KWAME NKRUMAH UNIVERSITY OF SCIENCE AND TECHNOLOGY,

KUMASI

COLLEGE OF SCIENCE

DEPARTMENT OF THEORETICAL AND APPLIED BIOLOGY

OCCURRENCE OF PROTOZOANS AND OTHER PATHOGENS IN SOME SELECTED SWIMMING POOLS IN THE KUMASI METROPOLIS

BY

SELINA BONDZIE

A THESIS SUBMITTED TO THE DEPARTMENT OF THEORETICAL AND APPLIED BIOLOGY, COLLEGE OF SCIENCE, KWAME NKRUMAH UNIVERSITY OF SCIENCE AND TECHNOLOGY IN PARTIAL FULFILMENT OF THE REQUIREMENTS FOR THE AWARD OF MASTER OF PHILOSOPHY DEGREE IN BIOLOGICAL SCIENCES.

JUNE, 2015

DECLARATION

I, the undersigned, hereby declare that this thesis is my own work undertaken under supervision in pursuit of the MPhil. Biological Sciences degree, and 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.

Selina Bondzie (PG 6300311) …… ……..
(Student Name and ID) Signature Date

Certified by:

Dr. J. A. LARBI …… ……..
(Supervisor) Signature Date

Certified by:

Dr. I. K. TETTEH …… ……..
(Head of Department) Signature Date

ACKNOWLEDGEMENT

My profound gratitude goes to the almighty God who has seen me through to this time. Combining official duties as a technologist and a postgraduate student has been a great challenge and a herculean task I have ever had to face and overcome. But the avid support, guidance, motivation, patience and tolerance of my supervisor Dr. John A. Larbi saw me through it all.

My husband, Samuel Joe Acquah has been of tremendous help in the pursuit of this vision. His wisdom, patience and direction helped immensely and needs my highest commendation and appreciation.

I am also grateful to Patricia Abbam, National Service Person at the Department of Crop and Soil Sciences and Emmanuel Oppong for their immense assistance in the completion of this project which deserve special commendation.

DEDICATION

I dedicate this work to all career and nursing mothers who want to pursure further studies to upgrade themselves.

TABLE OF CONTENTS

CONTENTS PAGE

DECLARATION ii

DEDICATION iv

TABLE OF CONTENTS v

LIST OF TABLES x

LIST OF FIGURES xi

LIST OF APPENDICES xii

LIST OF ACRONYMS xiii

CHAPTER ONE 1

1.0 INTRODUCTION 1

1.1 IMPORTANCE OF WATER 1

1.2 BENEFITS OF SWIMMING 1

1.3 PROBLEMS ASSOCIATED WITH SWIMMING POOLS 3

1.5 OBJECTIVE OF THE STUDY 5

1.6 SPECIFIC OBJECTIVES 5

CHAPTER TWO 6
LITERATURE REVIEW 6

2.1 SWIMMING POOL 6

2.2 DESIGN AND CONSTRUCTION OF SWIMMING POOLS 6

2.3 TYPES OF POOLS 7

2.4 TYPES OF POOL USERS 9

2.5 HAZARDS AND RISKS ASSOCIATED WITH SWIMMING POOLS 9

2.5.1 TYPES OF HAZARDS ENCOUNTERED IN SWIMMING POOLS 10

2.5.1.1 PHYSICAL HAZARD 10
2.5.1.2 MICROBIAL HAZARD 10

2.5.1.3 TOTAL COLIFORMS 13

2.6 *ESCHERICHIA COLI (E. coli)* 14

2.7 Protozoan Pathogen 15

2.7.1 *Giardia Species* 16

2.7.2 MORPHOLOGY OF *Giardia species* 16

2.7.3 Life Cycle Of *Giardia lamblia* 17

2.7.4 *Cryptosporidium* Species 19

2.7.5 Life Cycle of *Cryptosporidium* 20

2.8 WATER QUALITY OF SWIMMING POOL 22

2.8.1 WATER QUALITY MONITORING..... 22

2.9 SOME PARAMETERS USED TO DETERMINE WATER QUALITY IN POOLS 23

2.9.1 pH 23

2.9.2 TEMPERATURE 24

2.9.3 TURBIDITY 25

2.9.4 TOTAL DISSOLVED SOLIDS 26

2.9.5 CONDUCTIVITY 27

2.9.6 COLOUR 27

2.9.7 MICROBIAL QUALITY 28

2.9.7.1 PATHOGENS 28

2.10 DISINFECTANTS 28

2.10.1 CHLORINE 29

CHAPTER THREE 35

MATERIALS AND METHODS 35

3.1 STUDY AREA 35

3.3 COLLECTION OF POOL WATER SAMPLES 36

3.4 PHYSICO-CHEMICAL ANALYSIS OF POOL WATER 37

3.4.1 pH 38

3.4.2 DETERMINATION OF ELECTRICAL CONDUCTIVITY, TEMPERATURE, SALINITY, DISSOLVED OXYGEN (DO) AND TOTAL DISSOLVED SOLIDS (TDS) 38

3.4.3 TURBIDITY 39

3.4.4 COLOUR (PLATINUM COBALT METHOD) 39

3.4.5 FREE CHLORINE 40

3.5 MICROBIOLOGICAL ANALYSIS 40

3.5.1 TOTAL AND FAECAL COLIFORMS 40

3.5.2 *E. coli (THERMOTOLERANT COLIFORMS)* 41

3.6 PARASITOLOGICAL TEST TO IDENTIFY *Cryptosporidium Parvum and Giardia lamblia* 41

3.6.1 WET MOUNT TECHNIQUE 42

3.6.2 MODIFIED ZIEHL-NEELSEN (Zn) METHOD FOR *Cryptosporidium parvum*.. 42

3.7 QUALITY ASSURANCE 43

3.8 QUESTIONNAIRE ADMINISTRATION 43

3.9 STATISTICAL ANALYSIS 44

CHAPTER FOUR 45

RESULTS 45

4.1 Summary of the Results 45

4.1 Physicochemical Parameters of water samples from nine swimming pools. 46

4.1.1 pH 46

4.1.2 Temperature. 47

4.1.3 Dissolved Oxygen 47

4.1.4 Conductivity 48

4.1.5 Total dissolved solids (TDS) 49

4.1.6 Salinity 50

4.1.7 Free Chlorine 51

4.1.8 Colour 52

4.1.9 Turbidity 53

4.2 Microbiological parameters of water samples from nine swimming pools 54

4.2.1 Total coliforms 54

4.2.2 Faecal coliforms 55

4.2.3 *Escherichia coli (E.coli*) 56

4.2.4 *Cryptosporidium* 57

4.2.5 *Giardia* 58

4.3 Questionnaires Responses 60

CHAPTER FIVE 62
DISCUSSION 62

5.1 Physico-chemical parameters 62

5.1.1 pH 62

5.1.2 Temperature 63

5.1.3 Dissolved oxygen 64

5.1.4 Conductivity 64

5.1.5 Total Dissolved Solids (TDS) 65

5.1.6 Salinity 66

5.1.7 Free Chlorine 66

5.1.8 Colour 67

5.1.9 Turbidity 68

5.2. Total coliforms (TC), faecal coliforms (FC) and *Escherichia coli (E coli)* 68

5.3 *Cryptosporidium and Giardia* 70

5.4 Questionnaires Responses 71

CHAPTER SIX 72

CONCLUSIONS AND RECOMMENDATIONS 72

6.1 Conclusion 72

6.2 Recommendations 73

REFERENCES 75
LIST OF TABLES

TABLE PAGE

Table 1: Summary of Questionnaire Responses 61
LIST OF FIGURES

FIGURE PAGE

Fig. 2.1: Diagrammatic representation of total and faecal coliforms and *E. coli*. 15

Fig 2.2: Diagrammatic Morphology of *Giardia lamblia*. 17

Fig. 2.3: Diagrammatic representation of life cycle of *Giardia*. 18

Fig. 2.4: Diagrammatic representation of Life Cycle of *Cryptosporidium.* 21

Fig. 3.1: A map of the sample locations at the study site 37

Fig. 4.1: Mean pH values for before and after swimming samples from the nine pools. . 46

Fig 4.2: Temperatures levels for before and after swimming samples from all the pools under study. 47

Fig 4.3: Dissolved oxygen levels for before and after swimming samples from the nine pools. 48

Fig. 4.4: Conductivity levels recorded in before and after swimming from all the sampling sites. 49

Fig. 4.5: The levels of total dissolved solids recorded in before and after swimming from all the nine pools. 50

Fig 4.6: The salinity levels in before and after swimming water samples from the various pools under study. 51

Fig. 4.7: The free chlorine levels recorded in the before and after swimming samples collected from the various swimming pools under study. 52

Fig. 4.8: The mean values of colour recorded in the before and after swimming samples collected from the various pools under study. 53

Fig. 4.9: The turbidity levels determined in the before and after swimming samples collected from the nine swimming pools. 54

Fig.4.10: The total coliforms isolated in before and after swimming samples collected from the various nine pools under study. 55

Fig. 4.11: The faecal coliforms counts isolated in before and after swimming samples collected from the nine pools. 56

Fig 4.13: The *Cryptosporidium* oocysts counts in before and after swimming water samples collected from the nine swimming pools. 58

Fig 4.14: The *Giardia* cysts counts in before and after swimming water samples collected from the nine sampling sites. 59

LIST OF APPENDICES

APPENDIX **PAGE**

Appendices 86

Appendix a: Results of T-test for the treatments over the study period. 86

Appendix B: Results of T-test for before and after swimming samples for Temperature in the nine pools under study. 87

Appendix C: Results of T-test for before and after swimming samples for Dissolved Oxygen in the nine pools under study. 88

Appendix D: Results of T-test for before and after swimming samples for Conductivity in the nine pools under study. 89

Appendix E: Results of T-test for before and after swimming samples for Total Dissolved Solids in the nine pools under study. 90

Appendix F: Results of T-test for before and after swimming samples for Salinity in the nine pools under study. 91

Appendix G: Results of T-test for before and after swimming samples for Free Chlorine in the various pools under study. 92

Appendix H: Results of T-test for before and after swimming samples for Colour in the nine pools under study. 93

Appendix I: Results of T-test for before and after swimming samples for Turbidity in the nine under study. 94

Appendix J: Results of T-test for before and after swimming samples for Total coliforms in the nine pools under study. 95

Appendix K: Results of T-test for before and after swimming samples for faecal Coliform in the nine pools under study. 96

Appendix L: Results of T-test for before and after swimming samples for *E. coli* in the nine pools under study. 97

Appendix M: Results of T-test for before and after swimming samples for *Cryptosporidium oocysts* in the nine pools under study. 98

Appendix N: Results of T-test for before and after swimming samples for *Gardia lamblia cysts* in the nine pools under study. 99

LIST OF ACRONYMS

APHA - American Public Health Association

CDC - Center for Diseases Control and prevention

CPSC - Consumer Product Safety Commission

DBP - Disinfection by products

DO - Dissolved Oxygen

DPD - diethyl-p-phenylene diamine

EPA - Environmental Protection Agency

FC - Feacal coliforms

HOCl - hypochlorous acid

HPF - Higher power field

KMA - Kumasi Metropolitan Area

MPN - Most Probable Number

NaOCl - sodium hypochlorite solution

NH - Noda Hotel

NTU - Nephelometric Turbidity Units

ORP - oxidation- reduction potential

Pt/Co - Platinum Cobalt

RL H - Royal Lamerta Hotel

SD - Standard Deviation

SH - Silicon Hotel

STH - Sports Hotel

TC - Total Coliforms

TDS - Total Dissolved Solids

TLH - Treasure Land Hotel

TVH - True Vine Hotel

UNDP - United Nation Development Programme

WHO - World Health Organization

YH - Yegoala HOTEL

µS/cm - Microsiemens per centimeter

ABSTRACT

The beneficial role of the use of recreational water to health and well-being has long been recognized, yet, there may also be adverse health effects associated with recreational use, if the water is polluted or unsafe. This study was aimed at determining the physico-chemical properties of water in the pools and the presence of protozoans, total coliforms and other pathogenic microorganisms in the water; in some selected swimming pools in the Kumasi Metropolis.

- Water samples before and after swimming were collected from three different sections in each specific swimming pool during the study period (December 2012 to May 2013) for physiochemical and microbial analysis using standards methods. The results of the physicochemical, microbial and parasitological quality of the various sampled swimming pools in Kumasi revealed varying levels of contamination. The pH of the pool waters varied between a range of 5.95-8.83 over the sampling period. Pool water temperatures varied over a narrow range of 26.90 to 29.49 °C. The mean DO levels, colour and turbidity for before and after swimming samples of the various pools pointed to a trend of increased concentrations after use. Salinity levels of all the pool waters were generally similar for both before and after swimming samples and varied over a narrow freshwater range for all the sampled pools. With regards to microbial and parasitological (protozoa) contamination, coliform counts were generally elevated in the pool waters after use relative to their respective levels before use. *Cryptosporidium* oocysts were detected in five (56 %) out of the nine swimming pools while *Giardia* cysts were detected in all the swimming pools *Giardia* cysts (100 %). Prior to the physicochemical and microbial monitoring, questionnaires were administered to the swimmers which revealed that there was a level of dissatisfaction among the swimmers, some others had body itch after swimming while some others complained of foul odour. The results in this study indicated that most of the swimming pools did not meet the WHO (2011) standard for drinking water and therefore constitute a serious hazard to public health. In recommendationHealth authorities should regularly monitor the pools for compliance with regulations and also swimmers must be encouraged to shower and disinfect their foot before swimming. Swimmers should be cautioned about swimming in pools if they are suffering from gastroenteritis or other diseases.

CHAPTER ONE

1.0 INTRODUCTION

1.1 IMPORTANCE OF WATER

Water, is undoubtedly, a vital need of man for food and recreation. Water is basic to life on this planet earth, and for man, no substitute has ever been found to serve man in diverse ways that are crucial for mankind's survival and societal advancement as a whole (Cabelli, 2003; Alico and Dragonjac, 2006). Water is very basic to life and also functions among others, in, transportation, recreation, cooling of irrigation systems, and food production processes (Mackereth *et al.*, 2003). Swimming pool waters derive their source from natural waters and their potability is greatly enhanced by the frequency with which the water is changed and the use of chlorine as disinfectants. Normally concentrations of chlorine is maintained at about 1 ppm since chlorine of higher concentrations is usually known to irritate the skin and eyes (Alice, 1977; Fair *et al.*, 2001; Cairns and Dickson, 2003). Cairns and Dickson (2003) indicates that water from swimming pools must be odourless, tasteless and clear with freezing and boiling points at $0^{o}C$ and $100^{o}C$, respectively.

1.2 BENEFITS OF SWIMMING

Swimming, a popular pastime activity, creates fun and is active and a healthy way to relax and beat the heat in Africa (Evans, 2007). Swimmers can benefit from cardiovascular workout, an exercise that provides cushion for the joints, protection from the harsh impact normally associated with most forms of exercise, movement that gets the heart pumping and muscles working against the resistance of the water (Evans,

2007).

Another benefit is that a cure for boredom is always close at hand. For real fun, a pool is the ultimate interactive, reality experience. It is something one can enjoy alone, with a special one, with the family or with friends. “A pool never gets "old" and doing something one enjoys adds years to one’s life, not to mention an amazing number of special memories” (Evans, 2007).

Regular swimming builds endurance, muscle strength and cardio-vascular fitness. It can serve as a cross-training element to the regular workouts. The pool can sometimes serve as a warm-up agent prior to a dry land workout session. Swimming with increasing effort to gradually increase the heart rate and stimulate muscle activity is easily accomplished in the water. After a dry land workout, swimming a few laps can help the cooling down process and blood movement through the muscles to help the recovery and relaxation as one glides through the water (Luebbers, 2012). There are other psychological benefits to swimming; gaining a feeling of well-being, refreshed after every swimming and ready to go on with the rest of the day’s activities. Many swimmers find an in-direct benefit from swimming. Swimmers develop life skills such as sportsmanship, time-management, selfdiscipline, goal-setting, and an increased sense of self-worth through participation in the sport. Swimmers seem to do better in school, in general terms, than non-swimmers (Luebbers, 2012).

Swimming does burn calories at a rate of about 3 calories a mile per pound of bodyweight (Luebbers, 2012). However, many swimmers do not swim that quickly, and many cannot swim for a long distance or duration, so swimming to lose weight is not always the best plan. Swimming exercises almost the entire body - heart, lungs, and muscles - with very little joint strain. It is great for general fitness, just not a great way to drop excess pounds (Luebbers, 2012). Swimming for pleasure has been practiced by many land animals and

humans, and records of the pleasure of immersion in water go back several thousand years ago (Sule and Oyeyiola, 2010).

A swimming pool is an artificially enclosed body or basin or concrete tanks or large paved holes containing water constructed, designed, modified, or improved intended for swimming, diving, recreation or instruction and water based recreation and includes condominiums, schools/institutions, motels and hotels (Kuzgunkaya and Yildirim, 2010). Most people choose swimming pools over rivers and streams for its supposedly hygienic nature (Kuzgunkaya and Yildirim, 2010). Swimming pools have become one of the main side attractions in the marketing of tourism in Ghana, thus, they can be found in hotels, guest houses, restaurants, club houses and tertiary institutions, among others.

1.3 PROBLEMS ASSOCIATED WITH SWIMMING POOLS

There are set of operational rules and principles guiding each swimming pool which ensures the potability of the swimming pool and good hygiene maintenance. Some of these operational rules and principles stipulate that before entering the pool, each bather showers with soap; and those having any skin disease are disallowed from using the facility. Cruickshank *et al.,* (1975) indicated that pathogenic microorganisms may infect swimming pools directly or indirectly through the entry into the pool by sewage, soil, contaminated air, dust, and rain water. Furthermore, swimming pool users with infections may pollute the pool water with micro-organisms, through secretions from the nose and throat, skin, mouth, urine, accidental faecal release or by contaminated objects and clothes, airborne contamination, incoming water from unsanitary source, and droppings from birds (Sule and Oyeyiola, 2010). Polluted pool water results in diarrhoea, ulcers of the skin, upper respiratory infections, gastro-enteritis, conjunctivitis, trachoma, cholera, dysentery, eczema

infections of the ear like otitis media and skin diseases (Cairncross *et al.,* 2000; UNDP, 2004). Protozoan pathogens such as *Cryptosporidium* species and *Giardia* species are widely distributed in the aquatic environment and have been implicated in several outbreaks of waterborne diseases resulting from swimming pools (Bushon and Francy, 2003). Some characteristics of Giardiasis infection are: loss of appetite, fatigue, cramps, diarrhoea, foul-smelling stools and vomiting, and cryptosporidiosis is characterized by abdominal cramps, fever, vomiting and diarrhoea (CDC, 2006).

Pseudomonas aeruginosa, Mycobacteria spp, and Staphylococcus aureus are some of the non-enteric pathogenic micro-organisms commonly found in pools. Poor sanitary conditions and improper disinfection of swimming pools can lead to a serious draw back in the maintenance of public health (Farthing, 2000).

1.4 JUSTIFICATION

Recreational use of water can deliver important benefits to health and well-being, yet, there may also be adverse health effects associated with recreational use, if the water is polluted or unsafe. For most swimming pools in Ghana, the pool's capacity is determined by the number of people present for an occasion. There is little data if any on the quality of water in swimming pools in Ghana.

An increasing number of waterborne outbreaks caused by *Cryptosporidium* and *Giardia* have been documented worldwide which depict a trend in which protozoa and viruses are replacing bacterial pathogens as agents of primary concern in waterborne diseases (Bushon and Francy, 2003). Oocysts and cysts of parasitic protozoans are relatively resistant to conventional water treatment (disinfection) and survive longer in the environment posing a public health risk. In view of the serious health risk posed by swimming pools, there is a

sense of urgency to identify the type of microorganisms in our pools with emphasis on protozoan so that appropriate measures could be taken to ensure that health risks related to parasites in pool water can be significantly reduced or minimized if not completely eliminated.

1.5 OBJECTIVE OF THE STUDY

MAIN OBJECTIVE

The study was conducted to determine the microbial quality and the presence of protozoan in swimming pools during before and after swimming in the Kumasi Metropolis.

1.6 SPECIFIC OBJECTIVES

The study had the following specific objectives:

i. To determine the physico-chemical properties (pH, temperature, conductivity, total dissolved solids (TDS), dissolved oxygen, salinity, turbidity, colour and chlorine) of water in the pools.

ii. To identify the presence of total and faecal coliforms and other pathogenic microorganisms in the water iii. To isolate and characterize the protozoans in the water iv. To ascertain the perception of the populace on the use of pools and possible sources of infection

CHAPTER TWO

LITERATURE REVIEW

2.1 SWIMMING POOL

A swimming pool is an artificially enclosed body or basin of water constructed, designed, modified, or improved intended for swimming, diving, recreation or instruction. (Kuzgunkaya and Yildirim, 2010, Great Lakes Report, 1996).

2.2 DESIGN AND CONSTRUCTION OF SWIMMING POOLS

Swimming pools are generally made of inert, stable, non-toxic, watertight and enduring materials (Great Lakes Report, 1996). All corners are formed by intersection of walls.

Swimming pools' bottoms and sides must of necessity be white or light-coloured, with smooth and easily cleanable surfaces. The furnished surface of the bottom must be generally, slip-resistant (Great Lakes Report, 1996). The swimming pool is constructed to ensure that water circulation and the safety of pool users is not compromised. Underwater or overhead projections or obstructions must be avoided as these endanger pool users safety and can disrupt swimming pool operations (Pond, 2005). The boundary line between the shallow and deep areas is normally marked by a line of contrasting colours on the floor and walls of the pool, and by safety ropes (Great Lakes Report, 1996). The largest pool size for all activities is 75ft by 30ft. Boating safety and recreational swimming meets this minimum operational requirement for instruction programs. The minimum size pool required for offering a mandatory and elective program would be 25ft by 50ft (Galbraith *et al.*,, 1990).

Patrons diving off the edges or in the shallow ends of swimming pool results mostly in head and neck injuries. Mostly diving tanks have different depths with more established and developed tanks having 8ft to 10ft depth. An "L" shaped pool which detaches the diving area, is the most desirable pool but very expensive (Great Lakes Report, 1996). For safety purposes at least, 6ft of platform should be created around the sides of the pool. Also about 12ft deck space is required for instructions. Ladders or staircases are created at the shallow side or installed on each side of the pool. Pool ladders are corrosion-resistant and equipped with slip-resistant treads. Ladders are so designed as to provide a handhold. The ladders, and the staircase are easily cleaned, slip-free and designed in such a way that they drain into the pool. The depth of the pool is written clearly above the water surface on the vertical pool wall on both sides. The markings are usually written in feet (WHO, 2006). Shower rooms, office space and locker must be incorporated and planned with a practical measure of space contingent upon populace served. There must be separate areas for first aid, chemical storage and control station since safety is very important. Fresh water from the surface of the earth or beneath the earth and marine are usually the sources of water supply of swimming pools (WHO, 2005).

