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COLLEGE OF SCIENCE

DEPARTMENT OF ENVIRONMENTAL SCIENCE

ASSESSING THE IMPACT OF AIRPORT OPERATIONS ON SOME ASPECTS OF THE ENVIRONMENTOF THE KOTOKA INTERNATIONAL AIRPORT, GHANA

By

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MASTER OF SCIENCE IN ENVIRONMENTAL SCIENCE

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DECLARATION

I hereby declare that this submission is my own work towards the award of master of science in environmental scienceand that, to the best of my knowledge, it contains no material previously published by another person nor material which has been accepted for the award of any other degree of the University except where due acknowledgement has been made in the text.

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(HEAD OF DEPARTMENT)

DEDICATION

This work is dedicated to my beloved family

ACKNOWLEDGEMENT

First of all, I thank the Lord for granting me the strength, wisdom and knowledge to complete this thesis.

My profound gratitude goes to my Supervisor, Professor K. Obiri–Danso, for his continuous support and constant constructive criticism throughout the period of this study.

I am also indebted to all those who supported me in diverse ways especially in acquisition of the right data for this project work.

Finally, my appreciation goes to all my family and friends for their prayers and encouragement which saw this thesis to a successful end.

ABSTRACT

Globally, airports implement environmental management policy programmes to satisfy regulatory requirements in line with international standards and recommended practices. This study assessed the impact of aircraft operations on the immediate/ surrounding environment of theKotoka International Airport (KIA), Accra, Ghana, with regards to particulate matter (PM_{10}) concentration, noise levels and surface water contamination at three sampling sites (New Fire Station, Spintex Road and Runway 21 Take-off) using a mini vol potable air sampler, castle sonus (GA116) range of pocket sound level meter, H1 991300 water proof of pH/EC/TDS/Temperature meter and H1-83200-02 multi parameter photometer.All the sampled sites recorded high PM_{10} values, recording dust values above the World Health Organisation(WHO) and the Ghana Environmental Protection Agency (GEPA)air quality threshold limits of 50 μg/m³ and 70 μg/m³ respectively, with mean values ranging from 89.9 μg/m³ to91.1 μg/m³ respectively. TheGhana EPA permissible limits of 70 dB were not exceeded in any of the monitored sites. The highest noise level of 62.7dB was recorded at the New Fire Station site. pH, conductivity and hydrocarbons recorded at the study sites were generally within the Ghana EPA permissible levels. It is recommended that the Ghana Civil Aviation Authority (GCAA) as the regulator,should be empowered by legislation to ensure protection of the environment in relation to the aviation industry.The EPA should continue to act as the enforcement body in the case of environmental impact assessment of airport constructions and expansions. This will enable the two bodies limit possible future increases in emissions at our airports.

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ABBREVIATIONS

APU	Auxiliary Power Unit
CAEE	Committee Aircraft Engine Emissions
CAEP	Committee on Aviation Environmental Protection
CO	Carbon Monoxide
CO_2	Carbon Dioxide
EIA	Environmental Impact Assessment
EPA	Environmental Protection Agency
FAA	Federal Aviation Administration
GPU	Ground Power Unit
GSE	Ground Support Equipment
HAP	Hazardous Air Pollutants
HCs	Hydrocarbons
NO	Nitric Oxide
NO_2	Nitrogen Dioxide
NO_3	Nitrate
NO_x	Oxides of Nitrogen
PM	Particulate matter
PM_{10}	ParticulateMatter 10μm andsmaller in size
USEPA	United States Environmental Protection Agency
VOC	Volatile organic carbons
WHO	World Health Organisation

CHAPTER ONE

1.0 INTRODUCTION

1.1 INTRODUCTION

The growth of civil aviation in general and airports in particular, have helped to bring our worlds closer: the goods we send, the people and places we visit. Air travel has shaped the quality of modern life and heightened awareness of our global society (Ban Ki–Moon, 2010). Airtransport therefore impacts our lives in a variety of ways and the challenge is to balance the role of transport in promoting development whilst reducing carbon emissions and maintaining safe and secure networks that promote health, equality of transport opportunities, quality of life and the natural environment. The future of air transport as a catalyst for the economic, social and cultural development of our global society is directly related to our collective ability to reach and maintain the sustainability of civil aviation operations worldwide (Gonzalez, 2010).

It is around the airports that the economic contribution of the aviation industry is directly felt by the public. However, these benefits are made more fragile by adverse environmental concerns.

1.2BACKGROUND TO THE STUDY

The world's airlines carry around 2.3 billion passengers and 38 million tonnes of freight on scheduled services, representing more than 531 billion tonne kilometers combined.

Passenger traffic is expected to grow at an average rate of 4.8% per year through the year 2036(ICAO Environmental Report, 2010). Overall, global trends of aviation noise, emissions that affect local air quality and fuel consumption predict an increase through the year 2036 at less than the 4.8% growth rate in traffic. In 2006, the global population exposed to 55 day night (sound) level (DNL) aircraft noise was approximately 21million people (ICAO Environmental Report, 2010). This is expected to increase at a rate of 0.7% to 1.6% per year through the year 2036. In 2006, 0.25 Mt of NOxwere emitted by aircraft within the landing and takeoff (LTO) cycle globally. These emissions are expected to increase at a rate of between 2.4% and 3.5% per year. In 2006, aircraft consumed approximately 187metric tonnes (Mt) of fuel globally. International flights are responsible for approximately 62% of global aviation fuel consumption. Global aircraft fuel consumption is expected to increase at a rate of between 3.0% and 3.5% per year (ICAO Environmental Report, 2010). Environmental standards set by ICAO and the investments in technology and improved operational procedures are allowing aviation's noise, local air quality, and CO_2 footprints to grow at a rate slower than the demand for air travel. The ICAO Programme of Action on International Aviation and Climate Change, agreed in 2009, set a goal of 2% annual fuel efficiency improvement through the year 2050. It is the first and only globally-harmonized agreement from a sector on a goal and on measures to address its CO_2 emissions. ICAO continues to pursue even more ambitious goals for aviation's contribution to climate change(ICAO Environmental Report, 2010).

1.3 STATEMENT OF THE PROBLEM

The British colonial military administration initiated the development of air transport in Ghana as far back as October 22, 1918 when Vickers Aviation Limited of London conceived the idea of aerial transport in the then Gold Coast.This was followed by a series of aerial surveys and landing place was selected in Accra in 1928, culminating in a first on – land aircraft landing in Accra, which is today the Kotoka International Airport (KIA).

Kotoka International Airport is located approximately 10 kilometers from Accra. The Airport is located 63 meters or 205 feet above sea level and has a mean temperature of 35 degrees Celsius. It is classified as under ICAO Code 4E, provides both scheduled and charter commercial flights to destinations within Ghana and throughout the rest of the World. KIA is equipped with one runway, taxiways, and commercial aircraft parking apron, fuel, and aircraft rescues fire fighting facilities. Runway 03-21 is approximately 3,403 meters in length and 60 meters wide. The PNDC Law 151 of May 16, 1986 established the Ghana Civil Aviation Authority (GCAA) as an autonomous government agency responsible for the development of air transport in the country. The GCAA administered KIA until the decoupling of the Authority in 2006, separating the regulatory function from the airports.The KIA is the country's most busiest commercial service airport and has the capacity for large aircraft such as the Boeing 777, 747, Airbus 330, 340 and Antonov 124. In terms of aircraft movements, KIA has remained busy for the past five (5) years. Data available has indicated that traffic projections in Ghana indicated growth in aircraft movement from 15,225 in 2009 to 27,882 in 2024, with its accompanying passenger growth from 980,468 to 2,021,291 in that order, representing an average annual growth of 18 per cent, whiles cargo would grow from 60,550 in 2009 to 130,170 tonnes in 2024, representing 47 per cent growth over the projected period (Ghana Civil Aviation Authority MIS Report, 2010).

KIA is under increasing pressure to expand their operations to accommodate the growing demand for air travel, forecast by the Ghana Airports Company Limited (GACL) Project Development Report. This growing demand has heightened concerns among some communities, environmental groups, and others that airport operations may have an increasingly detrimental effect on the environment. Thus, environmental impacts of airport activities may intensify if an airport is undergoing expansion.

This research therefore seeks to assess the impact of airport operations on the environment of the Kotoka International Airport, with particular reference to air pollution, noise and surface water pollution.

