OCCURRENCE OF PARASITES' CYSTS, OOCYSTS AND EGGS ON BANK FACILITIES IN BENUE STATE, NIGERIA

BY

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SEPTEMBER, 2015.

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A DISSERTATION SUBMITTED TO THE SCHOOL OF POSTGRADUATE STUDIES AHMADU BELLO UNIVERSITY, ZARIA
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DEPARTMENT OF BIOLOGICAL SCIENCES
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SEPTMBER, 2015.

DECLARATION

I declare that the work in this dissertation entitled "**OCCURRENCE OF PARASITES' CYSTS, OOCYSTS AND EGGS ON BANK FACILITIES IN BENUE STATE, NIGERIA"** was carried out by me in the Department of Biological Sciences. The information derived from the literature has been duly acknowledged in the text and a list of references provided. No part of this thesis was previously presented for another degree or diploma at this or any other institution.

Elaigwu Alechenu Mark	_________________________	___________________
	Signature	Date

CERTIFICATION

This dissertation entitled "**OCCURRENCE OF PARASITES' CYSTS, OOCYSTS AND EGGS ON BANK FACILITIES IN BENUE STATE, NIGERIA"** by Elaigwu Alechenu Mark meets the regulations governing the award of the degree of M.Sc. Educational Biology of the Ahmadu Bello University, and is approved for its contribution to the knowledge and literary presentation.

Prof. I. S. Ndams Chairman, Supervisory Committee Department of Biological Sciences, Ahmadu Bello University, Zaria.	____________________ Signature	____________________ Date
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Prof. K. Bala Dean, School of Postgraduate Studies, Ahmadu Bello University, Zaria.	____________________ Signature	____________________ Date

DEDICATION

This research is dedicated to Almighty God the Creator of life and Giver of every good thing, my beloved wife Mrs. Christie Ogeyi Elaigwu and my Late father Barr. Matthew Ali Elaigwu

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ABSTRACT

Species of parasitic organisms whose cysts, oocysts and ova occurred on specific commercial banks' facilities and intensities of contamination were evaluated via environmental parasitological assays in the three towns of Benue State, Northcentral Nigeria. Eighteen (18) of the common commercial banks (six per town) with wide branch network in the state, that consented, were selected on random ballot and screened for resistant stages of parasitic organisms on twelve facilities-door handles(inner and outer handles), automated teller machines (ATMs)(down and upper instruction knobs), computer accessories (keyboards and mouse), Currency (paper and polymer notes), counting machines (cash loader and cash receiver) and counter/slab surfaces(banking hall and bulk room). Sterile cotton swabs wetted with sterile normal saline were used to swab the surfaces of interest at the designated banks, preserved in refrigerated capped universal bottles containing 10ml each of normal saline and 4% formalin and thereafter subjected to both the centrifugal sedimentation and Zinc sulphate floatation techniques to isolate parasite stages. Of the 396 facilities screened, the cysts/oocysts of seven parasitic protozoans were isolated, including *Entamoeba histolytica* 251/396 (63.38%), *Cryptosporidium* species 155/396 (39.14%), *Entamoeba coli* 44/396 (11.11%), *Giardia intestinalis* 33/396 (8.33%), *Balantidium coli* 9/396 (2.27%), *Cyclospora* species 7/396 (1.77%) and *Isospora* species 2/396 (0.51%). Ova of eight species of parasitic helminths encountered on the screened facilities included those of *Ascaris lumbricoides* 106/396 (26.77%), *Trichuris trichiura* 15/396 (3.79%), hookworm 14/396 (3.54%), *Taenia* species 14/396 (3.54%), *Dicrocoelium dendriticum* 6/396 (1.52%), *Capillaria* species 3/396 (0.76%), *Enterobius vermicularis* 2/396 (0.51%), *Toxocara canis* 2/396 (0.51%).