2.3 TYPES OF POOLS

Different types of swimming pools have different uses. These swimming pools may be supervised by professional attendants or unsupervised and these include domestic or private pools, semi-public involving hotels, schools, health clubs, housing complexes, cruise ships, or public pools (e.g. municipal). Swimming pools may either be domesticated indoors or situated outdoors and may be heated or unheated. Structurally, the main, public or municipal pools are universally known as the conventional pools. Traditionally, these pools are rectangular, with no extra water features except provisions for diving, and are meant

for persons in all age groups and abilities. Swimming pools described as temporary or portable pools used domestically or mainly in household settings are also available (WHO, 2006). Additionally, some particular user- type or specialist pools are available, for instance, pools for teaching and learning, diving pools, paddling pools and special feature pools like flumes or water slides. Even though, these are all referred to as swimming pools, these are mostly meant for various recreational activities, including aqua-aerobics and scuba diving (WHO, 2005).

Some swimming pool facilities are known to contain mineralised water and/or thermal water which are therapeutic in nature and also, as a result of certain water characteristics these pools possess, may receive minimal water quality treatment. Pools in this category are referred to as natural spa. There are also physical therapy pools managed by professionals who undertake and perform treatments of various physical symptoms on people having cardiac, neurological and orthopaedic or other diseases. These pools are purposely for special medical or medicinal cases and are referred to as 'hydrotherapy pools'. Some of these therapy pools contain small fishes which feed mainly on the scaly skin lesions caused by psoriasis (Rabi *et al*., 2008). There are public hygiene facilities in many countries mainly used as drain and fill swimming pools and individuals and families utilise them to bathe. Different types of pools have potentially different management problems. These potential management challenges must be anticipated by pool managers and appropriate solutions found to deal with them. Pool management is primarily concerned with the identification of some usage parameters including pool usage: expected number of users, daily opening hours, peak periods of use, and types of users; as well as special need and requirements including temperature, lanes and equipment (Galbraith *et al*., 1990).

2.4 TYPES OF POOL USERS

The general public, children and or babies, hotel guests tourists, leisure swimmers, competitive swimmers, health club members, exercise class members, non-swimmers, clients of outdoor camping parks, and specialist sporting users, including scuba divers, canoeists and water polo participants are among the patrons of swimming pools (Galbraith *et al*., 1990).

Some user groups of pools or patrons are more prompt to hazards than others. For instance, teens who swim for long hours are more likely to accidentally ingest pool water than adults. Similarly, the aged and handicapped users with health challenges and also immuno-compromised people have potentially higher risk from microbial infections or chemical hazards (Galbraith *et al*., 1990).

2.5 HAZARDS AND RISKS ASSOCIATED WITH SWIMMING POOLS

Generally, hazard and risk are terminologies mostly used interchangeably. Hazard, used accurately, refers to a set of events leading to danger or harm including illness, loss of life or injury. On the other hand, the risk of any event is the tendency that it will take place due to the exposure to a well calculated level of hazard. Simply, the tendency for harm to occur is hazard, while the probability that harm will possibly take place is referred to as risk (WHO, 2006).

Certain hazards are inherently present regarding the type, design and use of pools, for instance, sudden changes in depth, with the resultant effect of spectators wading briskly and noticing immediately that they are out of the pool depth. Bathers with high microbial loads in relation to the pool volume in hot tubs is a typical example of such cases and in

situations of rapid agitation of water and high water temperatures, maintaining satisfactory pH, microbial quality and disinfectant concentrations present a difficult challenge to deal with (WHO, 2003).

2.5.1 TYPES OF HAZARDS ENCOUNTERED IN SWIMMING POOLS

Physical hazards including drowning, near-drowning or injury, microbial hazard; and water quality issues are the hazards most frequently related to and connected with the patronage of pools and other recreational pool environments (Brenner, 2005).

2.5.1.1 PHYSICAL HAZARD

Drowning, near-drowning and spinal injuries are major physical hazards encountered in the swimming pool environment and the associated adverse health effects are of great concern to public health authorities. Risk of physical injuries is increased by human behaviour especially alcohol consumption. Even though injuries, like bruises and other injuries from trip, slip and fall accidents are not so severe, but creates a stressful moment and decreases the beneficial effects to good health obtained through recreation. General education, posting of warning signs at vantage positions, the use of rough surfaces, prohibiting the use of materials such as glass close to the pool, prevention of jumping and running around the pool, first aid services, easy communication with health and rescue services, the presence of lifeguards, and the cleaning of pools and such facilities are some preventive and remedial measures required to curtail physical hazards in and around swimming pools (Brenner, 2005).

2.5.1.2 MICROBIAL HAZARD

Swimming pool water may be polluted by pathogenic micro-organisms from infected swimmers, through secretions from the skin, mouth (example saliva, mucus, vomit), urine, throat and nose, accidental faecal release or by contaminated objects and clothes, airborne contamination, incoming water from unsanitary source, and droppings from birds (Sule and Oyeyiola, 2010). Contaminated swimming pool can cause a variety of diseases such as hepatitis, gastro-intestinal disorder, diarrhoea, giardiasis, asthma, bladder cancer, skin, ear and upper respiratory infections particularly if the swimmer's head is submerged or water swallowed (Sule and Oyeyiola, 2010). The amount of water swallowed during swimming determines the level of infection. Researchers, however, are yet to reach a value of agreement regarding the volume of water ingested by swimmers. According to Evans *et. al* (2001) swimmers ingest as much as 100 ml per hour and Allen *et al.* (1982) indicated bathers ingest 160 ml per hour whilst Shuval (1975) reported 10 ml of pool water per bathing day. WHO (2003) had also reported 20 to 50 ml per 60 minutes. Research conducted by Dufour *et al.* (2006) using cyanuric acid as a marker revealed that children ingest about twice (37 ml) as much volume of pool water as ingested by adults (16 ml) during 45 minutes of swimming.

Swimming pool granuloma, an infection which occurs frequently in swimming pools due to abrasions on elbows and knees usually result in localized lesions (Collins *et al.*, 1984). Swimmers of all kinds and social status normally shed *Staphylococcus aureus* (Robinton and Mood, 1966). This certainly results in otitis externa, wound infections, skin rashes, impetigo and some infections of the eye and urinary tract (Calvert and Storey, 1988; Rivera and Adera, 1991). Defecation by swimmers in pools or contamination from water source or direct animal contamination, for example, from birds and rodents may result in faecal contamination of swimming pools. Some of these diseases could result in death

(CDC, 2001)

Microbiological evaluation is used to check the sanitary and quality control status of recreational swimming pools and this is the most significant method widely used by pool operators. Indicator bacteria test is used to ensure effective quality control. The presence of enteric pathogenic bacteria and other microorganisms in swimming pool waters is a strong indication of faecal contamination. According to Mood (2007), *Mycobacterium baliteri, w*hich causes skin tuberculosis was reported to have been isolated from bathers who have patronised pools found to contain large amount of microorganisms. A conjunctivitis outbreak in a summer camp in USA revealed that the rate of infection amongst swimmers at the camp was 50 % higher over those who do not swim (Alice, 1977). The presence of *Pseudomonas aeruginosa* in swimming pool waters was found to be a potential health hazard in a report by Alcock (1977), which further indicated that this microorganism is very often isolated from the ears of bathers having otitis media infection. It has been found that, recreational swimming centers are monitored through the use of total plate count and a coliforms test, but these traditional tests are devoid of appropriate information on *Staphylococcus aureus* and *Pseudomonas aeruginosa*, since both organisms resist disinfectants (Okafor, 1985). Skin, eye, ear and gastroenteritis infections are diseases transmitted by recreational water and the health hazard associated with swimming pool waters is mostly determined by the levels of microorganisms present in the recreational water (Lagerkvist *et al.*, 2004). The quality of pool water can effectively be assessed during the time of sampling and collection of pool water for free chlorine, bather load estimation and also the pH. The control of the organisms responsible for the many infectious diseases inherently present in swimming pools is achieved through disinfection of the pools; however, the filter material or structural features in the pool may protect some of these organisms from total disinfection. A safety indicator for the assessment of swimming pool water is, however, in dispute (Palmer *et al.*, 2003; Esterman *et al.*, 2004). The use of

bacteria which indicate faecal contamination, such as faecal coliforms and enterococci, is the best method for measuring the microbial quality of swimming pools. Seyfried *et al.*, (2005a) suggested that the potential of swimmers getting infected is more linked to microorganisms that inhabit the upper respiratory tract, mouth and the skin of swimmers compared to faecal contamination. It is also considered that microorganisms which indicate hygienic conditions (total coliforms and heterotrophic bacteria) and faecal pollution are the best indicators (Seyfried *et al.*, 2005b; Mossel, 2006; Favero *et al.*, 2004; Mood, 2007; Favero, 2005; and Galbraith, 2000). Nevertheless, the issue of any microorganism reliably predicting the health risks connected to swimming pools is still in doubt. Assessing bathing water quality is an important factor which is proportional to the density of the swimmers. Swimmers with high densities risk infection with pathogens in a manner equal to the risk associated with bathing in water which is faecally polluted (Favero *et al.*, 2004; Mossel, 2006; Dutka, 2008). With all these doubts, Mood (2007) considers faecal coliforms, especially, *E. coli*, *Clostridium perfringens* and *Enterococcus faecalis* as the principal indicator bacteria in swimming pools.

2.5.1.3 TOTAL COLIFORMS

The coliform bacteria group is made up of various genera of bacteria belonging to the family *Enterobacteriaceae*. These are harmless bacteria and mostly originated in soil, water, plant material, certain industrial waste and the intestinal tract of warm blooded animals. Coliforms are mostly common indicator organisms and are frequently monitored as total or faecal coliforms (Bergey and Holt, 1994). The total coliforms (TC) [Fig.2.1] is a term used to refer to an enormous group of lactose fermenting (with gas formation within 48 hours at 35^0C) bacteria that rod-shaped, anaerobic and non-spore forming. Total coliforms are indicator organisms used to detect the presence of bacterial contamination in

water. Their presence indicates that a pathway for contamination exists and organisms that cause disease may be present, even though total coliforms themselves typically do not cause disease in healthy individuals. The most common symptoms caused by disease-causing organisms found in pools are nausea, vomiting and diarrhea. (Cheesbrough, 2007). The skin of the human body is the commonest point through which pathogens enter but more commonly they are ingested with drinking water and swimming pool waters (Blanch, 2007).

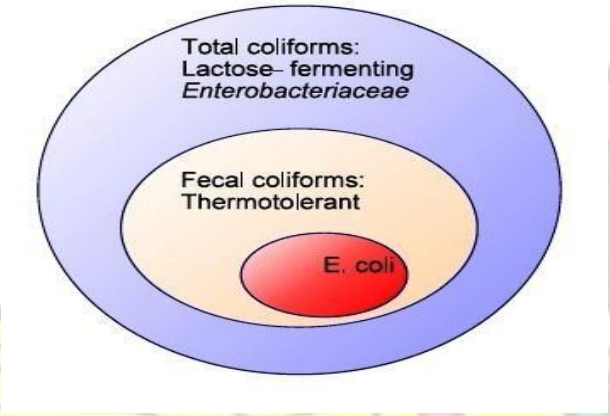
Faecal coliforms (FC) [Fig. 2.1] are a sub-division of total coliforms that are mostly found in faeces of humans and other warm blooded animals. Faecal coliforms can be defined as gram-negative, non-spore-forming, rod-shaped bacteria which ferment lactose with the production of gas at 44.5 ºC within 24 hours (Edberg *et al.*, 2000). They enter water bodies from human and animal waste. If a large number of fecal coliform bacteria (over 200 colonies/100 milliliters (ml) of water sample) are found in water, it is possible that pathogenic organisms are also present in the water. Fecal coliform are not pathogenic; they are indicator organisms, which indicate the presence of other pathogenic bacteria when they are present in water. Drinking water has zero-tolerance limit for both total coliforms and faecal coliforms (Chapra, 1997).

2.6 *ESCHERICHIA COLI (E. coli)*

E. coli (Fig 2.1) belongs to the large group of gram-negative rods, lactose fermenting bacteria referred to as enterobacteria. These include *Escherichia, Klebsiella, Enterobactor* and *Citrobactor*. They are naturally found in the intestinal tract, in soils and water. *E. coli* causes infections such as cystitis, peritonitis, sepsis, endotoxin induced shock, infections

of wounds, infantile gastroenteritis, traveller's diarrhoea, dysentery and haemorrhagic diarrhoea which may progress to haemolytic uraemic syndrome (CDC, 2001).

Morphologically, *E. coli* is a gram negative, usually, motile rod. Inactive strains (formerly described as Alkascens-Dispar) are non-motile. Minority of the strains are capsulated (CDC, 2001).



(Source: CDC, 2001).

Fig. 2.1: Diagrammatic representation of total and faecal coliforms and *E. coli*.

2.7 Protozoan Pathogen

Protozoan pathogens such as *Cryptosporidium* species and *Giardia* species are widely distributed in the aquatic environment and have been implicated in several outbreaks of waterborne diseases such as cryptosporidiosis and giardiasis respectively (Bushon and Francy 2003). These belong to the sub-Phylum Apicomplexa (Coccidia) and Mastigophora respectively. The major characteristic signs indicating the presence of cryptosporidiosis include abdominal cramps, diarrhoea, fever and vomiting, whereas that of giardiasis includes diarrhoea, loss of appetite, cramps, foul-smelling stools, vomiting and fatigue (Great Lakes Report, 1996; WHO, 2003). Acute diarrhoeal illnesses are caused by

Cryptosporidium and *Giardia* (Cryptosporidiosis and Giardiasis), which are faecally transmitted organisms. The infective form of these organisms is resistant to chlorine disinfection and this ensures that there is complete absence of all detectible organisms in the pool. Inactivation of the organisms require considerably longer time at lower temperatures and *Cryptosporidium parvum* Oocysts need higher dosages of

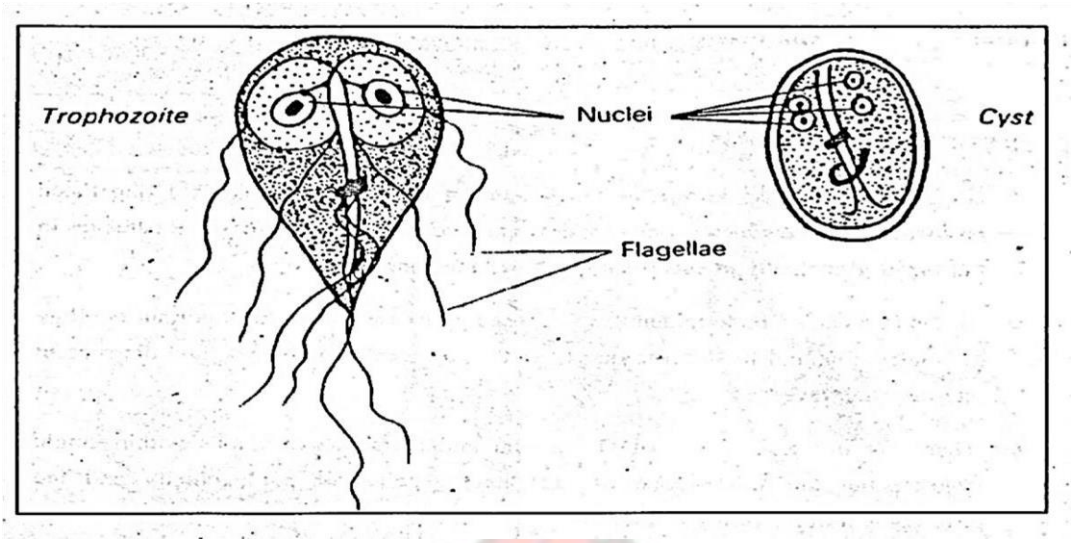
chlorine compared to that of *Giardia* (Oliveri *et al.,* 2006).

2.7.1 *Giardia Species*

In humans and other mammals, the *Giardia* species is the infecting agent which causes giardiasis and is called *Giardia duodenalis*, also known as *Giardia lamblia* or *Giardia intestinalis*. *Giardia muris*, another species, only infect rodents, birds and reptiles. *Giardia lamblia* infects the upper small intestine, the duodenum and causes both epidemic and sporadic diseases. It is an important etiology of water-borne and foodborne diarrhoea and day care center outbreaks. The most commonly known path of infection in giardiasis is by faecal or oral transmission and is particularly associated with foreign travels in developed countries (CDC, 2001).

2.7.2 MORPHOLOGY OF *Giardia species*

The parasite looks like the tennis racquet without a handle. The body is teardrop shaped with a convex dorsal surface and a concave ventral one. It has a single or double median body, and adhesive disks or four pairs of flagella as shown in Fig 2.2. It exists in two forms, trophozoites and cysts (Fig 2.2)



(Source: WHO, 2004)

Fig 2.2: Diagrammatic Morphology of *Giardia lamblia*.

2.7.3 Life Cycle Of *Giardia lamblia*

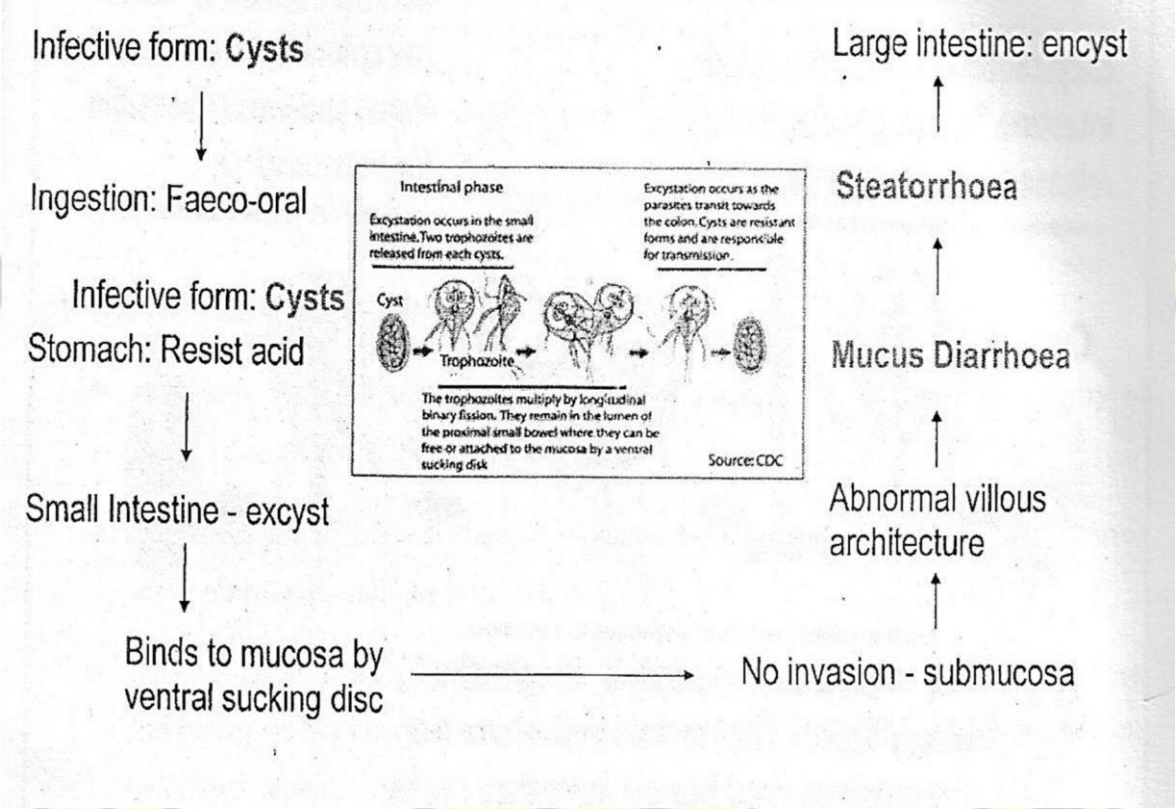
Giardia has a two-stage life cycle (Fig 2.3) namely, the cyst stage and the reproductive trophozoites stage. Cysts which are known to be infectious are usually egested in mammalian faeces and can remain infectious for a longer time in cool, damp

environments at less than 108 ^{o}C (Farthing, 2000).

The upper small intestine receives an ingested cyst and excystation occurs with the release of two trophozoites. These multiply quickly through asexual reproduction and then later colonise the small intestine. Symptoms occur at the trophozoite stage as a results of the damage caused to the mucous membrane of the duodenum and jejunum. The trophozoite measures between 9–15µm long, 5–15µm wide and 2-4µm thick, pearshaped, binucleate and contains four flagella which exhibits a tumbling motility as shown in Fig 2.3. Trophozoites, according to Smith (1993), possess an adhesive disk on the ventral surface for attachment to the mucosal surface of the duodenum and jejunum and this establishes residence in the proximal small bowel but does not invade or cause necrosis of the mucosal

epithelium. Encystation of some trophozoites completes the cycle in order to persist in the infectious form and this occurs in the large intestine. The cyst, ovoid in shape measures between 9–12µm long, is usually shed into the environment through faeces.

The infective dose for *Giardia* is between 10 and100 cysts and the incubation period in humans is typically 1–2 weeks. *Giardia* is the most commonly isolated parasite worldwide (Meyer and Jarroll, 1980).



(Source: Smith, 1993).

Fig. 2.3: Diagrammatic representation of life cycle of *Giardia*.

Symptoms typically include diarrhoea, steatorrhoea, abdominal cramps, bloating and flatulence. Chronic cases may lead to malabsorption of fat resulting in fatty stools most often and significant weight loss. The untreated disease can last for a minimum of 5 days or more

and can also reoccur. This is much common in asymptomatic carriers (Meyer and Jarroll, 1980).

