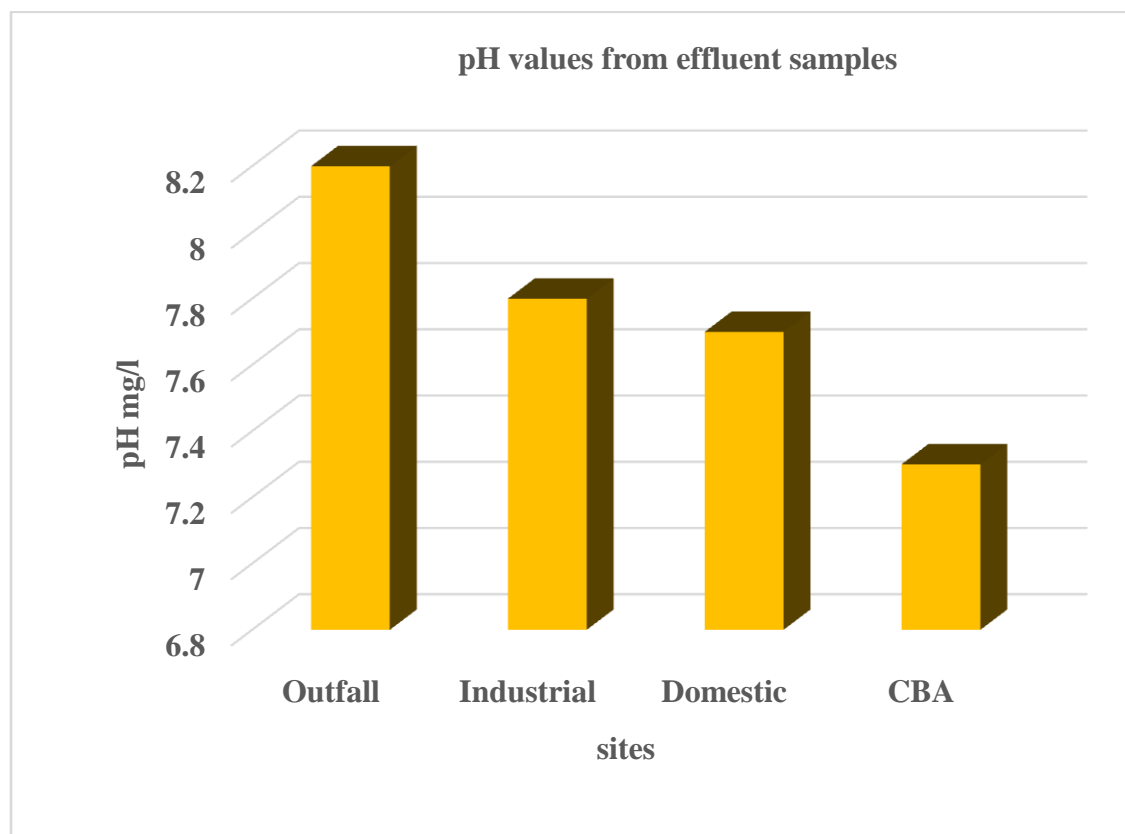


Fig 4.1: The variation in effluent pH of sampled wastewater in Tema Metropolis
Source: Field Survey, 2014.

4.1.3 Biochemical Oxygen Demand (BOD)

The results recorded BOD values from the domestic sewage with mean value of 53mg/l but recorded low for the industrial effluent with the mean value of 23 mg/l, 39mg/l (central business area) and extremely low values at the outfall point with 3.8mg/l. (Fig.4.3) Analysis of variance at 95% confidence interval revealed statistically significant differences in BOD ($P < 0.05$) between the samples from the various sites. However, when LSD was used to compare the means, there was significant difference between outfall and domestic, industrial and central business over the study period. The concentrations show high organic content loads in the sewage effluent. It therefore requires treatment before discharging into the environment. Figure 4.3 below shows map representing temperature and BOD levels in the sampled effluent.

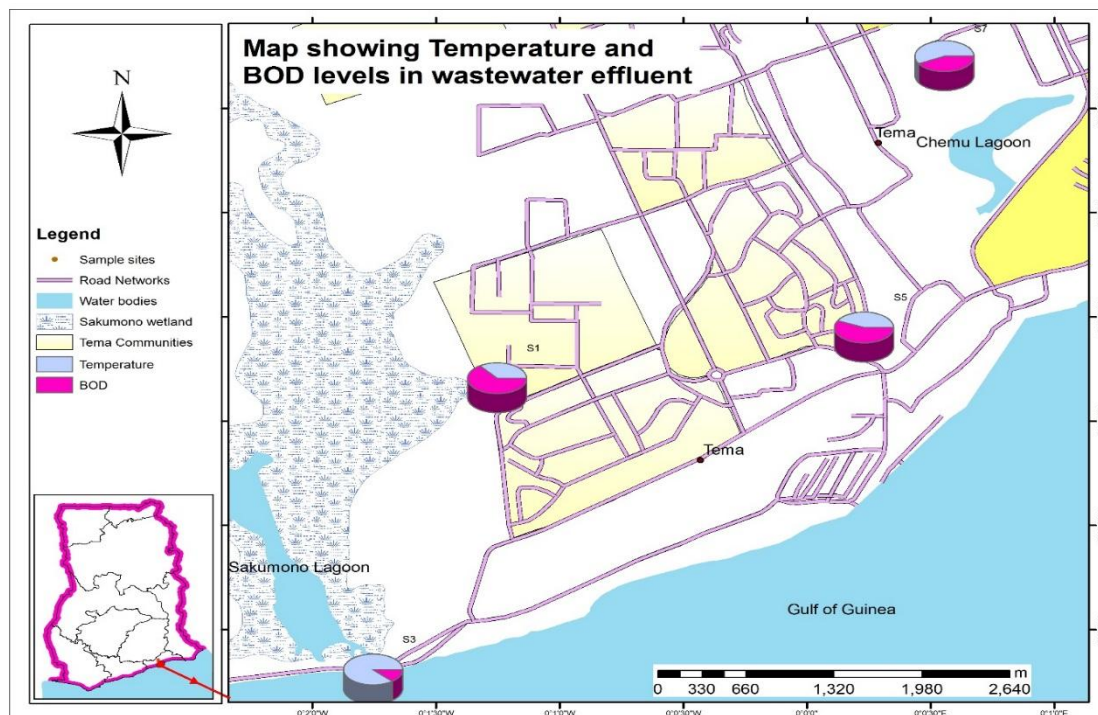


Fig 4.2: Map showing Temperature and BOD levels of sampled wastewater in Tema Metropolis

Source: Field Survey, 2014.

4.1.4 Dissolved Oxygen (DO)

The results of the Dissolved Oxygen recorded the highest mean value of 5.3(outfall) for the sample effluents and recorded low values for the various sampled sites with mean values of 0.8mg/l, 1.1mg/l, 2.4 mg/l for domestic, central business area and industrial sewage respectively. (Fig. 4.4). Analysis of variance at 95% confidence interval did not show any statistically significant differences for dissolved oxygen between the various samples from the sites.

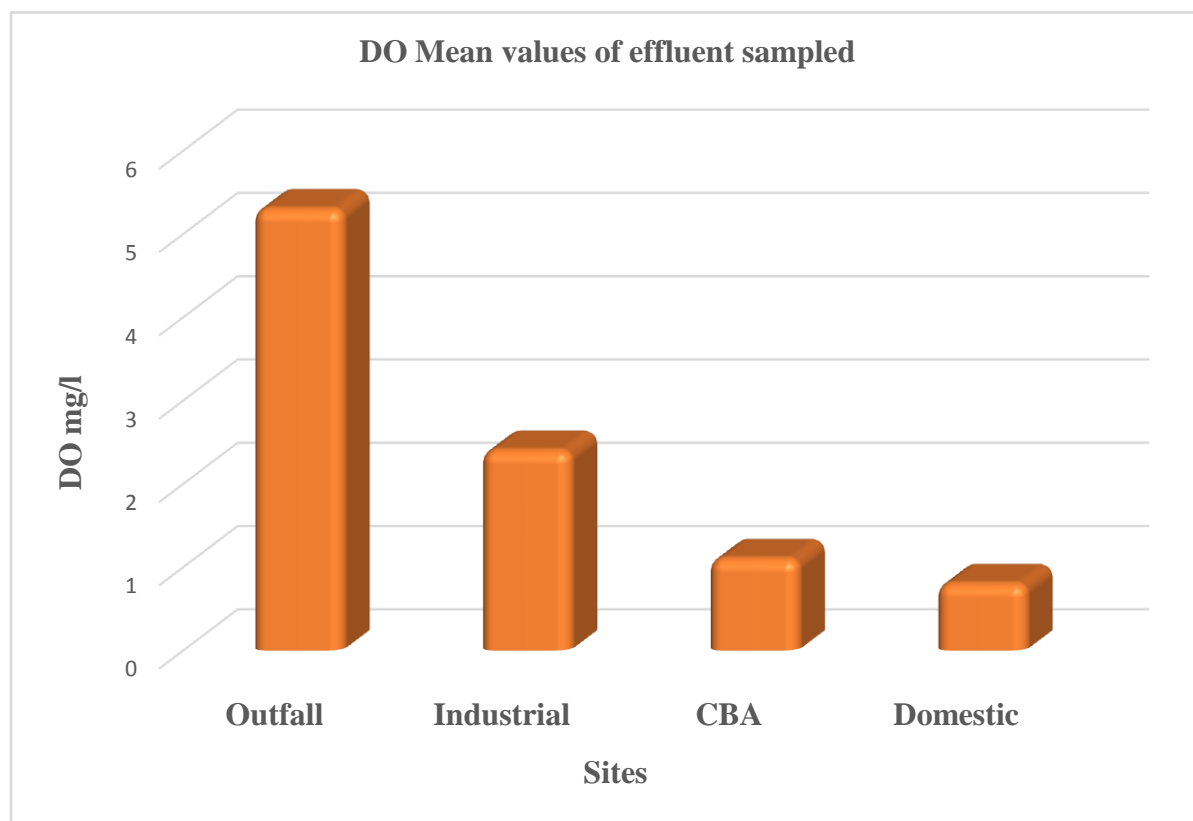


Fig 4.3: Mean variation in effluent demand oxygen of sampled wastewater in Tema Metropolis.

Source: Field Survey, 2014.

4.1.5 Chemical Oxygen Demand (COD mg/l)

The results recorded for COD were 357mg/l, 307mg/l and 330mg/l for samples for domestic, central business District, industrial and outfall points respectively. Analysis of variance at 95% confidence interval did not observe statistically significant differences in COD ($P > 0.05$) between the samples from various sites, however, when LSD was used to compare means it was observed that there was significant difference for COD concentrations between samples from outfall and central business area over the study period. (Fig.4.5)

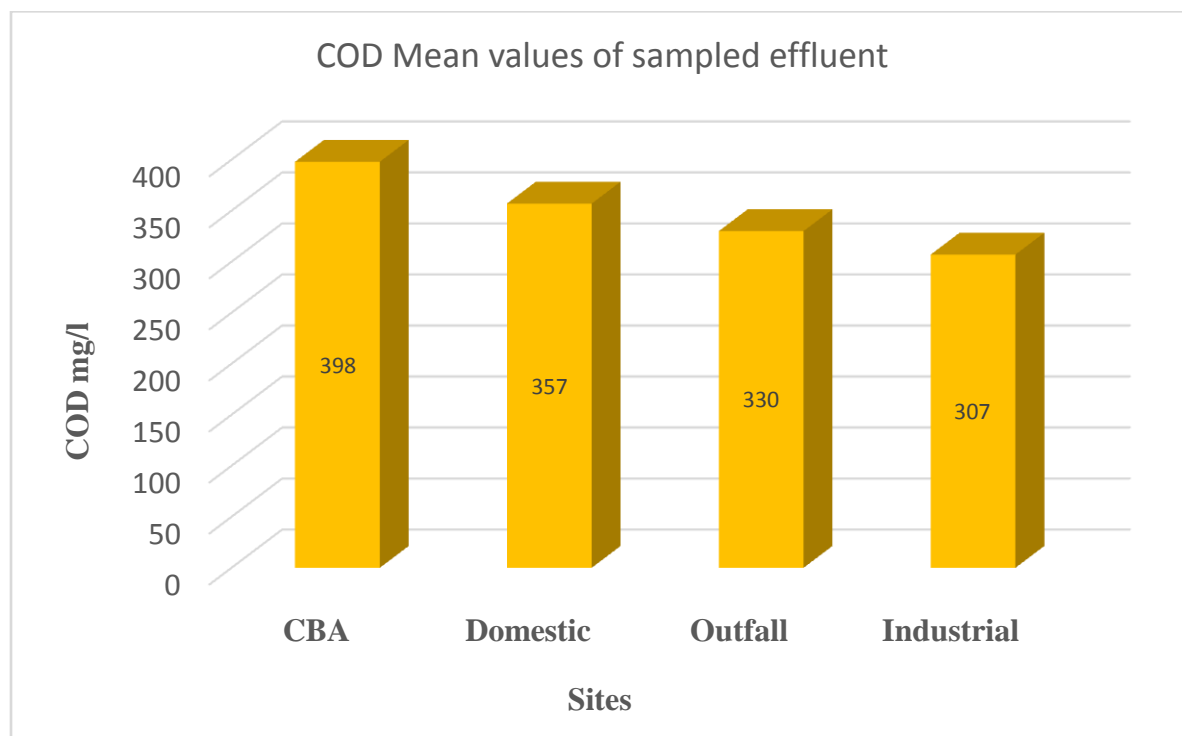


Fig 4.4: Mean COD values of sampled effluent
Field Survey, 2014.

4.1.6 Total Suspended Solids (TSS)

The mean total suspended solids of the waste water were generally high indicating; 467mg/l for domestic, 569mg/l, 128mg/l for central business area and industrial respectively except the outfall that recorded low value of 13.3mg/l. (Fig.4.6). Analysis of variance at 95% confidence interval did not show statistically significant differences for total dissolved solids ($P > 0.05$) between the samples from the various sites, however, when LSD was used to compare means, it was observed that there was significant difference for total dissolved solids between the various effluent samples site; outfall and domestic, industrial and central business over the study period. The recorded values for the various samples are presented in Appendix B.

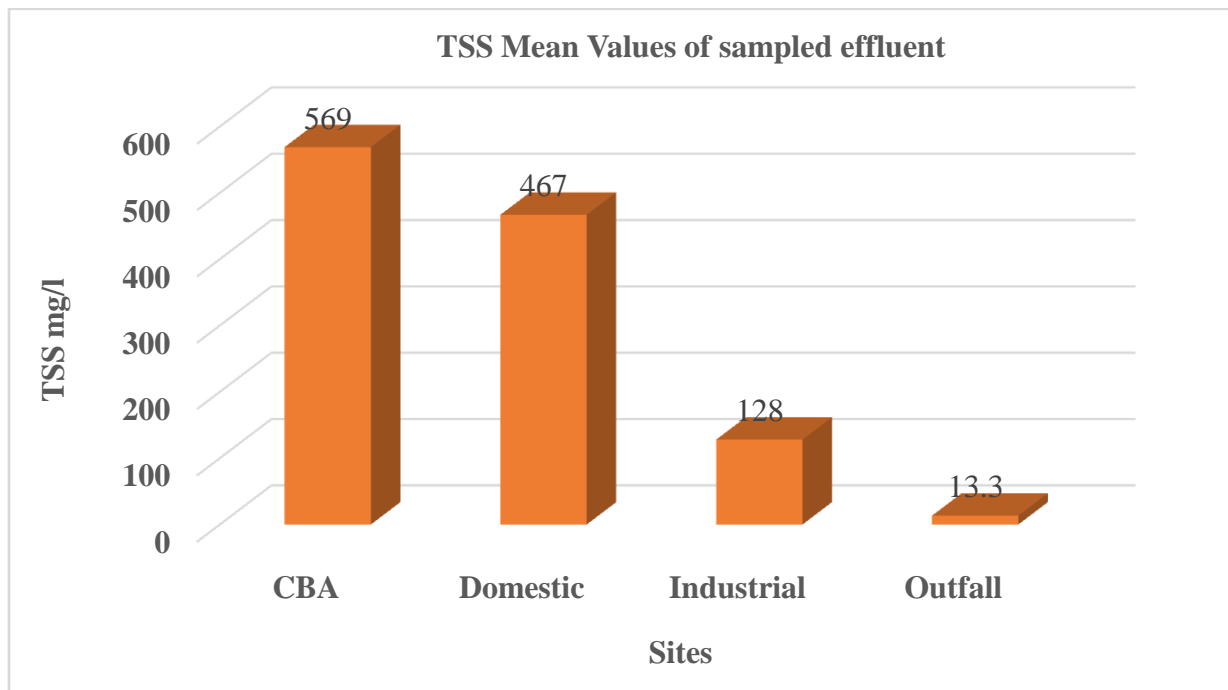


Fig 4.5: Mean variation in effluent total suspended solids of sampled wastewater in Tema Metropolis.

Source: Field Survey, 2014.

4.1.7 Electrical Conductivity (EC)

The mean conductivity values ranged from a minimum of 1767 $\mu\text{S}/\text{cm}$ (domestic), 17 $\mu\text{S}/\text{cm}$, to a maximum of 56828 $\mu\text{S}/\text{cm}$ (outfall).(Fig.4.7). Analysis of variance at 95% confidence interval observed statistically significant differences for EC ($P<0.05$) between the samples from the various sites. When LSD was used to compare the sample means, it was observed statistically that there was significant differences for EC between samples from domestic and outfall and central business area but did not show significance differences between domestic and industrial sampled effluent over the study period. (Appendix B).