Up to 304 (76.80%) of the six bank facility types were positive with cysts/oocysts of at least three of the seven protozoan parasites while 138 (34.8%) of the facilities were positive with ova of at least four of the eight helminth parasites. The study established that bank facilities are repositories of resistant stages of important zoonotic human and veterinary parasites thus highlighting their potential roles as contaminative transmission sources and public health risks.

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CHAPTER ONE

1.0 INTRODUCTION

1.1 Background

Parasites are organisms that live upon or within another living organism known as the host, at whose expense they obtain some advantages such as food, water, heat, habitat and dispersal as well as shelter, and in the process increase their fitness by exploiting the host for resources necessary for their survival (Blood and Virginia, 1988). Parasites reduce hosts' fitness in many ways, ranging from general or specialised pathology such as parasitic castration and impairment of secondary sex characteristics, to the modification of host behaviour (Blood and Virginia, 1988).

According to Kathleen and Arthur (2002), intestinal parasites occur worldwide among all human ages and socioeconomic groups. In the 1993 World Development Report, intestinal helminthes rank first as the main cause of disease burden in children aged 5 – 14 years where they constitute formidable health problems resulting in malnutrition, anaemia and disturbed appetite. These may ultimately result in retarded physical and cognitive development in children. The World Health Organization (WHO) estimated that helminth infections affect around 2 billion people among whom 5-10% are children, as a result of the ingestion of the cysts and ova of parasites (WHO, 2008). Parasites have been identified as the cause of morbidity and mortality throughout the world particularly in underdeveloped countries and in persons with comorbidities (Adeyeba and Akinlabi, 2002). It is known that individuals often exposed to and infected with multiple parasitic organisms and their harmful effects often aggravated by coexistence of malnutrition or micronutrient deficiencies (Adeyeba and Akinlabi, 2002).

The prevalence of intestinal parasitic infections is most significant because several of the enteric parasites have direct life cycles and do not need any intermediate host to infect a new host as they are spread via faecal contamination of food, drinks and other substances/surfaces. These faecal contaminative infections are often said to be caused by faecal-orally transmitted parasites (Hoeprich, 1975; Awodi *et al.*, 2000). Infections acquired through direct ingestion of infective ova and/or cyst of parasites are intimately linked with the level of personal hygiene of individuals and sanitation in such an environment which most times can be transmitted by fingers/hands directly to other persons or to food (www.globalhandwash.com), from contaminated clothing and perianal area or other potential surfaces (Hoeprich, 1975).

Other attitudes such as the wetting of hands or fingers with saliva or use of contaminated water to lubricate the hand while counting paper money could lead to possible transfer of parasites' cysts and ova from such media to the notes and finally get to the bank (Ameh and Balogun, 1997). Within the bank environments, opening of bank doors using the door handles, shaking of hands within and outside the bank premises, filling of deposit and withdrawal slips for paying and withdrawal of money, use of currency counting machines and touching other contaminated surfaces in the banks make the banks repositories for and important avenues for the spread of the cysts, oocysts and ova of important parasites. Paper money, especially in the Nigerian environment and elsewhere, presents a particular risk to public health since communicable diseases can be spread through contact with fomites (Hosen *et al.,* 2002; Xu and Moore 2005; Basavuvapappa and Suresh, 2005; Ogbu and Uneke, 2007; Lalonde, 2007; Umeh *et al.,* 2007). More so that money is probably the most sought after exchange of material that people use to barter for goods and services, or to accumulate as a safe for gathering of wealth. The high cravings for bank notes as means of depositing and saving wealth in banks necessitate different categories of people moving into the banks at one point or another and inadvertently contaminating bank facilities such as surfaces of automated teller machines (ATMs), counters, keyboards of computers, currencies, other bank surfaces and even the hands of the bankers when used for counting the money or touching contaminated surfaces within these banks.