Asymptomatic infection occurs in about sixty percent (60 %) of people exposed to *Giardia* and is seen in both children and adult and the asymptomatic cyst carriage can last over six months (Cheesbrough, 2007). Acute giardiasis occurs in less than half of the people infected with *Giardia*. The symptoms of acute giardiasis are diarrhoea, malaise, steatorrhoea, abdominal cramps and bloating, flatulence, nausea, weight loss and vomiting. Fever occurs in only ten to fifteen percent (10 to 15 %) of patients. The distinguishing features of giardiasis are the prolonged duration of symptoms, often two to four weeks and the significant weight loss that occurs in over fifty percent (50 %) cases (Cheesbrough, 2007). Chronic giardiasis may follow the acute phase of illness or may develop without an antecedent acute illness. Cheesbrough (2007) in a study reported that eighty-four (84 %) of experimentally infected people self-cured by a mean of 18.4 days following inoculation, while the remaining became chronically infected. A chronic syndrome can develop in as many as thirty to fifty percent (30 to 50 %) of symptomatic patients characterized by loose stools but usually not diarrhoea, steatorrhoea, profound weight loss and malabsorption. This can lead to vitamins A and B12, deficiencies, foliate deficiency, hypoalbuminemia and especially secondary lactose deficiency, malaise, fatigue and depression

2.7.4 *Cryptosporidium* Species

Cryptosporidium is a protozoa pathogen of the Phylum Apicomplexa and causes a diarrhoeal illness called cryptosporidiosis. Cryptosporidiosis, also known as crypto, is a parasitic disease caused by *Cryptosporidium*. It affects the intestines of mammals and is typically an acute short-term infection. It is spread through the faecal-oral route, often

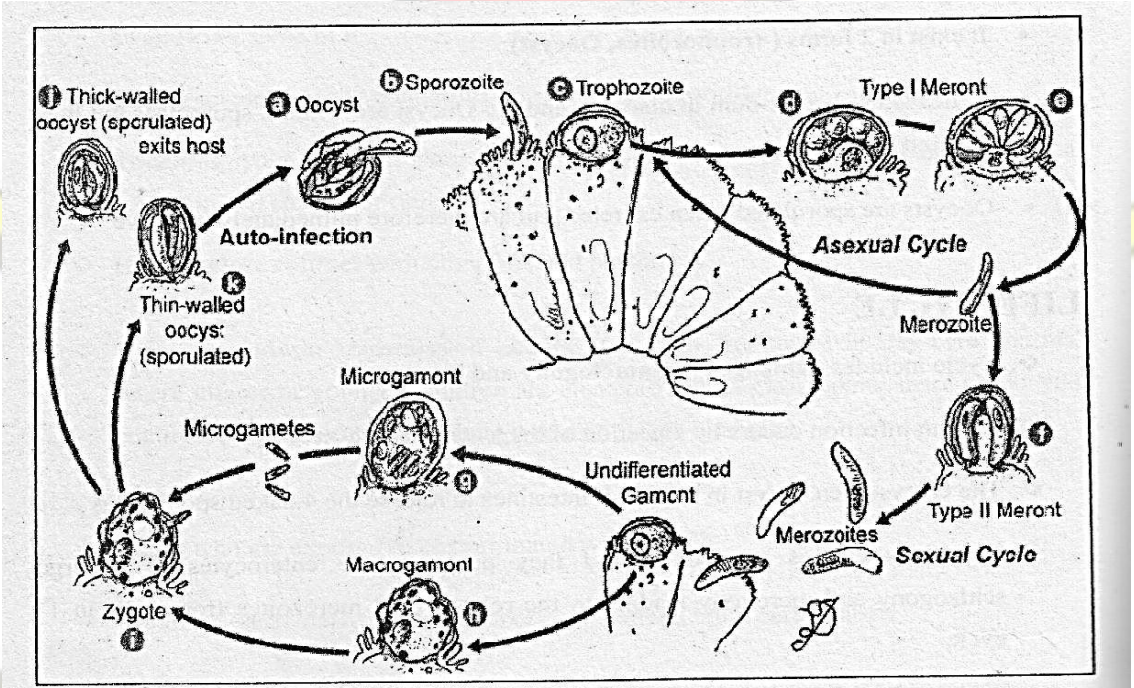
drinking contaminated water; swimming in water contaminated with *Cryptosporidium* and accidentally swallowing some of it, eating uncooked food contaminated with *Cryptosporidium*, touching contaminated surfaces and objects and having close contact with infected people (Fayer *et al*., 1990).

The main symptom is self-limiting diarrhoea in people with intact immune systems, life threatening illness, dehydration, weight loss, upper abdominal cramps, fever, nausea, vomiting, malaise, anorexia and flatulence. In immune-compromised individuals, such as HIV-AIDS patients, the symptoms are particularly severe and often fatal (Meyer and Jarroll, 1980). *Cryptosporidium* is the organism most commonly isolated in HIV positive patients presenting with diarrhoea. Treatment is symptomatic, with fluid rehydration electrolyte (Fayer *et al*., 1990).

2.7.5 Life Cycle of *Cryptosporidium*

The *Cryptosporidium* has one phase cycle (Fig.2.4) and completes its life cycle with mature oocysts which are shed off in faeces and becomes infective immediately for another available host. The cycle includes Schizogony, gametogony and sporogony. The Oocysts are between 4–6 µm in diameter and smaller than many other protozoa, containing four crescents shaped infective structures called sporozoites. These sporozoites are motile and penetrate the enterocytes to undergo schizogony and merogony leading to the release of eight merozoites as shown in Fig 2.4. Sporozoites are released in the small intestine when the oocysts excysts after ingestion, attacked the gut epithelium, thus commencing an infection. They undergo further stages of development through the processes of sexual and asexual multiplication, zygote formation, oocysts formation, and sporulation (Fayer *et al*., 1990). The organism's life cycle stages are occurred within the cell, spanning an incubation

period of two to ten (2–10) days in which case the pathogen gives rise to symptoms in the host (Meinhardt *et al.,* 1996). Abdominal pain and vomiting is indicative of *C. parvum* infection resulting in diarrhoea which is a very common symptom. Symptoms of the disease lasts longer than most bacterial gastrointestinal infections, lasting between one and two (1–2) weeks, and resulting in hospitalization, in some acute cases. Complete recovery is normally achieved in the case of people with fully functional immune systems, but severe with immunecompromised people which can results in life –threatening situations (Farthing, 2000).



Diagrammatic representation of life cycle

(Source: Meinhardt *et al.*, 1996).

Fig. 2.4: Diagrammatic representation of Life Cycle of *Cryptosporidium.*

2.8 WATER QUALITY OF SWIMMING POOL

Water quality is a term used to express the suitability of water to sustain various uses and is affected by a wide range of natural and anthropological (human) influences (Russell, 2006). Due to the health hazards associated with pool waters, it is necessary to check the water quality in pools, thus ensuring the safety of water and compliance with standards. Quality surveillance of pool water continuously is a necessary requirement as a means of controlling infection risks, assessing the efficiency of treatment and disinfection processes, changes in chemical and physical characteristics of swimming pool waters and behavioural evaluation of bathers which directly influences the water quality status. Water quality status is also dependent upon the total number of swimmers in the pools at any time, water temperature and environmental conditions (Russell, 2006).

2.8.1 WATER QUALITY MONITORING

The main elements of water quality monitoring involves on-site measurements, the collection and analysis of water samples in the laboratory, the study and evaluation of the analytical results and the reporting of the findings. Some of the common water quality monitoring strategies are Ambient monitoring, Baseline monitoring and Compliance or regulatory monitoring. Ambient water quality refers to the measurements of the prestine conditions of water bodies. Baseline monitoring is the reference point use to indicate the initial conditions of water against which future measurements are compared and Compliance monitoring refers to the collection and evaluation of water quality data including self-monitoring reports and verifications to show whether pollutant concentrations and loads contained in permitted discharges are in accordance with the limits and conditions specified in reference permit (Igbinosa and Okoh, 2009).

2.9 SOME PARAMETERS USED TO DETERMINE WATER QUALITY IN POOLS

2.9.1 pH

pH, by definition, is the negative logarithm of the hydrogen ion concentration of a solution and this is a measure of whether the liquid is acidic or basic. Universally, pH scale ranges from 0 (very acidic) to 14 (very alkaline) and this is derived from the ionization constant of water (Sule *et al.*, 2010). Controlling and monitoring the pH of swimming pool waters is carried out as a measure of ensuring total and efficient disinfection, coagulation, prevention of damage to the pool fabric and ensuring the comfort of users. For chlorine disinfectants, pH must be maintained around 7.2 and 7.8 whereas with bromine-based and other non-chlorine disinfectants, pH must be maintained between 7.2 and 8.0. The type of swimming pool determines the frequency of pH measurement and research indicate that: (1) the pH for public pools must be consistently checked and automatic adjustment made when necessary; (2) monitoring should be carried out twice in a day during operating hours for public and semi-public pools and (3) for domestic pools, measurement should be done prior to pool use (UNDP, 2004).

Maintaining an effective concentration of disinfectant is critically important in assuring the safety and health of swimming pool and spa users. When using pool chemicals it is very important to keep the pH of the pool in the range between 7.2 to 7.8 according to the Langelier Saturation Index.

Higher pH drastically reduces the sanitizing power of the chlorine due to reduced oxidation-reduction potential, while lower pH causes bather discomfort, especially to the eyes. However, according to the Langelier Index, a higher pH can reduce unnecessary chlorine

consumption while still remaining effective at preventing algae and bacteria growth. Generally, the disinfectant used in the pool determines the chemical needed for the adjustment of the pH value whether basic or acidic (WHO, 2006). For basic disinfectants, (e.g. sodium hypochlorite) pH correction is achieved through the addition of an acid, for instance, hydrochloric acid (HCL), sodium hydrogen sulphate and carbon dioxide. For acidic disinfectants such as chlorine gas, a basic solution of sodium carbonate (soda ash) is also used. According to a WHO (2006) report, there should not be any associated adverse health effects when the proper dosage of these chemicals are used in swimming pools and the pH range properly adjusted between 7.2 and 7.8.

2.9.2 TEMPERATURE

Temperature affects the behaviour and metabolic activity of organisms, and as well, alters the chemical and physical state of pollutants, thus affecting the exposure of organisms to pollutants (WHO, 2006). As water temperature increases, the rate of chemical reactions increases together with the evaporation and volatilization of substances from the water. For most swimmers, water temperature ranging between 26

C to 30 °C for prolonged times of moderate physical exertion is assumed comfortable. Psychological considerations rather than physiological ones account for the individual's comfortability regarding higher levels of water temperature which is assumed suitable for recreational immersion, according to Briancesco and Bonadonna (2005).

Water temperatures beyond 40 °C in hot tubs and natural spas may result in overheating of swimmers bodies, thus causing drowsiness, leading eventually to an unconscious state particularly if related to the consumption of alcohol and may result in drowning

(Calderon and Craun, 2005). In addition, heat strokes and deaths may result from high temperatures in pools. Hot water with extreme temperatures of approximately 43°C in hot tubs had caused several deaths according to CPSC reports. Water temperatures in hot tubs are therefore recommended to be retained at temperatures less than 40 °C (CPSC, 2004).

Plunge pools also exhibit same problems regarding temperature extremes, nonetheless, in a different direction. Plunge pool is a small deep pool which generally contains water with temperature ranging from 8°C to 10 °C, which is used in concurrence with steam baths. Extreme and sudden temperature changes in plunge pools may result in adverse health problems including immediate impaired coordination, loss of control of breathing and, after some time when the core body temperature falls, slowed heartbeat, hypothermia, muscle cramps and loss of consciousness (WHO, 2003).

General precautionary measures which need adoption in order to safeguard the health and lives of pool users include: pregnant women must not be exposed to extreme temperatures, young children and people having medical challenges, and prevention of immersion for long hours in hot tubs or other pools with high temperatures or precautions must be taken. Instructive shows and cautioning signs, notices from lifeguards and pool staff, regulation of length of time of exposure, as well as regulating the usage for medically challenged people are instances for the prevention of hazards related to temperature extremes (WHO, 2003).

2.9.3 TURBIDITY

Turbidity is the amount of suspended, dissolved and colloidal particulate matter such as clay, silts, and finely divided organic matter, plankton and other microscopic organisms in the swimming pool water. For more turbid waters, the clarity of the swimming pool water is very much reduced (Lamb, 1985). Turbidity is also another factor used to indicate the

quality of swimming waters with respect to colloidal and residual suspended matter. Controlling turbidity for safety and effective disinfection of the pools is very essential (Fricker *et al*., 2002). A universal turbidity value is considered inappropriate for the identification of foreign bodies at the bottom of pools since a lot hinges on the features of the swimming pool concerned, like surface reflection, materials used for the construction of the swimming pool and / or the construction design. Development of standards for each pool must necessarily be dependent on assessment of risk by each pool and the minimum recommendation is that, from the lifeguard's position in any particular pool at the time that the water surface is in typical use motion, it must be possible to observe or see a little kid at the base of the pool (Craun *et al.,* 2002).

Alternatively, maintenance of water clarity is essential to ensure that, track markings and other important features at the bottommost part of the pool, when viewing from the sides, are plainly observable. Pool managers have through years of experience determined these indicators as a turbidity equivalent and use them to check and monitor the turbidity consistently. An upper limit guideline for turbidity is currently set at 0.5 Nephelometric turbidity unit (NTU). This is a useful guideline, but not an absolute value and is used for effective disinfection. NTU is determined by the Nephelometric method (Sule *et al.,* 2010).

2.9.4 TOTAL DISSOLVED SOLIDS

The total dissolved solids (TDS) determine the presence of organic substances, inorganic sail, and other dissolved materials suspended the pool (EPA, 2004). Factors that determine TDS levels are: (1) disinfectants and other pool chemicals, and (2) bather pollution. Detection of increases in TDS levels is important since it serves as an indicator to swimming pool overloading or non-dilution of pools. Total dissolved solids levels are

usually checked by comparing pool water with the source of water and if TDS levels is found to be high, dilution is necessarily done as a correct management action (APHA, 2005).

2.9.5 CONDUCTIVITY

Conductivity or specific conductance is a measure of the ability of water to conduct an electric current and also indicates the presence of ions in the water. It is sensitive to variations in dissolved solids, mostly mineral salts. The degree to which these dissociate into ions, the amount of electrical charge on each ion, ion mobility and the temperature of the solution all have an influence on conductivity. Conductivity is expressed as microsiemens per centimetre (µS/cm) (Igbinosa and Okoh, 2009).

2.9.6 COLOUR

Colour in water may be attributed to humans, peat, plankton, vegetation and natural metallic ions (iron and manganese). Colour in swimming pools can originate from decomposition of organic matter and other contaminants of different materials in varying concentrations. Colour influences light penetration in the pool and also hamper absorption of oxygen from the atmosphere (Walakira, 2011). In some coloured swimming pool waters, colour is contributed principally by colloidal suspended materials. In general, colour is removed to make water suitable for domestic and commercial application (APHA, 2005).

2.9.7 MICROBIAL QUALITY

In well-managed pools having adequate residual disinfectant concentration and wellmaintained pH values at appropriate levels, well–managed filters and consistent checking of other parameters which are not microbial in nature, the risk of microbial

contamination and illness becomes significantly limited. This, notwithstanding, frequent monitoring of microbial parameters at appropriate intervals for water samples from semipublic and public swimming pools must be ensured. However, there is no guaranteed microbial safety regarding these tests and monitoring but these give indicative parameters upon which the effectiveness or otherwise of the pool can be judged and also the corrective or remedial actions applied (Slifko *et al.*, 2000).

2.9.7.1 PATHOGENS

Pathogens are disease-causing organisms that grow and multiply within the host. They are divided into categories with the most common groups associated with water pollution being bacteria, viruses, protozoa, helminthes (intestinal worms) and algae (Chapra, 1997). Swimming pool water often contains representatives of the different pathogen categories and colonization of water by pathogens through faeces. The usage of contaminated water therefore results in transmission of pathogens to man (Fayer *et al*., 1990).

2.10 DISINFECTANTS

Swimming pools and similar environments use various disinfectants to either kill or inactivate pathogens and other nuisance microorganisms (WHO, 2006). The disinfectant widely used in pools is chlorine. The swimming pool water undergoes treatment with other disinfectants like UV and ozone to eliminate microorganisms or make them inactive; however, disinfectant effect reaching the pool does not last and also has no lasting effect on its continuous action on chemicals and microorganisms in the pool water (WHO, 2006). Chlorine- or bromine-type disinfectants are employed in order to provide continuous disinfection effect in swimming pools in which ozone and UV disinfectants are used. The term “residual” or “free” chlorine is used for the active and accessible disinfectant in the

pool, to differentiate it from the non-disinfectant combined chlorine. Bromine and its combined forms are all disinfectants, hence no distinction is made between bromine and combined bromine, so the parameter of interest to measure is 'total' bromine (Alice, 1977).

Specific requirements of swimming pools determine the type and form of disinfectant needed and for small and domestic pools, essential requirements needed by disinfectants include: (1) how easy it is to handle, (2) how easy it is to use and (3) effectiveness of its use. The choice of disinfectant should be made only after consideration of the efficacy of a disinfectant under the circumstances of use and the ability to monitor disinfectant levels, in all swimming pools (WHO, 2006).

2.10.1 CHLORINE

Protection against cross bather infection is most commonly provided through the use of residual chlorine. The various forms in which chlorine is supplied to the swimming pool water are chlorine gas (Cl_2), sodium hypochlorite solution (NaOCl) or calcium hypochlorite. Chlorine dioxide as well as combination of chlorine and bromide salts is also used by some pools. When chlorine gas and hypochlorites dissolve in water, hypochlorous acid (HOCl) is produced. The conductivity, temperature and pH of the treated water normally determines the proportions of hypochlorous acid (HOCl) and hypochlorites (APHA, 2005).

Both kill microorganisms and bacteria by attacking the lipids in the cell walls and destroying the enzymes and structures inside the cell, rendering them oxidized and harmless. The difference between HOCl and OCl^- is the speed at which they oxidize. Hypochlorous acid is able to oxidize the organisms in several seconds, while the hypochlorite ion may take up to 30 minutes. Ideally, the level of pH in the pool should be

between 7 and 8. Therefore, pool cleaning can take much longer than normal if pH is high in the pool, due to the less amount of HOCl present in the pool (APHA, 2005).

pH 7.4 is ideal and this is the pH of human tears. Measurement of “residual” free chlorine for hypochlorous acid and hypochlorite ion is achieved through the ubiquitous DPD test and this is significant for the killing and inactivation of microorganisms in swimming pools and spas since it serves to indicate the effectiveness of the hypochlorous acid as a disinfectant compared to that of hypochlorite ion. HOCl and OCl^- are either broken down into single atoms or combine with other chemicals such as ammonia, when they are done cleaning the pool. Each of these processes results in making chlorine harmless, and are accelerated by sunlight (UNDP, 2004)

Even though chlorine is very useful in killing of bacteria, it has some side effects that can be annoying to humans, and possibly hazardous. The distinctive smell of chlorine to most people is unpleasant, and to others, overwhelming. There is also the "itch factor", where chlorine causes certain skin types to become itchy and irritated. Hypochlorite ion also causes many fabrics to fade quickly when not rinsed off immediately after exiting the pool. This is why some swimsuit looks faded and worn so early in the summer (Lisle and Rose, 1995).

Production of a range of disinfection by-products (DBPs) occurs as a result of a reaction between chlorine and a host of the common contaminants of swimming pools. Some of these DBPs are of great concern to swimming pool bathers and spectators as they present a potential risk to health, thus impacting negatively on the comfort of swimmers. However, sweat and urine which are introduced into the water by swimmers largely consist of water, ammonia and urea (Lisle and Rose, 1995).

Chlorine reacts with ammonia to produce chloramines as follows:

$Cl_2 + H_2O$ ----------→ $HOCl + HCl$

$HOCl + NH_3$ ----------→ $NH_2Cl + H_2O$ - monochloramine

$HOCl + NH_2Cl$ --------→ $NHCl_2 + H_2O$ - di-chloramine

$HOCl + NHCl_2$ -----→ $NCl_3 + H_2O$ - tri-chloramine (nitrogen trichloride)

The type of chloramine formed is dependent on the pH and the ratio of chlorine to ammonia. While monochloramine is not a particular problem, dichloramine results in a strong chlorine odour and may cause eye irritation. Tri-chloramine or nitrogen trichloride accumulates in cases where ventilation is inadequate and then released into the atmosphere. This releases a pungent smell and causes extreme discomfort to bathers and spectators (Thickett *et al.*, 2002).

Thickett *et al.* (2002) also reported that a strong correlation exist between serve asthma and nitrogen trichloride present in swimming pool which is of great concern to swimming instructors and life-guards since these pool side workers may be exposed during their working hours of the day to significant levels of nitrogen trichloride. Some corrective maintenance procedures in pool environments that minimize the formation and accumulation of chloramines include sufficient ventilation, pool water dilution, pH control and sufficient free chlorine levels. Free chlorine in pool waters is an ample indication suggesting the arrival at the point called “break-point” and this, principally, suggests the oxidation of chloramines into innocuous compounds. This, however, scarcely occurs in practice since some levels of chloramines are bound to be found in the pools always. In this vein, it is strongly suggested that further steps including application of powdered activated

carbon on the filters and UV treatment applied to keep chloramines at reasonably low levels (Wright *et al*., 2003).

Reaction of chlorine with organic contaminants produces trihalomethanes (THMs) and these include chloroform ($CHCl_3$), bromoform ($CHBr_3$), bromodichloromethane ($CHCl_2Br$) and dibromochloromethane ($CHClBr_2$). Trihalomethane levels in swimming pools according to German DIN19643 standards stipulates a maximum level of 2 µg/l. Eight swimming pools in London undertook some tests and reported an average concentration of chloroform of 121.1 µg/l and the chloroform concentration and total trihalomethanes (TTHMs) was reported to be in correlation to the number of swimming pool users and the concentration carbon substances (Chu and Nieuwenhuijsen, 2002).

Exposure to THMs in pools and their resultant effects have received some considerations particularly, the potential link existing between exposure to THM and cancer of the bladder and the apparent increases in the number of birth defects and low birth weights (Whitaker *et al*., 2003).

Chlorine residual in swimming pools have varied effects on various group of pathogens. In recent years, discoveries in medical science have greatly improved and thus, have enhanced the knowledge base on how microorganisms are affected by chlorine in water. Leucocytes (white blood cells) engulf pathogenic microorganisms in the body by phagocytosis. Currently, it is known that the leucocyte accomplishes this by destroying the pathogens through the release of oxidative toxins like hypochlorous acid (Hurst, 1989, Klebanoff, 1988). A number of studies have come off as result, seeking to discover the mechanisms by which hypochlorous acid (a toxin) causes the inactivation of their target organism (Wright *et al*., 2003).

White crystalline compounds called chlorinated isocyanurate which have slight chlorinetype odour when in solution and release free chlorine (as hypochlorous acid) are the source of chlorine which is very resistant to UV light. Chlorinated isocyanurate compounds are widely used in lightly loaded pools or outdoor pools. Chlorinated isocyanurate compounds provide chlorine indirectly.

The pH and free chlorine concentrations determine the relative amounts of chlorinated isocyanurate, free chlorine and cyanuric acid which are always in equilibrium. Chloroisocyanurates release more chlorine atoms to form hypochlorous acid as the disinfectant (HOCl) is used up and exhausted in the pool, resulting in the high amounts of cyanuric acid which is not easily removed by the processes of water treatment (Hurst and Barrette, 1989).

Maintaining a balanced equilibrium between cyanuric acid and free chlorine is difficult but very important to ensure that the cyanuric acid concentration in the swimming pool is kept at a satisfactory level through dilution of the pool water with fresh water. High cyanuric acid levels result in microbial situations best described as unsatisfactory and cyanuric acid in chlorinated water certainly reduces free chlorine quantities present in the pool water. Very little effect is experienced at low levels of cyanuric acid, however, the increase in cyanuric acid levels is accompanied by a progressive reduction in the oxidizing and disinfecting properties of the free chlorine (Wright *et al*., 2003).