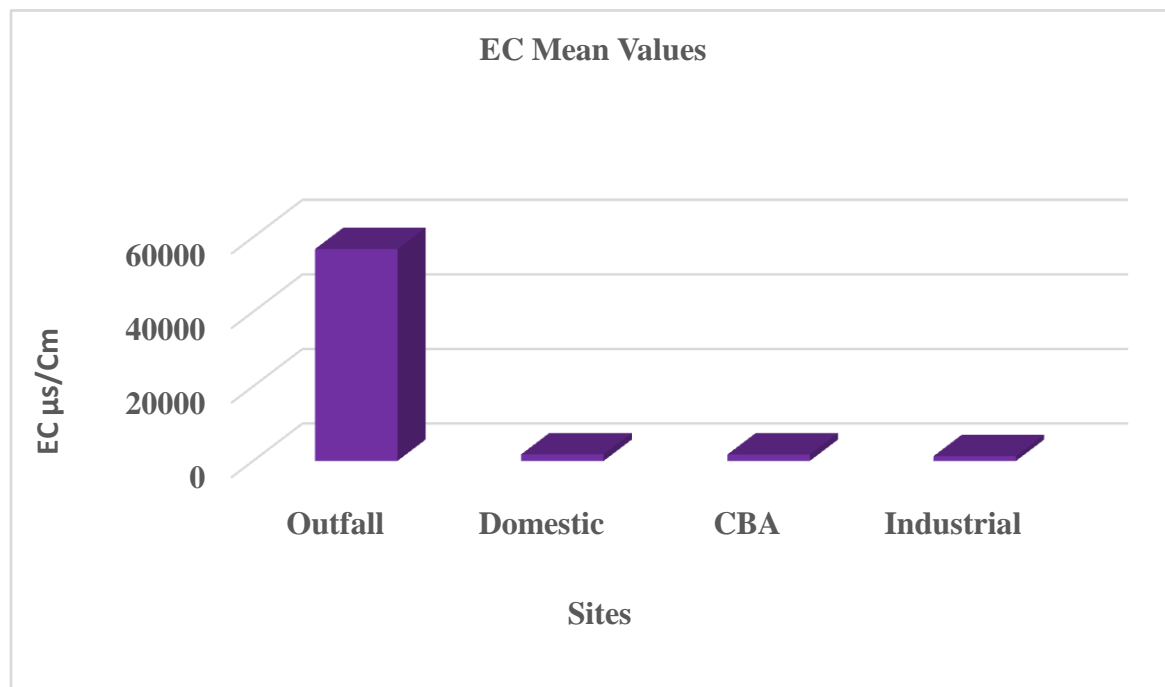


Fig 4.6: Mean variation in effluent total suspended solids of sampled wastewater in Tema Metropolis.

Source: Field Survey, 2014.

4.1.8 Nitrate-Nitrogen (NO_3^-)

Nitrate –nitrogen levels was generally low during the entire study period. The mean nitrate levels in the effluent ranged from a minimum of 1.5mg/l (outfall) to a maximum of 13.5mg/l (domestic). Samples from the central business district and industrial area however recorded 7.7mg/l and 2.4mg/l respectively. (Fig.4.8) Analysis of variance at 95% confidence interval did not show statistically any significant differences for Nitrate concentrations ($P>0.05$) between the samples from the various sites. (Appendix)

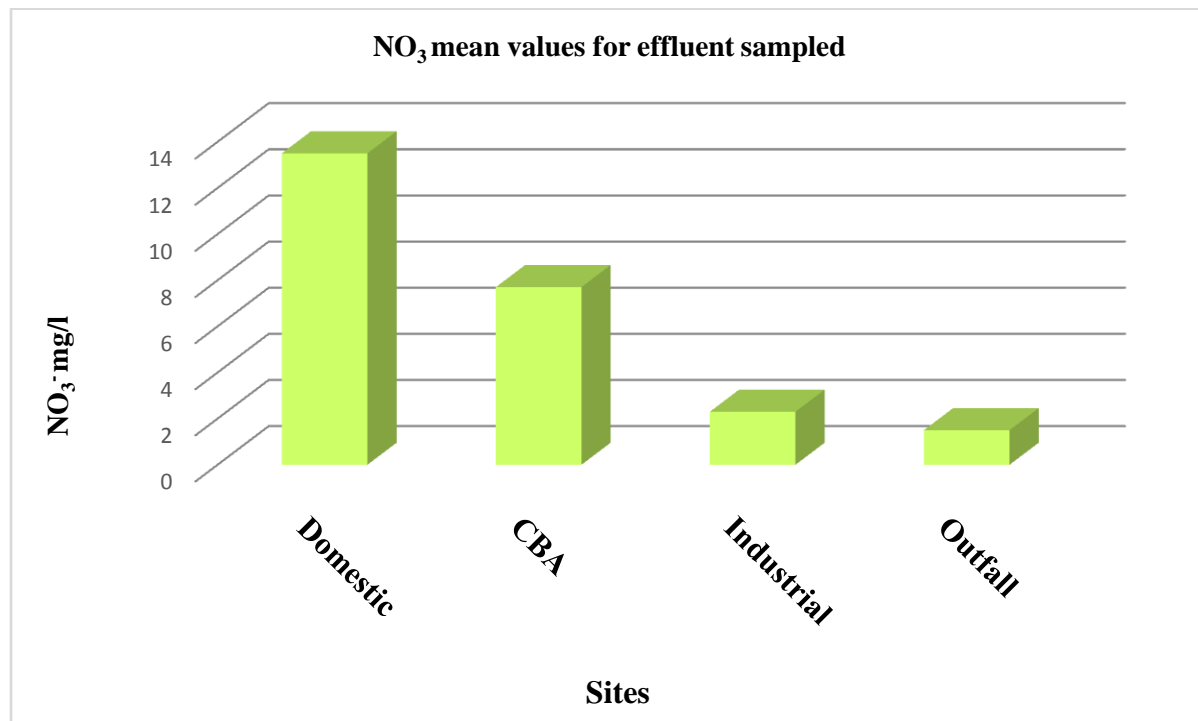


Fig 4.7: Mean variation in effluent nitrogen- nitrate of sampled wastewater in Tema Metropolis.

Source: Field Survey, 2014.

4.1.9 Nitrite - Nitrogen (NO_2^-)

The mean nitrite - nitrogen levels in effluents ranged from minimum value of 0.2mg/l (industrial) to maximum mean value of 11.6mg/l at domestic site. The results are showed in figure 4.9below. Analysis of variance at 95% confidence level revealed a significance difference ($P<0.05$) in nitrite nitrogen between the various samples. When the Least Significant Difference (LSD) was used to compare means, there were no differences between samples from domestic, central business area and outfall but there was difference between domestic and industrial area effluent. (Appendix A1).

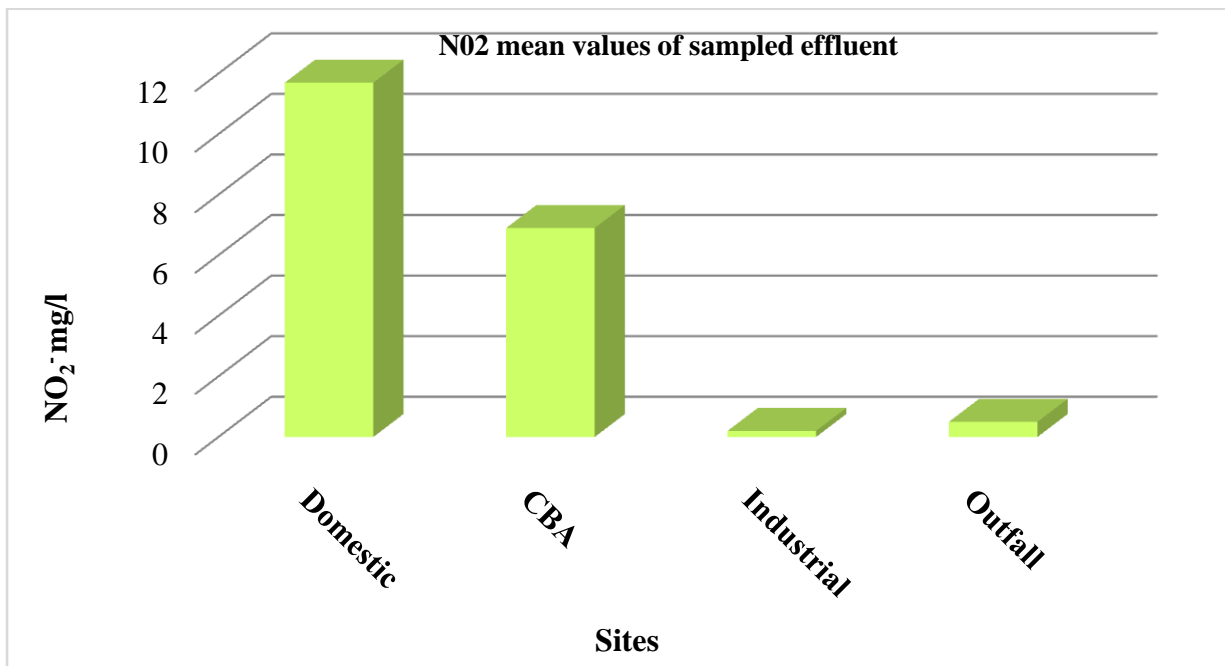


Fig 4.8: Mean variation in effluent nitrite - nitrogen of sampled wastewater in Tema Metropolis

Source: Field Survey, 2014.

4.1.10 Ammonia ($\text{NH}_3\text{-N}$)

The mean ammonia concentration ranged from a minimum of 0.2mg/l (outfall) to a maximum of 3.8mg/l (industrial)(Fig4.10). Analysis of variance at 95% confidence interval did not show statistically significant differences for $\text{NH}_3\text{-N}$ ($P>0.05$).

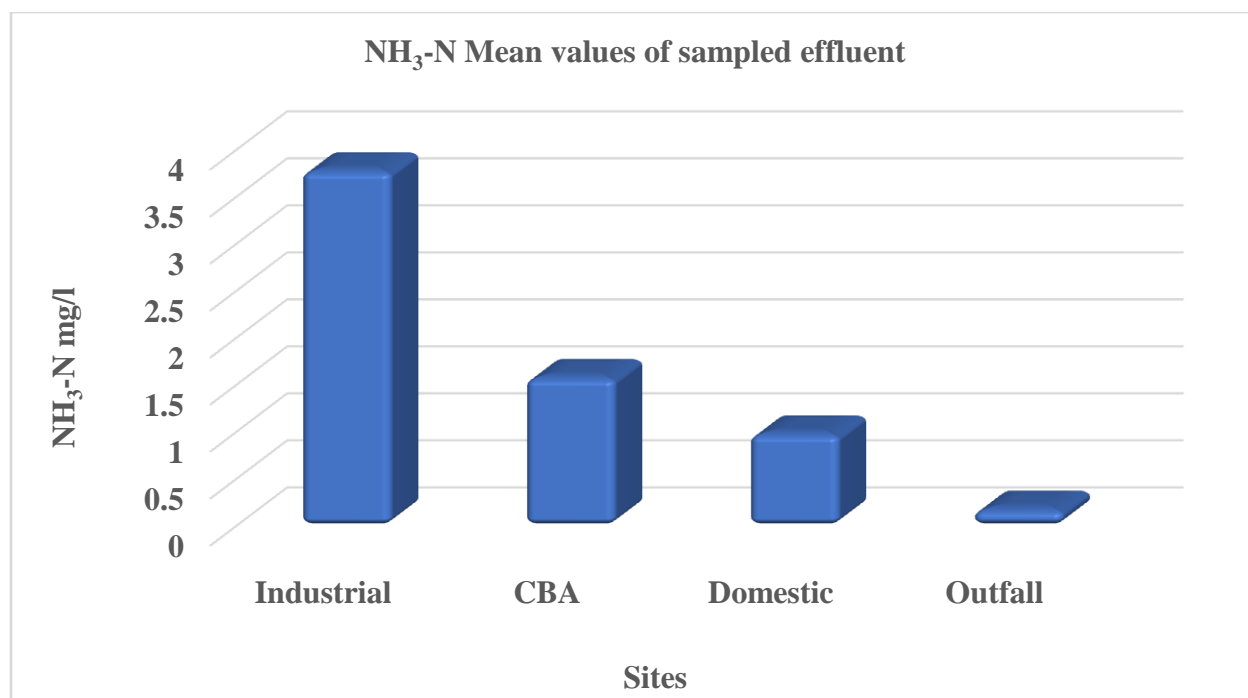


Fig 4.9: Mean variation in effluent Ammonia of sampled wastewater in Tema Metropolis.

4.1.11 Phosphate (PO_4^{3-})

The phosphate concentration in samples from domestic, central business area, industrial and outfall were 6.4mg/l, 4.9mg/l, 4.0mg/l and 0.6mg/l respectively (Fig.4.11). Analysis of variance at 95% confidence interval revealed statistically significant differences for phosphate ($P < 0.05$) between the various samples. When LSD was used to compare means, it was observed that there were differences between samples from outfall and domestic, industrial and central business over the study period. Figure 4.12 below shows a map representing the nutrient levels in samples from the various sites.

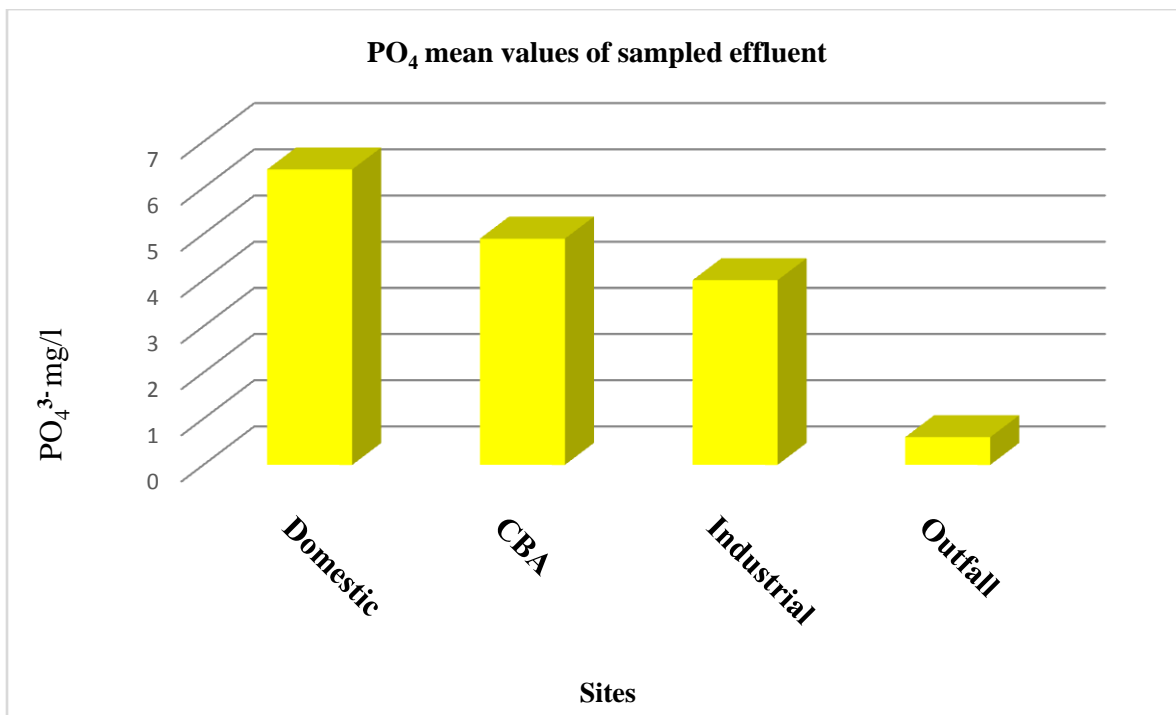


Fig 4.11: Mean variation in effluent phosphate of sampled wastewater in Tema Metropolis.

Source: Field Survey, 2014.

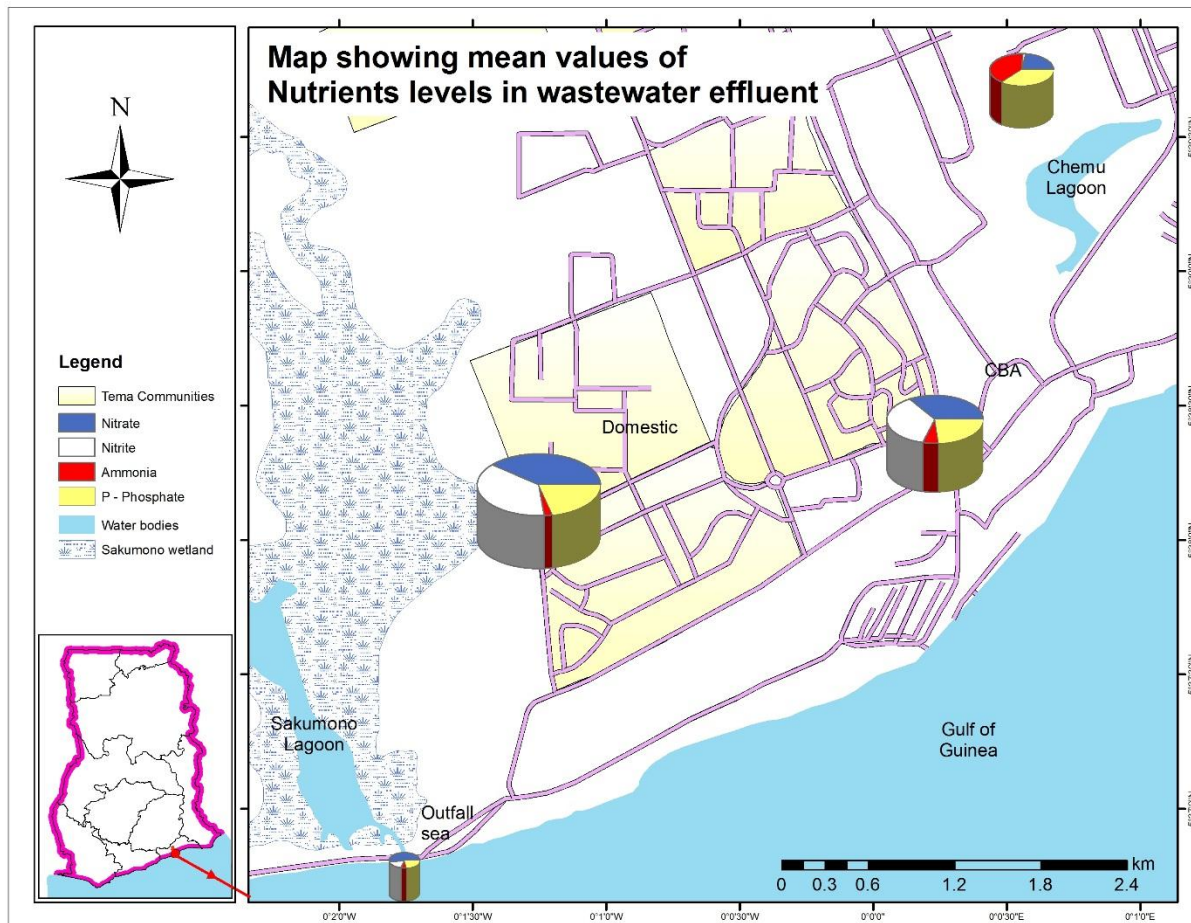


Fig 4.10 Map showing nutrient levels in the wastewater effluent in the Tema Metropolis

Source: Field Survey, 2014.