1.4 JUSTIFICATION OF THE STUDY

Although theaviation industry is one of the fastest growing sectors of the Ghanaian economy, the KIA has not undergone rigorous monitoring of some environmental concerns within the airport as per regulation. However, since the year 2000 there has been consistent growth in the Ghanaian aviation industry. Kotoka International Airport, as the country's only international airport, handles all of Ghana's international flights. The Airport alone handles over 800,000 passengers and 50,000 tons of freight annually (Ghana Civil Aviation Authority MIS Report, 2010). Passenger traffic has generally increased in recent years, growing at an average of 7 percent annually over the past five years. The recent growth in passenger and airline traffic is a reflection of Ghana's economic growth and political stability. With the advent of continuous political stability and discovery of oil and gas in commercial quantities, the economy of Ghana is expected to have strong dependence on air transport, with KotokaInternationalAirport being the main gateway to Ghana.

To meet this future demand, airport development and expansion projects may become increasingly necessary to accommodate the expected increase in aircraft operations in Ghana. A potential challenge would be community concern regarding airport environmental impacts. Airports have considerable effects on the natural environment, and large numbers of people live in close proximity to airports. Airport operations can adversely affect neighbouring communities with the generation of noise, air pollution, ozone depleting substances, as well as water contamination by spilled aviation oil through refrigeration and air conditioning among others.

Despite the obvious societal and economic benefits of the growing aviation industry in Ghana, there is clearly some negative impacts associated with aircraft noise, air quality, water quality, sanitation, public health and safety that need to be managed if the industry wishes to advocate and promote itself as being sustainable.

According to Saxe (1990) and Shrivastava (1995), improving the environmental performance of corporate bodies will eventually reduce the negative environmental effects that threaten modern society.

1.5 GENERAL OBJECTIVES

The main objective of this study was to assess the effect of operation at KIA on the immediate surroundingneighbouring environment.

The specific objectives of the study were to:

1. monitor the levels of noise at three different sites within the KIA

2. measure concentrations of particulate matter at three different sites within the KIA

3. monitor some physicochemical (pH, Electrical Conductivity and Hydrocarbons) and microbiological (coliform counts) in the streams within the KIA

CHAPTER TWO

2.0 LITERATURE REVIEW

2.1 GLOBAL DEMAND FOR AIR TRANSPORT SERVICES

Aviation activity is projected to grow substantially over the next few decades. A study by a consortium of institutions modeled that the number of passengers flying per year could double to 4 billion worldwide by 2020 in a scenario of very high growth (European Commission on Constrained Scenarios on Aviation and Emissions, 2005).

For instance, the provisional Airport Council International (ACI) airport statistics for 2010 which cover more than 900 out of its approximately 1,650 member airports accounted for about 93% of air traffic. Overall, this shows significant increase in global passenger and cargo traffic.

The provisional statistics record that passenger traffic grew by 6.3% when compared to the 2009 figure, while cargo tonnage increased by 15.2% to 82 million tons while aircraft movements recorded a slight rise to 64 million, up by 0.8%.

The ability for airports to meet this increasing demand for air travel has resulted in airport capacity expansion and development, which is likely to be environmentally damaging. There is a dilemma whether to control the problem by airport land – use planning, changing the aircraft type or enforcing suitable guidelines and legislations.

Airports have considerable effects on the natural environment, and large numbers of people live in close proximity to airports.Airport operations can adversely affect their neighbouring communities with the generation of noise and air pollution as well as through water contamination.Airports occupy relatively large areas of land and may detrimentally affect competing land uses, such as: other commercial uses; agriculture; fisheries and wildlife habitat, including endangered species and recreation.

2.2 OTHER EMISSIONS FROM COMMERCIAL AIRCRAFT

Gas turbine-powered aircraft emit a range of chemicals from their engines during operation. Approximately 70% of the emitted mass is carbon dioxide (CO_2), and 30% of the mass is water (H_2O) (Federal Aviation Administration, 2005). Less than 1% of the emitted mass from aircraft engines consists of nitrogen oxides (NOx), carbon monoxide (CO), sulfur oxides (SOx), unburned hydrocarbons (HCs), and small particles (known as particulate matter, or PM). Engine emissions also consist of trace compounds like bits of metals from engine abrasion as well as ions and radicals with a very short lifetime (Kugele*et al.*, 2005). A small subset of HCs, specifically, some volatile organic compounds (VOCs) and PM can cause cancer or other serious health effects such as birth defects. These toxic chemicals are referred to by the United States Environmental Protection Agency (USEPA) as hazardous air pollutants (HAPs).

2.2.1 Nitrogen Oxides

Nitrogen oxides are created during the high-temperature combustion of fuels in the presence of air, which contains nitrogen (Flagan and Seinfeld, 1988). The class of nitrogen oxides consists of a variety of compounds that contain nitrogen atoms, such as nitrous oxide (N_2O), and nitrogen dioxide (NO_2) (USEPA, 1993). Manufacturers of aircraft gas turbines must measure nitrogen oxides emissions from engines during testing for certification, as dictated by the International Civil Aviation Organization (ICAO, 2005).

2.2.2 Sulfur Oxides

Sulfur oxides are created when fuels containing sulfur are burned (Flagan and Seinfeld, 1988). Jet engine manufacturers do not have to measure sulfur oxides from engines during certification testing, but the maximum sulfur content of aviation fuels is set at 3000 parts per million (ppm) by international voluntary standards (ASTM International, 2007).

2.2.3 Carbon Monoxide (CO) and Unburned Hydrocarbons (HCS)

Carbon monoxide is created when carbon-based fuels undergo incomplete combustion in engines (Flagan and Seinfeld, 1988). ICAO regulations dictate that engine manufacturers must measure CO emissions during certification testing (International Civil AviationOrganization, 2005). Unburned hydrocarbons like formaldehyde and benzene are created by incomplete combustion of hydrocarbon-based fuels (Kugele*et al.*, 2005; Yelvington*et al.*, 2007), and engine manufacturers must measure HC content in engine exhaust for certification.

Volatile organic compounds (VOCs) are hydrocarbon vapors emitted from certain solids or liquids (U.S. Environmental Protection Agency, 1994). VOCs are also emitted by biogenic sources, such as plants (Kesselmeier and Staudt, 1999).

2.2.4 Particulate Matter

Particulate matter is composed of a combination of chemical components (species) of different sizes and compositions and is classified as Primary PM or secondary PM (USEPA, 2004). Primary PM is created directly by combustion, mechanical abrasion, or erosion processes (Kugele*et al.*,2005). Engine manufacturers do not have to measure primary PM directly when they test gas turbine engines for certification, but they must measure a quantity called smoke number (SN), which is related to visibility decreases caused by primary PM (ICAO, 2001).

Secondary PM is formed from chemical reactions involving NO_X, SO_X (particularly SO_2), VOCs, ammonia, and other compounds in the ambient atmosphere some time after these gases (known in this context as precursor emissions) are emitted by various sources (Kugele*et al.*, 2005 ; U.S. Environmental Protection Agency, 2004). For example, SO_2 and NO_X contribute to the formation of ammonium nitrate and ammonium sulfate particles in the atmosphere (U.S. Environmental Protection Agency, 2004). Without a better understanding of PM emissions from airport sources, airport operators will be unable to address the regulatory and community demands for assurance that airports are not damaging the local environment or the health of their workers or nearby residents. Without these assurances, airports may not be allowed to expand to meet the growing demands for their services, which are only expected to increase over the coming years.

2.2.5 Emissions from airport operations

There are other aviation-related sources of emissions that must be considered when assessing the impact of aviation activity on the environment. The non-aircraft aviationrelatedsources usually considered are aircraft auxiliary power units (APUs), aircraft ground support equipment (GSE), and ground access vehicles (GAVs). Stationary power sources like power plants at airports, the handling and storage of fuel (which can emit fuel-related vapors), and the activity of emergency response teams and training fires aswell as airport-specific construction are also aviation-related emission sources (Ratliff, 2007).

Auxiliary power units are used to provide power for heating, air conditioning, and electrical systems when aircraft are on the ground. APUs embedded in aircraft are often small gas turbine engines. The usage of APUs depends on aircraft size, ground traffic, and weather conditions as well as procedures that are specific to each airline, and ultimate decisions on usage rest with an aircraft's pilot (Ohsfeldt*et al.*,2007). Ground support equipment (GSE) are also critical to airport operations; these are vehicles that assist with aircraft servicing procedures such as refueling and the loading and unloading of baggage. They are mostly hydraulic machines that are powered by a range of sources, from diesel engines to electric motors (Morrow *et al.*, 2007). Ground access vehicles (GAVs) are road vehicles that pass through airport boundaries while transporting people and cargo; just like other vehicles currently on roads, GAVs have a diverse set of power sources.