'Chlorine lock', a situation arising from high levels of cyanuric acid, occurs when cyanuric acid (stabilizer) and high chlorine concentrations completely locked together in a pool, not making chlorine available to be used as a disinfectant. Chlorine lock situations mostly occur at cyanuric acid levels at 200 mg/l or higher, and this, however, suggests monitoring and

controlling cyanuric acid levels in direct relation to chlorine residual. The cyanurate levels is recommended at 100 mg/l (Wright *et al*., 2003).

CHAPTER THREE

3.0 MATERIALS AND METHODS

3.1 STUDY AREA

The study was conducted in the Kumasi Metropolitan Area (KMA) of the Ashanti Region of Ghana. The Ashanti Region is the third largest region after Northern and Brong Ahafo of the ten administrative regions in Ghana, occupying a total land surface area of 10.2 per cent of the total land area of Ghana. According to the 2000 census, it is the most populated region accounting for 19.1 per cent of Ghana's total population and was projected to be 1,889,934 by 2010 (Ghana statistical services 2010).

Kumasi is the second largest city in Ghana and the capital of the Ashanti Region, located in the middle belt of the country. It is humid with relative humidity ranging between 53% - 93%. The city lies within the tropical rainforest zone between the northern and southern savanna zones of Ghana (Latitude 6^0 30' and 7^0 00' North and Longitude 1^0 30' and 2^0 00' West). The vegetation is primarily of tropical moist semi-deciduous forest type. The climate is marked by a fairly high incidence of solar radiation with temperature ranging from a minimum of 20.2 ^{0}C to a maximum of 37.1 ^{0}C on the average. The rainfall pattern is seasonal with an annual rainfall varying between 127cm and 165cm. The rainy (wet) season consists of two rainy periods namely the major season from March- July with peak in June and the minor season which runs from August to October.

November to February is the dry (Harmattan) period (Meteorological Services Department, Ashanti, 1994).

Kumasi's gorgeous layout and vegetation concurred it the award; "Garden City of West

Africa".

The city is growing rapidly with 5.47 per cent growth rate annually (Regional Statistical Office, Kumasi). It covers about 90 rural areas, several of which have been absorbed into it as an aftereffect of growth process and physical expansion. Kumasi is a tourism attraction center and also the business hub of Ghana boasting of a lot of industries and business concerns. Business men and tourists from different parts of the world visit the city for various reasons hence there are more hotels in Kumasi. The hotels in the Kumasi metropolis rate from one star to four star hotels. The hotels with swimming pools fall within the two-star to four- star hotels category. (Hotels.com, 2016).

3.2 SELECTION OF SAMPLE SITES

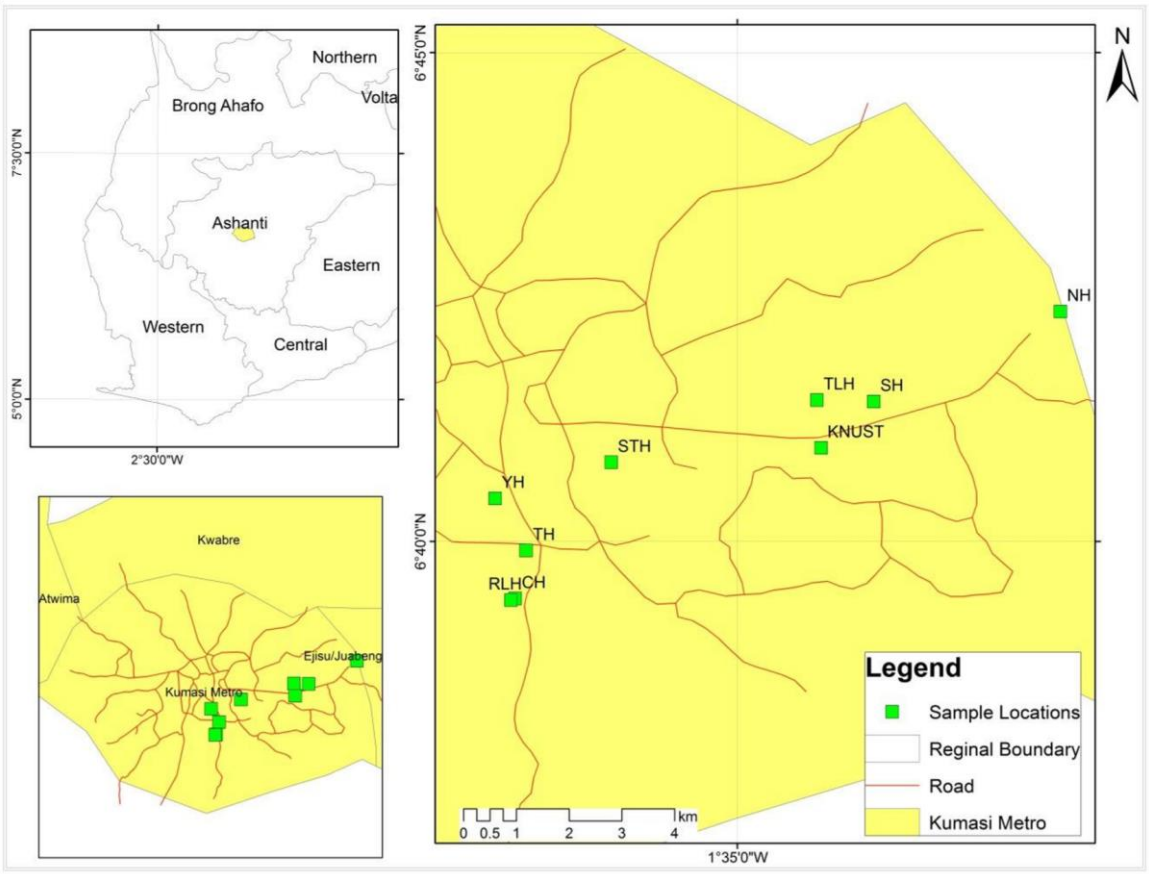
A survey of hotels was conducted in Kumasi and eight hotels with swimming pools were selected as well as KNUST pool based on the consent of the management of the hotels and accessibility. The selected swimming pools were coded as follows;

- ✓ 2 Star Hotels (RL Hotel, C Hotel, TV Hotel, Y Hotel, ST Hotel)
- ✓ 3 Star Hotels (TL Hotel, S Hotel, N Hotel)
- ✓ KNUST Pool

3.3 COLLECTION OF POOL WATER SAMPLES

The samples were collected at two different times of the day (Friday to Sunday). The first batch (before swimming) was collected from 6am to 10am and the second batch (after swimming) was collected from 5pm to 6:30pm. For each of the nine selected swimming pools, two (2) separate 1.5 L water samples were collected from three different sections of each specific pool of which samples collected from each section were in duplicates. For the two samples collected, one was used for physiochemical analysis and the other for

microbial analysis. The water samples were collected into sterile sampling bottles with little amount of sodium thiosulphate which served as inhibitor of chlorine action, properly corked, placed on ice and transported to the laboratory within twenty-four (24) hours for analysis. The sampling was done twice a month for six months, from December 2012 to May 2013. A total of 324 samples were collected from the entire sampling site during the study. Laboratory analyses were carried out on all the pool samples collected from the field and brought to the laboratory.



(Source : Wild life Department 2016)

Figure 3.1: A map of the sample locations at the study site

3.4 PHYSICO-CHEMICAL ANALYSIS OF POOL WATER

The water samples were analyzed for pH, temperature, conductivity, total dissolved soils (TDS), dissolved oxygen and salinity using the water quality multi-parameter probe HI9828 pH/ORP/EC/DO. The samples for the analyses of residual chlorine, turbidity and colour were also analyzed using the appropriate standard methods (APHA, 2005).

3.4.1 pH

Samples for pH was measured with HI9828 pH/ORP/EC/DO pH meter. The pH meter was first calibrated using standardized buffer 4, 7 and 10 solutions. Enough water was poured into a plastic container and the probe was rinsed with distilled water before placing in the sample. The probe was then placed in the sample for 10 minutes for the meter to attain equilibrium before recording the reading (APHA, 2005).

3.4.2 DETERMINATION OF ELECTRICAL CONDUCTIVITY, TEMPERATURE, SALINITY, DISSOLVED OXYGEN (DO) AND TOTAL DISSOLVED SOLIDS (TDS)

The Sonde YSI 650 Multi-parameter model was used to determine electrical conductivity, temperature, salinity, dissolved oxygen and total dissolved solids. The function of the ionic concentration of water at constant temperature is its electrical conductivity. The conductivity probe is sensitive to the ionic charges in solution and the factor controlling the current carrying the water sample in turn helps the meter provide direct reading of the conductivity of the test sample. The conductivity test is delicate to the ionic charges in arrangement and the variable controlling the ebb and flow conveying the water test thus helps the meter give direct perusing of the conductivity of the test

These parameters were analysed on site (at the pool side). The plastic container was rinsed with distilled water and a portion of the sample. Enough of the sample was collected into the plastic container. The probe was rinsed with distilled water and immediately inserted into the well shaken sample. The readings for electrical conductivity, temperature, salinity, dissolved oxygen and total dissolved solids were recorded after the values have stabilized.

3.4.3 TURBIDITY

Photometer was used to determine the turbidity of the samples. 10 ml of distilled water was measured using a measuring cylinder into an already cleaned cell. Then the cell containing the blank distilled water was put into the light cabinet of the photometer and covered with the light shield to determine the blank. With the aid of a measuring cylinder, 10 ml of each sample was measured and transferred into the clean cell. Using a tissue paper, the sample cell was cleaned, wiped dry and placed in the light cabinet of the photometer and covered with the light shield and reading recorded. The turbidity readings were recorded in NTU (Nephelometric Turbidity Units) (APHA, 2005).

3.4.4 COLOUR (PLATINUM COBALT METHOD)

The colour of the samples was determined by Smart 2 Colorimeter 2.04 by LaMotte. Colour determination was done using colorimeter calibrated with platinum cobalt concentration standards. The colorimeter was switched on and colour mode (28) was selected from the testing menu. Distilled water was used to rinse the glass tube and then again filled with 10ml distilled water to the mark. The tube was inserted into the chamber, closed lid and selected scan blank. Then the tube was removed from the colorimeter and content discarded. The glass tube, rinsed with small portion of the test sample was then filled with the water sample to the 10 ml mark. Tube with sample water was inserted into the chamber,

lid closed and scan sample mode was selected. The results were recorded as true colour since turbidity was removed by filtering the samples with filter paper (APHA, 2005).

3.4.5 FREE CHLORINE

This analysis was done by using Wagtech WTD Chlorine test photometer.

Pink colouration is produced by the reaction between free chlorine and diethyl-pphenylene diamine (DPD) in buffered solution. There is a correspondence between the free chlorine concentration and the colour intensity. The intensity was measured using WTD Photometer. About three drops of the sample was left after rinsing the tube with the sample.

One DPD tablet was added, crushed and topped up with the sample to the mark. The sample was mixed thoroughly to obtain pink colouration and free chlorine reading was taken immediately.

3.5 MICROBIOLOGICAL ANALYSIS

The pool samples collected from the nine sampling points were analyzed for microbiological quality (total and faecal coliforms and *E coli*) and parasitological properties (microscopic identification of *Cryptosporidium parvum* and *Giardia lamblia*) using appropriate standard methods (APHA, 2005).

3.5.1 TOTAL AND FAECAL COLIFORMS

The total and faecal coliforms were determined using the Multiple – Tube Fermentation technique. In this technique serial dilution of 10^{-1} was done by pipetting 1 ml of the sample into 9 ml sterile distilled water into a tube. Then 1 ml of the sample was pipetted from the 10^{-1} dilution into 9ml sterile distilled water to form 10^{-2} dilutions and this was repeated for 10^{-3} and 10^{-4} dilutions. One milliliter aliquots from each of the previous dilutions were

inoculated into three different test tubes of five ml MacConkey Broth and incubated at 35^0C for determination of total coliforms and another set was incubated at 44^0C for faecal coliforms, both incubated for 24 hours. Test tubes which exhibited colour change from purple to yellow were marked positive for both total and faecal coliforms. Counts per 100 ml were calculated from Most Probable Number (MPN) tables (APHA, 2005).

3.5.2 *E. coli (THERMOTOLERANT COLIFORMS)*

The Multiple – Tube Fermentation technique was used to determine *E. coli* in the water samples. In this technique, all the positive tubes identified as faecal coliforms from 3.5.1 were further used to determine the *E. coli*. A drop of each of the positive tubes was transferred into a 5 ml test tube containing trypton water and incubated at 44^0C for 24 hours. A drop of Kovacs' reagent was then added to the tube of trypton water and the sample. All tubes showing red ring colouration development after gentle agitation indicated the presence of indole recorded as presumptive for themotolerant coliforms (*E. coli*). Counts per 100 ml were calculated from Most Probable Number (MPN) tables (APHA, 2005).

3.6 PARASITOLOGICAL TEST TO IDENTIFY *Cryptosporidium Parvum and Giardia lamblia*

The Wet Mount Technique and Modified Ziehl-Neelsen methods (Cheesbrough, 2007) were used to identify *Cryptosporidium parvum* and *Giardia lamblia* in the water samples. Each sample was vigorously shaken and dispensed into sixteen sterile test tubes. The test tubes with the samples were centrifuged at 2000 rpm for 5 minutes. The supernatant fluid for each test tube was discarded and the residual sediments were immediately examined microscopically.

3.6.1 WET MOUNT TECHNIQUE

A drop of the residual sediment of each sample was placed on one side of a cleaned slide, covered with a cover glass and using a tissue pressed gently on the cover glass to make thin preparation. Also, a drop of eosin reagent was placed on the other end of the slide and mixed with a drop of the residual sediment of the sample and covered with a cover glass. Living trophozoites are not stained by eosin reagent but offers a pinkish background which makes identification easier. Microscopically, both preparations were first examined using the 10X objective lens with closed condenser iris (sufficiently) to provide good contrast. Afterwards, objective lens (40X) was used for the identification of motile trophozoites or cyst of *Giardia lamblia* and Oocysts of *Cryptosporidium parvum.* The slides with the presence of motile trophozoites or cyst of *Giardia lamblia* and oocysts of *Cryptosporidium parvum* are identified as positive (Cheesbrough, 2007).

3.6.2 MODIFIED ZIEHL-NEELSEN (Zn) METHOD FOR *Cryptosporidium parvum*

The positive slides without eosin reagent were air-dried. Each slide was fixed with methanol for 2-3 minutes. Then, the slides were stained with unheated carbol fuchsin for 15 minutes. The stain was washed off with water and the slides were decolorized with 1% acid alcohol for 15 seconds and again washed off with water. The slides were counterstained with methylene blue for 30 seconds. The slides were air-dried in a draining rack and examined microscopically. The low power objective was used to determine the presence of oocysts and the oil immersion objective was used for identification (Cheesbrough, 2007).

Plate 1. Sampling at one of the swimming pools under study.

3.7 QUALITY ASSURANCE

The precision and accuracy of the scientific procedures were evaluated by the examinations of reference materials and blank reagents before the analysis of samples using deionised water. Field instruments were calibrated according to manufacturers' instruction and water analysis standard methods.

3.8 QUESTIONNAIRE ADMINISTRATION

In order to ascertain the perception of patrons and users of swimming pools on the use of pools and possible sources of infection, questionnaires, observations and interviews were employed. In this regard, fifty questionnaires were issued out by hand to pool and users or patrons.

3.9 STATISTICAL ANALYSIS

The student t- test was used to determine the difference between the variables whiles the one-way analysis of variance (ANOVA) was used to determine significant differences ($p<0.05$) among the sampling location. The results are given as means ± SDs and presented as tables and graphs. All graphs and statistical analyses were done using the

GraphPad Prism (Version 5.01) statistical software for Windows.

CHAPTER FOUR

4.0 RESULTS

4.1 Summary of the Results

Generally, the results of the physicochemical and microbial quality of the various pools waters in Kumasi revealed varying levels of contamination. The pH of the pool waters varied between a range of 5.95±0.30 and 8.83±0.61 over the sampling period. Pool water temperatures varied over a narrow range of 26.90±2.57 °C to 29.49±0.26 °C. The mean DO levels of pool water before and after used showed a trend of increased concentrations ranging from 2.88±1.1mg/L to 7.57±1.58 mg/L and 5.38±0.97 mg/L to 9.72±6.12 mg/L, respectively.

Conductivity and total dissolved solids levels on the other hand did not appear to follow a particular trend. Salinity levels of all the pool waters were generally similar in before and after swimming and varied over a narrow range for all the pools samples. As expected free chlorine levels were generally higher, 0.15±0.22 to 2.17±1.72 in before swimming than after swimming, 0.10±0.13 to 0.83±0.51 with levels decreasing after pool being used.

Conversely, colour and turbidity values in the sampled pool water after use were higher than before use. With regards to microbial contamination, coliform counts and *Giardia* cysts counts were generally elevated in the after swimming samples relative to their respective levels in before swimming samples.

4.1 Physicochemical Parameters of water samples from nine swimming pools.

4.1.1 pH

The mean pH values of the before swimming samples ranged from 5.94 to 8.83, with the highest mean value of 8.83 recorded at CH while the lowest mean value of 5.94 was recorded at KNUST. For after swimming, the mean pH were quite high ranging between 7.02 and 8.86 (fig 4.1). The highest mean of 8.86 and the lowest mean of 7.02 were recorded at STH and KNUST respectively. There were significant differences ($p < 0.05$) in TLH, NH, SH and STH for both before and after swimming samples (Appendix A).

Figure 4.1, shows the differences in pH levels for before and after swimming samples in the various sampling locations. From the figure, all the levels of pH for before swimming samples were higher than after swimming in all the sampling sites except SH, KNUST and STH.

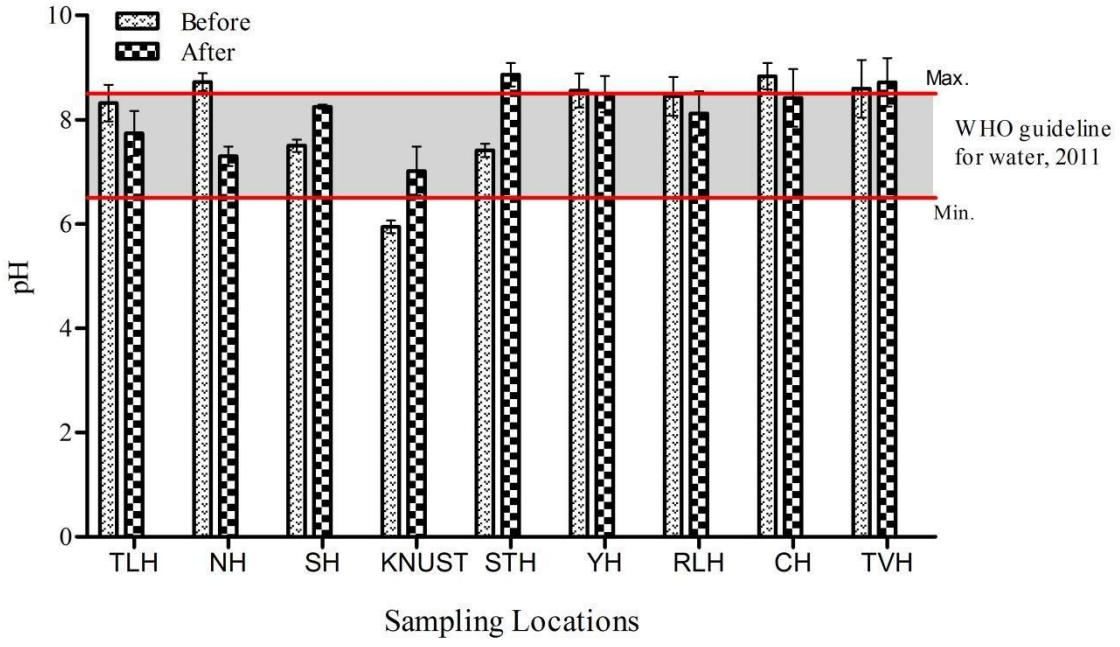


Fig. 4.1: Mean pH values for before and after swimming samples from the nine pools.

4.1.2 Temperature.

The mean temperature values for before swimming ranged from 26.90 ^{o}C to 29.49 ^{o}C (Fig 4.2). The highest mean value of 29.49 ^{0}C was recorded at RLH while the lowest value of 26.90 ^{0}C was recorded at TLH sampling location. For before swimming, the highest mean temperature value of 29.11 ^{0}C was recorded at SH, whilst the lowest mean value of 26.09 ^{0}C was recorded at NH. There were significant differences ($p<0.05$) in NH and STH for both before and after swimming samples. However, there was no significant difference in the other sampling locations (Appendix B).

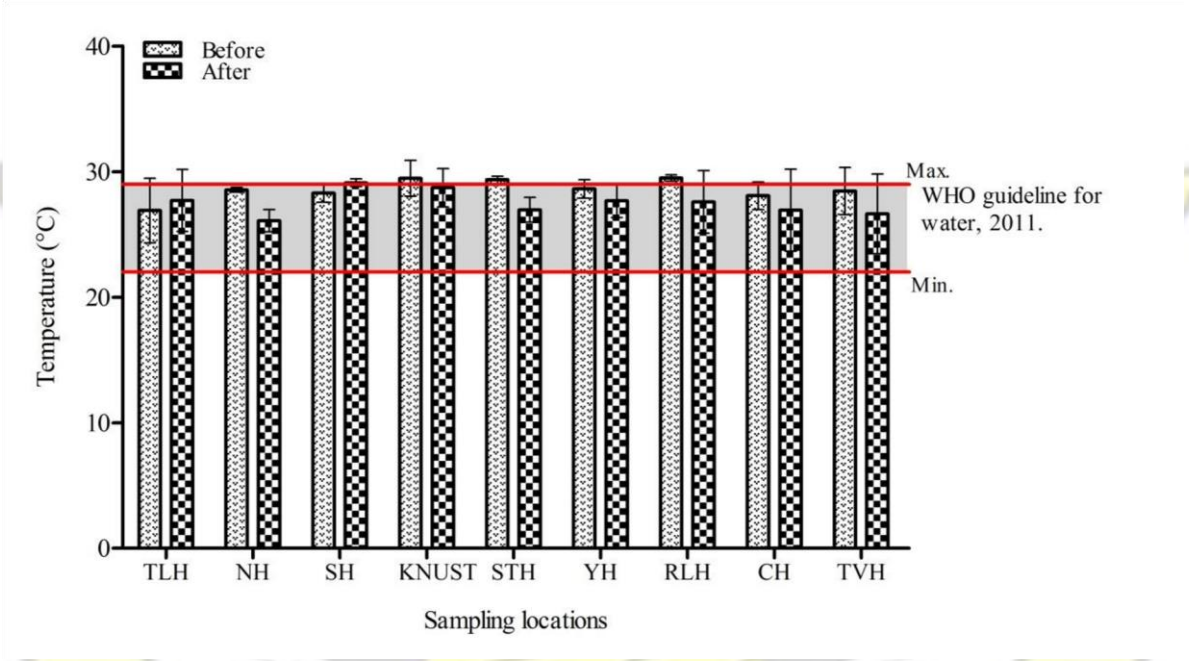


Fig 4.2: Temperatures levels for before and after swimming samples from all the pools under study.