This leaves the surfaces of bank facilities without an exemption of being contaminated with the cysts and ova of parasites. More so that these parasites are just about everywhere in our environment, making it easy to become infected (WHO, 2008). This justifies the constant study of cysts of protozoans and eggs of helminths in the environment. The danger is evidently obvious, the hands could easily be contaminated with the cysts and eggs from these sources and passed directly to the mouth or contaminate food (Nock and Tanko, 2000). Thus surfaces of bank facilities could be major potentially biologically contaminated vehicles for the spread of cysts and ova of parasites. Hence the objective of this study was to determine the occurrence of parasite cysts and ova on bank facilities in Benue State, Nigeria.

1.2 Statement of Research Problem

The Nigerian environment has been described as basically poor in terms of hygiene on account of poor sanitary habits of the inhabitants (Fashuyi, 1983). Several studies in Nigeria have shown that cysts and eggs of parasites were available on children's fingernails (Dyek, 2001), on the soles of shoes (Nock and Tanko, 2000), in soil (Nock and Duniya, 2004), on water- closet handles in homes and business areas (Nock and Geneve, 2002) and on the surfaces of the Nigerian currency notes (Awodi *et al.*, 2000). These indicate the widespread presence of parasite cysts and ova in human environments which could translate to a high propensity of contact with infective stages of parasitic organisms.

The danger of contracting parasitic diseases via hands contaminated by the cysts and ova of parasites from contaminated surfaces and inadvertent ingestion is very high in public places frequented by large number of individuals on a daily basis.

One of such public places are the numerous branches of commercial banks at which several humans compulsively touch automated teller machines (ATM), keys of computer keyboards, handles of doors to entrances and exits, bank notes, counting machines, counters or slab surfaces and other facilities and surfaces.

The role of banks as public institutions where infective stages (ova, oocysts and cysts) of human enteric parasites are domiciled and could be transmitted have been poorly studied, thus leaving a gap in the knowledge of roles of banks in the epidemiology of parasitic intestinal diseases.

1.3 Justification of the Study

Banks are financial institutions that attract a high density of human population on a daily basis. This makes banks to be amenable to contamination with infective stages and transmission of enteric parasites amongst human populations. Investigations into the diversity of parasitic organisms (ova, oocysts and cysts) available in banks, their distribution across geographical areas and the types of bank facilities supporting their presence are highly desirable in environmental parasitology and disease epidemiology. These will not only shed light on the health risk of making contact with bank facilities, but will also create needed awareness on the need to take precautionary measures to forestall disease transmission via bank environments.

1.4 Aim of the Study

To investigate the occurrence of cysts, oocysts and eggs of parasites on bank facilities in Benue State, Nigeria.

1.5 Objectives

1. To identify and determine the prevalence of parasitic organisms whose cysts, oocysts and eggs occur on bank facilities in the study area.
2. To determine the type and diversity of bank facilities on which cysts and eggs of parasites occur.
3. To evaluate differences in the intensities of cysts, oocysts and eggs of parasites among banks facilities and banks in the study area.

1.6 Hypotheses (Null)

1. There are no species of parasitic organisms whose cysts, oocysts and eggs occur on bank facilities in the study area.
2. There are no bank facilities on which cysts and eggs of parasites occur in the study area.
3. There are no significant differences in the intensities of cysts, oocysts and ova of parasites among the bank facilities and banks in the study area.

CHAPTER TWO

2.0 LITERATURE REVIEW

2.1 Species of Parasitic Organisms Producing Contaminative Cysts, Oocysts and Ova in the Environment

A Parasite is a term applied to any infectious agent, however, by convention it is generally restricted to infections caused by protozoa (which are microorganisms that multiply within their vertebrates host), and helminths (which are macro parasites) (Taylor *et al* 1997; Suleiman, 2005). Intestinal parasites are acquired through contact with and or ingestion of contaminated cysts, ova or immature larval stages produced by different species of parasites. Almost all of these intestinal parasites have their infective stages transmitted by faecal-oral route. Faecal-oral transmission involves the ingestion of food or water contaminated with cysts or oocysts available in the immediate environment. These cysts and eggs are excreted with the faeces and are somewhat resistant to the environment as entry points to human infections.