The apportionment of aviation-related emissions between aircraft and other sources is not generally known and has only been determined for specific airports. For instance, Heathrow airport in the United Kingdom is one airport where such an apportionment has been done. In the year 2002, airside vehicles (vehicles within the airport boundary, such as ground support equipment) contributed 5.2% of Heathrow's total NO_X emissions and 20.4% of the total PM_{10} emissions; stationary sources contributed another 3.9% of NO_X and 25.2% of PM_{10} in the same year (AEA Energy and Environment, 2007).

2.3 OVERVIEW OF INTERNATIONAL EMISSIONS REGULATIONS

Aviation is regulated at international and at State levels. Regulations for noise and emissions from aviation are analyzed, established, and updated at the international level by the ICAO's Committee on Aviation Environmental Protection (CAEP) (International Civil Aviation Organization, 2007). ICAO is a body of the United Nations and consists of 190 member states from around the world. The organization was created in 1944 in Chicago, USA, as an agreement between States. The agreement, known as the Chicago Convention was signed in order that international civil aviation may be developed in a safe and orderly manner and that international air transport services may be established on the basis of equality of opportunity and operated soundly and economically.

ICAO regulations are published as Annexes that prescribe standards and recommended practices (SARPs) for member states to ratify. After a standard is established or updated, ICAO member states are expected to comply or submit written notifications of any differences between their standards and ICAO standards. The Chicago Convention allows disputes to be raised against member states that do not follow ICAO regulations, and states found non-compliant through the dispute process are at risk of losing their voting power in the ICAO Council and Assembly.

In addition, Article 33 of the Convention states that members can derecognize aircraft airworthiness certificates from other member states that do not establish standards "equal to or above the minimum standards which may be established from time to time pursuant to" the Chicago Convention (International Civil Aviation Organization, 1944).

The environmental effects of aviation gained greater attention several decades after the establishment of ICAO. At the United Nations Conference on the Human Environment in 1972, ICAO recognized the responsibility to "achieve maximum compatibility between the safe and orderly development of civil aviation and the quality of the human environment" (International Civil Aviation Organization, 2005). The first guidance document for the control of aviation vented fuel as well as aviation emissions (including smoke and gaseous emissions) was released by ICAO in 1977. The body created the Committee on Aircraft Engine Emissions (CAEE) in that same year, and standards for noise and emissions were proposed for an annex to the Chicago Convention in 1980. Finally, in 1983, the CAEE and ICAO's Committee on Aircraft Noise (CAN) merged to form the Committee on Aviation Environmental Protection (CAEP) (International Civil Aviation Organization, 2007).

CAEP proposes, analyzes, and updates Standards and Recommended Practices (SARPs) for the mitigation of aviation's impacts upon the environment.The SARPs governs fuel venting as well as emissions from subsonic and supersonic turbojet and turbofan engines; the document also gives appropriate procedures for the measurement of engine emissions. The first SARPs for aircraft engine emissions were issued by ICAO in 1981 (ICAO, 2007).

2.4 GHANA'S ENVIRONMENTAL LEGISLATION

The following provide a summary of Ghana's national environmental regulations.

Research results indicate that the key environmental legislations in Ghana are:

1. The Environmental Protection Council Decree, 1974 (National Redemption Council Decree 239);
2. Environmental Protection Council (Amendment) Decree, 1976 (Supreme Military Council Decree 58);
3. The National Environmental Policy (NEP), 1990;
4. The National Environmental Action Plan (NEAP), 1990;
5. The Environmental Protection Agency Act, 1994 (Act 490);
6. The Forest and Wildlife Policy, 1994;
7. The Pesticides Control and Management Act, 1996 (Act 528);
8. The Environmental Assessment Regulations, 1999 (Legislative Instrument 1652);
9. The Environmental Assessment (Amendment) Regulations, 2002; and,
10. The Environmental Sanitation Policy, 1999.

2.4.1 National Environmental Policy

In March 1988, Ghana assembled a group of experts whose purpose was to review existing environmental protection policies and develop a strategy to address deforestation, land management, forestry and wildlife, water management, marine and coastal ecosystems, mining, manufacturing industries and hazardous chemicals, human settlements, legal and institutional issues, environmental education and environmental data systems. This resulted in the adoption of the National Environmental Action Plan (NEAP) and National Environmental Policy (NEP). The NEP provided the framework for the implementation of the Action Plan to ensure sound management of resources over a ten-year period, from 1991 through 2000. The NEAP endorsed a preventive approach to environmental management and emphasized a need to promote socioeconomic development within acceptable environmental standards to achieve sustainable development. The adoption of the NEAP set into motion structural and organizational changes including the replacement of the Environmental Protection Commission (EPC) by the Environmental Protection Agency (EPA). The EPC was the government institution that advised and coordinated all environment-related issues in Ghana prior to the creation of the EPA.

2.4.2 Environmental Assessment Regulations

In recent times the environment has taken center stage in development planning and policy–decision making with emphasis on sustainability and better management of development in harmony with the environment. The EPA through their regulations and laws have established processes to manage the environmental impact of projects like airport operations and expansion. The concept of Environmental Impact Assessment (EIA) was first introduced in the United States some 50 or more years ago and gradually caught up with the rest of the world including Ghana. EIA is a systematic process that investigates the environmental consequences of development actions in advance. The emphasis here compared to other mechanisms for environmental protection, is on prevention. Munn (1979) defines EIA as the need to identify and predict the impact on the environment and man's health and well being of legislative proposals, policies, programmes, projects and operational procedures and to interpret and communicate information about the impact.Ghana's Environmental Protection Agency refers to EIA as a planning and decision making tool, applied in Ghana to proposed activity, projects, structure, investment, plan, programme, the development of which may have a significant impact on the environment.

Ghana like many other nations endorsed the concept of EIA in 1989 but lacked legal backing. In an effort to ensure that the country follows a sustainable path, the environmental assessment regulation LI 1652 was promulgated on 24^{th} June 1999. The environmental assessment regulation requires that all development projects, prior to the commencement has been registered by the Agency and an environmental permit issued by the Agency in respect of the project. Thus, this can help ensure that environmental implications of new developments are fully explored before planning decisions are made.

It does this in a systematic and transparent manner and should lead to less environmentally damaging developments, and unacceptable proposals going back to the drawing board. Airports are part of schedule two (2) projects and as such should go through the EIA process, but the Kotoka International Airport (KIA) was in existence before the introduction of EIA processes. GACL has currently engaged PW Ghana Limited to further rehabilitate the KIA as part of its Phase 3 Development Project. In accordance with the EPA Laws, GACL through its consultant provided an EIA and an EMP to the EPA before commencing the project in 2010. Whether the EMPs captured in all past and present EIA reports to the EPA on KIA expansion development projects have been dealt with would be an area to consider in the future.

CHAPTER THREE

3.0 MATERIALS AND METHODS

3.1 STUDY AREA

The study was conducted at the Kotoka International Airport (KIA), Accrawhich is owned and operated by Ghana Airports Company Limited (GACL). KIA covers a total area of about 740 hectares and shares boundaries with the Air force Base, and industrial and residential areas (Figure 1). The existing site comprises of large areas of surfaced and sealed hard-standings apron surface and aircraft stand (Plates 1 and 2). The surface type of the apron is asphalt and the surface of each aircraft stand is concrete, with ground profile of graveled surface. It is rounded by streams (Figure 1). The site being the main InternationalAirport in Ghana is characterized by aircrafts landing and taking off, support equipment movement, heavily trafficked roads bordering three sides of the site, pollutants from aircrafts and vehicular emissions.

Plate 1: Apron/ parking view of Kotoka International Airport

Plate 2: Aerial view of the Kotoka International Airport Runway and Taxiway

Figure 1: Map of the study area – Kotoka International Airport

3.2 SAMPLING

A survey was conducted to assess the impact of aircraft operation and ground support equipment on noise, air quality and surface water quality at the airport. Data was collected from three selected sampling sites from January to December 2010 (Plate 3).

3.3 SAMPLING SITES

Samples were collected from the New Fire Station, adjacent the Ghana Air Force (GAF) Base (most aircrafts land and takeoff at this point), Spintex Road Area (is the airport's approaching point for landing aircraft and is not less than 95% for all landing aeroplanes), and Runway 21 Take - Off (is the end point where all departing aircraft do their initial speed).