4.1.3 Dissolved Oxygen

The mean dissolved oxygen values for both before and after swimming samples ranged from 2.88 mg/l to 7.57 mg/l and 4.03 mg/l to 9.72 mg/l, respectively. Before swimming,

KNUST recorded the highest mean value of 7.57 mg/l whilst TVH sampling location recorded the minimum mean value of 2.88 mg/l (Fig4.3). STH sampling location measured the maximum mean value of 9.72 mg/l for the after swimming whilst the minimum value of 4.03 mg/l was recorded at SH sampling location (Fig4.3). There were no significant differences ($p>0.05$) in DO for all the sampling locations except SH where statistical difference ($p=0.0008$) existed between before and after swimming samples (Appendix C).

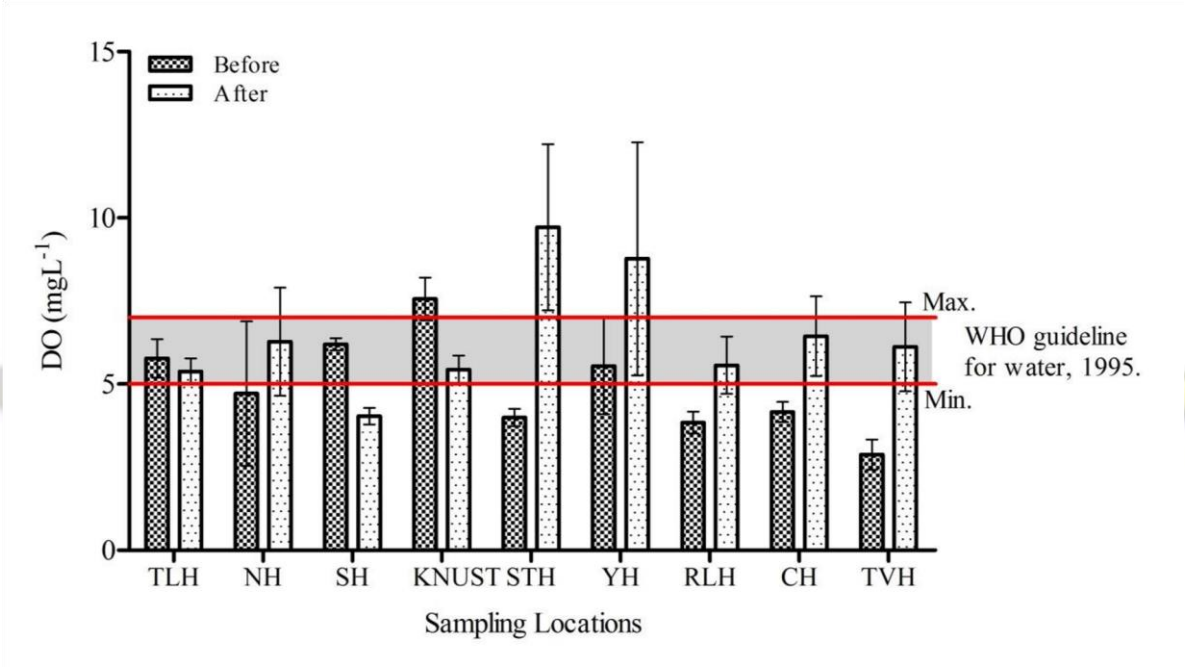


Fig 4.3: Dissolved oxygen levels for before and after swimming samples from the nine pools.

4.1.4 Conductivity

The conductivity levels recorded in both before and after swimming ranged from 155.8 µS/cm to 1027.0 µS/cm. KNUST recorded the highest mean conductivity value of 1027.0 µS/cm whereas the lowest value of 155.8 µS/cm was recorded at SH sampling location (Fig 4.4). However, the mean conductivity values for before swimming samples were high and varied between 230.2 µS/cm and 700.4 µS/cm. The highest mean value of 700.4 µS /cm was recorded at CH whilst the lowest mean value of 230.2 µS/cm was recorded at YH (Fig

4.4). However, the differences in conductivity levels between before and after swimming in these sampling locations: NH, SH, KNUST, STH, YH were

statistically significant ($p<0.05$) (Appendix D).

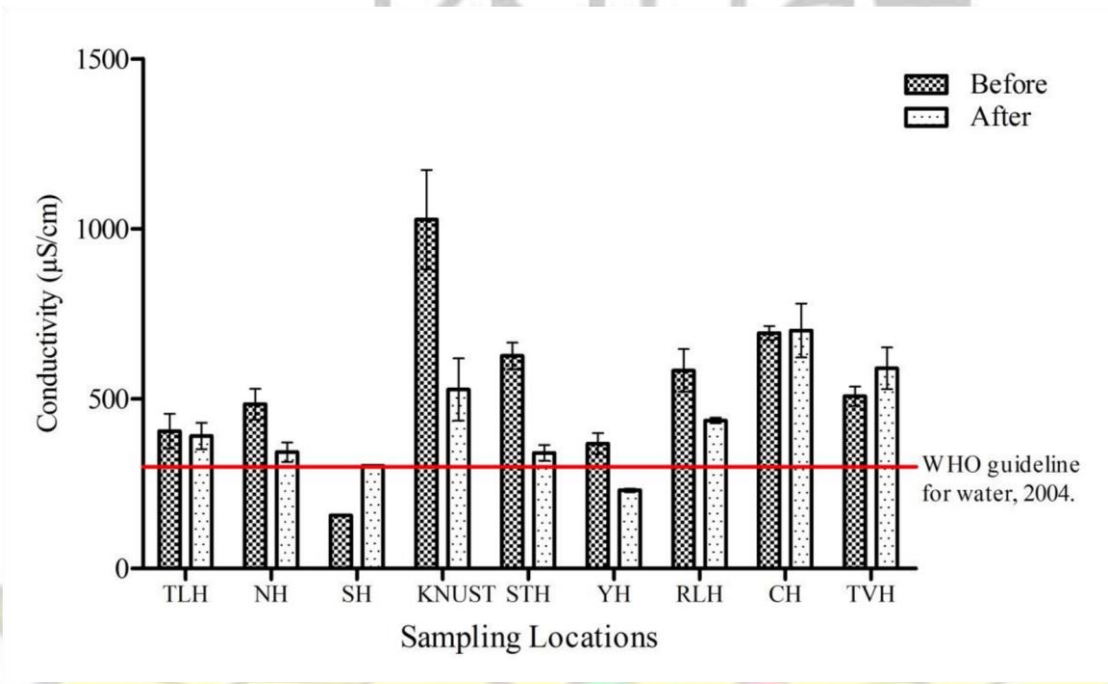


Fig. 4.4: Conductivity levels recorded in before and after swimming from all the sampling sites.

4.1.5 Total dissolved solids (TDS)

Total dissolved solids (TDS) in the before swimming samples recorded mean values ranging from 77.89 mg/l to 513.50 mg/l whilst the after swimming values ranged from 115.60 mg/l to 350.21 mg/l. Before swimming, the highest TDS mean value of 513.50 mg/l was recorded in KNUST sampling point, whilst the lowest mean value of 77.89 mg/l was recorded in SH (Fig. 4.5). With regards to the after swimming samples, CH recorded the highest TDS value of 350.21 mg/l whereas YH recorded the lowest value of 115.60 mg/l (Fig. 4.5). However, there was a significant difference ($p<0.05$) in TDS levels between

before and after swimming samples at NH, SH, KNUST, STH, YH sampling locations (Appendix E).

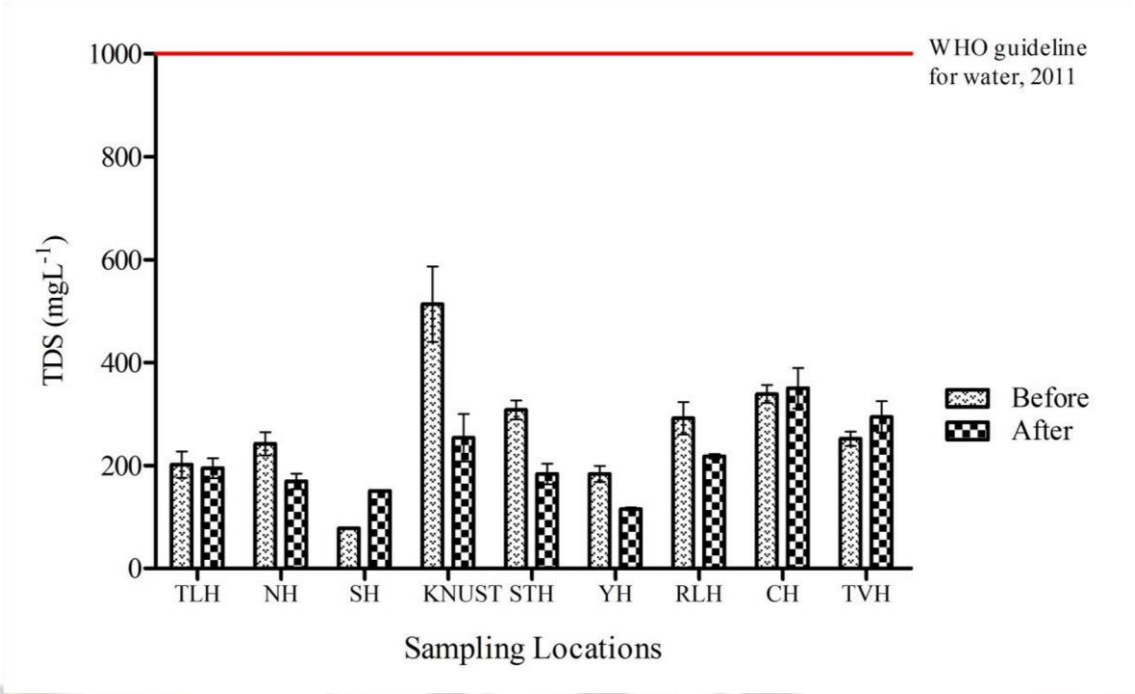


Fig. 4.5: The levels of total dissolved solids recorded in before and after swimming from all the nine pools.

4.1.6 Salinity

The mean salinity values of the before pool samples ranged from 0.13 to 0.52. KNUST sampling site recorded the highest mean salinity value of 0.52 and the lowest mean value of 0.13 also recorded at SH sampling site (Fig 4.6). However, the mean salinity values of the after swimming samples were low and varied between 0.11 and 0.35. The highest average value of 0.35 was recorded at CH whilst the lowest average value of 0.11 was recorded at the YH sampling point (Fig 4.6). Statistically, there was a significant difference ($p<0.05$) of salinity levels existing between before and after swimming pool samples at the following sampling locations: NH, KNUST, SH, YH, and CS (Appendix

F).

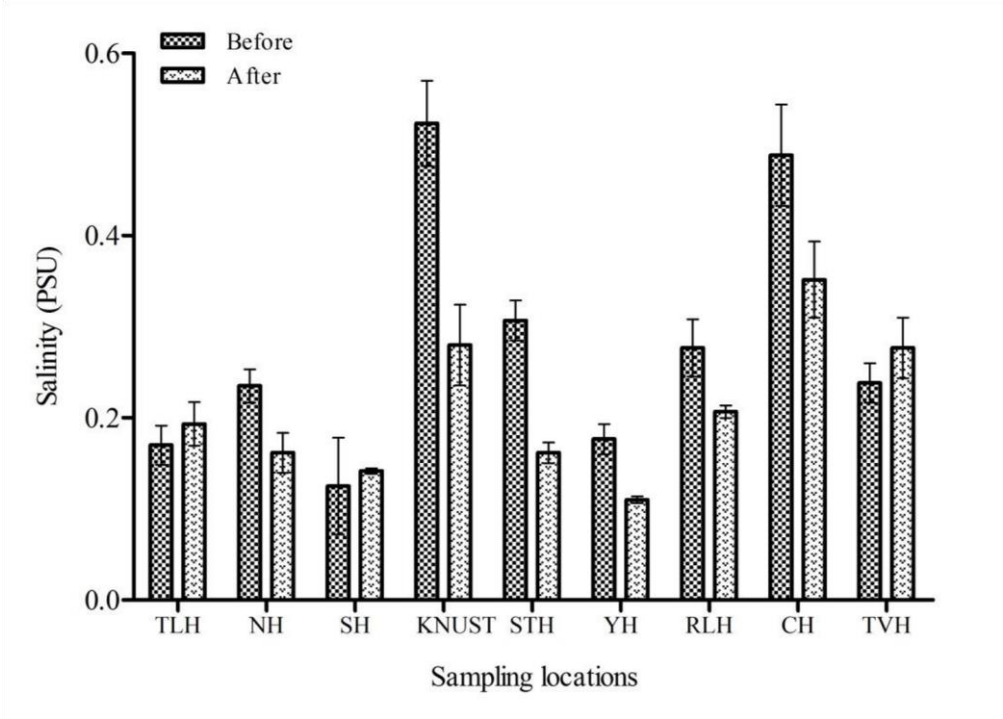


Fig 4.6: The salinity levels in before and after swimming water samples from the various pools under study.

4.1.7 Free Chlorine

The mean values of free chlorine recorded in the before swimming samples were very low and ranged from 0.15 mg/l to 2.17 mg/l. NH recorded the highest mean value (2.17 mg/l) and RLH recorded the lowest mean value (0.15 mg/l) (Fig 4.7). The after swimming samples recorded mean values of free chlorine between 0.10 mg/l and 0.83 mg/l. NH recorded the highest mean value of 0.83 mg/l whilst RLH recorded the lowest value of 0.10 mg/l (Fig. 4.7). However, there was a significant difference ($p<0.05$) in free chlorine levels between before and after swimming samples at NH, SH, KNUST,

STH, and TVH sampling points (Appendix G).

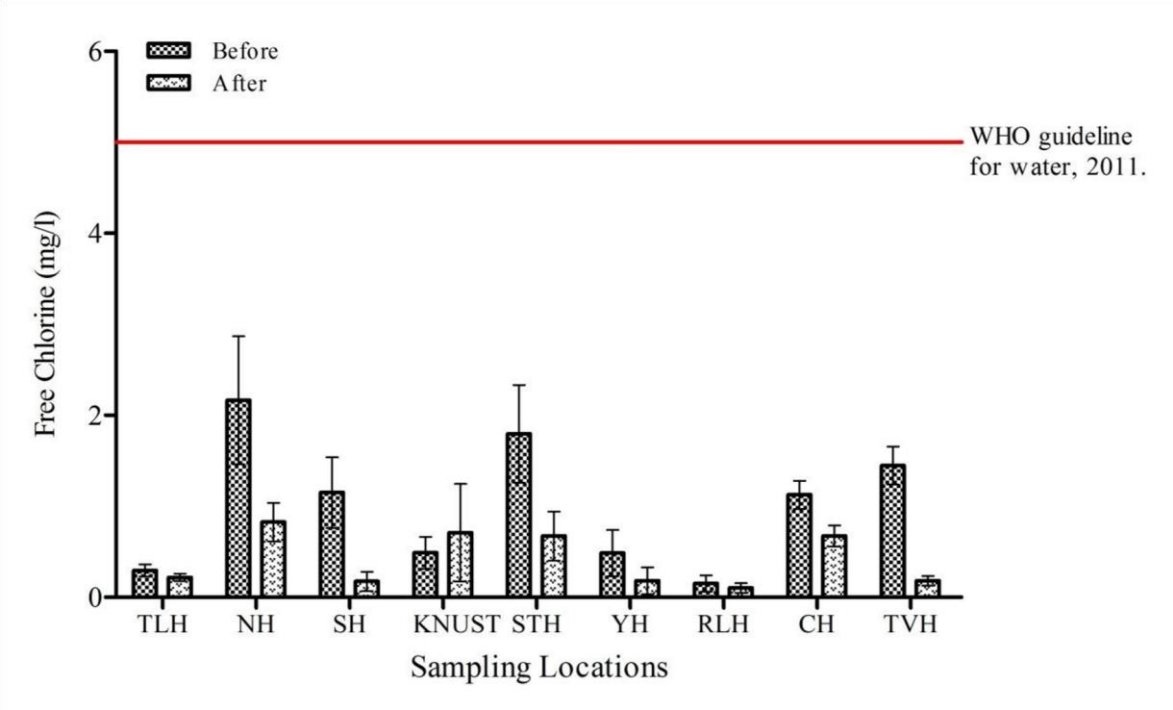


Fig. 4.7: The free chlorine levels recorded in the before and after swimming samples collected from the various swimming pools under study.

4.1.8 Colour

The mean colour values for before and after swimming samples ranged from 4.50 Pt/Co to 21.10 Pt/Co and 8.04 Pt/Co to 31.75 Pt/Co respectively. Before swimming, the highest mean value of 21.10 Pt/Co was recorded at TVH whilst the lowest value of 4.50 Pt/Co was recorded at SH sampling point (Fig 4.8). After swimming, the highest mean colour value of 31.75 Pt/Co was recorded at TVH sampling point and the lowest mean value of 8.04 Pt/Co was recorded at the STH sampling location (Fig 4.8). The differences in mean colour for both before and after swimming samples collected from the respective pools were statistically significant ($p<0.05$) expect YH (Appendix H).

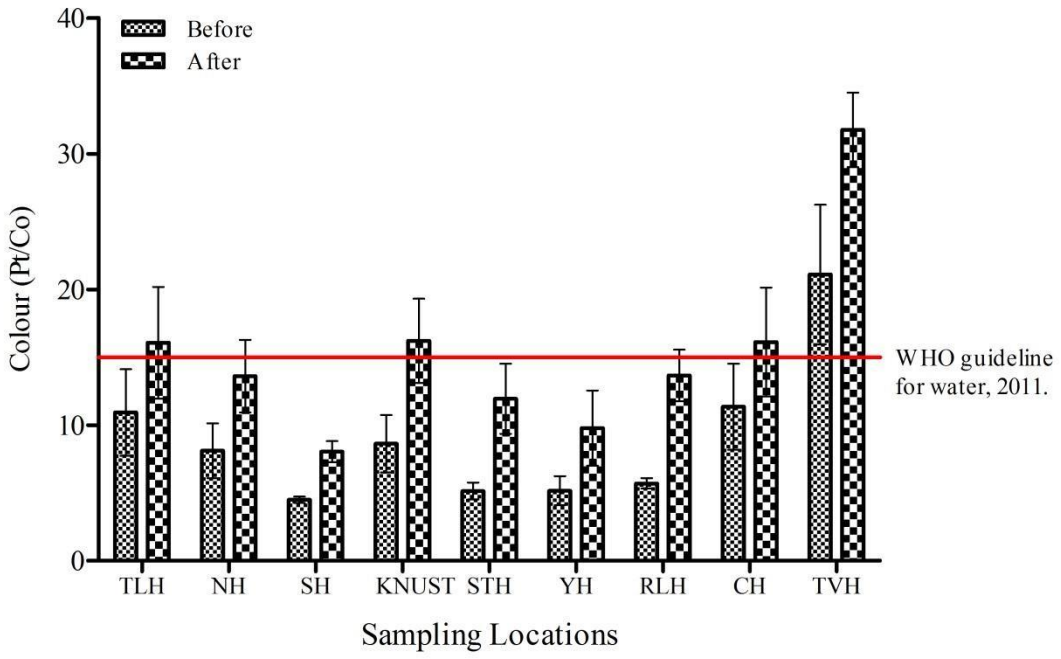


Fig. 4.8: The mean values of colour recorded in the before and after swimming samples collected from the various pools under study.

4.1.9 Turbidity

The mean values for turbidity determined in the before swimming samples ranged from 1.71 NTU to 4.56 NTU whilst the after swimming samples ranged from 3.34 NTU to 7.26 NTU. The highest mean value of 4.56 NTU for the before swimming samples was recorded at KNUST sampling location whilst the lowest mean value of 1.71 NTU was recorded at the RLH sampling point (Fig 4.9). After swimming, KNUST recorded the highest mean value of 7.26 NTU whilst YH recorded the lowest value of 3.34 NTU (Fig 4.9). There was a statistical difference ($p<0.05$) in turbidity levels between the before and after swimming samples for all the swimming pools (Appendix I).

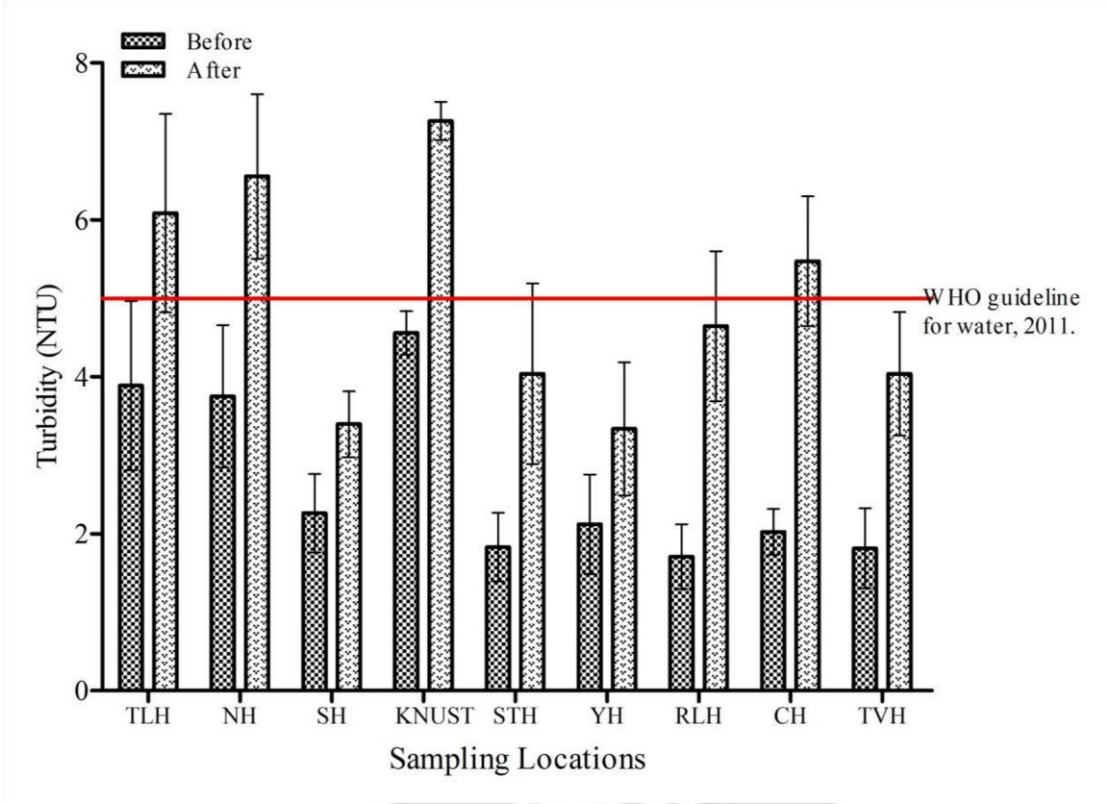


Fig. 4.9: The turbidity levels determined in the before and after swimming samples collected from the nine swimming pools.