4.2 Bacteriological Parameters

4.2.1 Total Coliform

The mean concentrations of the total coliform in the effluents sample indicated; 5761cfu/100ml , 860cfu /100ml, 1289cfu/100ml and 6.6 cfu/100ml for samples from domestic, central business area, industrial and outfall respectively.

. (Fig.4.13) Analysis of variance at 95% confidence interval revealed statistically significant differences fortotal coliform ($P<0.05$) between the samples from the various sites, however, when LSD was used to compare means it was observed that there was significant difference for total coliform between samples from outfall and domestic, but observed no differences between samples from domestic, industrial and central business over the study period.

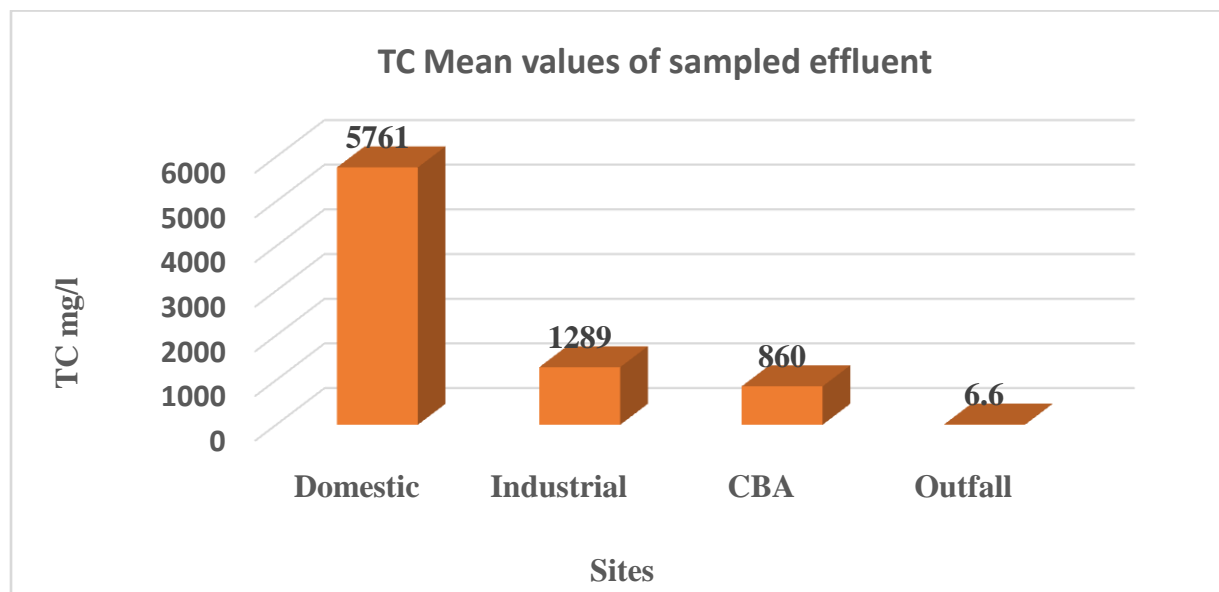


Fig 4.11: Mean variation in effluent total coliform of sampled wastewater in Tema Metropolis.

Source: Field Survey, 2014.

4.2.2 Faecal coliform

The mean concentrations of the total coliform in the effluents sample indicated; 36cfu/100ml, 15 cfu/100ml, 139 cfu/100ml and 0.6 for domestic, central business area, industrial and outfall respectively (Fig.4.14) Analysis of variance at 95% confidence interval revealed statistically significant differences in total coliform ($P < 0.05$) between the various sampled sites, however, when LSD was used to compare means it was observed that there is significant difference in faecal coliform between outfall and domestic, but observed no differences between domestic, industrial and central business over the study period.

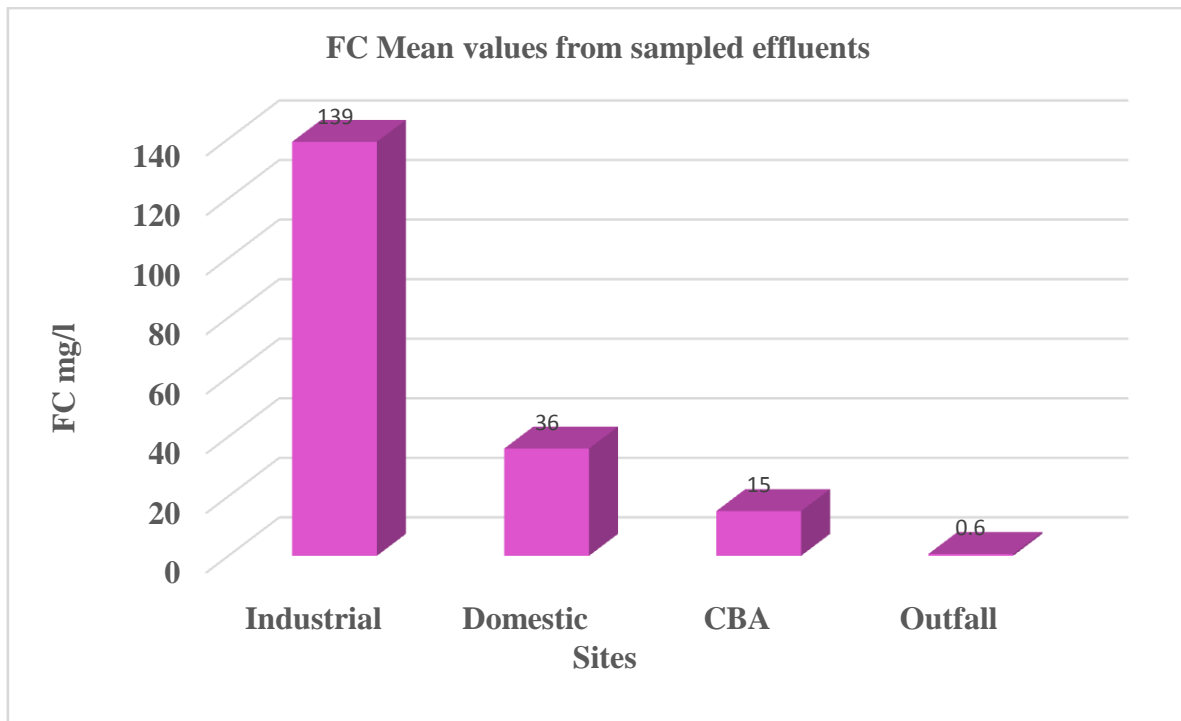


Fig 4.12: Mean variation in effluent faecal coliform of sampled wastewater in Tema Metropolis

Source: Field Survey, 2014.

4.2.3 *Escherichia-coli* (*E. coli*)

The mean concentration of *E-coli* in the sampled effluent from the various sampled sites in the study area varied from 14cfu/100ml, 8cfu /100ml, 34cfu /100ml, and 0.0cfu/100ml for domestic, central business area, industrial and outfall observed respectively (Fig4.15). Analysis of variance at 95% confidence interval observed statistically significant differences for *E.coli* concentrations of sampled effluent ($P<0.05$) from the various sites. When LSD was used to compare the means, it was observed that there was significant difference for *E. coli* counts between samples from the domestic and industrial and also between samples from the industrial and domestic, outfall and central business area over the study period.

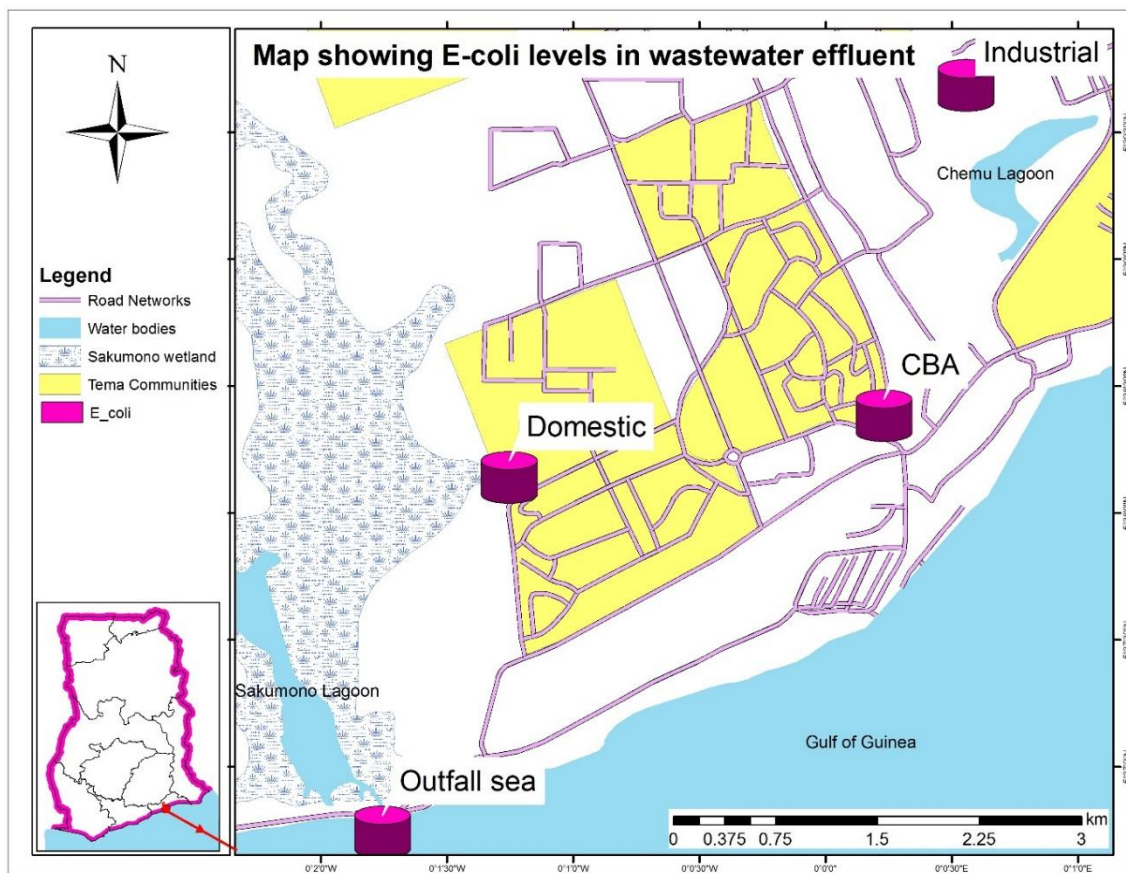


Fig 4.13: Map showing E.coli levels in wastewater effluent in the Tema Metropolis.

Source: Field Survey, 2014.

4.3 Correlation between the Physico-chemical parameters in the water sample

To investigate the association, between the Physico-chemical and bacteriological parameters of the effluent in the study area in the Tema Metropolis, Pearson's Product moment correlation coefficient was used. During the study period, considerable numbers of significant positive correlation were observed between the following Physico-chemical and bacteriological parameters: Temperature and BOD ($r=0.78$; $P<0.01$), Temperature and TDS ($r=0.58$; $P<0.05$), Temperature and TSS ($r=0.74$; $P < 0.01$), EC and BOD ($r=0.78$; $P<0.01$), BOD and TSS ($r=0.66$; $P<0.05$), BOD and PO_4^{3-} ($r=0.70$; $P<0.05$) EC and PO_4^{3-} ($r=0.73$; $P<0.05$), TDS and TC ($r=0.98$; $p<0.05$), NO_3^- and NO_2^- (0.98 ; $P<0.05$), NO_3^- and PO_4^{3-} ($r=0.79$; $P<0.05$), NO_2^- and PO_4^{3-} ($r=0.75$; $P<0.05$). Table 4.1 shows the significant strong positive correlation matrix between the Physico-chemical and bacteriological parameters of the effluent samples. The entire correlation matrix however is shown in Appendix C.

The highly significant positive correlation between temperature and BOD is of environmental concern because an increase in temperature leading to a corresponding increase in BOD can cause depletion of natural oxygen resource which will affect the aquatic life in the receiving water bodies.

The positive correlation between conductivity and phosphate is also of significant concern since the highest concentrations of ions detected in the effluent sample was phosphate which may have arisen as a result of detergents and phosphorus rich industrial and domestic waste. This may cause undesirable phytoplankton growth in the receiving water body leading to cultural eutrophication.

Table 4.1: correlation matrix for physico-chemical and bacteriological parameters of effluent sampled

VTEMEC	BOD	TDS	pH	TSS	NO ₂ ⁻	NO ₃ ⁻	PO ₄ ³⁻	TC
TEM	1	-0.350.78**	0.58*	-0.23	0.74**	0.42	0.530.560.62*	
EC		1	0.78**	0.19	0.26	0.26	-0.23-0.39	0.63* 0.29
BOD			1	0.38	0.20	0.66*	0.24	0.44 0.70* 0.50
TDS				1	0.010.27	0.14	0.04	0.06 0.98**
pH					1	0.09	-0.68*	0.70** 0.53 0.05
TSS						1	0.32	0.33 0.27
NO ₂ ⁻							1	0.98** 0.75** 0.07
NO ₃ ⁻								1 0.79** 0.11
PO ₄ ³⁻								
TC								

** Correlation is significant at the 0.01 level (2-tailed). * Correlation is significant at 0.05 level (2-tailed).

TEMP: Temperature, TDS: Total dissolved solids, TSS: Total suspended solids, TC: Total coliform

Table 4.1 Correlation matrix of physio-chemical and bacteriological effluent sampled.

4.4 Social Survey

4.4.1. Background of Respondent

The results of the analysis with respect to gender of the respondents 45% were males while 55% were females. Figure 4.1 shows distribution of respondents of various communities in the study area of Tema Metropolis.

Table 4.2 Distribution of Respondents in various communities in the study area

Communities	Percentage of respondents
Community 1	10
Community 2	15
Community 4	20
Community 6	10
Community 8	15
Community 9	10
Community 11	10
Community 12	10

Source: Field Survey, 2014

4.4.2 Age Composition of Respondents

Figure 4.16 indicates the age composition of respondents in the study area of the Tema Metropolis. Age distribution of respondents varies. Greater percentage (27%) of respondents from the communities were between the ages of 51-60 while the lowest percentage of (7%) was recorded for the age 71-80 and age 80 and above at the time of the interview.