3.4 PARTICULATE MATTER MONITORING

Using a Mini Vol Sampler, particulate matter was sampled at the three (3) locations for every 24 hours to measure the PM_{10} at each site. Samples were collected over a period of twelve (12) months. The samplers were oriented in the directions of the wind flow and placed at heights approximately 3m above ground level to avoid readings being influenced by dust from gusty winds.

A flow rate of 5L/min was set for each sampler. Pumped air was siphoned through a 47mm quartz filter paper, mounted in the sampling unit and measurements were taken every 24 hours.

3.4.1Analysis and Calculation

Sampler filters were pre-weighed before installation in the sampler. After sampling, sampler filters were removed from the sampler, put in a desiccator, and re-weighed. Re-weighing was done three times and the average reading taken.The difference in initial weight and post sample weight was used in calculating concentrations of particulate matter in µg/m^3.

3.5NOISE MONITORING

Castle sonus (GA116) range of pocket sound level meter was used to monitor noise emissions at all three sampling locations to establish the existing ambient noise levels.

Noise was monitored for 48 hours at each sampling location for twelve (12) months.

The noise monitors were capable of logging data at a minute interval over the sampling period. Monitors were located approximately 1.5m above the ground and not closer than 3m to any reflecting surface.

Plate 3: Noise monitoring sites

3.6SURFACE WATER MONITORING

Water samples were collected from three sampling sites; A, B and C from January to December, 2010, which were all located below the KIA runway 21 take - off area

(Plate 4). These are streams running outside the PW Ghana Limited maintenance and batching yards which are also close to the Spintex Road Area.

The samples were collectedearly in the morning before sunrise. Samples were taken three (3) times a week for twelve (12) months. Samples were collected during the dry and wet seasons.

Water samples were collected in sterilized 1.5L plastic bottles as described by Obiri-Danso and Jones (1999). Samples were transported to the PW Ghana Limited Laboratory in a cool box with ice packs and analyzed within six hours. Conductivity and pH were determined using a hand held Hanna Instrument on site.

Total and faecal coliforms were estimated using the Three Tube Most Probable Number method (MPN) according to Standard Methods (Fisher *et al.,* 2000; Obiri-Danso and Jones 1999; 2000; Anon 1992). Dilutions of 10^{-1} to 10^{-14} of the stream water samples were prepared using 9 ml sterilized distilled water. One milliliter aliquots from each of the dilutions were inoculated in triplicate into 5 ml of minerals modified glutamate medium (Oxoid CM607) with inverted Durham tubes. Three tubes from each dilution were incubated at $37^{o}C$ and an additional three at $44.5^{o}C$. Tubes showing acid and gas productions after incubation for 24 hrs at 37ºC were recorded as presumptive total coliforms and tubes showing acid and gas at $44.5^{o}C$ after 24 hrs were confirmed as faecal coliforms. Counts per 100ml were calculated from MPN tables and expressed as MPN/100ml (Collins *et al.,* 1989).

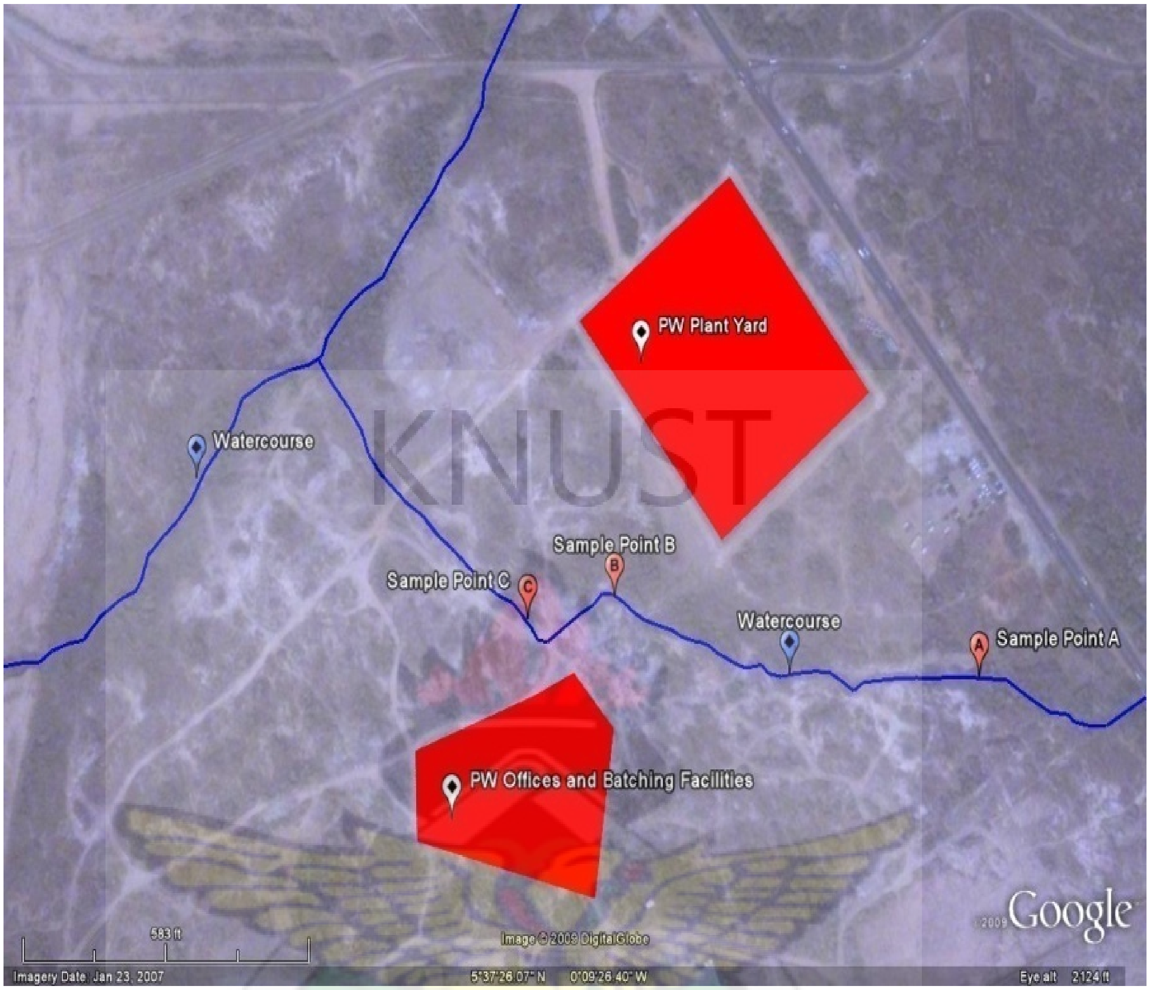

Plate 4: Surface water monitoring points

CHAPTER FOUR

4.0 RESULTS

4.1PARTICULATE MATTER (PM_{10}) CONCENTRATION

Particulate matter concentrations (PM_{10})at the three sampling sites are shown in figure 4.1.Particulate matter concentration at the Fire Station site were high and above the WHO limit of 50 µg/m³ for all the sampling months except during the months of June, July, September and October which incidentally coincided with the raining season in Ghana (Figure 4.1). The maximum PM_{10} concentration at the fire station was 155.8 µg/m³ with an average of 80.9 µg/m³ over the 12 month period. The WHO air quality guideline of 50 µg/m³ was exceeded 8 times indicating that the area was characterized with high ambient PM_{10} pollutants.