4.2 Microbiological parameters of water samples from nine swimming pools

The microbiological parameters used to assess water quality in the nine different sampling locations were total coliforms, faecal coliforms, *E.coli*, *Giardia lamblia* and *Cryptosporidium.* The mean values for total coliforms, faecal coliforms, *E. coli*, *Giardia lamblia* and *Cryptosporidium* from the nine sampling locations are presented below.

4.2.1 Total coliforms

The total coliforms isolated in both before and after swimming samples ranged from 2.5×10^4 MPN/100 ml to1.65×10^5 MPN/100 ml and 3.88×10^4 MPN/100 ml to 1.21×10^6 MPN/100 ml, respectively. Before swimming, the highest total coliforms of 1.65×10^5 MPN /100 ml was recorded at TVH sampling location whilst the lowest mean value of 2.56×10^4

MPN/100ml was recorded at TLH sampling location (Fig 4.10). The CH sampling site recorded the highest value of 1.21×10^6 MPN/100 ml whilst NH recorded the lowest of 3.88×10^4 MPN/100 ml for after swimming. The differences in total coliforms count for before and after swimming samples collected from the respective pools were statistically significant ($p<0.05$) except KNUST and STH (appendix J).

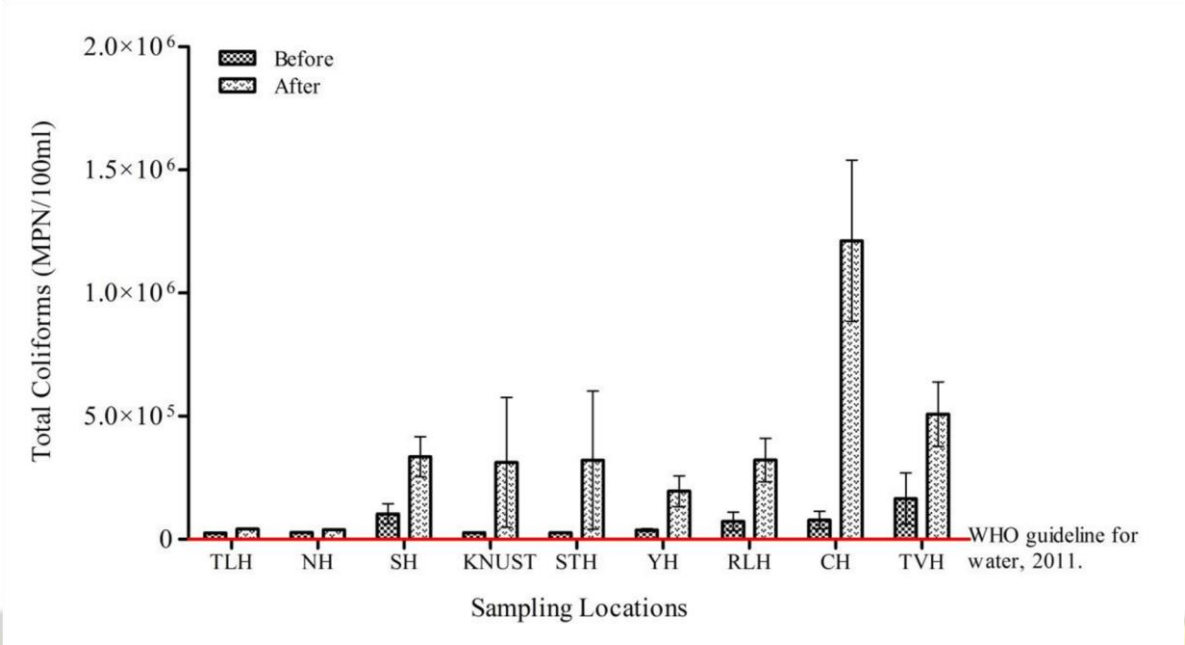


Fig.4.10: The total coliforms isolated in before and after swimming samples collected from the various nine pools under study.

4.2.2 Faecal coliforms

The faecal coliforms isolated in both before after swimming samples ranged from 1.35×10^4 MPN /100 ml to 1.55×10^5 MPN/100 ml. The highest faecal coliforms count of 1.55×10^5 MPN/100 ml was recorded at SH whereas STH recorded the lowest count of 1.35×10^4 MPN/100 ml for the before swimming samples (Fig 4.11). For the after swimming samples, the faecal coliforms counts were generally high and ranged from

1.66×10^4 MPN/100 ml to 1.85×10^5 MPN /100 ml. The highest value was recorded at SH and the lowest value at NH (Fig 4.11). The NH and YH recorded no count in the before samples, but recorded quiet high mean values of 1.66×10^4 MPN /100ml and 5.47×10^4 MPN /100ml in the after swimming samples.

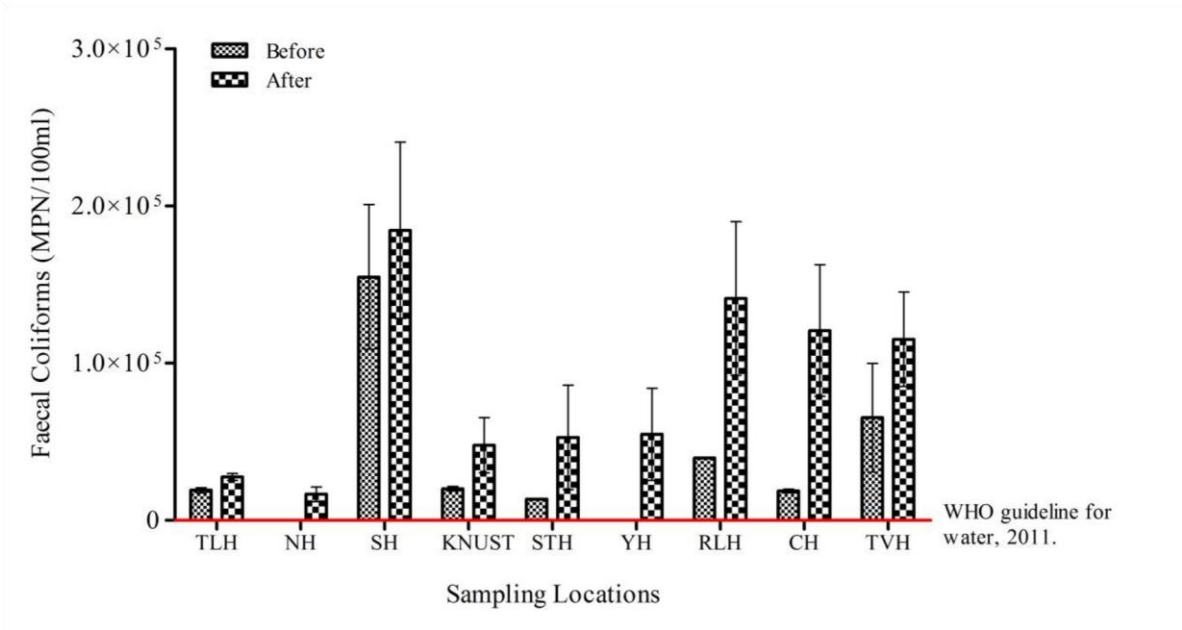


Fig. 4.11: The faecal coliforms counts isolated in before and after swimming samples collected from the nine pools.

4.2.3 *Escherichia coli (E.coli*)

Escherichia coli (E. coli) isolated in the before and after swimming samples varied from 0 MPN/100 ml to 3.03×10^4 MPN/100 ml. The highest count of 3.03×10^4 MPN/100ml was recorded in TLH sampling point followed by 1.94×10^4 MPN/100ml recorded in KNUST sampling location. All the other sampling locations, recorded 0 MPN/100ml.

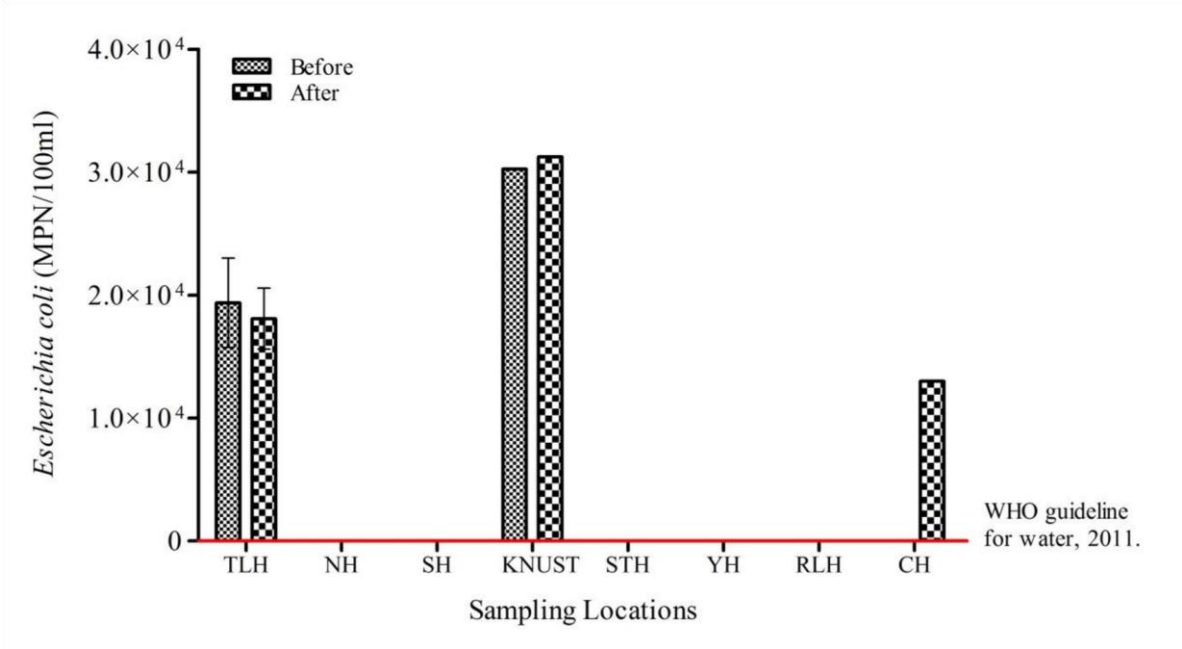


Fig 4.12: The *Escherichia coli (E.coli*) counts isolated in before and after swimming samples collected from the various nine swimming pools under study.

4.2.4 *Cryptosporidium*

All water samples collected before swimming did not contain any oocysts. However, the *Cryptosporidium* oocysts determined in the after swimming water samples ranged from 0/HPF to 3.29×10^{-6}/ HPF. The highest value of 3.29×10^{-6}/ HPF was recorded at KNUST and the lowest was recorded in NH, STH, YH and CH (Fig 4.13). There was a statistical different ($p<0.05$) in the oocysts count between the before and after swimming samples collected from the nine pools.

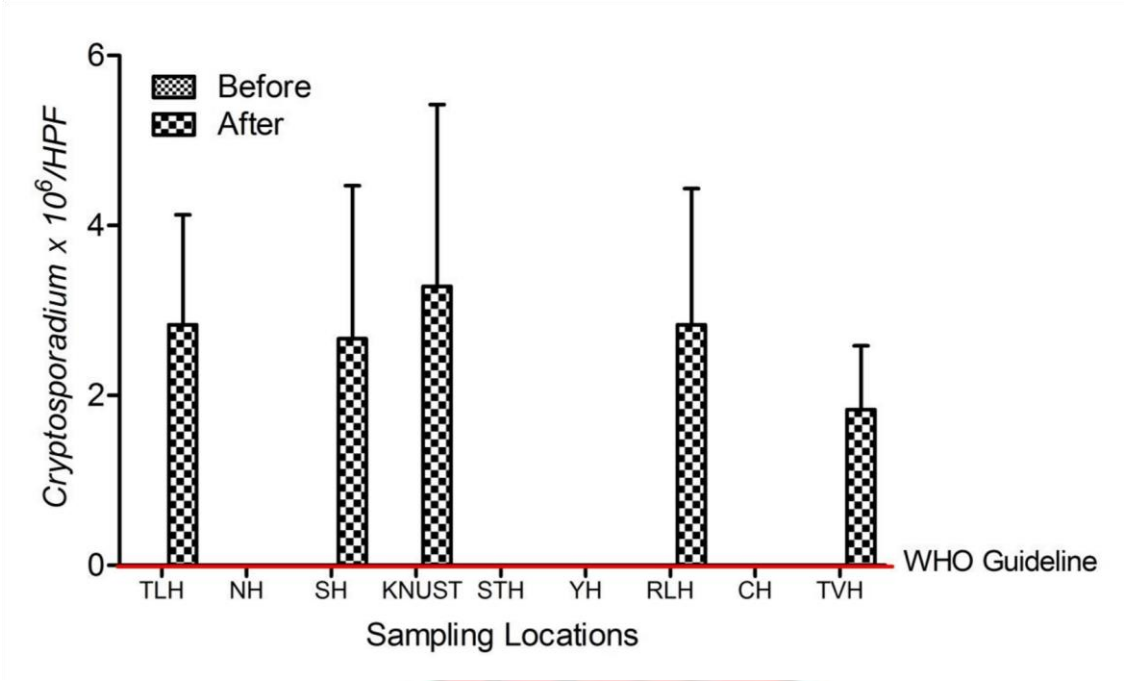


Fig 4.13: The *Cryptosporidium* oocyts counts in before and after swimming water samples collected from the nine swimming pools.

4.2.5 *Giardia*

All water samples collected before swimming did not contain any cysts. The *Giardia* cysts determined in the after swimming water samples ranged from 3.00/HPF to 8.93/HPF. The highest value of 8.93/HPF cysts count was recorded in TVH whilst the lowest, 3.00/HPF was recorded in STH (Fig 4.14). The differences in *Giardia* cysts count in the before and after swimming samples collected from the various nine pools under study were statistically significant ($p<0.05$).

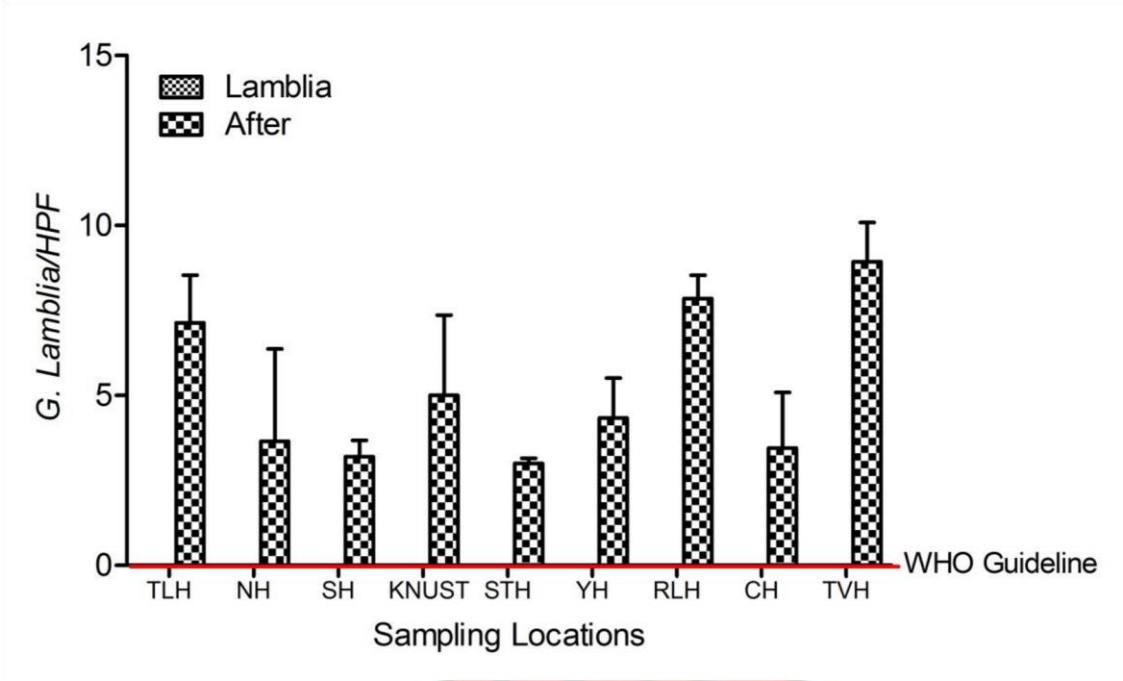


Fig 4.14: The *Giardia* cysts counts in before and after swimming water samples collected from the nine sampling sites.

Plate 2: Examining *cryptosporidium oocytes* and *Giardia cysts* under the microscope

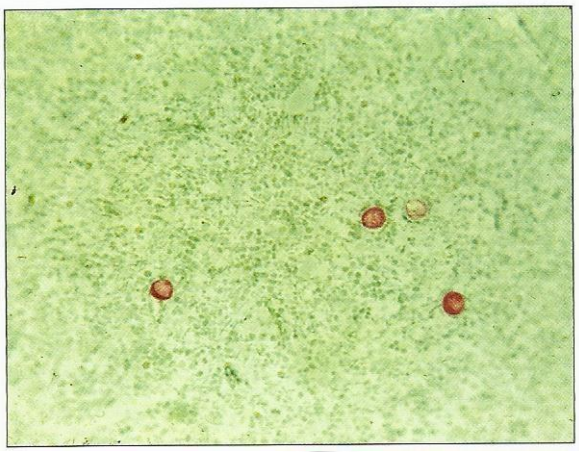


Plate 3: Pink-red stained *Cryptosporidium* oocyts in modified Ziehl-Neelsen stained smear.

4.3 Questionnaires Responses

Observations and interviews were employed to find out the perception of swimmers regarding the use of pools and possible sources of infection. A response rate of 96 % was recorded. From Table 1, 50 % of the swimmers perceived that some of the pool waters were clean while 40 % were satisfied with the general hygiene of the pool environment and 8% of the respondents responded neutral to the perception of the pool water being clean or not. It was also found that 42 % of the respondents experienced burning sensations of the eyes and 74 % of the swimmers swallowed some of the pool water during swimming. Also, 70 % of the respondents experienced body itching during and after using the pool and 18 % suffered from other forms of skin diseases. Data gathered indicated that 60 % of the pool users do not shower before and after swimming. From Table 1, 30 % of respondents indicated they spit in the pool while 22 % urinate in the pool. Furthermore, the study revealed that none of the swimmers disinfected the feet with liquid disinfectant before swimming.

Table 1: Summary of Questionnaire Responses

Variable	Number	Percent
A) Pool/Pool Area Cleanliness		
Perception of pool water being clean	25	50
Perception of pool environment being hygienic	20	40
No perception about the pool water being clean	4	8
B) Health Implications of Using Pool Water		
Burning sensation in the eye	21	42
Body itch	35	70
Skin diseases/infections	9	18
C) Observance of strict personal hygiene		
Showering before or after swimming	30	60
Swallowing pool water	37	74
Spitting in the pool water	15	30
Urinating in the pool water	11	22

CHAPTER FIVE

5.0 DISCUSSION

The physical and chemical compositions of the parameters studied from the nine swimming pools are discussed below.

5.1 Physico-chemical parameters

5.1.1 pH

The pH of water is an important parameter in swimming pools necessary for the efficient disinfection and coagulation, prevention of the pool fabric from damage and also ensuring the comfort of users (Thicket *et al*., 2002). The pH values recorded in four sampling

locations before use were far above the WHO (2011) permissible range of 6.25-8.5 for drinking water. Although the values indicated that the pool water samples were slightly basic, they were in agreement with what had been reported in similar studies (Edimeh *et al.*, 2011; Aremu *et al.*, 2011). This could be as a result of excessive addition of sodium hypochlorite for chlorination or sodium carbonate (soda ash) added to correct the pH, when the pool water was acidic (WHO, 2006). However, the lowest pH value of 5.94 observed at KNUST sampling location in this study was probably due to excessive addition of sodium hydrogen sulphate, carbon dioxide or hydrochloric acid solutions for pH correction.

The after use pool samples were within WHO (2011) accepted range of 6.5-8.5 except SH and TV which recorded mean values of 8.86 and 8.72 respectively. This may be due to increase in ammonia in the pool as a result of bathers urinating in the pool (Beech *et al.*, 1980). This is in agreement with the work done by Adrian *et al.* (1984) who recorded that 37% of swimming pools in South Australian had pH above the recommended level.

Higher pH drastically reduces the sanitizing power of chlorine due to reduced oxidation-reduction potential (ORP) and it's also an indication that the pool had high levels of HOCl and therefore cleaning can take much longer than normal. Low pH in a swimming pool facilitates the formation of chlorates and this when ingested by swimmers forms methemoglobin. Again, low pH in pools causes irritations of the eye and skin as well as being responsible for the itching of the body of some pool users (Beech *et al.*, 1980).

5.1.2 Temperature

Season time of the day, cloud cover, air circulation, latitude, altitude and the depth of the pool has effect on the temperature of swimming pool water. In effect, temperature affects physical, chemical and biological processes in the pool water. As temperature increases, the rate of chemical reactions generally increases together with the evaporation and volatilization of substances from the water (Chapman, 1996). The mean temperature values obtained for before swimming samples were generally high with RLH recording the highest

value of 29.49 ^{0}C which was slightly above the WHO (2011) guidelines of 22 ^{0}C- 29 ^{0}C. The higher values of temperature observed in the study could be attributed to the period of investigation - dry season. Also, temperature could be affected by the weather due to the different times of sampling from the pools (Fritz, 2001). The values reported for after swimming were within the recommended range of 22 ^{0}C - 29 ^{0}C by WHO (2011). This conforms to results of various studies by Edimeh *et al.* (2011), Manilla and Frank (2009) and Clarke *et al.* (2004).

Temperature increases encourage bacteria growth and influences swimming pool water contamination directly through microbial growth increases. This study was consistent with other studies done by Leoni *et al.* (2001), Leoni *et al*. (1999) and Martinys *et al*.

(1995).

5.1.3 Dissolved oxygen

The concentrations of dissolved oxygen (DO) have a vital influence on marine life and is vulnerable to insignificant environmental variations. High respiration activity in a water body often results in oxygen depletion. DO is therefore used broadly as a delineating factor for the quality of water and is also used to assess the level of swimming pool water freshness (Fakayode, 2005). Again, DO is a vital limnological parameter specifying of quality and the extent of biological contamination in the water body (Wetzel and Likens, 2006).