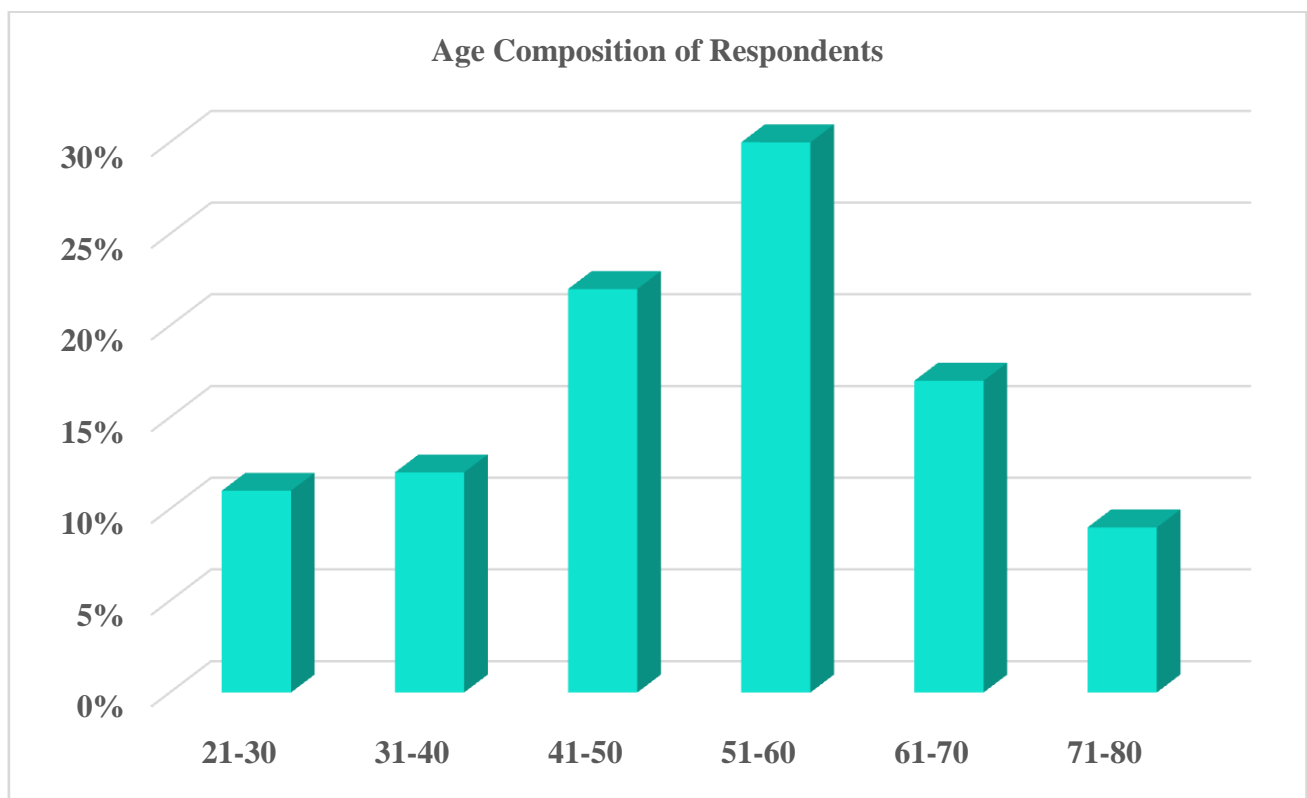


Fig 4.14: Age Distribution of Respondents

Source: Field Survey, 2014

4.4.3 Educational Background and Occupancy Ratio of Respondents

As part of the social appraisal, the educational levels of the respondents were sought as it plays a significant role in comprehensive understanding of issues relating to sanitation. It came up that about 20% of the respondents had advanced education while 34% had tertiary education and 30% and 16% had secondary and basic education respectively indicating greater percentage of respondent may have better understanding of sanitation and therefore wastewater management and its related issues. Figure 4.17 illustrates the educational level of the respondents in the study area.

With reference to households size in the study area, 52% of the respondents have household size (2-5,) recorded as the highest percentage while only 2% records (20-25) occupancy ratio in the Tema Metropolis.

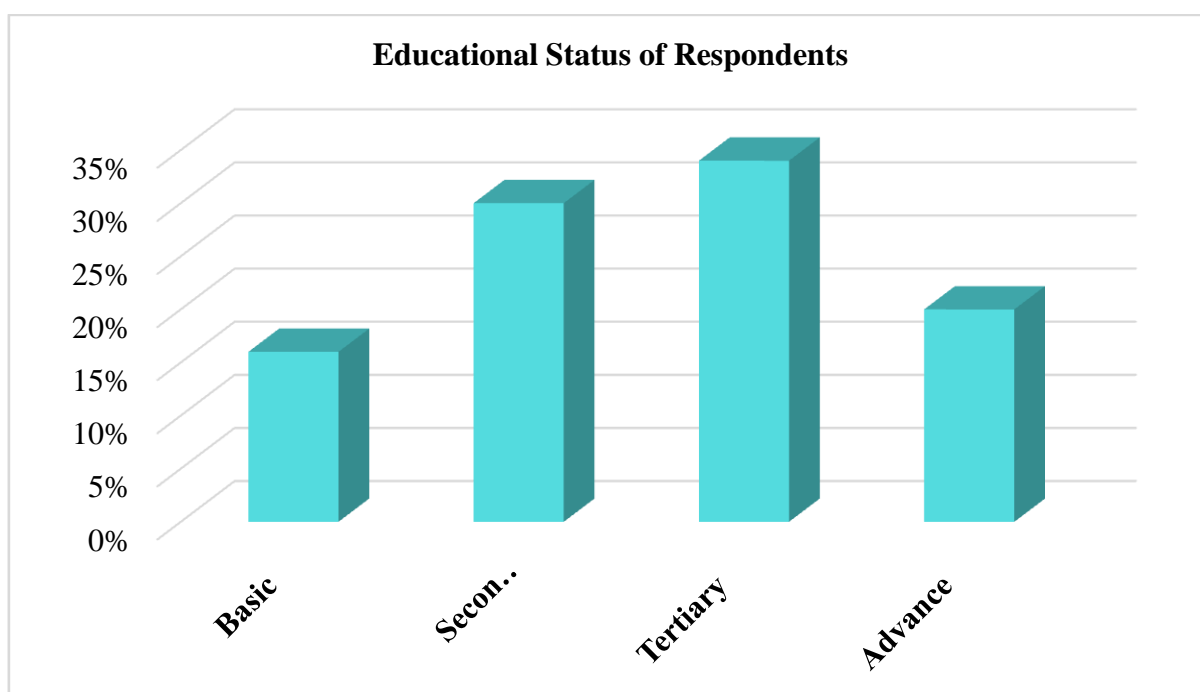


Fig 4.15: Educational level of respondents in the study area of Tema Metropolis

Source: Field Survey, 2014.

4.4.4 Occupation of Respondents

Similarly the occupational level of the respondents in the study area were also sought. The survey revealed that thirty-five percent (35%) were Civil servants, 40% engage in various trading activities and 13% were students as shown in Fig.4.18.

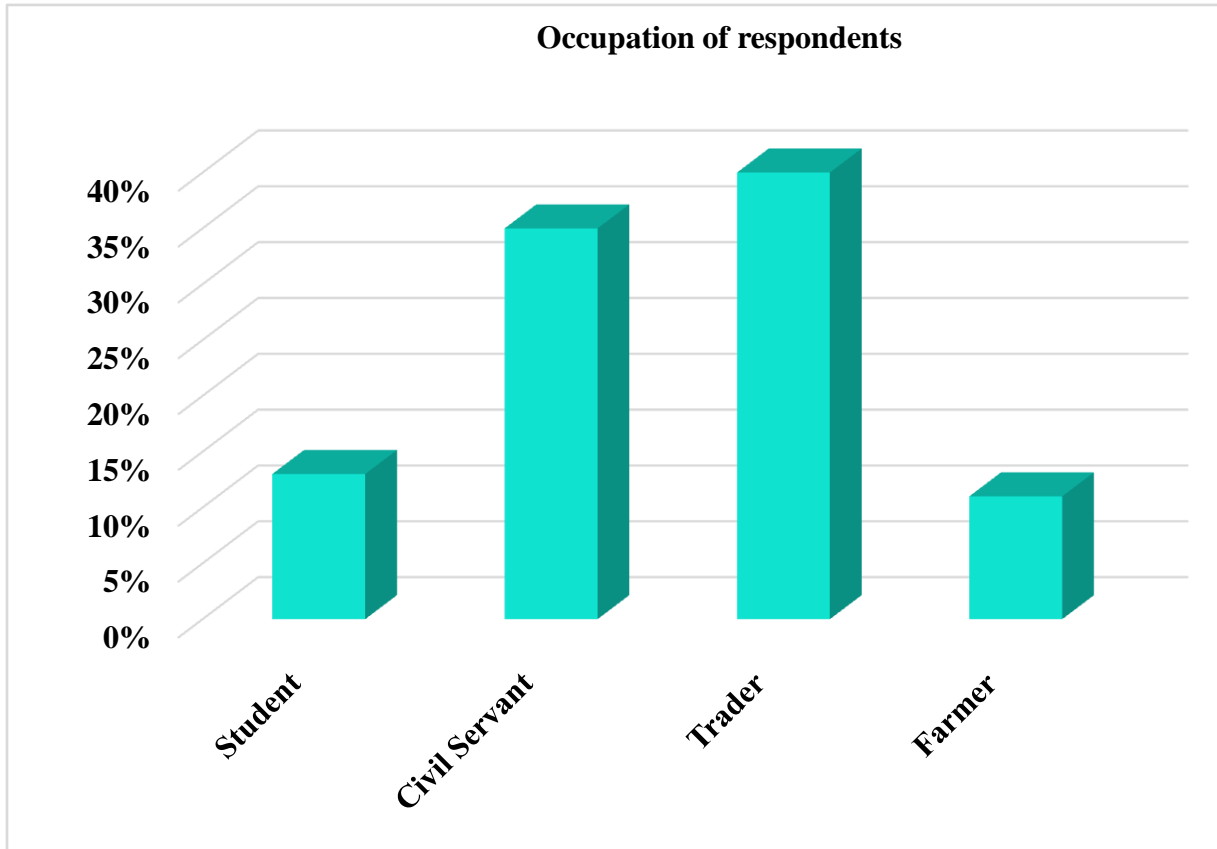


Fig 4.16: Occupation of the Respondents in the study area of Tema Metropolis

Source: Field Survey, 2014.

4.5 Management of the sewage facility

The survey revealed that most respondents (57%) strongly agreed that the system has not been maintained, 25% responded to annual maintenance while 6% and 5% responded to quarterly and monthly maintenance respectively. Seven percent(7%) of the respondents had no idea about the maintenance of the sewage facility.

Regarding payment of sewer tariff, the results show that 18% of respondents refused to pay due to frequent overflows they experienced. Forty-three percent (43%) of the respondents which is the majority attributed the non-payment phenomenon to damaged sewer pipes while 23%, 11% and 5% were of the view that poor maintenance, expensive tariffs and unavailability of revenue collectors respectively were the reasons for not paying sewage maintenance fees.

Figure 4.19 shows the respondents views on which of the stakeholders should be responsible for the maintenance of the sewage facility; 34% and 17% said TMA and the Government respectively while 13%, 12%, 11%, 7% and 6% of the respondents indicated Assembly members or Member of parliament, occupants, TDC, community members and landlords respectively must be responsible for the maintenance of the sewage facility.

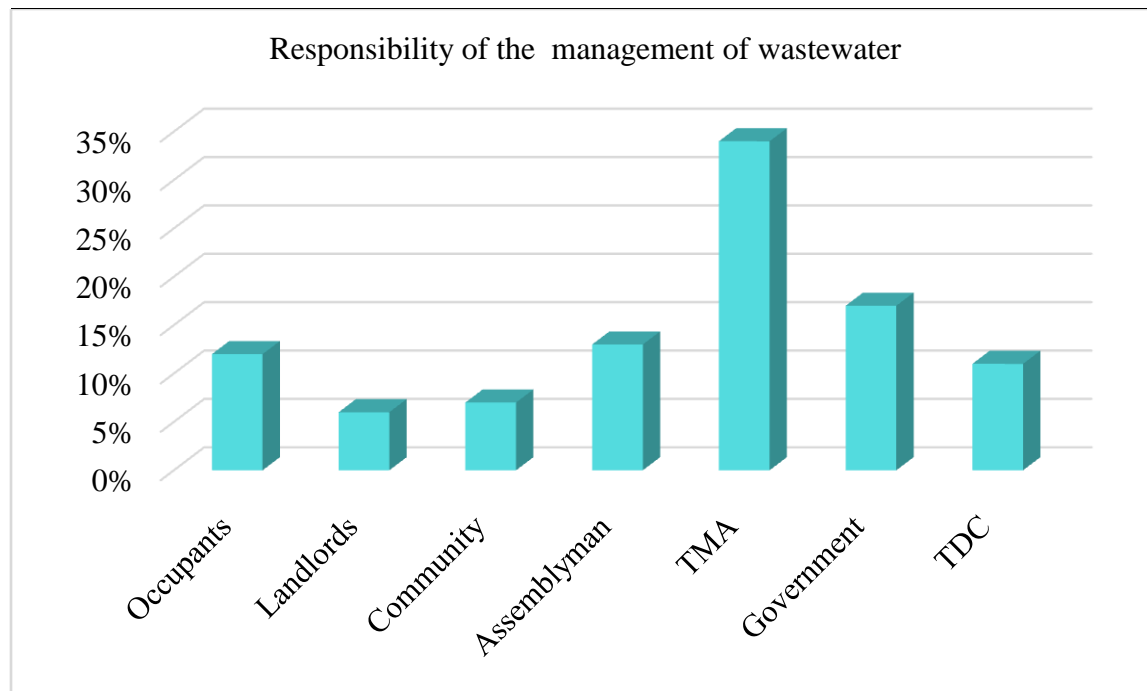


Fig 4.17: Respondents views of the responsibility of the maintenance of the sewage facility.

Source: Field survey, 2014.

4.5.1 Household Perception on Performance of Sewerage System

In all, 48% and 37% responded poor performance and very poor performance respectively while only 8% said good and 7% were uncertain about the performance of the system in the study area of Tema Metropolis.

In the assessment of residence views on the institutional capacities that are needed in relation to the management of the facility, different views came up as shown in figure 4.20. Some(32%) of the respondents mentioned legislation, 22% policies, 21% Byelaws, 25% human resources development respectively as a way to improve general sanitation issues in relation to wastewater pollution in the Metropolis.

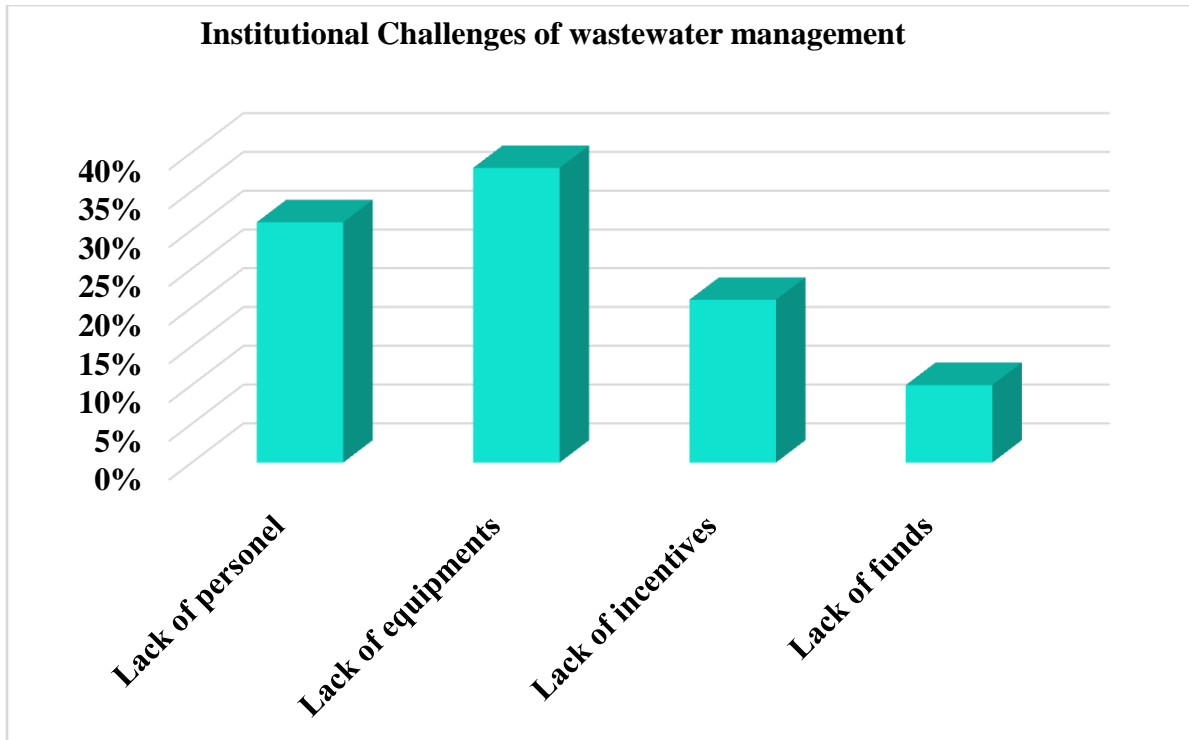


Fig 4.18: Respondents views on the institutional challenges of wastewater management

Source: Field Survey, 2014.

Technical problems that affect the management and efficient performance of the sewage facility were assessed in the study. The results are that 13% aged pipes, undersized pipes 21% and 20% damaged pipes while 17%, 13% and 16% were attributed to tree root intrusion, broken manholes and open manholes respectively as shown in figure 4.21.