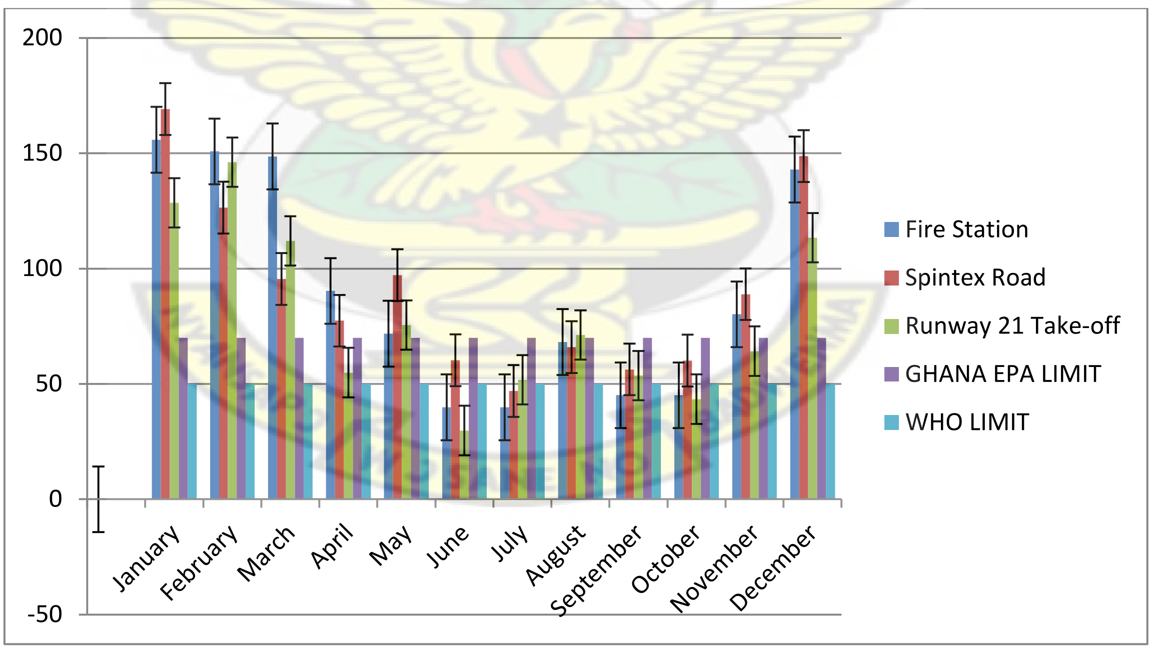

Figure 4.1: Monthly concentrations of particulate matter at the three (3) sampling sites for a year.

The Spintex Road sampling site recorded the highest average PM_{10} concentration of 91.1 µg/m³ (Figure 4.1).With the exception of July, PM_{10} concentrations were high throughout the year, with January, recording the maximum value of 169.1 µg/m³. The WHO air quality guideline of 50 µg/m³ was exceeded 11 times over the 12 month period, indicating that the Spintex Road was characterized by very high ambient PM_{10} pollutants.

The lowest PM_{10} concentration of 29.8µg/m³ occurred at the Runway 21 sampling site compared to all the three sampling sites (Figure 4.1). Except for the months of June and October, high PM_{10} levels occurred at the Runway 21 Take-off throughout the year. December, January, February and March recorded relatively high values with the maximum PM_{10} concentration of 146.1 µg/m³ in the month of February. The WHO air quality guideline of 50 µg/m³ was exceeded 10 times with an average of 78.7 µg/m³ over the 12 month period.

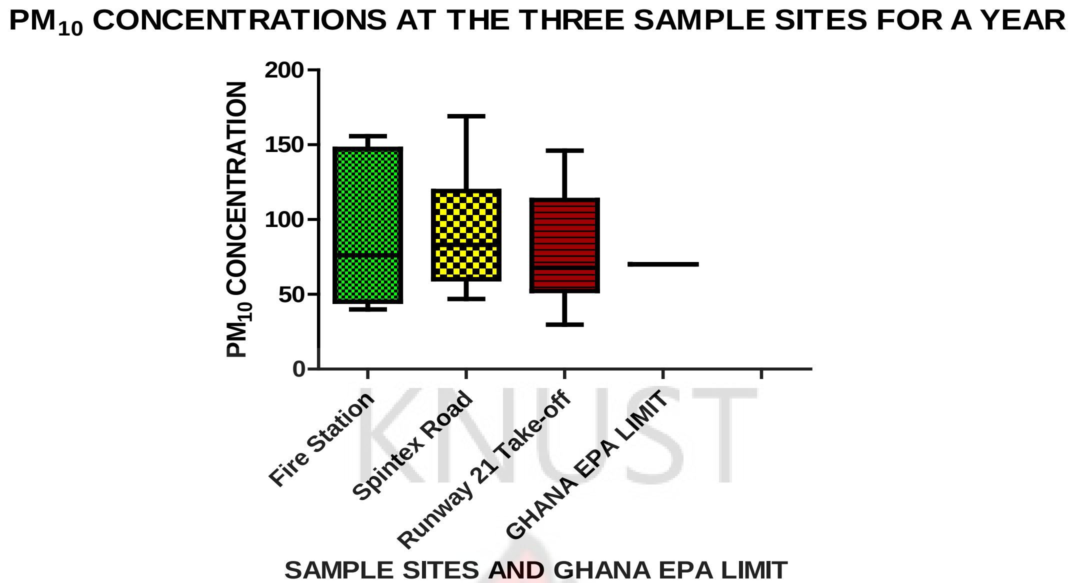

Figure 4.1a: Boxplots comparing monthly concentrations of particulate matter of the three (3) sampling sites using the Ghana EPA Limits as the reference.

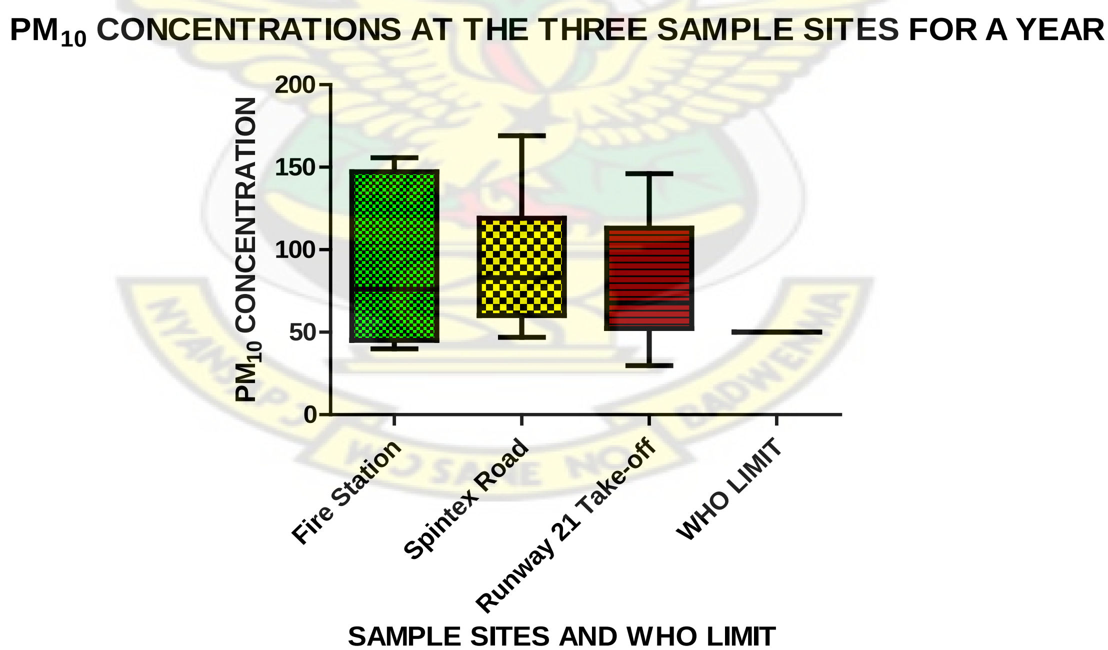

Figure 4.1b: Boxplots comparing monthly concentrations of particulate matter of the three (3) sampling sites using the WHO Limits as the reference.

The data for the two graphs above were analyzed using the GraphPad Prism 5.0 software using one way ANOVA at a confidence interval of 95%. Figure 4.1a shows that apart from the Fire Station where the 25th percentile of the PM_{10} concentrations fell below the WHO air quality threshold limit, all the other sampling sites had their 25th percentiles well above the WHO limit. All the inter-quartile ranges overlapped, with PM_{10} values recorded ranging from 29.8μg/m³ at the Runway 21 Take-off site to 169.1 μg/m^3 at the Spintex Road. The analysis on the data collected from the sample sites using the EPA as a control or reference point yields a P value of 0.4300 at 95% confidence interval whiles that using the WHO Limit yielded a P value of 0.0246. There was no significant change in the means for the data for Fig. 4.1a as with the comparison between the Ghana EPA and the various sample sites. For Fig. 4.1b there was a significant change in the means for the data as with the comparison between WHO Limit and the Fire Station and the WHO Limit and the Spintex Road. Statistically the PM_{10} concentrations at all the three sampling sites are skewed towards the lower ranges and the levels of impact to the environment do not vary much from one sampling location to the other.