Dissolved Oxygen (DO) values were generally lower for the treated water samples than samples after swimming. The lowest mean value of 2.88 mg/l was observed at TVH before swimming and 56 % of the mean values of the treated samples were below the WHO (1995)

permissible limit of 5 mg/l-7 mg/l. The low dissolved oxygen content could be attributed to warmer temperatures. Warmer temperatures decrease oxygen solubility in water while at the same time increases metabolic rates that affect sediment oxygen demand, nitrification, photosynthesis, and respiration (Fakayode, 2005). For the after swimming samples, the highest mean value of 9.72 mg/l was recorded at STH. In these water samples, about 22 % of the mean values were above the WHO (1995) permissible limits of 5 mg/l-7 mg/l for drinking water. The high levels of DO recorded in the after swimming samples could be due to temperature and biological activities occurring in the swimming pool water (Chapman and Kimstach, 1992).

5.1.4 Conductivity

Conductivity gives a degree of the capacity of water to conduct an electric current; the greater the content of ions in the water, the more current the water can carry (Dharmappa *et al*., 2000). It is correlated to total solids and therefore a good and rapid method to measure the total dissolved ions in water body. This implies that, the value of dissolved solids is directly proportional to the amount of ions in the water (Bhatt *et al*., 1999).

All the conductivity mean values recorded during the study for before and after swimming samples were above the WHO guideline of 300 µS/cm for drinking water except for the SH and YH. Mean values of 155.8 µS/cm and 230.2 µS/cm were recorded for SH and YH, respectively, which were below the WHO guideline. High conductivity in all the sampling locations could be related to the high concentrations of dissolved ions in the swimming pools since the source of swimming pool water is ground water with dissolved salts. These could be attributed to differences in geochemical conditions and soluble ions in the locations analysed (Dharmappa *et al*., 2000). The low conductivity means recorded in the

two swimming pools indicated contaminations due to dissolved ions in the pools. This study was similar to studies done by Marshall and Winterbourn (1979).

5.1.5 Total Dissolved Solids (TDS)

The total dissolved solids (TDS) determine the biological matter, mineral salts, and other suspended materials in pools (EPA, 1991). Total dissolved solids (TDS) levels in swimming pools increases with the pollution of sweat and urine, overloading and lack of dilution (EPA, 1991).

The mean values of total dissolved solids (TDS) recorded for both before and after swimming samples were within the acceptable range of 1000 mg/l recommended by WHO for drinking water. However, before swimming samples were generally higher than after swimming samples and this may be due to the presence of inorganic salts and other dissolved materials in the pool (EPA, 1991). The values in this study differ from that reported by Aremu *et al.*, (2011).

5.1.6 Salinity

Salinity is an indication of the concentrations of dissolved salts in water. The ions responsible for salinity include the major cations: calcium, magnesium, sodium, and potassium and the major anions: carbonates, bicarbonates, sulphate and chloride. The increase in concentration of any of the cations or anions would increase salinity level that is recommended by WHO for drinking water (Bhatt *et al*., 1999). Mean values recorded for both before and after swimming samples were generally low. However, the mean values determined in before swimming samples were higher than that recorded for after swimming

samples. This may be due to the presence of dissolved salts in the swimming pools since most of the source water is from well water (Magit, 2002)

5.1.7 Free Chlorine

Free Chlorine is the most common disinfectant used for disinfecting the swimming pool against cross bather infections. Chlorine may be supplied to the pool water in a variety of forms including chlorine gas (Cl_2), sodium hypochlorite solution (NaOCl) or calcium hypochlorite (Sule *et al.*, 2010). The free Chlorine levels recorded in before swimming samples were higher than the values recorded in after swimming samples. This could be as a result of formation of chloramines in the after swimming samples. Chlorine reacts rapidly with urea, ammonia, and other nitrogen containing wastes such as sweat and urine introduced by bathers into the water, thus forming chloramines (monochloramine, dichloramine and nitrogen trichloride). Urea hydrolysis result in the release of more ammonia in the water and nitrogen containing amino acids undergo chemical reactions with hypochlorite producing organic chloramines which causes eye irritation and high chlorine odour (Isaak and Morris, 1980).

Nitrogen trichloride is a pungent-smelling chemical which causes extreme discomfort to bathers and spectators (Thickett *et al.*, 2002). This confirmed what was recorded in the questionnaire, in which 70% of all swimmers suffered from eye irritation after swimming. The low mean free Chlorine levels may also be related to high cyanuric acid formed when isocyanurate compounds are added to the pool water to prevent the breakdown of chlorine easily by UV light. Cyanuric acid in chlorinated pools reduces the amount of free chlorine in the swimming pools resulting in poor disinfection which leads to contaminations in the swimming pools (Wright *et al*., 2003).

5.1.8 Colour

Colour in water may be attributed to human activities, peat, plankton, vegetation and natural metallic ions. Colour in swimming pools may originate from decomposition of organic matter and other contaminants of different materials in varying concentrations. Colour interferes with penetration of light in the pool and may also hamper oxygen absorption from the atmosphere (Walakira, 2011).

All the mean values obtained for the samples before swimming were within the WHO (2011) guideline for drinking water of 15 Pt/Co except CH sampling location which observed a mean value of 21.10 Pt/Co. This may be principally due to organic matter and other colloidal suspended materials in the pool (Craun *et al.,* 2002). The mean values recorded for after swimming samples were generally high in all the nine pools. The TLH, KNUST, RLH, CH and TVH recorded mean values of 16.06 Pt/Co, 16.21 Pt/Co, 16.11 Pt/Co and 31.75 Pt/Co, respectively, which were above the WHO guideline of 15 Pt/Co. These could be attributed to contaminants from bathers in the pool (Sule *et al.,* 2010).

5.1.9 Turbidity

The turbidity of water depends on the quantity of organic and inorganic solid matter present in the suspended state and measures the light-emitting properties of water (Durance, 2009). Turbidity test is used to indicate the quality of waste discharge with respect to colloidal matter depending on the source of water for the swimming pool and the activities of human in the pool water (Craun *et al.,* 2002).

The mean values observed for before swimming samples were lower than after swimming samples. All the mean values obtained in the before swimming samples were low except

TLH, NH and KNUST which recorded mean values of 3.89 NTU, 3.75 NTU, and 4.56 NTU, respectively, were within the WHO (2011) guideline of 5 NTU for drinking water. While, the values obtained for after swimming samples were higher than the WHO (2011) guideline for drinking water with the highest recorded value of 7.26 NTU occurring at KNUST sampling location. This may be attributed to the organic matter and colloidal matter discharged from bathers during swimming since majority of swimmers do not shower before swimming as revealed in the questionnaire. This study is similar to a work done by Lamb (1985) which also recorded high turbidity values. The greater the turbidity of the swimming pool water, the higher the risk of gastro-intestinal diseases (Eric and Catherine, 1997).

5.2. Total coliforms (TC), faecal coliforms (FC) and *Escherichia coli (E coli)*

Coliforms originate most often in the intestinal tract of warm blooded animals, including humans. The routs of entry into the human body by pathogens include the skin and more commonly by the ingestion of drinking water and water from swimming pools (Chapra, 1997). Swimming pools with significant numbers of coliforms is a strong indication that there is deficiency in the treatment of the pool water or the source of raw water is inadequately protected (Borchardt and Walton, 1971). The mean values of TC and FC recorded in the nine sampling locations were generally high. Both before and after swimming water samples recorded high values of TC and FC. The mean values for TC and FC were above the recommended value of zero for WHO (2011) guideline for drinking water.

Escherichia coli, a human pathogen, was encountered in three swimming pools (TLH and KNUST and CH). This was probably due to faecal contamination by cold-blooded and warm-blooded organisms. Studies by Stanier *et al.* (1987) and also by Carbell *et al.*

(1975) showed that, swimmers usually contribute *Escherichia coli* species in the pools. Robinton and Mood (1986) suggested similar occurrence in a report on quantitative and qualitative appraisal of microbial pollution of water by swimmers. However, Bonde (1985) and Itah *et al.* (1996) indicated that the presence of *E. coli* in water strongly suggests that the source of pollution is close or near to the sampling site. The presence of *E. coli*, an indicator bacteria, amply suggests the possible presence of enteric and pathogenic bacteria in the swimming pool water. The occurrence of this condition may constitute a health hazard to the public since pool bathers may accidentally ingest contaminated water from pools in the course of swimming in which case outbreak of cholera, typhoid and gastroenteritis and diarrhoea is the result (Itah *et al.,* 1996; Okafor, 1985). The occurrence of *E. coli* in pools also indicates poor pool management and lack of thorough disinfection of the pool and insufficient or lack of safeguarding measures of the raw water source (Barrell *et al.,* 2000). This is probably due to the fact that the pipes used for water distribution from the source to the pools were rusty thus allowing seepage of microbial contaminants in the pools (Borchardt and Walton, 1971). *Escherichia coli* when ingested into the body system produces enterotoxin, and as result poses a risk to public health when present since they are usually ingested with water by active pool swimmers (Anozie and Antai, 1987; Itah, 1999).

Some of the pools considered in the study recorded high levels of *Escherichia coli* and coliforms that do not meet the recommended levels set by the WHO for swimming pools (WHO, 2011). This is because according to Edberg *et al.,* (2000), water sample from swimming pools should not have any organism of coliforms in a 100 ml of water since most swimmers swallow some of the pool water.

5.3 *Cryptosporidium and Giardia*

Cryptosporidium and *Giardia* are pathogenic protozoan parasites that cause gastroenteritis in humans. Infections of *Giardia* may be asymptomatic but infections may be severe and life- threatening in immunocompromised persons (Arrowood, 1997).

The detection of *Cryptosporidium* oocysts and *Giardia* cysts in swimming pools has great public health significance and implications. In this study, the results obtained for after swimming samples showed that *Cryptosporidium* oocysts were detected in five (56 %) out of the nine swimming pools and *Giardia* cysts (100 %) were consistently recorded in all the nine swimming pools. *Cryptosporidium* and *Giardia* were absent from the before swimming samples for all nine swimming pools and this confirmed similar research works carried out in some other countries (Horman *et al*., 2004; RimhanenFinne *et al*., 2004; Briancesco and Bonadonna, 2005). The infectious dose in humans of Cryptosporidium is estimated to be 30 oocysts and *Giardia* 10 cysts (DuPont *et al*., 1995 and Adam, 2001). The presence of both protozoans in all the swimming pools may be attributed to insufficient protection of the untreated water source (Borchardt and Walton, 1971). Although the oocysts and cysts viability were not determined or assessed under this research, the situation poses a potential risk for waterborne infection to public health.

5.4 Questionnaires Responses

Observations and interviews were employed to find out the perception of swimmers regarding the use of pools and possible sources of infection. In pursuit of this, responses from the respondents indicated most bathers refused to bath or shower before swimming and this increases the organic matter and the colloidal matter in the pool. This causes the turbidity of the pool to increase. Hence the greater the turbidity of the pool water, the higher the risk of gastro- intestinal diseases (Eric and Catherine, 1997).

Also from the questionnaire responses, bathers discharge urine and saliva into the pool, which introduce pathogens into the pool and increasing the pools microbial load. Urine, sweat, nitrogen containing organic compound, react with the hypochlorite in the pool water to form organic chloramines (Isaak and Morris, 1980). This causes eye irritation and high chlorine odour as revealed in the questionnaire responses.

CHAPTER SIX

6.0 CONCLUSIONS AND RECOMMENDATIONS

6.1 Conclusion

Results of the study revealed that most of the physicochemical parameters studied were not within the guidelines set by the WHO (2011) for drinking water, except for a few swimming pools (STH, SH, NH) where some of these indicators fall within the required limits. The samples collected before swimming performed better in most of the indicators measured than after swimming samples. Generally, conductivity was high in all the swimming pools for both before and after swimming samples. The concentrations of free chlorine for all the swimming pools were generally low, even though the concentrations of free chlorine for before swimming samples were higher than after swimming samples.

The levels of FC and TC in both before and after swimming samples were generally high. *Escherichia coli,* was encountered in three swimming pools (TLH, KNUST and CH). *Cryptosporidium* oocyts and *Giardia* cysts were detected in most of the swimming pools *(Cryptosporidium* oocyts were detected in five (56 %) out of the nine swimming pools and *Giardia* cysts in all nine swimming pools studied (100 %).

In conclusion, the results of this study indicated that most of the swimming pools studied did not meet the WHO (2011) guidelines for drinking water. This can lead to serious hazard to the health of the public from a bacteriological and parasitological perspectives since *Cryptosporidium* oocysts and *Giardia* cysts present in swimming pools pose health risk as swimmers accidentally swallow some of the pool water.

6.2 Recommendations

The following recommendations are made based on the outcome of this study:

i. Swimming pools operators should use the required disinfection regime allowed rather than super-chlorination and the disinfectant should be thoroughly mixed in the pools. Stringent and modern inspection procedures must be adopted by the Ministry of Health and used to monitor pool water treatment especially during the weekends and public holidays when the pools are most heavily patronised.

ii. Continuous monitoring of swimming pools for water quality indicators, (pH, temperature, conductivity, turbidity) especially when the number of users increases to 20 or more in the pool.

iii. Maintenance of parasitological - safe swimming pool water can be done though regular inspection of the condition of the swimming pool filters and continuous checking of the effectiveness of the filtration process.

iv. Poster signs should be enforced in every swimming pool to educate and enlighten swimmers about good sanitary habits since some of the pools did not have these signs posted at the pool side.

v. Health authorities should regularly monitor the pools for compliance with regulations and also swimmers must be encouraged to shower and disinfect their foot before swimming to minimize soil contamination since most people do not shower or wash their feet before swimming.

vi. Finally, swimmers should be cautioned about swimming in pools if they are suffering from gastroenteritis or other diseases. Also, the viability and quantification of the oocysts and cysts should be done.

REFERENCES

Adam, R. D. (2001). Biology of *Giardia lamblia*. *Clinical Microbiological Review* 14: 447–475

Adrian E., David M. R., Cameron A. S., Robinson B. S., Reginald P. W., Jane A. L. and Peter E. C. (1984). Determinants of Microbiological Characteristics of South Australian Swimming pools. *Journal of Applied and Evironmental Microbiology.* 47 (2): 325-328

Alcock, S.R. (1977). Acute otitis external in divers working in the North Sea. A Microbiological survey of seven saturation divers. *Journal of Hygiene*; 18: 359409

Alice, L. S. (1977). Principles of Microbiology. *London: CV Mosby;* 8 (8): 661-710 Retrieved from *http://www.ijastnet.com/journals/Vol_2* [accessed 2013 November 27]

Alico, R. K. and Dragonjac, M. F. (2006). Evaluation of culture media for recovery of Staphylococcus aureus from swimming pools. *Applied Environmental Microbiology*.51:699-702. Retrieved from *www.ajol.info/index. php/ajest/ article/download/110340/100078* [accessed 2013 November 14]

Allen, L. M., Briggle, T. V. and Pfaffenberger, C. D. (1982). Absorption and excretion of cyanuric acid in long-distance swimmers. *Drug Metabolism*; 13 (3): 499–516

American Public Health Association [APHA], (2005). Standard Methods for Examination of Water and Waste Water. New York, 20th Edition. Washington DC. USA. Pp. 1268

Anozie, S. O. and Antai, S. P. (1987). Incidence of infantile diarrhea due to enteropathogenic *E. coli* in Port Harcourt Metropolis. *Nigerian Journal of Microbiology*; 7: 66-70

Aremu, M. O. Olaofe, Ikokoh, P. P. and Yakubu, M. M. (2011). Physicochemical characteristics of stream, well and borehole water sources in Eggon, Nasarawa State, Nigeria. *Journal of Chemical Society of Nigeria*; *36 (1)*: 131-136

Arrowood, M. J. (1997). Diagnosis in *Cryptosporidium and cryptosporidiosis*, (ed). Fayer, R. CRC Press, Boca Raton, Florida. Pp 4364. Retrieved from *http://www.ncbi.nlm.nih.gov/pmc/articles/PMC3793167/* [Accessed 2013 January, 15]

Barrell, R. A. E., Hunter, P. R. and Nichols, G. (2000). Microbiological standards for water and their relationship to health risk. *Commun Dis Public Health;* (3): 813

Beech, A. J., Diaz, R., Ordaz, C. and Palomeque, B. (1980). Nitrates, chlorates and trihalomethanes in swimming pool water. *America Journal Public Health*; 70:1

Bergey, D. H. and Holt, J. G. (1994). Bergey's Manual of Determinative Bacteriology. 9th ed. Publisher: Williams and Wilkins; Baltimore. Pp 115-117

Bhatt, L. R., Lacoul, P., Lekhak, H. D. and Jha, P. K. (1999). Physicochemical characteristics and phytoplankton of Taudaha Lake, Kathmandu Poll. *Res*. 18(14): 353-358

Blanch, A. R., Galofre, B., Lucena, F., Terra-dillos, A., Vilanova, X. and Ribis, F. (2007). Characterization of bacterial coliform occurrence in different zones of a drinking water distribution system. *Journal of Microbiology*. 102:711-721

Brenner R. (2005). Swimming lessons, swimming ability and the risk of drowning: Handbook on drowning. Prevention, rescue and treatment. Pp 12 -21.
Retrieved from *http://www.who.int/water_sanita tion_health/bathing/ srwe2chap 2.pdf* [Accessed July 14, 2012]

Bonde, G. J. (1985). Bacteriological methods of estimation of water pollution. Public Health Laboratory Services, New York. 15: 124-8

Borchardt J. A. and Walton G. (1971). Water quality and treatment: A handbook of public water supply. American Water Works Association. 1-52. Retrieved from *http://www.ijastnet.com/journals/Vol_2_No_8_October_2012/11.pdf* [Accessed December 12, 2014]

Briancesco, R. and Bonadonna, L. (2005). An Italian study of *Cryptosporidium* and *Giardia* in wastewater, fresh water and treated water. *Environmental Monitoring Assessment* 104: 445–457

Bushon, R. N. and Francy, D. S. (2003). Protozoan pathogens: National Field Manual for the Collection of Water-Quality Data. U.S. Geological Survey Techniques of Water-Resources Investigations. Book 9-A7 (third edition). Pp. 3-10.
Retrieved from http://pubs.water.usgs.gov/twri9A/. [Accessed November 15, 2015]

Cabelli, V. J. (2003). Swimming-associated illness and recreational water quality criteria. *War. Science Technology* 21: 13-21

Cairncross, S. C., Curtis, D. G., Feahem, R. L. and Bradley, G. H. (2000). Evaluation for village water supply planning. Chichester: *John Wiley and Sons*. 55-220

Cairns J. J. and Dickson, K. L. (2003). Biological methods for the assessment of water quality. *American Water Works Association Bulletin*; pp. 5-13

Calderon, R. L. and Craun, M. F. (2005). Outbreaks associated with recreational water in the United States. *International Journal of Environmental Health Resources*; 15 (4): 62-243

Calvert, J. and Storey, A. (1988). Microorganisms in swimming pools. Are you looking for the right one? *Journal of the Institution of Environmental Health Officers*. 96(7): 12

Carbell, U. J., Levin, M. A., Dufour A and McCabel, J. (1975). The development of criteria for recreational water. Progress in water technology. London. International Symposium on Discharge of Sewage from Sea Outfalls. Pp.37-47

CDC (2001). Prevalence of parasites in faecal material from Chlorinated swimming pools, United States. *Morbidity and Mortality Weekly Report*. 50: 410–412

Chapman, D. (1996). Water quality assessment, a guide to the use of biota, sediment and water in environmental monitoring, Second edition, Publication by E & FN Spon, Printed by University Press, Cambridge, UK. ISBN 0419215905 (HB)

Chapman, D. and Kimstach, V. (1992). Selection of water quality variables in water Assessment UNESCO, WHO and UNEP. 59-126

Chapra, S. C. (1997). Surface Water-Quality Modeling. McGraw- Hill Series in Water Resources and Environmental Engineering Inc., McGraw- Hill Companies, New York, USA. Pp. 844-846

Cheesbrough, M. (2007). District Laboratory Practice in Tropical Countries. Cambridge, 2nd Edition Vol 1. Washington DC USA.

Chu, H. and Nieuwenhuijsen, M. (2002). Distribution and determinants of trihalomethane concentrations in indoor swimming pools. *Occupational and Environmental Medicine.* 59: 243-247

Clarke, E. O., Anetekhai, M. A., Akin-Oriola, G. A., Onanuga, A. I. S., Olaninmoye, O. M., Adaboyejo, O. A. and Agboola, I. (2004). The Diatom (Bacillariophyta) diversity of an open access lagoon in Lagos, Nigeria. *Journal Research and Review in Science*. *3:*70-77

Collins, C. H., Grange, J. M. and Yates M. D. (1984). A review: Mycobacterium in water. *Journal of Applied Bacteriology*, 57(2): 193–211

CPSC (2004). *Spas, hot tubs, and whirlpools*. Washington, DC, United States Consumer Product Safety Commission. Retrieved from http://www.cpsc.gov/cpscpub /pubs/5 112.html, [Accessed, November 15, 2013]

Craun, G. F., Nwachuku, N., Calderon, R. L. and Craun, M. F. (2002). Outbreaks in drinking-water systems. *Journal of Environmental Health* 65: 16–23

Cruickshank, R., Duguid, J. P., Marmion, B. P. and Swain, R. H. A. (1975). Medical microbiology: A guide to laboratory diagnosis and control of infections. 12th ed. Vol 1. Edinburgh. Churchhill Livingstone: p 585

Dharmappa, H. B., Wingroove, K., Sivakuma, M. and Singh, R. (2000). Wastewater and Stromwater minimization in a cool mine. *Journal of Cleaner Production* 8: 2334

Dufour, A. P., Evans, O., Behymer, T. D. and Cantu, R. (2006). Water ingestion during swimming activities in a pool: A pilot study. *Journal of Water and Health* 4: 425-430 Retrieved from http://iesp.uic.edu/Publications/Faculty% 20 Publications/ Dorevitch/ Dorevitch WaterIngestion.pdf [Accessed January 16, 2014]

DuPont, H. L., Chappell, C. L., Sterling, C. R., Okhuysen, P. C., Rose, J. B. and Jakubowski, W. (1995). The infectivity of *Cryptosporidium parvum* in healthy volunteers. New England Journal of Medicine. 332: 855–859

Durance, J. L. (2009). United State Geological Survey water Science for School. *Science World Journal*; 7: 1-8. Retrieved from http://ga.water.usgsgov/edu/earthgw-qulity.htm [Accessed 4, April, 2012]

Dutka, B. J. (2008). Methods for microbiological analysis of waters, wastewaters and sediments. Inland Waters Directorate, Ontario. pp. 1144-1147

Edimeh, P. O., Eneji, I. S., Oketunde, O. F. and Sha'ato, R. (2011). Physico-chemical parameters and some Heavy metals content of Rivers Inachalo and Niger in Idah, Kogi State. *Journal Chemical Society Nigeria* 36 (1): 95-101

Edberg, S. C., Rice. E. W., Karlin, R. J. and Aden, M. J. (2000). *Escherichia coli*: The best biological drinking water indicator for Public Health Protection *Journal of Applied Microbiology*, 88:106 -116

Environmental Protection Agency of Ghana (1991). Ghana Environmental Action Plan. Volume 1 Environmental Protection Council, Accra-Ghana

Environmental Protection Agency (EPA) (2004). *Guidelines for Water Reuse*. 625/R-04/108.Environmental Protection Agency. Washington, D.C. U.S.