Human societies have always been challenged by infectious diseases caused by helminth and protozoan parasites, especially the pathogenic parasites producing cysts, oocysts and ova on contact surfaces (Awodi *et al.,* 2000; Dyek, 2001; Nock and Geneve, 2002; Apichai *et al.,* 2005).

Species of parasites producing cysts in the human environments include such pathogenic protozoans as *C. parvum, E. histolytica, G. intestinalis and B. coli* inhabiting the gastrointestinal tracts of humans (Baqui *et al.,* 1992; Kathleen and Arthur, 2002). These pathogens cause human disorders worldwide (Fontanet *et al.,* 2000; Apichai *et al.,* 2005).

Human intestinal helminths include *S. stercolaris, E. vermicularis, T. saginata and T. solium* among others. The common round worm known scientifically as *A. lumbricoides*, the whipworm or *T. trichiura* and the hookworms *Necator americanus* and *Ancylostoma duodenale* are regarded as the four most important soil transmitted helminths (STHs) because they have the highest prevalence rates and they cause the greatest burden on human health (Hotez *et al.*, 2008), with their major public health significance being the chronic morbidities they cause in their hosts (WHO, 2002).

2.1.1 Protozoa

The name 'proto-zoa' literally means 'first animals' as they are believed to be primitive relatives of animals. There are four major groups of protozoans traditionally classified according to their means of locomotion, they include amoeboid, sporozoids, flagellates and ciliated protozoans.

Protozoans are eukaryotic organisms (with a membrane-bound nucleus) which exist as structurally and functionally independent individual cells (including those species which are gregarious or form colonies). Most species of protozoa are microscopic organisms, only a few grow to a size large enough to be visible to the naked eye. As unicellular eukaryotes, protozoans display all the same essential life activities as higher metazoan eukaryotes, they move about to survive, feed and breed (www.carolina.com), retrieved 13th April, 2014).

Protozoans live as predators and parasites with their developed relatively complex subcellular features (membranes and organelles) that enable them to survive the rigors of their environments. As parasites they have adjusted to attack and live in cells and tissues of other organisms. They live inside humans in the bloodstream, in the tissue and in the intestinal tract (Hardeep, 2009).

Many of the intestinal (oo)cysts producing protozoan parasites inhabit the gastrointestinal tracts of humans (Baqui *et al.,* 1992). They include, among others, *G. intestinalis* , *Dientamoeba fragilis*, *Chilomastix mesnili*, *Enteromonas hominis*, *Retortamonas intestinalis*, *Trichomonas hominis*, *Entamoeba histolytica*, *Entamoeba dispar*, *Entamoeba coli*, *Entamoeba hartmanni*, *Entamoeba polecki*, *Entamoeba moshkovskii*, *Endolinmax nana*, *Iodamoeba butschlii*, *Cryptosporidium parvum*, *Cryptosporidium hominis*, *Cyclospora cayetanensis*, *Isospora belli*, *Enterrocytozoon bieneusi*, *Encephalitozoon intestinalis*, *Blastocystis hominis* and *Balantidium coli* (Fontanet *et al.,* 2000; Arora and Arora, 2009). However, majority of them are non-pathogenic commensals or only result in mild disease while a few of them like *C. parvum*, *E. histolytica* and *G. intestinalis* are pathogenic and have been associated with human gastrointestinal disorders worldwide (Fontanet *et al.,* 2000; Apichai *et al.,* 2005).