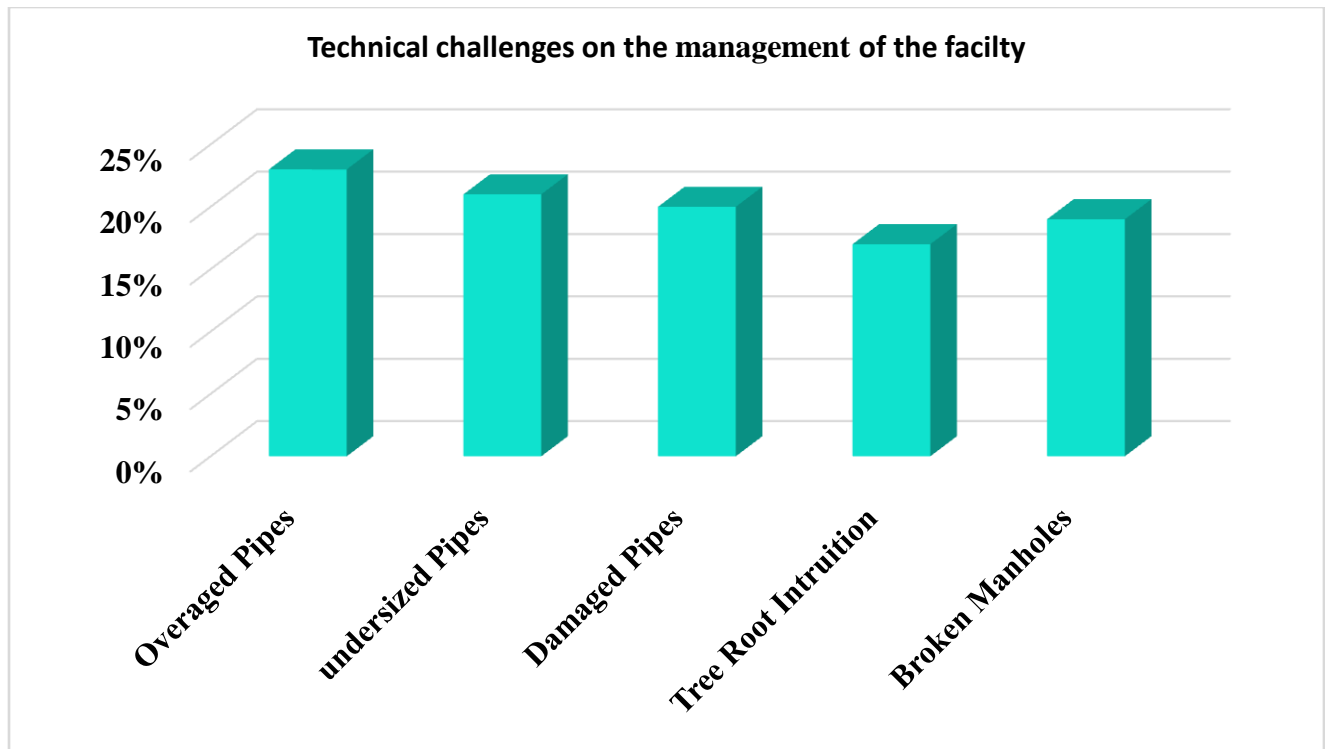


Fig 4.19: Respondents views on respondents views on technical problems affecting the facility

Source: Field survey, 2014.

Social problems attributed to the poor management and performance of the sewage facility are shown in fig.4.22. Thirty six (36%) of the respondents indicated user attitudes, 25% illegal connections, 20% building of extensions on sewer lines, 9% non-payment of tariff as the major social problems confronting sewage management in T.M.A. odour, exposing vermin to the fecal matter that can contribute to disease outbreak in the communities(plate 4.1).

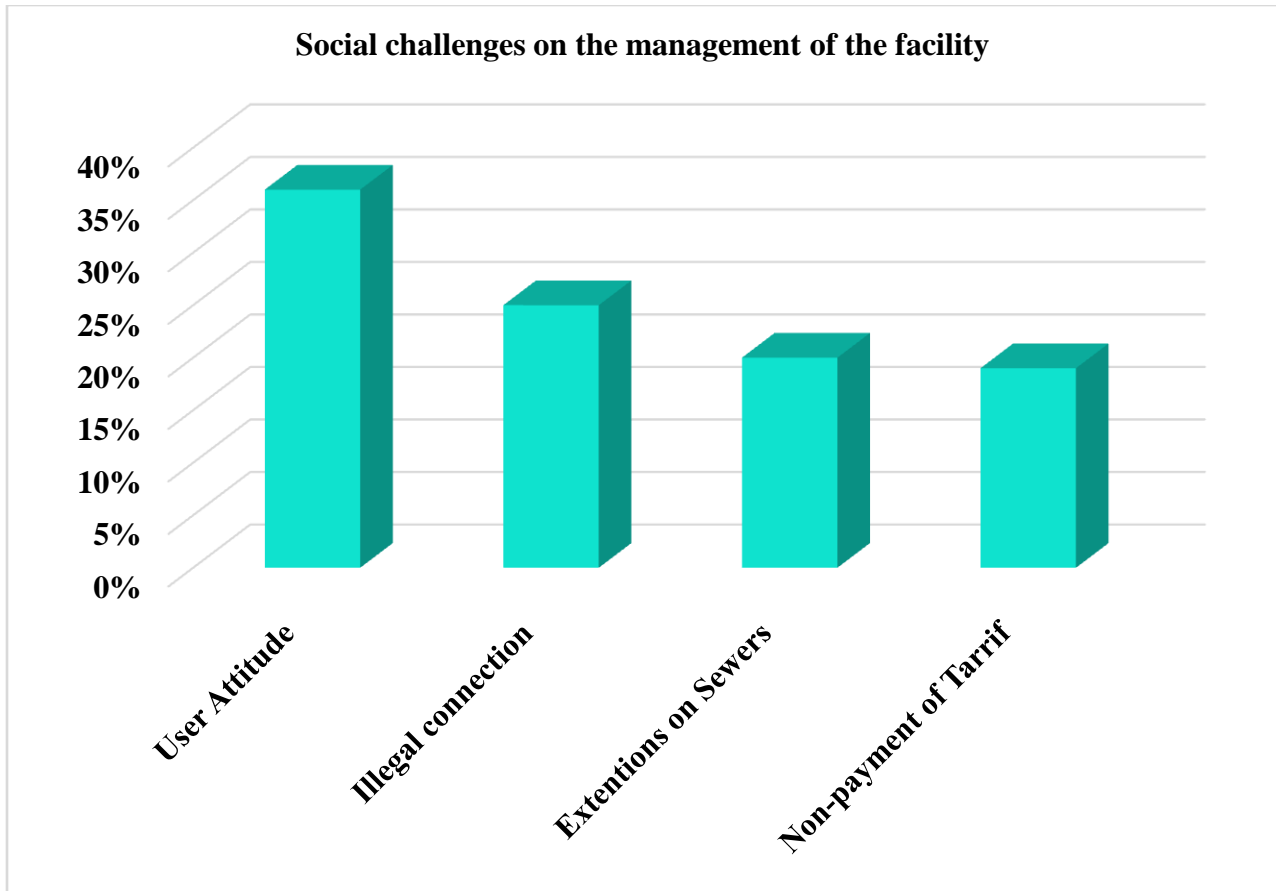


Fig 4.20: Respondents views on social problems affecting the system

Source: Field Survey, 2014.



Plate 4.1 picture showing sewage pollution in the Tema Metropolis

Source: Field Survey, 2014

In assessing household perception on environmental effects of sewage pollution, 51% responded offensive odour, as the sewage overflowing in their environment emits offensive odour which makes them uncomfortable in their own house and are likely to have effect on their health while (29%) sewage overflow, (13%) insects and rodents breeding and 7% ascertain to the leakage of sewer and water pipes are likely to pollute water supply. As shown in fig.4.23 respectively.

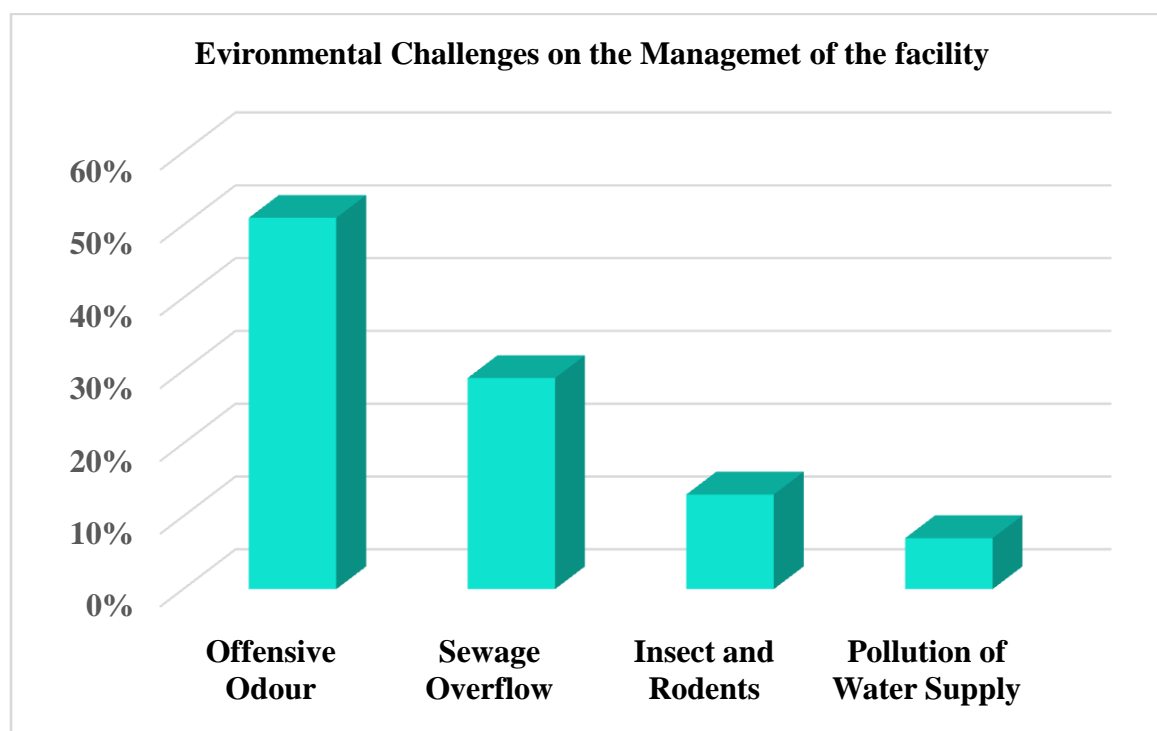


Fig 4.21: Respondents views on environmental problems associated with the facility

Source: Field Survey, 2014.

4.5.2 Household Perception on the Causes of Sewage Overflow

Assessing household perception on the causes of sewage overflow in the communities, 44% responded to poor performance, lack of education(20%) on the usage of the system also contributes the frequent chockage of the sewer pipes (20%), Irresponsibility on the part of

stakeholders especially the institutions (13%), while 23% of the respondents also had their divergent views and attributed it to the population growth and pressure on populations (Fig.4.24).

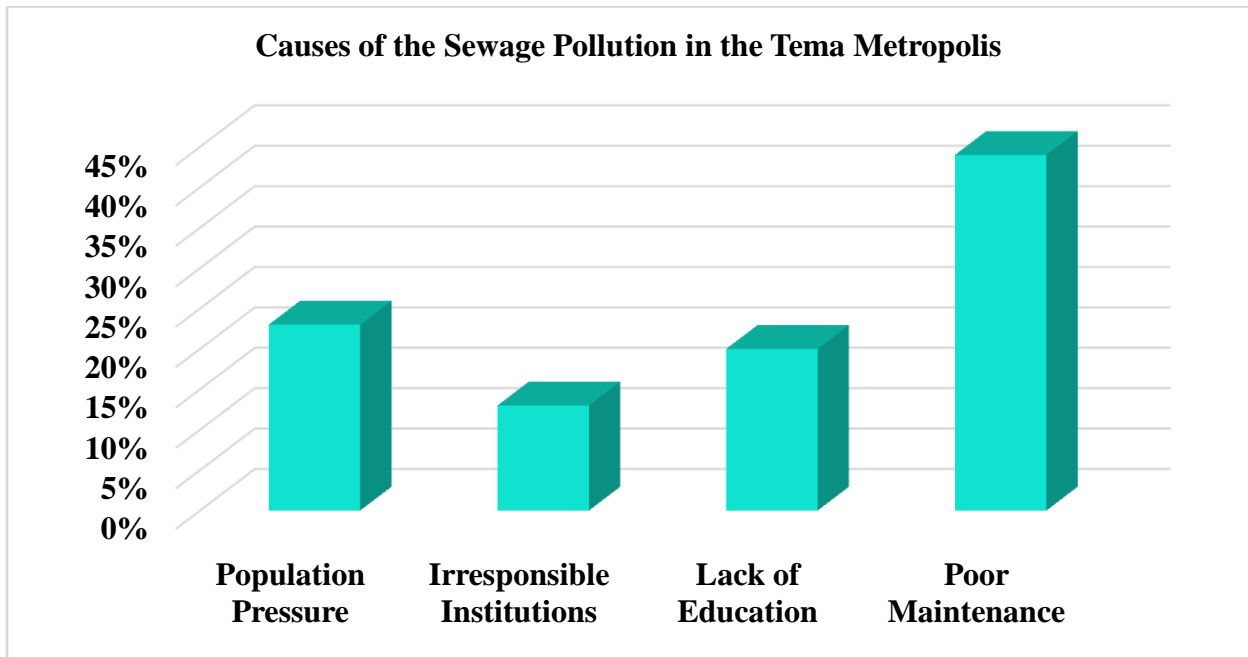


Fig 4.22: Respondents views on the causes of the problems associated with the facility

Source: Field Survey, 2014

4.5.3 Household Perception on Diseases Associated with Sewage Pollution

Twenty-five (25%) of the respondents indicated that cholera was a common disease contracted by ingestion of water or food contaminated with sewage while 35% indicated Typhoid, Diarrhea (22%) and Dysentery (18%) was the least as illustrated in Fig.4.25

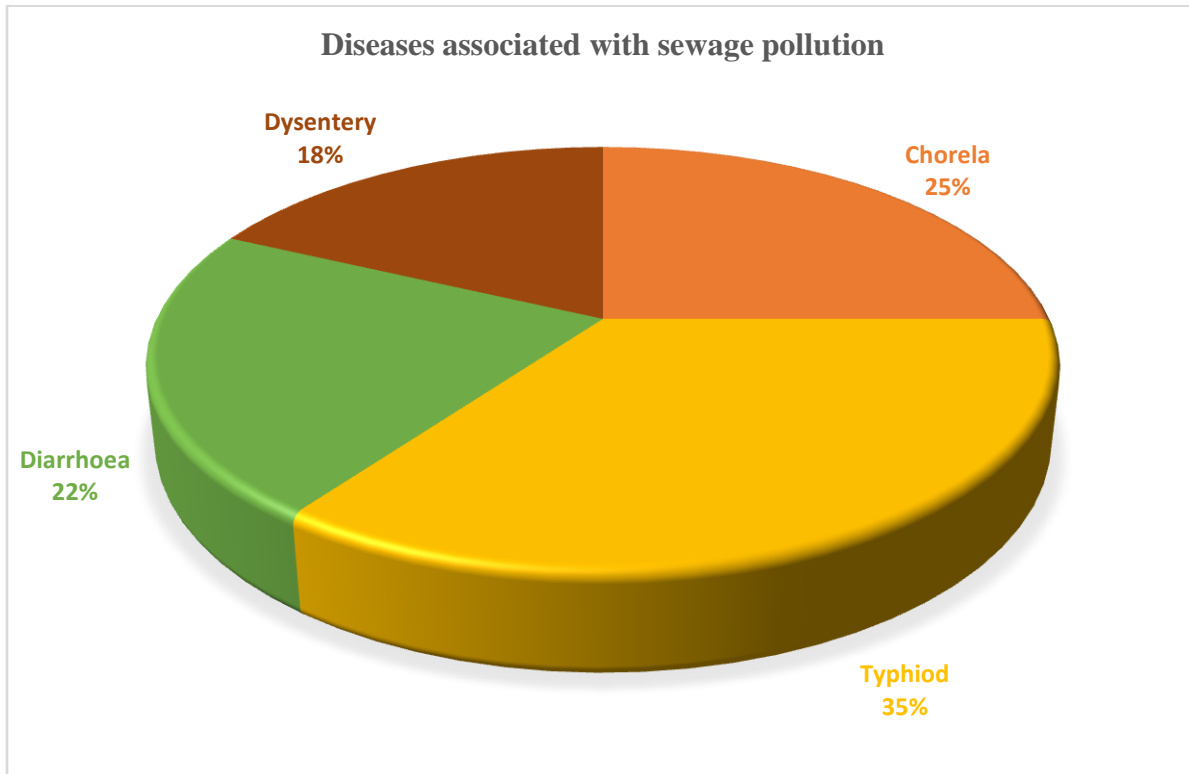


Fig 4.23: Household perceptions on diseases associated with sewage pollution

Source: Field Survey, 2014

4.5.4 Household perception on mitigation measures on sewage pollution

Over all, the respondents gave their views on measures to mitigate the causes of sewage pollution on the metropolis. 30% mentioned that the best way is to practice periodic maintenance of the sewer network, 20% said the provision of equipment and logistics, 15% treatment of wastewater, 20% agreed on rehabilitation and 15% advocated for health education on the wastewater management and disposal as illustrated in figure 4.26

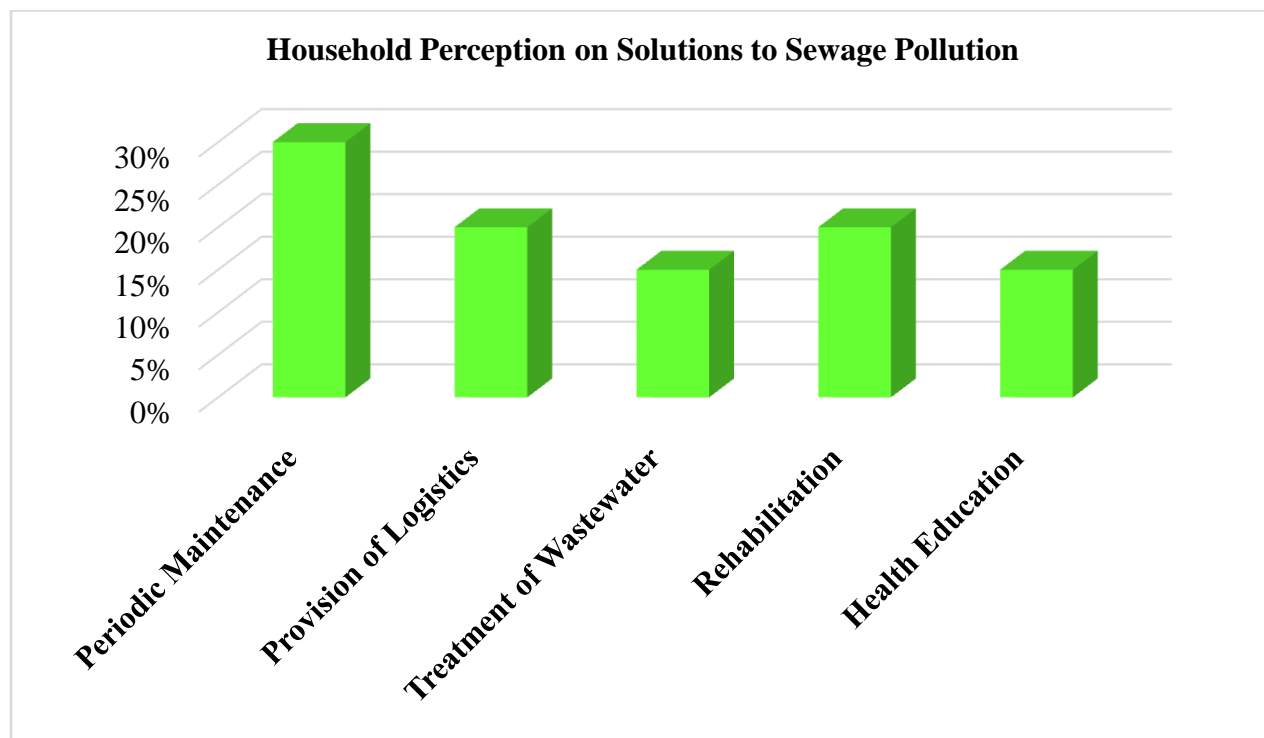


Fig 4.24: Household Perception on mitigation measures on sewage pollution

Source: Field Survey, 2014

CHAPTER FIVE

DISCUSSION

5. Introduction

Chapter five is devoted to the discussion of results from the effluent sampled and the social survey in respect to other literature views about sewage quality.