Eric, D., and Catherine, A. M. (1997). Respiration and critical case medicine, 59:162-172.http:/ /green .atsjournals.org/cgi /content /fully/158/11/166) [Acces sed June12, 2013]

Esterman, A., Roder, D. M., Cameron, A. S., Robinson, B. S., Waiters, R. P., Lake, J. A. and Christy, P. E. (2004). Determinants of the Microbiological characteristics of

South Australian swimming pools. *Applied Environmental Microbiology*. 47: 325-328

Evans, J. (2007). Except from Total Swimming. Pp 224 ISBN 13:9780736068482 http://www.humankinetics.com/products/all-products/janet-evans-totalswimming. [Accessed March 15, 2015]

Evans, O., Cantú, R, Bahymer T. D., Kryak, D. D. and Dufour, A. P. (2001). A pilot study to determine the water volume ingested by recreational swimmers. Paper presented to Annual Meeting of the Society for Risk Analysis, Seattle, Washington, 2–5

Fair, G. M., Gerger, J. C. and Okun, D. A. (2001). Water purification and waste water treatment disposal. New York: John Wiley and Sons. Pp. 31-192

Fakayode, S.O. (2005). Impact Assessment of Industrial Effluent on Water Quality `of the Receiving ALaro River in Ibadan, Nigeria. Ajeam-Ragee . *International Journal of Environmental Science and Technology.* 10: 1-13

Farthing, M. J. G., (2000). Clinical aspects of human cryptosporidiosis. In: Petry, F. (Ed.), Cryptosporidiosis and Microsporidiosis, Contrib. *Microbiology*; 6: 50–74

Favero, M. S. (2005). Microbiological indicators of health risks associated with swimming. *American Journal of Public Health* 75: 1051- 1054

Favero, M. S., Drake, C. H. and Randall, B. (2004). Use of *Staphylococc*i as indicator of swimming pool pollution. *U.S. Public. Health Report*. 79: 61 70

Fayer, R., Speer, C. A., Dubey, J. P., (1990). The general biology of *Cryptosporidium*. In: Fayer, R. (Ed.), *Cryptosporidium* and Cryptosporidiosis. CRC Press, Boca Raton, pp. 1 –41

Fricker, C.R., Medema, G. D. and Smith, H. V. (2002). Protozoan parasites (*Cryptosporidium*, *Giardia*, *Cyclospora*). In Guidelines for Drinking-Water Quality. Geneva: World Health Organization. pp. 70–118

Fritz, C. (2001). Watershed Information Network: A Watershed Report and Suggested Framework for Integrating Water Quality Monitoring Efforts. Pp. 10 -24

Galbraith, N. S. (2000). Infections associated with swimming pools. *Environmental Health* 15: 31-33

Galbraith S, Palmer S., Arnold E. (1990). General epidemiology. eds. Topley and Wilson's principles of bacteriology, virology and immunity. In: Smith GR, Easmon CSF,.Vol. 3. Bacterial diseases. London, pp. 11–29

Ghana Statistical Service (2012). 2010 Population and Housing Census. Summary Report of Final Results. A publication of the Ghana Statistical service, Accra.

Great Lakes - Upper Mississippi River Board (Glumrb) (1996). Swimming Pool: Recommended Standards for Swimming Pool Design and Operation Policies for the Review and Approval of Plans and Specifications for Public Pools. Great Lakes - Upper Mississippi River Board (GLUMRB). Pp: 12-48. Retrieved from http://10statesstandards.com/ swimmingpoo des ignn.pdf [Accessed March 20, 2015

Guideline for Safe Recreational Water Environments, (2006). Vol. 2: Swimming Pools and Similar Environments. World Health Organization.

Horman, A., Rimhanen-Finne, R., Maunula, L., Von Bonsdorff, C. H., Torvela, N., Heikinheimo, A. and Ha¨nninen, M. L. (2004). *Campylobacter spp., Giardia spp., Cryptosporidium spp.,* Noroviruses, and indicator organisms in surface water in southwestern Finland. *Applied Environmental Microbiology* 70(1): 87–95

Hotels.com (2016). Hotels with Pools in Kumasi. Retrieved from http://www. hotels.com/de567519-am128/pool-hotels-kumasi-ghana. [Accessed April 25, 2016]

Hurst, K. J. and Barrette, W. C. (1989). Leucocytic Oxygen Activation and Microbicidal Oxidative Toxins. *Critical Reviews in Biochemistry and Molecular Biology.* Vol. 24 (4), pp. 271 -328

Igbinosa, E. O. and Okoh, A. I. (2009). Impact of discharge wastewater effluents on the physio-chemical qualities of a receiving watershed in a typical rural community. *International Journal of Environmental, Science and Technology*. 6(2): 175-182

Isaak, R. A. and Morris, J. (1980). Rates of transfer of active chlorine between nitrogenous substrates. In : Jolly Rl, ed. *Water chlorination. Vol.3.* Ann Arbor, Ml, Ann Arbor Science Publishers. Retrieved from http://www. who.nt/water_sanitation_health/bathing/srwe2chap4.pdf [Accessed April 25, 2015]

Itah, A. Y., Etukudo, S. M. and Akpan, E. J. (1996). Bacteriological and chemical analysis of some rural water supplies in Calabar, Nigeria. *West Africa Journal Biology of Applied Chemistry.* 41: 1-10

Itah, A.Y. (1999). Ileal loop reactive *Escherichia coli* serotypes isolated from infantile diarrheal stools in Calabar, *Nigerian Journal Science of Engineering and Technology*; 6: 1577-88

Klebanoff, S. J. (1988). Phagocytic Cells. Products of Oxygen Metabolism Inflammation: Basic Principles and Correlates. Eds. J.I Gallin, I.M. Goldstein, and R. Snyderman. Raven Press, Ltd. New York. Pp. 391 - 444

Kuzgunkaya, E. and Yildirim, N. (2010). Pre- Feasibility Study of a Swimming Pool Complex for a University Compus. A report for Proceedings World Geothermal Congress 2010: Bali, Indonesia. Pp. 1-7

Lagerkvist, B. J., Bernard, A. B., Bergstrom, E. F., Holmstrom, K. and Karp, K. G. (2004). Pulmonary epithelial integrity in children: Relationship to ambient ozone exposure and swimming pool attendance. *Environmental Health Perspect* 112: 1768-1771

Lamb, J. C. (1985). Water Quality and its control, John Wiley and Sons, New York. Pp 131

Leoni, E., Legnani, P., Buccisabattini, M. A. and Righi, F (2001). Prevalence of *Legionella species* in swimming pool environment. *Pergamon*; 35(15): 3749– 3753

Leoni, E., Legnani, P., Mucci, M. T. and Pirani, R. (1999). Prevalence of Mycobacteria in a swimming pool environment. *Microbiology*, 87: 683–688

Lisle, J.T. and Rose, J.B. (1995). *Cryptosporidium* contamination of water in the USA and UK. A mini review. *Journal of Water Supply Research Technology*, 44: 103–117

Luebbers, M. (2012). Just Swimming the Best Way to Lose Weight. Retrieved from http://swimming.about.com/od/nutrition/qt/Is_Swimming_a_Good_Exercise_for_Weight_Loss_.htm. [Accessed January 10, 2014]

Mackereth, F. H., Heron, J. and Talling, J. F. (2003). Water analysis. Ambleside: *Fresh Water Biological Association Scientific Publication*. 43-69

Magit, R. F. (2002). Analysis of Ground waters in Gindiri Area, Mangu LGA. Plateau State, Nigeria. B.Sc Thesis, University of Jos. Pp 59-61

Manilla, P. N. and Frank, O. M. (2009). Lakes of the Niger Delta Flood Plain chemical Characteristics of five lakes (Akpide, Egbedidi, Esiribi, Aboh and Egbinya) in Bayelsa State. *Journal of* Chemical *Society of Nigeria, 34 (2)*: 43-49

Marshall, J. W. and Winterbourn, I. M. J. (1979). An Ecological study of a small New Zealand stream with particular reference to the Oligochaeta. *Hydrobiology*. 65:199-208

Martinys, M. T., Sato, M. I. Z. and Alves, M. N., Stoppe, N. C., Prado, V. M. Sanchez, P. S. (1995). Assessment of Microbiological Quality for Swimming Pools in South America. *Pergamon*. *29(10:)* 2417-2420

Meinhardt, P. L., Casemore, D. P. and Miller, K.B., (1996). Epidemiologic aspects of human cryptosporidiosis and the role of waterborne transmission. *Epidemiology Reviews* .18 (2): 118–136

Meteorological Services Department (1994). Meterological data. Ashanti Regional office, Kumasi

Meyer, E. A. and Jarroll, E. L., (1980). Giardiasis. *American Journal of Epidemiology* 111: 1 – 12

Mood, E. W. (2007). Bacterial indicators of water quality in swimming pools and their role. In Bacterial Indicators Health Hazards Associated with Water. ASTM STP635. Am. Soc. Test. Mater., Philadelphia, Pa. pp. 239- 246

Mossel, D. A. (2006). Microbiological markers for swimming associated infectious health hazards. *American Journal of Public Health.* 76: 2

Okafor N. (1985). Aquatic and waste microbiology.1st ed. Fourth Dimension publishing Company Ltd Enugu Nigeria Pp.187-219 ISBN 9781561270.

Oliveri, R., Di Piazza, F., Marsala, B., Cerame, G., Firenze, A. and Di Benedetto, M. A. (2006). Occurrence of *Giardia* cysts and *Cryptosporidium* oocysts in swimming pools in the province of Palermo. Italy. 18:367–74

Palmer, M. D., Lock, J. D. and Gowda, T. P. (2003). The use of bacteriological indicators for swimming water quality. *Water Pollution Control Manual* 122: 14-18

Patra, R. W. and Azadi, M. A. (1987). Ecological Studies on the planktonic organisms of the Halda river. *Bangladesh Journal of Zoology*. 15:109-12

Pond K. (2005). Water recreation and disease: An expert review of the plausibility of associated infections, their acute effects, sequelae and mortality. IWA on behalf of the World Health Organization, London, UK.

Rabi A., Khander Y., Alkafoja A., Abu A. A. (2008). Sanitary Conditions of Public swimming pools in Amman Jordan. *Journal of Environmental Res. Public Health*, 5(3): 152-157

Report of committee of the Great Lakes (ed. 1996). Recommended Standards for swimming pools, Designs and operation. Upper Mississipi River Board of States and Provincial Public Health and Environmental Managers. USA.

Rimhanen-Finne, R., Vuorinen, A., Marmo, S., Malmberg, S. and Ha¨nninen, M. L. (2004). Comparative analysis of *Cryptosporidium, Giardia* and indicator bacteria during sewage sludge hygienization. *Applied Microbiology* 38: 301– 305

Rivera, J. B. and Adera, T. (1991). Assessing water quality. *Staphylococci* as Microbial indicators in swimming pools. *Journal of Environmental Health*, 53(6): 29–32

Robinton, E.D. and Mood, E.W. (1986). Quantitative and qualitative appraisal of microbial pollution of water by swimmers: A preliminary report. *Journal of Hygiene*; 31: 489-499

Russell D. L. (2006). Practical Wastewater Treatment. John Wiley and Sons, Inc., Hoboken, New Jersey. Pp 39 – 88

Schets, F. M., Engels, G. B. and Evers, E. G. (2004). *Cryptosporidium* and *Giardia* in swimming pools in the Netherlands. *Journal of Water Health*. 2:191–200

Seyfried, P. L., Tobin, R. S., Brown, N. E. and Ness, P. F. (2005a). A prospective study of swimming-related illness Swimming-associated health risk. *American Journal of Public Health* 75: 1068 1070.

Seyfried P. L., Tobin R. S., Brown N. E. and Ness P. F. (2005b). A prospective study of swimming-related illness, Morbidity and the Microbiological quality of water. *American Journal of Public Health* 75: 1071- 1074.

Shuval, H. I. (1975). The case for microbial standards for bathing beaches. In: Discharge of Sewage from Sea Outfalls (ed. Gameson, A. L. H.), Pergamon Press, Oxford, England. pp. 95–101.

Slifko, T. R., Smith, H. V. and Rose, J. B. (2000). Emerging parasite zoonoses associated with water and food. *International Journal of Parasitology* 30: 1379–1393.

Smith, J. L. (1993). Cryptosporidium and Giardia as agents of foodborne disease. *Journal of Food Protection*. 56: 451– 461.

Stanier, R. Y., Ingraham, J. L., Wheelis, M. L., Painter, P. R. (1987). General Microbiology. 5th ed. London. Macmillan Press. Pp. 689

Sule, I. O., and Oyeyiola, G. P. (2010). Bacteriological Assessment of some Swimming Pools within Ilorin Metropolis, Kwara of Nigeria. *Bioresearch Bulletin* 1 : 2933

Sule, I. O., Agbabiaka, T. O., Saliu, B. K. and Oyerinde, E. O. (2010). Physico – chemical and Bacteriological Assessment of some Swimming Pools within Ilorin Metropolis, Kwara of Nigeria. *Biological and Environmental Sciences. Journal for the Tropics* 7(4): 108 – 112

Thickett, K. M., Mccoach, J. S., Gerber, J. M. and Burge, P.S. (2002). Occupational asthma caused by chloramines in indoor swimming-pool air. *European Respiratory Journal*, 19:827-832

United Nation Development Programme (UNDP) [2004]. Water as a source of sickness. United Nation Development Programme Source: a short guide. 1: 11-13.

Walakira, P. (2011). Impact of industrial Effluents on Water Quality of Receiving Streams in Nakawa-Ntinda. Msc. Thesis, Makerere University. Uganda. *Journal of Applied Science and Environmental Management*. Vol.15 (2). Pp 289-296.

Wetzel, R. G. and Likens, G. E. (2006). Limnological analysis. Third Edition. SpringerVerlag, New York, 391.

Whitaker, H. J., Nieuwenhuijsen, M. J. and Best, N. G. (2003). The Relationship between Water Concentrations and Individual Uptake of Chloroform: A Simulation Study. *Environmental Health Perspectives* Vol.111 (5).

Wildlife and Range Management Department (2016). GIS unit, Faculty of Renewable Natural resources, Kwame Nkrumah University of Science and Technology.

World Health Organization (WHO) [2011] Guidelines for Drinking water Quality, 4th ed. World Health Organization, Geneva, Switzerland.

World Health Organization (WHO) [(2006]. Guidelines for Safe Recreational Water Environments Volume 2: Swimming Pools and Similar Environments. World Health Organization, Geneva, Switzerland.

World Health Organization (WHO) [2005]. Guide to ship Sanitation. Volume 2 World health organization, Geneva, Switzerland.

World Health Organization (WHO) [2004]. Guidelines for drinking water quality 3rd ed., vol 1-Geneva, Switzerland, 89(112):143—168.

World Health Organization (WHO) [2003]. Guidelines for safe recreational water environments. Vol. 1. Coastal and Fresh waters, World Health Organization, Geneva, Switzerland.

World Health Organization (WHO) [1995]. Guideline for Drinking Water Quality. 4th ed. World Health Organization, Geneva, Switzerland.

Wright, J. M., Schwartz, J. and Dockery, D. W. (2003). Effect of trihalomethanes exposure on fetal development. *Occupational. Environmental Medicine.* 60:173-180

APPENDICES

APPENDIX : RESULTS OF T-TEST FOR THE TREATMENTS OVER THE STUDY PERIOD.

Appendix A: Results of T-test for before and after swimming samples for pH in the various pools under study.

	P-value	Significant? (P<0.05)	P-value summary
pH			
TH	0.0040	Yes	**
NH	< 0.0001	Yes	***
SH	0.0042	Yes	**
KNUST	0.1013	No	ns
STH	0.0038	Yes	**
YH	0.8564	No	ns
RH	0.6866	No	ns
CH	0.4802	No	ns
TVH	0.9248	No	ns

ns = not significant

Appendix B: Results of T test for before and after swimming samples for Temperature in the nine pools under study.

	P-value	Significant? ($p < 0.05$)	P-value summary
Temperature			
TLH	0.0548	No	ns
NH	0.0010	Yes	***
SH	0.0505	No	ns
KNUST	0.2311	No	ns
STH	0.0028	Yes	**
YH	0.1345	No	ns
RH	0.1293	No	ns
CH	0.4375	No	ns
TVH	0.1597	No	ns

ns = not significant

Results of T-test for before and after swimming samples for

Appendix C: Dissolved

Oxygen in the nine pools under study.

	P-value	Significant? (p< 0.05)	P-value summary
DO			
TLH	0.9984	No	ns
NH	0.0935	No	ns
SH	0.0008	Yes	***
KNUST	0.0545	No	ns
STH	0.0617	No	ns
YH	0.2532	No	ns
RH	0.0832	No	ns
CH	0.0555	No	ns
TVH	0.0503	No	ns

ns = not significant

Results of T- samples for

Appendix D: test for before and after swimming

Conductivity in the nine pools under study.

	P-value	Significant? (p< 0.05)	P-value summary
Conductivity			
TLH	0.4967	No	ns
NH	0.0336	Yes	*
SH	< 0.0001	Yes	***
KNUST	0.0153	Yes	*
STH	< 0.0001	Yes	***
YH	0.0101	Yes	*
RH	0.0611	No	ns
CH	0.9207	No	ns
TVH	0.3233	No	ns

ns = not significant

Results of T-test for before and after swimming samples for

Appendix E: Total

Dissolved Solids in the nine pools under study.

	P-value	Significant? (p< 0.05)	P-value summary
TDS			
TLH	0.4962	No	ns
NH	0.0333	Yes	*
SH	< 0.0001	Yes	***
KNUST	0.0148	Yes	*
STH	0.0001	Yes	***
YH	0.0100	Yes	**
RH	0.0615	No	ns
CH	0.7677	No	ns
TVH	0.3160	No	ns

ns = not significant

Results of T- samples for

Results of T-test for before and after swimming samples for Appendix F: Salinity in

the nine pools under study.

	P-value	Significant? P< (0.05)	P-value summary
Salinity			
TLH	0.1463	No	ns
NH	0.0483	Yes	*
SH	0.7819	No	ns
KNUST	0.0178	Yes	*
STH	0.0002	Yes	***
YH	0.0100	Yes	**
RH	0.0533	No	ns
CH	0.0485	Yes	*
TVH	0.4097	No	ns

ns = not significant

Results of T-test for before and after swimming samples for

Appendix G: Free

Chlorine in the various pools under study.

	P-value	Significant? (P< 0.05)	P-value summary
Free Chlorine			
TLH	0.0574	No	ns
NH	0.0229	Yes	*
SH	0.0398	Yes	*
KNUST	0.0406	Yes	*
STH	0.0424	Yes	*
YH	0.1552	No	ns
RH	0.0570	No	ns
CH	0.0809	No	ns
TVH	0.0016	Yes	**

ns = not significant

Results of T-test for before and after swimming samples for

Appendix H: Colour in

the nine pools under study.

	P-value	Significant? (P< 0.05)	P-value summary
Colour			
TLH	0.0131	Yes	*
NH	0.0031	Yes	**
SH	0.0026	Yes	**
KNUST	0.0024	Yes	**
STH	0.0115	Yes	*
YH	0.0582	No	ns
RH	0.0071	Yes	**
CH	0.0064	Yes	**
TVH	0.0032	Yes	**

ns = not significant

Results of T-test for before and after swimming samples for

Appendix I: Turbidity

in the nine under study.

	P-value	Significant? (p< 0.05)	P-value summary
Turbidity			
TLH	0.0015	Yes	**
NH	0.0010	Yes	**
SH	0.0030	Yes	**
KNUST	< 0.0001	Yes	***
STH	0.0484	Yes	*
YH	0.0113	Yes	*
RH	0.0336	Yes	*
CH	0.0170	Yes	*
TVH	0.0132	Yes	*

ns = not significant

Results of T-test for before and after swimming samples for

-test for before and after swimming

Appendix J: Results of T samples for Total coliforms in the nine pools under study.

	P-value	Significant? (P < 0.05)	P-value summary
Total coliform			
TLH	< 0.0001	Yes	***
NH	0.0325	Yes	*
SH	0.0134	Yes	*
KNUST	0.3300	No	ns
STH	0.3492	No	ns
YH	0.0435	Yes	*
RH	0.0422	Yes	*
CH	0.0168	Yes	*
TVH	0.0197	Yes	*

ns = not significant

-test for before and after swimming

Appendix K: Results of T samples for faecal

Coliform in the nine pools under study.

	P-value	Significant? (P < 0.05)	P-value summary
Faecal Coliform			
TLH	0.0030	Yes	**
NH			
SH	0.2223	No	ns
KNUST	0.0083	Yes	**
SH			
YH			
RH			
CH	0.0570	No	ns
TVH	0.3200	No	ns

ns = not significant

-test for before and after swimming samples for

Appendix L: Results of T *E. coli* in

the nine pools under study.

	P-value	Significant? (P < 0.05)	P-value summary
E. coli			
TLH	0.5000	No	ns
NH			
SH			
KNUST			
STH			
YH			
RH			
CH			
TVH			

ns = not significant

-test for before and after swimming

-test for before and after swimming samples for
Appendix M: Results of T

Cryptosporidium oocysts **in the nine pools under study.**

Table Analyzed	Cryptosporadium/HPF
Column A	Before
vs	vs
Column B	After
Paired t test	
P value	0.0003
P value summary	***
Are means signif. different? (P < 0.05)	Yes
One- or two-tailed P value?	Two-tailed
t, df	t=11.32 df=4
Number of pairs	5
How big is the difference?	
Mean of differences	-2.690
95% confidence interval	-3.350 to -2.031
R squared	0.9697
How effective was the pairing?	
Correlation coefficient (r)	Linear correlation requires at least four points.
P Value (one tailed)	
P value summary	

-test for before and after swimming samples for

Appendix N: Results of T *Gardia*

***lamblia cysts* in the nine pools under study.**

Table Analyzed	G. Lamblia
Column A	Lamblia
vs	vs
Column B	After
Paired t test	
P value	0.0001
P value summary	***
Are means signif. different? (P < 0.05)	Yes
One- or two-tailed P value?	Two-tailed
t, df	t=6.960 df=8
Number of pairs	9
How big is the difference?	
Mean of differences	-5.173
95% confidence interval	-6.886 to -3.459
R squared	0.8583
How effective was the pairing?	
Correlation coefficient (r)	Linear correlation requires at least four points.
P Value (one tailed)	
P value summary	