4.2 AMBIENT NOISE LEVELS

4.2.1 Monthly Ambient Noise Levels at Fire Station

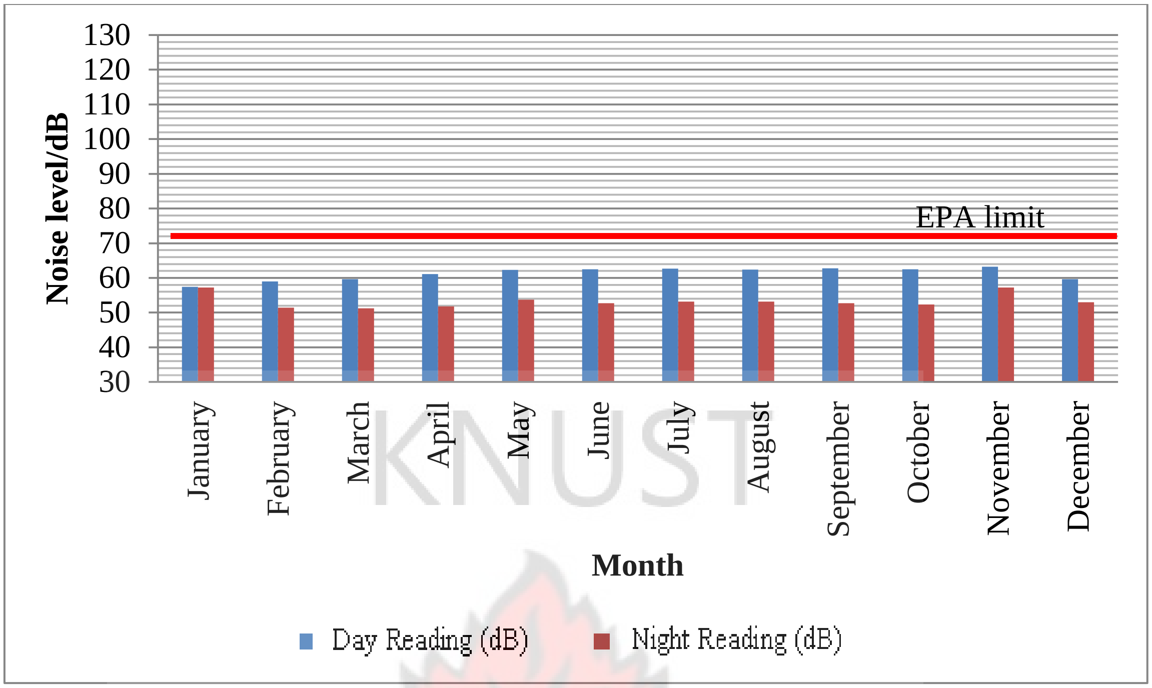

Figure 4.2: Monthly day and night time noise levels at the Fire Station.

Figure 4.2 shows that the EPA limit of 70 dB was not exceeded in any of the months at the fire station during the day and night time recordings. The maximum daytime noise level of 62.7 dB occurred in the month of July with an overall average of 52 dB. Generally there was a steady rise in noise levels between January and May, followed by a stable, almost-linear noise levels until November. In all, noise levels were clearly below 70 dB.

For the night time, maximum bi-modal noise levels of 57.2 dB occurred in the months of November and January with an overall average of 49.2 dB. In all, noise levels were clearly below 70 dB. The trend for the rest of the year remained stable and almost linear throughout the night time.

4.2.2 Monthly Ambient Noise Levels at Runway 21 take off

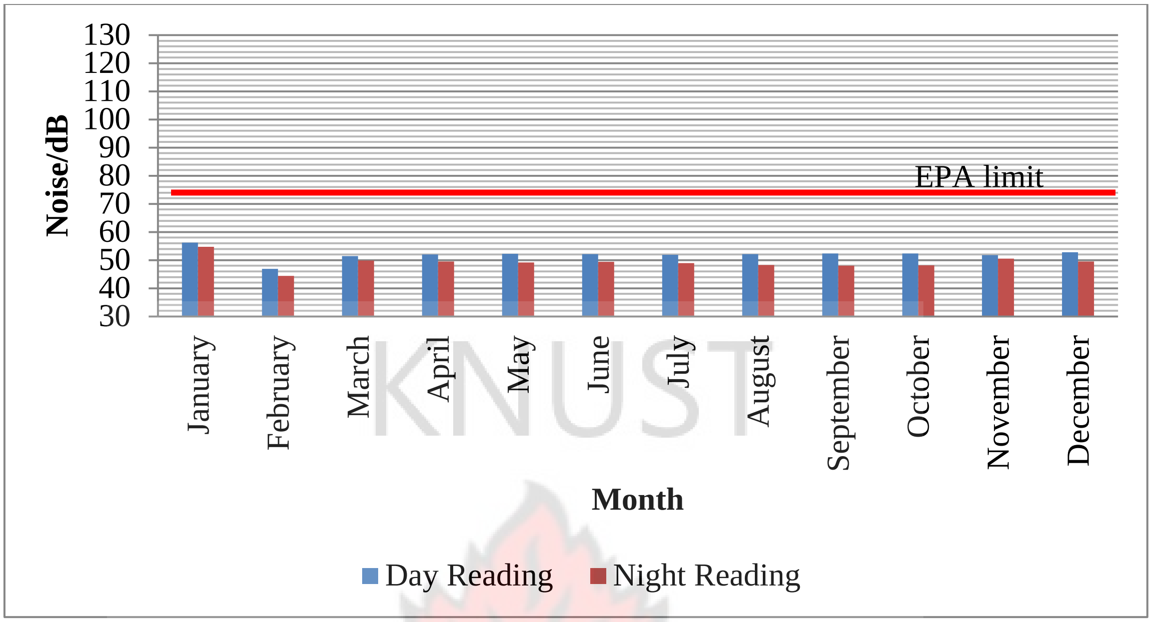

Figure 4.3: Monthly day and night time noise levels at Runway 21 Take-Off area

Figure 4.3 shows that noise levels were higher during the day as compared to the levels during the night. The month of January recorded the highest noise level in the daytime. On the average the month of February had the lowest average noise level whereas January recorded the highest. The overall daytime-nighttime average was 57.3 dB.

No significant differences wereobserved in ambient noise levels for day and night.

Figure 4.3 shows that the EPA limit of 70dB was not exceeded in any of the months at the Runway 21 Take – Off area during the night time recordings. Maximum noise level of 56.2 dB occurred in the month of January. The chart shows a linear trend, with slight variations from an almost steady measurement of 48 dB.

4.2.3Comparison of daytime andnighttime noise levels

Noise levels were higher during the day as compared to the levels during the night.On the average the month of February had the lowest noise level whereas January recorded the highest reading, with an overall daytime-nighttime average of 50.6 dB for the lowest and highest months.There werestatistically significant (P=0.0001)variations between daytime and nighttime noise levels.

4.3Electrical Conductivity, pH and Hydrocarbonin thesurface water samples

Mean surface waters pH at sampling sites A, B, and C were 7.57±0.85, 7.28±0.48 and 5.98±0.00respectively. There were no statisticallysignificant differences (P>0.005) in pH between the different sites. pH values were all within the Ghana EPA permissible range of 6.0-9.0 (Table 4.1).

Mean electrical conductivity ranged from a minimum of 489.40±239.29 µS/cm at sampling site A to a maximum of 557.40±322.72 µS/cm at site C with statistically significant differences (P<0.05) between the different sites (Table 4.1).

Hydrocarbon in the surface water samples at site A recorded the highest mean concentration of 537.40±314.77 mg/L whilst site C recorded the least value of 6.68±4.09 mg/L with statisticallysignificant differences (P<0.05) between the different sites.

Table 4.1: Some physicochemical parameters in surface water samples at the sites

pH(pH units)			
Parameter	**Mean**	**Std. Deviation**	**EPA limit**

Sample point A	7.566	±0.85	6.0 - 9.0
Sample point B	7.284	0.48	6.0 - 9.0
Sample point C	5.978	--	6.0 - 9.0
EC(μS/m)			
Sample point A	489.4	239.29	1500
Sample point B	537.4	314.77	1500
Sample point C	557.4	322.72	1500
HC(mg/l)			
Sample point A	537.4	314.77	N/A
Sample point B	6.68	4.09	N/A
Sample point C	8.4	2.39	N/A

KEY

Sample A: Water course around the Spintex Road area.