5.1 Physico-Chemical Parameters

5.2.1 Temperature and pH

The effluents have slight variations in temperature and recorded an average temperature of 30.3 °C during the sampling period. Temperature is important parameter in wastewater treatment and it affects both chemical and biological activities (Amoatey & Bani, 2010). The temperature variation could be due to the changes in sampling time. According to Sudthanom *etal.*(2011), the composition of wastewater varies by place, time and source. The organic and nutrient load and the temperature are the important parameters that vary in terms of time. Increased temperature, for example, could cause a change in the species of fish that could exist in the water body (Okoh, 2010). The average temperature in the study was within the Ghana Environmental Protection Agency guideline value of <30°C and therefore suitable for biological processes treatment of wastewater.

Another important example of the effects of temperature on water chemistry is its impact on oxygen. Warm water holds less oxygen than cool water, so it may be saturated with oxygen but still not contain enough for survival of aquatic invertebrates or certain fish. Some compounds are also more toxic to aquatic life at higher temperatures (Okoh, 2010).Furthermore, to design the

most suitable biological processes or treatment facility for wastewater, temperature is a significant parameter to consider (Sudthanomet. *al*, 2011).

pH is a fundamental factor for water quality which mainly depends upon a variety of chemical factors such as dissolved gases, organic acids, humic fractions and inorganic salts. The decomposition of organic fractions of wastewater, mainly by microbes in water, produces some acidic species of mineralized organic materials (CO₂, ammonia, NO₃ - and organic acids) which plays an important role in shifting of pH of treated water (Belhaj *et al.*, 2014)

The general alkaline state of the effluent at the outfall with a pH of 7.5-8.4 might be partly due to the influence of seawater dilution (Riley & Chester, 1971). The determination of pH value of sewage is necessary because certain methods of sewage treatment for their efficient working require sewage of pH value in particular range, since most microbial life occur within a narrow pH range (typically 6-9), the hydrogen-ion concentration is of great concern in relation to biological treatment. Influent water with exceptional high or low pH-values (typically industrial wastewater) can be hard to treat by biological means. (Kvernberg, 2012).

5.2.2 Dissolved Oxygen (DO), Biochemical Oxygen Demand (BOD), Total suspended solids

There was relatively low Dissolved Oxygen levels observed at different points due to high organic content of the wastewater from industrial and domestic activities. However, samples from the outfall recorded high Dissolved Oxygen. This could be attributable to the influence of wave action enriching wastewater with Oxygen before discharging into the sea. Dissolved

Oxygen consumption and production is influenced by plant and algal biomass, and light intensity and water temperature are subject to diurnal and seasonal variations (Cornell & Miller, 1984). This was not the case for this study because of the fact that, the sewage system is underground and the effect of these climatic factors were not pronounced to improve on the oxygen level. The low levels confirm the view by Rangwala *et. al*, (2011) who reported raw sewage has almost zero oxygen. This result is an evidence of the fact that the natural conditions add a lot of oxygen to exposed sewage to aid in treatment. Dissolved oxygen is a key element in water quality that is necessary to support aquatic life. A demand is placed on the natural supply of dissolved oxygen by many pollutants in wastewater. If the effluent has a high content of organic pollutants, it will demand more oxygen from the water and leave the water with less oxygen for supporting fish and other aquatic life (Suthanom, 2011).

The importance of BOD in pollution monitoring has been well established (Reish, 1972). High values of BOD are indicative of excessive organic matter contained in the effluent from both domestic and industrial sewage. The results recorded BOD values from the domestic sewage with mean value of 53mg/l, but recorded low for the industrial effluent with the mean value of 23 mg/l, 39mg/l central business area and extremely low values at the outfall point with 3.8mg/l which indicate low organic matter content at the outfall at sakumono beach.

The characteristic of municipal wastewater is based on its physical properties as well as its organic and inorganic pollutants. Organic pollutants contain phenols, hydrocarbons, biological oxygen demand (BOD), carbohydrates, fats and starches. The characteristics of municipal wastewaters are varied, depending upon the sources of discharge, the effluents from industries, land uses and groundwater levels (Bansode, 2002).

The study revealed low BOD values at the outfall of sakumono beach. The low BOD and TSS values did not indicate severe pollution threat at the outfall point and its environs in spite of the discharge of raw sewage from inland. This negative impact is significantly reduced less than 1km offshore as a result of dilution and self-purification effects of the open ocean.

5.2.3 Chemical Oxygen Demand (COD mg/l), *Total Suspended Solids (TSS)*

COD is an important indicator of organic loads of urban wastewater. Chemical oxygen demand is the amount of Oxygen used up from effluent sample by organic and inorganic chemicals as they breakdown (Simpson & Charles, 2000). Since the organic matter in the sewage indicate sewer pollution, the chemical oxygen demand were generally high due to the organic content in the sewage.

5.2.4 *Electrical Conductivity*

The conductivity gives an indication of the amount of dissolved minerals and ions present in solution (Hem, 1989). The conductivity of the discharge outfall with mean value 56828 $\mu\text{S}/\text{cm}$ indicating high dissolved minerals salt may be due to the ions in the sea. However, the conductivity values for samples were generally high indicating high amount of dissolved minerals salts in the sewage effluent.

5.3 Nutrients

5.3.2 Nitrates, Phosphates, Ammonia

Nitrate –nitrogen levels of 4.8mg/l mean value was recorded during the study of the sampled effluents from the various sampling points and were generally of low concentration. The domestic recorded mean value of 13.5 mg/l concentration of Nitrate which recorded highest in effluent sampled. Samples from Central business area recorded 7.7mg/l concentration mean values while samples from industrial site was 2.3vmg/l and 1.5mg/l for the outfall site. The lower levels recorded at outfall and industrial site could be due to the use of cleansing detergents and soaps from sanitary sewers and also suggest that nitrate is reduced to ammonia due to the alkaline nature of the industrial effluent, thus should account for the generally high ammonia concentrations in the industrial effluent.

The Phosphate concentration was generally high due to the use of detergents and other cleansing materials used in both domestic and industrial activities. The phosphorus concentration for both domestic, central business area, industrial and outfall samples were 6.4mg/l, 4.9mg/l, 4.0mg/l and 0.6mg/l respectively. Phosphate concentration in the sampled effluent though not too high at the discharge point at the Sakumono beach, still have the potential to cause eutrophication if raw wastewater is discharged continuously into the sea.

The study revealed that, ammonia concentration is relatively higher in the industrial effluent than the domestic sewage. It has been reported that acute toxicity of ammonia to fish increases with low dissolved Oxygen concentrations in aquatic environment (Cornel & Miller, 1986).The

ammonia, nitrate and phosphate levels provide indication of nutrient contents in the effluents hence the use of raw sewage for irrigating vegetable farms in the areas.

5.3.3 *Faecal coliform, Total coliform, E-coli*

Microbial load of effluent determines the extent of contamination of the wastewater and its quality for treatment or discharged and its related environmental and public health threat.

The concentrations of total coliform in the effluents were 5761cfu/100ml counts, 860cfu /100ml counts, 1289cfu/100ml and 6.6 cfu/100ml for domestic, central business area, industrial and outfall respectively, while faecal coliforms counted 36cfu /100ml, 15cfu/100ml, 136cfu/100ml, and 0.6cfu/100ml counts represent domestic, central business area, industrial and outfall faecal coliform concentration respectively in the effluents during the study period. All coliform bacteria are indicator of a potential public health risk. Fecal coliform bacteria are bacteria that originate from intestinal tracts of homothermic animals. Their presence indicates fecal contamination of water. Total and fecal coliform bacteria are sensitive and commonly used indicators of bacterial pathogen contamination of natural waters. Their presence implies the potential presence of microorganisms that are pathogenic to humans. Fecal coliform bacteria have a strong correlation with fecal contamination of water from warm-blood animals (Chapra, 2007).

Furthermore, irrigation of vegetable farms with this wastewater of poor quality in terms of bacteria needs to be prevented due to its potential for the spread of disease-causing microorganisms to both farmers while handling such water and consumers. In Accra, irrigation waters used for vegetable farming are sourced mainly from drains, streams and pipes (Gbireh 1999; IWMI 2006; Obuobie *et al*, 2006; Amoah *et al*. 2006, 2007).

Disease associated with enteric bacteria ranged from bacteria that cause mild to life threatening gastroenteritis, hepatitis, skin infection, wound infections, conjunctivitis, respiratory infections, and generalized infections (Moe, 1997).

E-coli causes wide range of infections, including urinary tract infections (UTI) and diarrhea diseases in all age groups (Chesbrough, 2006). The concentration of E-coli in the sampled effluents from the various sites in the study area counted 14cfu/100ml, 7.6cfu /100ml, 34cfu /100ml, and 0.3 cfu/100ml for domestic, central business area, industrial and outfall points' samples respectively.

5.3. Household perception on the management of the sewage facility and their perceived effects

There are differences in human perception regarding the performance of the sewerage system in the study area. Respondent's perception about the performance of the sewage was not different from Awuah & Asante (2010), study on the facility that recorded very poor performance of the sewerage system and sewage overflows in the communities exposing residents and animals to hazard.

Sewerage treatment facility requires periodic maintenance and cleansing to keep its efficiency and performance standards. To establish a baseline with respect to the management of the facility a question was posed for households to state the condition and performance of the facility. The survey revealed that most respondents (60%) strongly agreed that the system has not been maintained for many years and continue to deteriorate and cause leakage and pollution of the environment.

To avert the continuous deterioration of the system, the causes and responsible people must be identified, by so doing the appropriate measures can then be taken to address the problem. On this basis the study established that, in terms of stakeholders responsibility on the wastewater in the Metropolis, everybody within the network coverage must be responsible for its maintenance, however Government intervention through the Assembly will be appreciated for total revamp of the facility.

According to analysis of the study results, institutional problems, technical problems, and social problems were observed as challenges in the management of wastewater in the study area of Tema Metropolis. According to Keriata *et al.*,(2011), Ghana's current urban sanitation infrastructure seems not to be keeping pace with population growth rate of about only 4-5% of the population.

Observation from the study area also indicates several extensions of buildings on the sewer pipe lines which has compounded the already existing challenges of changing damaged and undersize pipes in the communities. Also the iron steel covers of the manholes have been stolen exposing the manholes to solids and silt which cause blockages in the sewer pipes affecting the flow rate of effluent.

Gyampo (2009), reported that most untreated wastewater ends up in storm-water gutters, stream and other water bodies which are often used as sources for irrigation water. Sewage overflow was observed during the study that was recorded as environmental threat as it overflows to the Sakumo, Gao and Chemu lagoon and the nutrient concentrations in the effluent are likely to cause eutrophication in these water bodies.

Assessing household perception on the causes of sewage overflow in the communities, it came up that poor performance of the system due to poor maintenance has led to accumulation of silt and sediment in the sewers causing constant blockage and reducing flow rate of the system. Additionally, the proposition that lack of education on the usage of the system was also attributed to the constant blockage. Salifu, (2009) recorded anal cleansing material blockage in his research on the facility.

Irresponsibility on the part of stakeholders especially the institutions, without collaboration has attributed the causes of the problems due to non-enforcement of the laws and implementations of policies and strategies in place for the management and protection of environmental resources. Finally the respondents also had their divergent views and attributed to the population pressure. This overloads the system and cause overloads during peak times. This agrees with the study conducted by Maji, (1999) in which the process of rapid urbanization generates serious challenges to towns and cities, which are struggling to provide and maintain the already inadequate level of urban sanitation services and healthy environment. Coupled with the vast consumption of resources is the production of massive amounts of waste, much of which re-enters the environment as pollutant.

The respondents also noted health problems that are associated with sewage pollution. Almost all of the respondents interviewed were aware of at least one disease that were associated with sewage pollution. According to Ministry of Health, Ghana, (2000) enteric diseases are second to malaria in the number of cases reported in the nation's hospitals. About 400, 000 cases of enteric diseases are reported annually in the country, Ghana.

The measures to prevent sewage pollution and protect public health were perceived as rehabilitation of the entire sewerage system, expansion of its capacity to accommodate the current pressure, education on the usage of the facility and also public health issues in relation to sewage pollution and finally sustainable management plan for wastewater from generation stage to disposal without compromising the environment.

CHAPTER SIX

CONCLUSION AND RECOMMENDATION

6.1 Introduction

Wastewater is and will always be with us because we cannot survive without water. When water supplied is used for the numerous human activities, its characteristics is changed and therefore become wastewater. Wastewater can and must be treated to ensure a safe environment and foster public health.

In most developing countries like Ghana, low-cost, low-technology methods such as energy generating technology such as biogas plants, waste stabilization ponds and on-site septage treatment facility can be employ to improve the effluent quality to meet the set standards for disposal into the environment.

6.2. Conclusion

Physico-chemical and bacteriological quality of effluent samples in the Tema Metropolitan area were assessed to investigate the pollutant concentrations in the effluent and its environmental and perceived health effects associated with sewage pollution.

In the study generally, the Physico-chemical parameters such as temperature, Electrical conductivity, dissolved oxygen, Biological oxygen demand, chemical oxygen demand, total dissolved solids, total suspended solids, and turbidity measured for samples from the domestic, central business district and industrial point were above the recommended guidelines of Ghana Environmental Protection Agency guidelines. The pH recorded for the samples from the various

sites were within the permissible standard. Nutrients concentrations and microbial loads in the domestic, central business district and industrial effluents were high.

However the level of compliance of effluent at the outfall point were all within the EPA permissible standards for wastewater discharge at the outfall point at the sakumono beach. Sewage outfall area were less polluted and which may be a result by dilution of sea water. The study showed that the quality of the final effluent would not have any adverse effect on the sea (receiving body) because the volume of the sea is adequate enough to dilute the final effluent. However the mouth area of the outfall are not suitable for primary and secondary contact due to the occurrence of large numbers of coliform bacteria. Although the nutrient levels were not too high, there is the potential to cause eutrophication especially in the water bodies that sewage overflow into such as Chemu, Gao and Sakumono lagoon.

The results of the social survey revealed that the level of sewage pollution and poor effluent quality in the Tema metropolis is due to poor maintenance and management of the central sewerage system, inadequate logistics and equipment and indifferent attitude of the people. The study also revealed that occurrence of diseases, provision of breeding grounds for mosquitoes, and emission of unpleasant odour are the major effects of sewage pollution. Despite about 90% of the community having a good educational background, they continue to dispose and discharge solid materials and refuse into the manholes therefore causing constant blockage in the sewers. Though there are a large number of government sector stakeholders directly or indirectly involved in wastewater management of the area, the degree of interactions and collaborations among them vary widely.

6.3 Recommendation

6.3.1 Immediate and short term interventions

As the environment continues to deteriorate and degrade, such factors contributing to environmental pollution especially water pollution and the reduction of its capacity to perform its supportive role for human, animals and the environment must be addressed. Based on the research findings the following recommendations are however made.

1. Government intervention, must enforce the regulations on wastewater standards, and equip institutions and agencies responsible to enforce sanitary laws on treatment of industrial and domestic waste, improved infrastructure for waste treatment and disposal
2. The sewage maintenance unit of the waste management department must be strengthened. The institutional strengthening should be holistic and include:
 - a. The provision of basic tools and equipment such as mechanical rodding machine, backhole, Trans boring machine, sewer cameras and mist blows for disinfection and disinfestations.
 - b. Replacement of all missing manhole covers to prevent dumping of solids into manholes.
 - c. Reconstruct/rehabilitate damage manholes
 - d. Conduct constant cleaning of sewers to reduce frequent blocking of the system
 - e. Replace undersized, aged and damaged sewers in the metropolis

- f. Intensify public education and awareness on the use and maintenance of sewerage system.
- g. Evaluate and upgrade the human resource capacity of the sewerage unit.
- h. Education and awareness creation must be intensified to promoted and sensitized the public on the importance of wastewater management and also draw the interest of local communities attention and educate them on the proper use and maintenance of the facility and good sanitary practices to reduce pollution and promote public health

6.3.2 *Long term measures*

- a. Rehabilitate and increase the capacity of the three pumping stations and associated pumping mains
- b. Rehabilitate and revamp the sewerage treatment and adopt new technologies for wastewater management like decentralized waste stabilization ponds with energy recovery technologies like biogas, water for aquaculture and greening to promote energy recovery and cost recovery and sustainable management of the system.
- c. Provision of wastewater treatment to reduce the nutrient that is entering the water bodies from industrial and domestic wastewater to avoid accumulation and eutrophication.
- d. The Tema sewerage system currently serves about 35,000 households, and about 160 small scale to medium industries and over 5,000 commercial houses. The exact

number of beneficiaries of the system especially those in the commercial sector have to be determined by conducting further studies. Further studies to collect data and analyze data on the generation of sewage and waste water. Such data are also required to assist the assembly in fixing reasonable but cost effective tariffs which will take into account the total cost of operation and maintenance and guarantee the quality of effluent discharge. (Polluter pay principle).

- e. Further study must also be conducted to assess the nutrient loads that is entering the three lagoons in the Tema Metropolis that the effluent overflows into, that is Chemu lagoon, Gao lagoon and Sakumo lagoon

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APPENDICES

APPENDIX A: ANOVA WASTEWATER QUALITY SAMPLE

		Sum of Squares	Df	Mean Square	F	Sig.
Temperature	Between Groups	6.217	3	2.072	9.527	.005
	Within Groups	1.740	8	.217		
	Total	7.957	11			
Electrical conductivity	Between Groups	6866985302.667	3	2288995100.889	5087.187	.000
	Within Groups	3599624.000	8	449953.000		
	Total	6870584926.667	11			
Biological Oxygen Demand	Between Groups	4016.896	3	1338.965	33.916	.000
	Within Groups	315.833	8	39.479		
	Total	4332.729	11			
Chemical Oxygen Demand	Between Groups	3482.250	3	1160.750	.218	.881
	Within Groups	42526.000	8	5315.750		
	Total	46008.250	11			
Total Dissolved Oxygen	Between Groups	188506230.896	3	62835410.299	.987	.446
	Within Groups	509469131.167	8	63683641.396		
	Total	697975362.063	11			
Total Suspended Solids	Between Groups	367013.583	3	122337.861	4.505	.039
	Within Groups	217270.667	8	27158.833		
	Total	584284.250	11			
pH	Between Groups	.497	3	.166	.271	.845
	Within Groups	4.898	8	.612		
	Total	5.395	11			

Phosphate	Between Groups	56.266	3	18.755	2.512	.132
	Within Groups	59.739	8	7.467		
	Total	116.005	11			
Nitrate	Between Groups	277.257	3	92.419	1.039	.426
	Within Groups	711.500	8	88.938		
	Total	988.757	11			
Nitrite	Between Groups	279.500	3	93.167	.700	.578
	Within Groups	1064.344	8	133.043		
	Total	1343.844	11			
Ammonia	Between Groups	21.811	3	7.270	.909	.479
	Within Groups	64.010	8	8.001		
	Total	85.821	11			
Dissolve Oxygen	Between Groups	10.487	3	3.496	.774	.540
	Within Groups	36.133	8	4.517		
	Total	46.620	11			
Turbidity	Between Groups	295222.643	3	98407.548	4.363	.042
	Within Groups	180450.460	8	22556.308		
	Total	475673.103	11			
Total Coliform	Between Groups	59767358.333	3	19922452.778	1.415	.308
	Within Groups	112624730.667	8	14078091.333		
	Total	172392089.000	11			
Feacal Coliform	Between Groups	31827.583	3	10609.194	44.780	.000
	Within Groups	1895.333	8	236.917		
	Total	33722.917	11			
Ecoli	Between Groups	1880.667	3	626.889	25.940	.000
	Within Groups	193.333	8	24.167		
	Total	2074.000	11			

APPENDIX B: MULTIPLE COMPARISON

LSD

Dependent Variable			Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
						Lower Bound	Upper Bound
Total Coliform	Domestic	outfall	5754.66667	3063.55908	.097	-1309.9132	12819.2466
		Central Business	4900.66667	3063.55908	.148	-2163.9132	11965.2466
		Industrial	4472.00000	3063.55908	.182	-2592.5799	11536.5799
	outfall	Domestic	-5754.66667	3063.55908	.097	-12819.2466	1309.9132
		Central Business	-854.00000	3063.55908	.787	-7918.5799	6210.5799
		Industrial	-1282.66667	3063.55908	.686	-8347.2466	5781.9132
	CBA	Domestic	-4900.66667	3063.55908	.148	-11965.2466	2163.9132
		outfall	854.00000	3063.55908	.787	-6210.5799	7918.5799
		Industrial	-428.66667	3063.55908	.892	-7493.2466	6635.9132
	Industrial	Domestic	-4472.00000	3063.55908	.182	-11536.5799	2592.5799
		outfall	1282.66667	3063.55908	.686	-5781.9132	8347.2466
		Central Business	428.66667	3063.55908	.892	-6635.9132	7493.2466
Ph	Domestic	outfall	-.54667	.63888	.417	-2.0199	.9266
		Central Business	-.26667	.63888	.687	-1.7399	1.2066
	Industrial	-.12333	.63888	.852	-1.5966	1.3499	
	outfall	Domestic	.54667	.63888	.417	-.9266	2.0199

		Central Business	.28000	.63888	.673	-1.1933	1.7533
		Industrial	.42333	.63888	.526	-1.0499	1.8966
	Central Business	Domestic	.26667	.63888	.687	-1.2066	1.7399
		outfall	-.28000	.63888	.673	-1.7533	1.1933
		Industrial	.14333	.63888	.828	-1.3299	1.6166
	Industrial	Domestic	.12333	.63888	.852	-1.3499	1.5966
		outfall	-.42333	.63888	.526	-1.8966	1.0499
		Central Business	-.14333	.63888	.828	-1.6166	1.3299
Total Suspended Solids	Domestic	Outfall	278.66667	134.55812	.072	-31.6249	588.9583
		Central Business	11.66667	134.55812	.933	-298.6249	321.9583
		Industrial	408.00000*	134.55812	.016	97.7084	718.2916
	outfall	Domestic	-278.66667	134.55812	.072	-588.9583	31.6249
		Central Business	-267.00000	134.55812	.083	-577.2916	43.2916
		Industrial	129.33333	134.55812	.365	-180.9583	439.6249
	Central Business	Domestic	-11.66667	134.55812	.933	-321.9583	298.6249
		Outfall	267.00000	134.55812	.083	-43.2916	577.2916
		Industrial	396.33333*	134.55812	.019	86.0417	706.6249
	Industrial	Domestic	-408.00000*	134.55812	.016	-718.2916	-97.7084
		Outfall	-129.33333	134.55812	.365	-439.6249	180.9583
		Central Business	-396.33333*	134.55812	.019	-706.6249	-86.0417
Total Dissolved Solids	Domestic	Outfall	8484.00000	6515.80854	.229	-6541.4814	23509.4814
		Central Business	9621.83333	6515.80854	.178	-5403.6481	24647.3148

		Industrial	9208.33333	6515.80854	.195	-5817.1481	24233.8148
	outfall	Domestic	-8484.00000	6515.80854	.229	-23509.4814	6541.4814
		Central Business	1137.83333	6515.80854	.866	-13887.6481	16163.3148
		Industrial	724.33333	6515.80854	.914	-14301.1481	15749.8148
	Central Business	Domestic	-9621.83333	6515.80854	.178	-24647.3148	5403.6481
		Outfall	-1137.83333	6515.80854	.866	-16163.3148	13887.6481
		Industrial	-413.50000	6515.80854	.951	-15438.9814	14611.9814
	Industrial	Domestic	-9208.33333	6515.80854	.195	-24233.8148	5817.1481
		Outfall	-724.33333	6515.80854	.914	-15749.8148	14301.1481
		Central Business	413.50000	6515.80854	.951	-14611.9814	15438.9814
Chemical Oxygen Demand	Domestic	Outfall	-35.00000	59.53010	.573	-172.2767	102.2767
		Central Business	-30.00000	59.53010	.628	-167.2767	107.2767
		Industrial	-46.00000	59.53010	.462	-183.2767	91.2767
	outfall	Domestic	35.00000	59.53010	.573	-102.2767	172.2767
		Central Business	5.00000	59.53010	.935	-132.2767	142.2767
		Industrial	-11.00000	59.53010	.858	-148.2767	126.2767
	Central Business	Domestic	30.00000	59.53010	.628	-107.2767	167.2767
		Outfall	-5.00000	59.53010	.935	-142.2767	132.2767
		Industrial	-16.00000	59.53010	.795	-153.2767	121.2767
	Industrial	Domestic	46.00000	59.53010	.462	-91.2767	183.2767
		outfall	11.00000	59.53010	.858	-126.2767	148.2767
		Central Business	16.00000	59.53010	.795	-121.2767	153.2767
BOD	Domestic	outfall	49.16667*	5.13025	.000	37.3363	60.9970

		Central Business	14.00000*	5.13025	.026	2.1696	25.8304
		Industrial	29.66667*	5.13025	.000	17.8363	41.4970
	outfall	Domestic	-49.16667*	5.13025	.000	-60.9970	-37.3363
		Central Business	-35.16667*	5.13025	.000	-46.9970	-23.3363
		Industrial	-19.50000*	5.13025	.005	-31.3304	-7.6696
	Central Business	Domestic	-14.00000*	5.13025	.026	-25.8304	-2.1696
		outfall	35.16667*	5.13025	.000	23.3363	46.9970
		Industrial	15.66667*	5.13025	.016	3.8363	27.4970
	Industrial	Domestic	-29.66667*	5.13025	.000	-41.4970	-17.8363
		outfall	19.50000*	5.13025	.005	7.6696	31.3304
		Central Business	-15.66667*	5.13025	.016	-27.4970	-3.8363
Electrical conductivity	Domestic	outfall	-55060.66667*	547.69395	.000	-56323.6512	-53797.6821
		Central Business	56.66667	547.69395	.920	-1206.3179	1319.6512
		Industrial	490.66667	547.69395	.396	-772.3179	1753.6512
	outfall	Domestic	55060.66667*	547.69395	.000	53797.6821	56323.6512
		Central Business	55117.33333*	547.69395	.000	53854.3488	56380.3179
		Industrial	55551.33333*	547.69395	.000	54288.3488	56814.3179
	Central Business	Domestic	-56.66667	547.69395	.920	-1319.6512	1206.3179
		outfall	-55117.33333*	547.69395	.000	-56380.3179	-53854.3488
		Industrial	434.00000	547.69395	.451	-828.9845	1696.9845
	Industrial	Domestic	-490.66667	547.69395	.396	-1753.6512	772.3179
		outfall	-55551.33333*	547.69395	.000	-56814.3179	-54288.3488

		Central Business	-434.00000	547.69395	.451	-1696.9845	828.9845	
Temp	Domestic	outfall	1.36667*	.38079	.007	.4886	2.2448	
		Central Business	.30000	.38079	.453	-.5781	1.1781	
	outfall	Industrial	1.73333*	.38079	.002	.8552	2.6114	
		Domestic	-1.36667*	.38079	.007	-2.2448	-.4886	
Phosphate		Central Business	-1.06667*	.38079	.023	-1.9448	-.1886	
	Central Business	Industrial	.36667	.38079	.364	-.5114	1.2448	
		Domestic	-.30000	.38079	.453	-1.1781	.5781	
		Outfall	1.06667*	.38079	.023	.1886	1.9448	
	Industrial	Industrial	1.43333*	.38079	.006	.5552	2.3114	
		Domestic	-1.73333*	.38079	.002	-2.6114	-.8552	
		Outfall	-.36667	.38079	.364	-1.2448	.5114	
			Central Business	-1.43333*	.38079	.006	-2.3114	-.5552
	Domestic	Outfall	5.92333*	2.23120	.029	.7782	11.0685	
		Central Business	1.61333	2.23120	.490	-3.5318	6.7585	
	outfall	Industrial	2.53333	2.23120	.289	-2.6118	7.6785	
		Domestic	-5.92333*	2.23120	.029	-11.0685	-.7782	
		Central Business	-4.31000	2.23120	.089	-9.4552	.8352	
	Central Business	Industrial	-3.39000	2.23120	.167	-8.5352	1.7552	
		Domestic	-1.61333	2.23120	.490	-6.7585	3.5318	
		Outfall	4.31000	2.23120	.089	-.8352	9.4552	
Industrial		.92000	2.23120	.691	-4.2252	6.0652		

Nitrate	Industrial	Domestic	-2.53333	2.23120	.289	-7.6785	2.6118
		Outfall	3.39000	2.23120	.167	-1.7552	8.5352
		Central Business	-.92000	2.23120	.691	-6.0652	4.2252
	Domestic	Outfall	11.96667	7.70011	.159	-5.7898	29.7231
		Central Business	5.83333	7.70011	.470	-11.9231	23.5898
	outfall	Industrial	11.20000	7.70011	.184	-6.5565	28.9565
		Domestic	-11.96667	7.70011	.159	-29.7231	5.7898
		Central Business	-6.13333	7.70011	.449	-23.8898	11.6231
	Central Business	Industrial	-.76667	7.70011	.923	-18.5231	16.9898
		Domestic	-5.83333	7.70011	.470	-23.5898	11.9231
		Outfall	6.13333	7.70011	.449	-11.6231	23.8898
	Industrial	Industrial	5.36667	7.70011	.506	-12.3898	23.1231
		Domestic	-11.20000	7.70011	.184	-28.9565	6.5565
		Outfall	.76667	7.70011	.923	-16.9898	18.5231
			Central Business	-5.36667	7.70011	.506	-23.1231
Nitrite	Domestic	outfall	11.23467	9.41782	.267	-10.4829	32.9522
		Central Business	4.40600	9.41782	.652	-17.3115	26.1235
	Outfall	Industrial	11.44033	9.41782	.259	-10.2772	33.1579
		Domestic	-11.23467	9.41782	.267	-32.9522	10.4829
		Central Business	-6.82867	9.41782	.489	-28.5462	14.8889
	Central	Industrial	.20567	9.41782	.983	-21.5119	21.9232
		Domestic	-4.40600	9.41782	.652	-26.1235	17.3115

	Business	outfall	6.82867	9.41782	.489	-14.8889	28.5462	
		Industrial	7.03433	9.41782	.476	-14.6832	28.7519	
		Domestic	-11.44033	9.41782	.259	-33.1579	10.2772	
	Industrial	outfall	-.20567	9.41782	.983	-21.9232	21.5119	
		Central Business	-7.03433	9.41782	.476	-28.7519	14.6832	
		Domestic	.83667	2.30959	.727	-4.4893	6.1626	
	Ammonia	Domestic	outfall	.83667	2.30959	.727	-4.4893	6.1626
			Central Business	-.62000	2.30959	.795	-5.9459	4.7059
			Industrial	-2.80333	2.30959	.259	-8.1293	2.5226
	Outfall	Domestic	-.83667	2.30959	.727	-6.1626	4.4893	
		Central Business	-1.45667	2.30959	.546	-6.7826	3.8693	
		Industrial	-3.64000	2.30959	.154	-8.9659	1.6859	
Central Business	Domestic	.62000	2.30959	.795	-4.7059	5.9459		
	outfall	1.45667	2.30959	.546	-3.8693	6.7826		
	Industrial	-2.18333	2.30959	.372	-7.5093	3.1426		
Industrial	Domestic	2.80333	2.30959	.259	-2.5226	8.1293		
	outfall	3.64000	2.30959	.154	-1.6859	8.9659		
	Central Business	2.18333	2.30959	.372	-3.1426	7.5093		
Turbidity	Domestic	outfall	242.16667	122.62764	.084	-40.6132	524.9465	
		Central Business	-142.43333	122.62764	.279	-425.2132	140.3465	
	Outfall	Industrial	207.56667	122.62764	.129	-75.2132	490.3465	
		Domestic	-242.16667	122.62764	.084	-524.9465	40.6132	
		Central Business	-384.60000*	122.62764	.014	-667.3798	-101.8202	
		Industrial						

		Industrial	-34.60000	122.62764	.785	-317.3798	248.1798
	Central Business	Domestic	142.43333	122.62764	.279	-140.3465	425.2132
		outfall	384.60000*	122.62764	.014	101.8202	667.3798
		Industrial	350.00000*	122.62764	.021	67.2202	632.7798
	Industrial	Domestic	-207.56667	122.62764	.129	-490.3465	75.2132
		Outfall	34.60000	122.62764	.785	-248.1798	317.3798
		Central Business	-350.00000*	122.62764	.021	-632.7798	-67.2202
Feacal Coliform	Domestic	Outfall	21.33333	12.56760	.128	-7.6476	50.3143
		Central Business	21.33333	12.56760	.128	-7.6476	50.3143
		Industrial	-103.00000*	12.56760	.000	-131.9809	-74.0191
	outfall	Domestic	-21.33333	12.56760	.128	-50.3143	7.6476
		Central Business	0.00000	12.56760	1.000	-28.9809	28.9809
		Industrial	-124.33333*	12.56760	.000	-153.3143	-95.3524
	Central Business	Domestic	-21.33333	12.56760	.128	-50.3143	7.6476
		Outfall	0.00000	12.56760	1.000	-28.9809	28.9809
		Industrial	-124.33333*	12.56760	.000	-153.3143	-95.3524
	Industrial	Domestic	103.00000*	12.56760	.000	74.0191	131.9809
		Outfall	124.33333*	12.56760	.000	95.3524	153.3143
		Central Business	124.33333*	12.56760	.000	95.3524	153.3143
DO	Domestic	Outfall	-1.83333	1.73526	.322	-5.8348	2.1682
		Central Business	.73333	1.73526	.684	-3.2682	4.7348
		Industrial	-.36667	1.73526	.838	-4.3682	3.6348
	outfall	Domestic	1.83333	1.73526	.322	-2.1682	5.8348

		Central Business	2.56667	1.73526	.177	-1.4348	6.5682
		Industrial	1.46667	1.73526	.423	-2.5348	5.4682
	Central Business	Domestic	-.73333	1.73526	.684	-4.7348	3.2682
		Outfall	-2.56667	1.73526	.177	-6.5682	1.4348
		Industrial	-1.10000	1.73526	.544	-5.1015	2.9015
	Industrial	Domestic	.36667	1.73526	.838	-3.6348	4.3682
		Outfall	-1.46667	1.73526	.423	-5.4682	2.5348
		Central Business	1.10000	1.73526	.544	-2.9015	5.1015
Ecoli	Domestic	Outfall	13.66667*	4.01386	.009	4.4107	22.9227
		Central Business	6.33333	4.01386	.153	-2.9227	15.5893
		Industrial	-20.00000*	4.01386	.001	-29.2560	-10.7440
	Outfall	Domestic	-13.66667*	4.01386	.009	-22.9227	-4.4107
		Central Business	-7.33333	4.01386	.105	-16.5893	1.9227
		Industrial	-33.66667*	4.01386	.000	-42.9227	-24.4107
	Central Business	Domestic	-6.33333	4.01386	.153	-15.5893	2.9227
		outfall	7.33333	4.01386	.105	-1.9227	16.5893
		Industrial	-26.33333*	4.01386	.000	-35.5893	-17.0773
	Industrial	Domestic	20.00000*	4.01386	.001	10.7440	29.2560
		outfall	33.66667*	4.01386	.000	24.4107	42.9227
		Central Business	26.33333*	4.01386	.000	17.0773	35.5893

*. The mean difference is significant at the 0.05 level.