Sample B: PW Ghana Limited plant yard facility

Sample C: PW Ghana Limited Offices and batching facility**N/A:** Not Applicable

4.4 Heavy Metals concentrations in the water samples from the study area

Mean iron concentration in the samples ranged from 0.72±0.01 mg/l at site B to 0.73±0.01 mg/l at site A. Iron concentrations at all the sites were below the tolerable limit of 10 mg/l given by Ghana EPA (Figure 4.4).

Mean manganese values from all the three (3) sampled sites were higher than the Ghana EPA recommended standard of 0.1 mg/l, with values ranging from 0.12 mg/l to 0.72 mg/l respectively (Figure 4.4).

The results from figure 4.4 recorded the least mean values forcopper, zinc, nickel and chromiumconcentrations at all three (3) sampling areas respectively, which fell below the Ghana EPA standards.

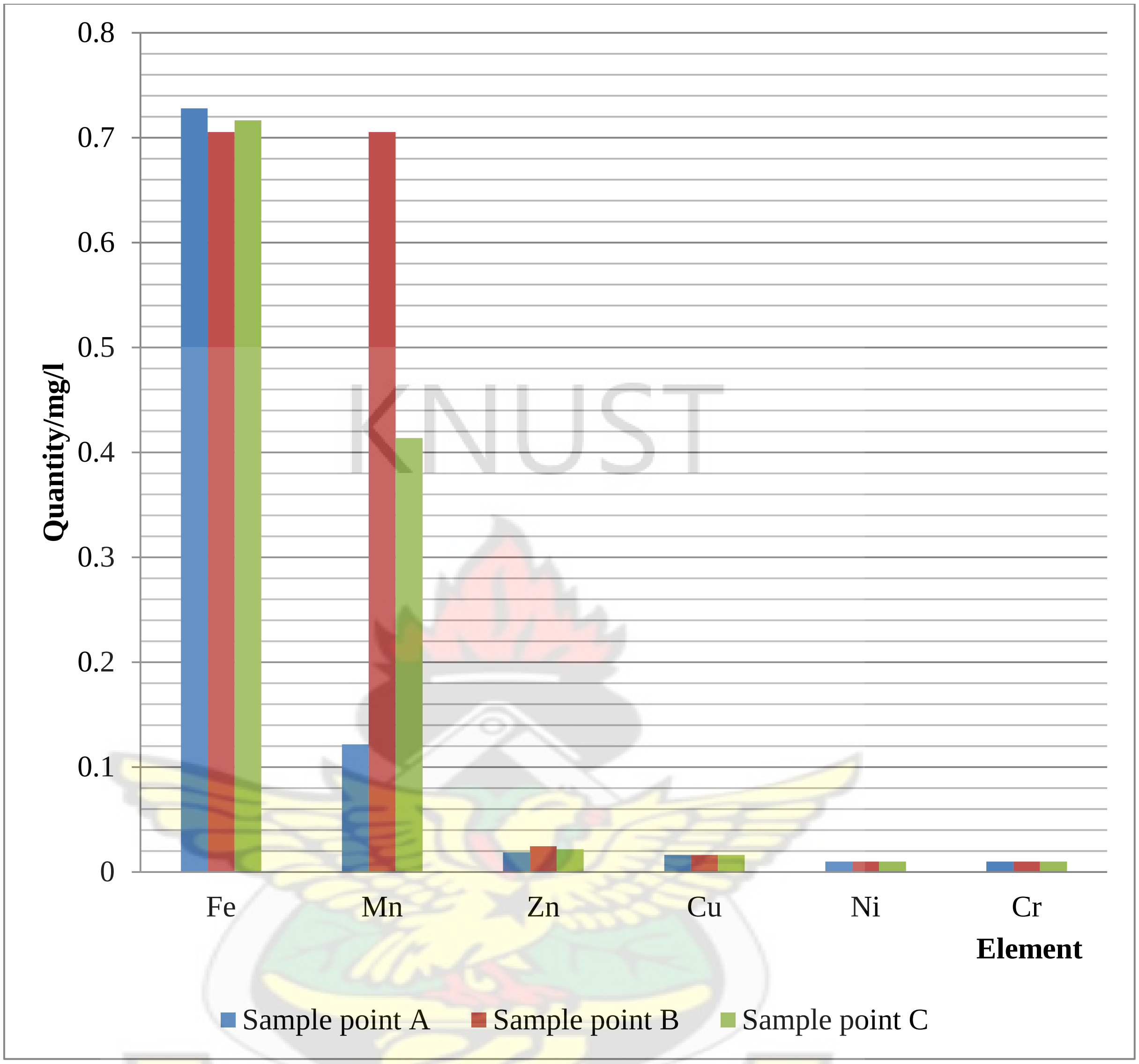

Figure 4.4: Heavy metals concentrations in surface waters around the airport

Table 4.2: Microbial analysis in the surface water from the study area

Parameter (Coliform counts) Total plate counts (E. coli)	Spintex Road	Runway 21Take - Off	PW Facilities
Mean Coliform forming Unit/100ml	4925.60	5107.80	5471.40
Standard deviation	4236.91	4745.31	4976.91
EPA limit	400.00	400.00	400.00

Coliform counts in surface waters sampled from all the three (3) sampling sites; Spintex road, Runway 21 take-off and PW Ghana Facilities are presented in Table 4.2 above. The mean microbial counts in the water samples were 4925.6 CFU/100ml, 5107.8 CFU/ml and 5471.4 CFU/ml at Spintex, Runway 21 take off and PW Facilities respectively.These results showed that surface waters around the KIA are grossly polluted with coliform organisms.

CHAPTER FIVE

5.0 DISCUSSION

5.1 PARTICULATE MATTER (PM_{10})

This study indicates that the aviation industry and its related activities at the Kotaka International Airport, Accra, Ghana have contributed to high particulate matterconcentration(PM_{10}) in the surrounding environment. An assessment of particulate matter data obtained over the twelve month period revealed high levels of PM_{10} values in all the selected sampling sites, with all the sites recording dust values above the WHO and Ghana EPA air quality threshold limits of 50µg/m³and 70µg/m³,respectively. KIA's new Fire Station which is adjacent to the Ghana Air Force and Spintex Road had mean values of 89.9µg/m³and 91.1µg/m³respectively. Aircraft brakes and tyre emissions during landing at the new Fire Station area of the runway could be the main reasons for the high results obtained.In addition to this, the high values are also due to wind blowing toward the sampled stations at the time of sampling events. Theophanides and Anastassopoulou (2009) and Kurniawan*et al.*(2011),showed the effect of aircraft emissionsand the rapid increase of aviation activities on the environment of Athens International Airport.Even though their work did not conclude on the effect of emissions on PM concentration, they study reports recorded the effect of airport pollution on neighbouring cities.

In January and December (dry season) particulate matter concentrations were highest compared to the months of June and July (wet season). However, at runway 21 take-off, particulate matter concentrations were generally lower than the Ghana EPA recommended value of 70µg/m³. This could be attributed to reduced performance of aircrafts in taxiing to position for take-off, as well as the decrease in usage of GSE and human activities in the proximity of the Runway 21 take-off. These findings agree with Ghose and Majee (2000) and Chaulya (2005) in Kenya. They also showed that particulate matter concentrations reached their maximum levels during the month with minimum rains.

In contrast to these findings, Lee *et al.* (2010) used two aerosol spectrometers simultaneously to sample and record particulate matter levels in a regional commercial airport in the United States and reported PM_{10} content in air samples around airports as high as 952 mg/m^3. Such high records could be attributed to the sites from which the samples were taken which were mainly around smoking rooms in the airport, in addition to the daily airport activities.Relatively low PM_{10} concentrations have also been reported by Sivertsen (2003) which were attributed to the size of the airports as well as aviation activities that were carried out daily (Theophanides and Anastassopoulou, 2009).

5.2 AMBIENT NOISE

Data from this study suggests that generally noise levels at the KIA are low compared to the National Environmental Standards Regulation (EPA, 2000) on noise. There was a steady rise in noise levels between January and May and remains steady until November.This agrees with Signe *et al.*,(2009)atTallinn and Tartuairports**,** both in Estonia. Such airports can be placed under zone C2 groups, with permissible noise level of 70dB (B) in the day (0600 GMT – 2200 GMT) and 65dB (B) in the night. The low night noise levels could be attributed to the reduction in other noise generating sources, like the airside construction. It is also an indication of quieter, newer aircraft which have been introduced by airlines operating in the study area during such hours (ICAO, 1971).

On the contrary higher levels of noise have been reported at Indianapolis and Heathrow international airports (Noiseand Vibration Bulletin, 2009). These were attributed to the high growth in air traffic, urbanization and uncoordinated planning around airports (van der Merwe and von Holdt, 2005).