APPENDIX C: CORRELATIONS

	Temp	Electrical conductivity	Biological Oxygen Demand	Chemical Oxygen Demand	Total Dissolved Solids	Total Suspended Solids	Dissolved Oxygen	pH	Turbidity	Nitrate	Nitrite	Ammonia	Phosphate	Total Coliform	Feacal Coliform	Ecoli
Temperature	1	-.359	.777**	-.289	.585*	.740**	-.474	-.238	.557	.536	.429	-.015	.564	.620*	-.497	-.283
		.252	.003	.363	.046	.006	.120	.457	.060	.072	.164	.063	.056	.032	.100	.374
Electrical conductivity	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12
	1	-.787**	.062	-.117	-.266	.424	.269	-.468	-.293	-.237	-.322	-.633*	-.401	-.603*	-.038	-.033*
		.002	.849	.717	.403	.169	.397	.125	.355	.458	.308	.027	.356	.196	.038	.038
Biological Oxygen Demand	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12
	1	-.107	.383	.662*	-.441	-.200	.582*	.447	.364	.214	.703*	.508	-.066	.136	.672	.136
		.741	.219	.019	.152	.533	.047	.145	.245	.504	.011	.092	.838	.672	.122	.122
Chemical Oxygen Demand	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12
	1	-.635*	.088	.025	-.088	.225	.196	.309	.154	.631*	.160	.091	.778	.028	.619	.778
		.027	.785	.938	.785	.482	.541	.328	.632	.785	.028	.619	.778	.028	.619	.778
Total Dissolved Oxygen	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12
	1	.271	-.254	.014	-.061	.041	-.144	.042	.068	.982**	-.107	.010	.970	.010	.970	.010
		.394	.425	.966	.851	.899	.655	.835	.000	.741	.975					

										17		5		4
										12		12		12
Ammonia										1	.299	.093	.570	.380
											.345	.773	.053	.223
Phosphate											12	12	12	12
											1	.190	.136	.293
												.554	.674	.356
Total Coliform												12	12	12
												1	-.019	.130
													.954	.687
Feacal Coliform													12	12
													1	.928**
														.000
Ecoli														12
														1

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

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

APPENDIX D: RAW DATA

SAMPLE 1

SITE	TEMP	DO	BOD	EC	TDS	pH	TSS	TURB	COD	NO3	NO2	NH4
S1	31.1	0.6	47	2235	1115	6.87	415	442	365	31.4	34.8	0.5
S2	30.8	0.4	65	2014	1007	6.74	460	446	418	26.8	28.9	1.45
S3	29.7	5.2	2	56933	28466	7.67	15	10.7	216	1.5	1.5	0.2
S4	30.4	0.8	52	1876	938	6.65	256	208	362	2.6	17.6	2
S5	31.4	0.7	45	1367	6835	6.93	484	502	388	19.6	20.6	1.95
S6	32.4	3.3	23	4417	2208	6.46	481	194	374	4.2	6.3	1.9
S7	29.3	4.3	15	1890	945	7.21	12	15.2	306	2.6	0.8	0.6
S8	30.8	3.6	24	4142	2017	6.88	59	29	312	5.7	5.8	0.4

SAMPLE 2

SITE	TEMP	DO	BOD	EC	TDS	pH	TSS	TURB	COD	NO3	NO2	NH4
S1	32	1	56	2237	1026	7.98	485	163	352	7.7	0.103	2.08
S2	31.4	1.1	57	1706	785	7.8	334	160	448	6.4	0.106	0.12
S3	29.8	5.1	0.5	56833	2841.5	8.7	9	10.2	416	1.5	0.01	0.19
S4	31.4	1.7	50	1340	612	7.78	425	232	384	8.6	0.004	1.6
S5	30.9	1.4	35	1039	476	7.88	341	118	448	2.2	0.099	0.5
S6	31	1.3	27	1718	793	7.69	133	15.2	384	1.9	0.016	9
S7	29.9	1.7	22	1183	545	8.08	61	11.7	256	1.7	0.018	10.2
S8	32	1.6	25	2777	1276	8.07	99	6.33	224	1.5	0.31	6.6

SAMPLE 3

SITE	TEMP	DO	BOD	EC	TDS	pH	TSS	TURB	COD	NO3	NO2	NH4
S1	30.6	0.8	56	830	378	8.33	502	164.5	355.2	1.5	0.314	0.62
S2	30.2	1.8	49	814	375	8.14	566	194.4	358.4	2.1	0.157	2.6
S3	30.1	5.8	9	56720	28360	8.45	16	22.1	358.4	1.7	0.003	0.3
S4	28.9	0.9	48	692	316	9.17	542	167.4	364.8	4.5	0.0974	2.81
S5	30.5	1.3	37	2725	1251	7.17	882	576.8	358.4	1.3	0.273	2.61
S6	30.9	0.8	20	1668	765	7.81	105	41.8	342.5	0	0.025	2.02
S7	29.3	1.2	33	759	349	8.26	312	119.6	361.6	2.7	0.078	0.81
S8	32.3	2.9	42	2757	1268	8.58	146	10.9	355.2	0.9	0.015	0.51

SITE	TEMP	DO	BOD	EC	TDS	pH	TSS	TURB	COD	NO3	NO2	NH4	PO4
S1	31.1	0.6	47	2235	1115	6.87	415	442	365	31.4	34.8	0.5	10.96
S1	32	1	56	2237	1026	7.98	485	163	352	7.7	0.103	2.08	4.92
S1	30.6	0.8	56	830	378	8.33	502	164.5	355.2	1.5	0.314	0.62	3.76
MEAN	31.23333	0.8	53	1767.333	839.6667	7.726667	467.3333	256.5	357.4	13.53333	11.739	1.066667	6.546667
STDEV	0.70946	0.2	5.196152	811.7551	402.2839	0.762255	46.11218	160.6495	6.773478	15.78047	19.97169	0.879621	3.865816
MAX	32	1	56	2237	1115	8.33	502	442	365	31.4	34.8	2.08	10.96
MIN	30.6	0.6	47	830	378	6.87	415	163	352	1.5	0.103	0.5	3.76

SITE	TEMP	DO	BOD	EC	TDS	pH	TSS	TURB	COD	NO3	NO2	NH4	PO4
S2	30.8	0.4	65	2014	1007	6.74	460	446	418	26.8	28.9	1.45	5.35
S2	31.4	1.1	57	1706	785	7.8	334	160	448	6.4	0.106	0.12	2.84
S2	30.2	1.8	49	814	375	8.14	566	194.4	358.4	2.1	0.157	2.6	4.52
MEAN	30.8	1.1	57	1511.333	722.3333	7.56	453.3333	266.8	408.1333	11.76667	9.721	1.39	4.236667
STDEV	0.6	0.7	8	623.2346	320.6265	0.730205	116.1436	156.142	45.6076	13.19558	16.60952	1.241088	1.278762
MAX	31.4	1.8	65	2014	1007	8.14	566	446	448	26.8	28.9	2.6	5.35
MIN	30.2	0.4	49	814	375	6.74	334	160	358.4	2.1	0.106	0.12	2.84

SITE	TEMP	DO	BOD	EC	TDS	pH	TSS	TURB	COD	NO3	NO2	NH4	PO4
S3	29.7	5.2	2	56933	28466	7.67	15	10.7	216	1.5	1.5	0.2	0.35
S3	29.8	5.1	0.5	56833	28415	8.7	9	10.2	416	1.5	0.01	0.19	0.34
S3	30.1	5.8	9	56720	28360	8.45	16	22.1	358.4	1.7	0.003	0.3	1.18
MEAN	29.86667	5.366667	3.833333	56828.67	28413.67	8.273333	13.33333	14.33333	330.1333	1.566667	0.504333	0.23	0.623333
STDEV	0.208167	0.378594	4.536886	106.5661	53.01258	0.537246	3.785939	6.730775	102.9527	0.11547	0.86228	0.060828	0.482113
MAX	30.1	5.8	9	56933	28466	8.7	16	22.1	416	1.7	1.5	0.3	1.18
MIN	29.7	5.1	0.5	56720	28360	7.67	9	10.2	216	1.5	0.003	0.19	0.34

SITE	TEMP	DO	BOD	EC	TDS	pH	TSS	TURB	COD	NO3	NO2	NH4	PO4
S4	30.4	0.8	52	1876	938	6.65	256	208	362	2.6	17.6	2	5.25
S4	31.4	1.7	50	1340	612	7.78	425	232	384	8.6	0.004	1.6	0.34
S4	28.9	0.9	48	692	316	9.17	542	167.4	364.8	4.5	0.0974	2.81	4.52
MEAN	30.23333	1.133333	50	1302.667	622	7.866667	407.6667	202.4667	370.2667	5.233333	5.900467	2.136667	3.37
STDEV	1.258306	0.493288	2	592.8822	311.1206	1.262233	143.7857	32.65353	11.97553	3.066486	10.1322	0.616468	2.649321
MAX	31.4	1.7	52	1876	938	9.17	542	232	384	8.6	17.6	2.81	5.25

MIN	28.9	0.8	48	692	316	6.65	256	167.4	362	2.6	0.004	1.6	0.34
SITE	TEMP	DO	BOD	EC	TDS	pH	TSS	TURB	COD	NO3	NO2	NH4	PO4
S5	31.4	0.7	45	1367	6835	6.93	484	502	388	19.6	20.6	1.95	7.24
S5	30.9	1.4	35	1039	476	7.88	341	118	448	2.2	0.099	0.5	5.32
S5	30.5	1.3	37	2725	1251	7.17	882	576.8	358.4	1.3	0.273	2.61	2.24
MEAN	30.93333	1.133333	39	1710.333	2854	7.326667	569	398.9333	398.1333	7.7	6.990667	1.686667	4.933333
STDEV	0.450925	0.378594	5.291503	893.9001	3469.355	0.493997	280.3373	246.1532	45.65143	10.31552	11.78635	1.079367	2.522327
MAX	31.4	1.4	45	2725	6835	7.88	882	576.8	448	19.6	20.6	2.61	7.24
MIN	30.5	0.7	35	1039	476	6.93	341	118	358.4	1.3	0.099	0.5	2.24
SITE	TEMP	DO	BOD	EC	TDS	pH	TSS	TURB	COD	NO3	NO2	NH4	PO4
S6	32.4	3.3	23	4417	2208	6.46	481	194	374	4.2	6.3	1.9	3.48
S6	31	1.3	27	1718	793	7.69	133	15.2	384	1.9	0.016	9	5.72
S6	30.9	0.8	20	1668	765	7.81	105	41.8	342.5	0	0.025	2.02	5.34
MEAN	31.43333	1.8	23.33333	2601	1255.333	7.32	239.6667	83.66667	366.8333	2.033333	2.113667	4.306667	4.846667
STDEV	0.83865	1.322876	3.511885	1572.901	825.1523	0.747195	209.4692	96.47266	21.65833	2.103172	3.625474	4.064989	1.198722
MAX	32.4	3.3	27	4417	2208	7.81	481	194	384	4.2	6.3	9	5.72
MIN	30.9	0.8	20	1668	765	6.46	105	15.2	342.5	0	0.016	1.9	3.48
SITE	TEMP	DO	BOD	EC	TDS	pH	TSS	TURB	COD	NO3	NO2	NH4	PO4
S7	29.3	4.3	15	1890	945	7.21	12	15.2	306	2.6	0.8	0.6	0.9
S7	29.9	1.7	22	1183	545	8.08	61	11.7	256	1.7	0.018	10.2	6.6
S7	29.3	1.2	33	759	349	8.26	312	119.6	361.6	2.7	0.078	0.81	4.54
MEAN	29.5	2.4	23.33333	1277.333	613	7.85	128.3333	48.83333	307.8667	2.333333	0.298667	3.87	4.013333
STDEV	0.34641	1.664332	9.073772	571.3706	303.7631	0.561516	160.9358	61.31071	52.82474	0.550757	0.435203	5.482946	2.886266
MAX	29.9	4.3	33	1890	945	8.26	312	119.6	361.6	2.7	0.8	10.2	6.6
MIN	29.3	1.2	15	759	349	7.21	12	11.7	256	1.7	0.018	0.6	0.9

SITE	TEMP	DO	BOD	EC	TDS	pH	TSS	TURB	COD	NO3	NO2	NH4	PO4
S8	30.8	3.6	24	4142	2017	6.88	59	29	312	5.7	5.8	0.4	4.6
S8	32	1.6	25	2777	1276	8.07	99	6.33	224	1.5	0.31	6.6	1.3
S8	32.3	2.9	42	2757	1268	8.58	146	10.9	355.2	0.9	0.015	0.51	4.68
MEAN	31.7	2.7	30.33333	3225.333	1520.333	7.843333	101.3333	15.41	297.0667	2.7	2.041667	2.503333	3.526667
STDEV	0.793725	1.014889	10.11599	793.9196	430.1445	0.872372	43.54691	11.98905	66.86265	2.615339	3.258153	3.548244	1.928765
MAX	32.3	3.6	42	4142	2017	8.58	146	29	355.2	5.7	5.8	6.6	4.68
MIN	30.8	1.6	24	2757	1268	6.88	59	6.33	224	0.9	0.015	0.4	1.3

APPENDIX E: QUESTIONNAIRE**UNIVERSITY OF GHANA****INSTITUTE OF ENVIRONMENT AND SANITATION STUDIES****M.PHIL ENVIRONMENTAL SCIENCE PROGRAMME****TOPIC: ENVIRONMENTAL RISK ASSESSMENT OF SEWAGE POLLUTION: A CASE OF TEMA METROPOLITAN ASSEMBLY.**

INTRODUCTION: The administration of this questionnaire is to solicit responses from households and community members in order to assist the establishment of facts wastewater management and household perception on environmental and health hazards associated with sewage pollution. All the information is strictly for academic purposes and will be highly treated with the greatest level of confidentiality.

Locality.....

Interviewer.....

PART A: DEMOGRAPHIC INFORMATION OF RESPONDENTS

1 .House number.....

2. Sex male female

3. Age 21-30 31-40 41-50 51-60 61-70 71+

4. Household size 2-5 5-10 10-15 15-20 20-25 25+

5. Marital status single married divorced widowed

6. Occupation Working Homemaker Servant Student

7. Level of Education Basic Secondary Tertiary Advanced

PART B: HOUSEHOLD PERCEPTION ON THE MANAGEMENT OF THE SEWER SYSTEM

8. Are you connected to the sewage facility in your house Yes No

8a. if yes what is the performance of the facility in your community?

good poor very poor unknown

8b. if no where do you disposed off wastewater?

S_{ewer} tank drains others, specify.....

9. Has there been any maintenance on the facility Yes No

9a. If yes how often? Monthly quarterly annually others

10. Are there main manholes located in your compound? Yes No

10a. If yes, do you have extension on them yes No

11. How often do you experienced overflow in your compound?

11b. what are the causes of the frequent overflow poor maintenance user's attitude institutional irresponsibility population pressure

12. Do you pay maintenance fees

13 If no why? Damaged pipe frequent overflow no maintenance expensive no revenue officer in my community

PART C: HOUSEHOLD PERCEPTION ON THE ENVIRONMENTAL AND HEALTH EFFECT OF WASTEWATER MANAGEMENT IN THE TEMA METROPOLIS

14. Do you think there are challenges in the management of Tema metropolis Yes No

14a. if yes what kind of challenges?

technical social environmental

14b what are some of the technical problems.....

14b what are some of the social problems.....

14d what are some of the environmental problems.....

15. Who do you think is responsible for the management of sewage pollution in the metropolis?

occupants landlords community assemblyman Government TMA T

16. What are some of the environmental effects of sewage pollution? Offensive odour

Sewage overflow insects and rodents pollution of water supply

17a. Do you perceived any health hazards associated with sewage pollution?

yes

18(b) what are some of the diseases that are associated with sewage pollution?

pleraTyphoidD heaDysentery

19. What mitigation measures would you suggest for the management of wastewater in the metropolis ewater treatmentperiodic intenance provision logistics

Rehabilitation health education

20 comments.....
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Thank you.