5.3 PHYSICO-CHEMICAL ANALYSIS OF SURFACE WATER

Data obtained from January to December, 2010 from thestudy shows that day to day operations at KIA do not have significant effect on surface waters around the airport. Both conductivity and hydrocarbon content in the surface waters were lower than limits set by Ghana EPA(EPA, 2000). pH values recorded at the Spintex Road, PW plant yard (runway 21 take – off) and PW batching facility were generally within EPA permissible levels of between 6 to 9, except that water sample from the batching facilityrecorded a mean pH value that was slightly lower than the recommended value of between 6 to 9. There were also recorded trace amounts of iron, manganese, zinc, chromium, nickel and cadmium.

The fairly acceptableparameters measured for the surface waters around the airport could be due to highly trained environmental airport waste management staff; proper waste management practices; absence of leaking airport vehicles and proper maintenance of ground support equipment; use of appropriate chemicals; and legal dumping of substances in the airport's waste-water/rainwater sewage system (Raftopoulou*et al.*, 2004). Direct or indirect discharges of substances into the aquatic environment mostly come from runoffs from the airport pavements which enter nearby water bodies to alter the properties of the natural ecosystems and water chemistry. Surface water may also become contaminated when leaks or spills of fluids seep through the soil into the ground water (Raftopoulou*et al.,* 2004).

5.4 MICROBIOLOGICAL ANALYSIS OF SURFACE WATER

The study indicates that coliform counts were higher in all the three sampling sites; Spintex road, Runway 21 take-off and PW facilities area (Table 4.2), with all sites recording values higher above the Ghana EPA recommended standards for bathing water. The high coliform counts in the streams could be due to unrestricted dumping of refuse, which normally contains human excreta. Within the Kotoka international Airport (KIA), there is only one stream which flows throughout the year, though, predictably the water level and flow rate increases during the wet season. The stream collects storm water runoff from part of East Legon, a suburb on the north west of the airport. This stream is often polluted upstream by people who use this area as a place of convenience. Hence, water samples from sites A, B and Ccontinue to fall outside the EPA limits. This stream also flows to join a larger stream within 0.5km downstream from the Spintex area, where the PW office is located. Hydrocarbons and iron content in the stream were also high making it unsuitable for drinking purposes.

CHAPTER SIX

6.0 CONCLUSION AND RECOMMENDATIONS

6.1 CONCLUSION

The research has shown that particulate matter (PM_{10}) in the Kotoka International Airport area is comparatively higher than corresponding EPA standards required for ambient air quality, which raises serious concern about the health and safety of airport staff. It was observed that the high dust concentrations is due to aircraft landing and taking – offs as well as the phase three (3) airport expansion works at these areas.

The research has also established thatnoise at the monitoring stations generally were within theGhan EPA permissible limits.

The assessment of surface waters in the study area indicates that pH levels fell within EPA acceptable limits, conductivity levels were also lower than the acceptable limits of EPA (EPA, 2000). Bacterial indicator numbers were high in the surrounding surface waters. Fe, Mn, Zn, Cu, Ni and Cr contents in the streams were low.

6.2 RECOMMENDATION

According to the major findings from this study, air quality, noise and water quality monitoring stations should be created to measure and monitor environmental impacts arising from aircraft operations, construction and expansion of airports. Emission levels collected as a result of this study could be used to create a database on a whole range of knowledge that, among other things will lay the foundation for implementing environmental management system for the international airport and all other airports in the country in accordance with national and international environmental best practices.

Again, based on the outcome of this work and future research, there will be the need to prepare environmental abatement guidelines or plan for the aviation industry in Ghana, taking into consideration the impact of the industry to environment as regards the location of airports' within established communities like KIA.

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APPENDICES

Appendix 1: Descriptive Statistics for Particulate Matter (PM_{10})

Place	**N**	**Minimum/ mg/m^3/month**	**Maximum/ mg/m^3/month**	**Mean/mg**	**Std. Deviation**
FIRE STATION	12	39.90	155.80	89.8833	46.91689
SPINTEX ROAD	12	46.90	169.10	91.0750	38.86200
RUNWAY 21	12	29.80	146.10	78.7000	37.13597

Appendix 2a: ANOVA for Particulate Matter (PM_{10}) Concentrations at Three Sample Sites for a Year Using EPA Limits for Ghana as a Reference.

Table Analyzed	Data 2				
One-way analysis of variance					
P value	0.4300				
P value summary	ns				
Are means signif. different? (P < 0.05)	No				
Number of groups	4				
F	0.9389				
R squared	0.06016				
Bartlett's test for equal variances					
Bartlett's statistic (corrected)					
P value					
P value summary	ns				
Do the variances differ signif. (P < 0.05)	No				
ANOVA Table	SS	df	MS		
Treatment (between columns)	3584	3	1195		
Residual (within columns)	56000	44	1273		
Total	59580	47			
Dunnett's Multiple Comparison Test	Mean Diff.	q	Significant? P < 0.05?	Summary	95% CI of diff
GHANA EPA LIMIT vs Fire Station	-19.88	1.365	No	ns	-55.33 to 15.56
GHANA EPA LIMIT vsSpintex Road	-21.08	1.447	No	ns	-56.52 to 14.37
GHANA EPA LIMIT vs Runway 21 Take-off	-8.700	0.5974	No	ns	-44.15 to 26.75

Appendix 2b: ANOVA for Particulate Matter (PM_{10}) Concentrations at Three Sample Sites for a Year Using EPA Limits for WHO as a Reference.

Table Analyzed	Data 3				
One-way analysis of variance					
P value	0.0246				
P value summary	*				
Are means signif. different? (P < 0.05)	Yes				
Number of groups	4				
F	3.443				
R squared	0.1901				
Bartlett's test for equal variances					
Bartlett's statistic (corrected)					
P value					
P value summary	ns				
Do the variances differ signif. (P < 0.05)	No				
ANOVA Table	SS	df	MS		
Treatment (between columns)	13140	3	4381		
Residual (within columns)	56000	44	1273		
Total	69140	47			
Dunnett's Multiple Comparison Test	Mean Diff.	q	Significant? P < 0.05?	Summary	95% CI of diff
WHO LIMIT vs Fire Station	-39.88	2.739	Yes	*	-75.33 to -4.436
WHO LIMIT vsSpintex Road	-41.08	2.820	Yes	*	-76.52 to -5.628
WHO LIMIT vs Runway 21 Take-off	-28.70	1.971	No	ns	-64.15 to 6.747

Appendix 3: Descriptive Statistics for fire station noise levels

Period	N	Minimum	Maximum	Mean	Std. Deviation
Daytime	12	57.40	63.20	61.2583	1.88798
Night time	12	51.20	57.20	53.3000	1.96977

Appendix 4: Descriptive Statistics for Runway 21 Take-Off noise levels

Period	N	Minimum	Maximum	Mean	Std. Deviation
Daytime	12	46.90	56.20	52.0000	2.02125
Night time	12	44.40	54.80	49.2000	2.33977

Appendix 5: Comparison of descriptive statistics for average noise levels

Sampling site	**N**	**Minimum**	**Maximum**	**Mean**	**Std. Deviation**
Fire station	12	55.20	60.20	57.2667	1.33439
Runway 21 Take Off Area	12	45.60	55.50	50.5750	2.13504

Appendix 6: Mean and standard deviation of the heavy metal concentrations in the surface water samples from the study area.

Site Name	Fe (mg/L)	Mn(mg/L)	Zn(mg/L)	Cu(mg/L)	Ni(mg/L)	Cr(mg/L)
Sample point A	0.728	0.1218	0.0188	0.0162	0.01	0.01
Sample point B	0.7054	0.7054	0.0244	0.0162	0.01	0.01
Sample point C	0.7167	0.4136	0.0216	0.0162	0.01	0.01
Mean	**0.7167**	**0.4136**	**0.0216**	**0.0162**	**0.01**	**0.01**
Std. deviation	**0.0113**	**0.2918**	**0.0028**	**0**	**0**	**0**
EPA limit	**10.0**	**0.1**	**5.0**	**2.5**	**0.5**	**0.1**
Baseline						
Sample point A	0.83	0.02	0.01	<0.02	<0.01	<0.01
Sample point B	0.6	0.01	0.06	<0.02	<0.01	<0.01
Sample point C	0.77	0.04	0.01	<0.02	<0.01	<0.01