2.1.1.1 *Cryptosporidium* Species

Cryptosporidium is a protozoan parasite, originally described by Tyzzer in 1907, (Fayer *et al.,* 1997; USEPA, 2001). *Cryptosporidium* species were regarded as commensals, until their association with diarrhoea in young turkeys (*Cryptosporidium meleagridis*) in the 1950s, and with large outbreaks of diarrhoea in calves (*Cryptosporidium parvum*) in the 1970s (Fayer *et al.,* 1997). In 1976, it was identified at John Hopkins School of Medicine in the United State of America involving a 3 year old girl from rural Tennessee as the causative agent of a human disease called cryptosporidiosis (USEPA, 2001 and

Arora and Arora, 2009). However, the pathogenic potential of *C. parvum* as an intestinal protozoan affecting humans was not fully appreciated until 1982. This was when it started gaining recognition as a result of the onset of HIV/AIDS and its prevalence in the number of some other severely immunocompromised individuals due to cancer chemotherapy and organ transplant (Anonymous, 1997 and Oyibo *et al.,* 2009).

Current classification of *Cryptosporidium* is based upon a variety of parameters including host preference, cross-transmissibility, morphological differences, sites of infection and molecular taxonomic methods (Smith *et al.*, 2007). Taxonomically, the genus *Cryptosporidium* with several species being pathogenic are classified as phylum Apicomplexa, class Sporozoasida, Subclass Coccidiasina, order Eucoccidiorida, family Cryptosporidiidae and genus *Cryptosporidium*. However, only *C. parvum* has been associated with gastrointestinal illnesses (Teunis and Havelaar, 2002).

Cryptosporidium is transmitted between individuals through oocysts that are already eliminated in the infectious form (O'donoghue, 1995). Transmission can occur via any mechanism by which materials contaminated with viable oocysts can be ingested by any susceptible host (Smith, 2004; Oyibo *et al.,* 2009). The environmental routes of transmission include all vehicles that contain sufficient infectious oocysts (Smith *et al.*, 2007). However, oocysts are most commonly transmitted by faecal-oral route of host-to-host contact and indirect contamination of food or water as aerosol transmission of oocysts has also been reported (Hojlyng *et al*, 1987). Cases of human-to-human transmissions have been reported between family members, sexual partners, children in daycare centers, and hospital patients and staff (Koch *et al.,* 1985; Current and Garcia

1991). Zoonotic transmission has been confirmed by epidemiological studies involving pets, farm animals and by accidental infection of veterinary workers (Anderson *et al.*, 1982; Reese *et al.,* 1982). Food handled by contaminated or infected person and food exposed to contaminated water have been sources for food-borne cryptosporidiosis (CDC, 1998). Food grown in soil fertilized with farmland manure are also a potential source of infection, however contaminated food and water are the primary sources of infection with higher prevalence in areas where people with poor sanitation and hygiene live, due to their low economic status (Smith *et al.*, 2007; Oyibo *et al.,* 2009). *Cryptosporidium* oocysts may remain viable in water for over 140 days (Hooda *et al.*, 2000) and are very resistant to the most common disinfectants (Smith *et al.,* 2007) making them difficult to destroy by conventional chlorination treatment. Outbreaks have been associated with contamination of surface waters, well waters, swimming pool and public water supplies (CDC, 1998, 2001) and other inanimate surfaces.

2.1.1.2 *Entamoeba histolytica*

Amoeba is a single-celled protozoan belonging to the class Rhizopoda, possessing organs of locomotion known as pseudopodia. Several protozoan species of the genus *Entamoeba* exist, they may be parasitic (for example *E. histolytica*), commensal or free living. Eight amoeba (*E nana, E. coli, E. histolytica, E. dispar, E. hartmanni, E. moshkovskii, E. polecki,* and *I. bütschlii)* reside in the human intestinal lumen as evident commensals, deriving a niche and sustenance (Diamond and Clark 1993; Tanyuksel and Petri 2003; Mehmet and Petri, 2003).The recent reclassification of *E. histolytica* into different species as pathogenic *E. histolytica* and the non-pathogenic *E. dispar* and *E. moshkovskii* has further added to the complexity of the epidemiology (Samie and Ra'ed*.*, 2012).

Although the reclassification is of great value because all invasive disease before now was known to be caused by *E. histolytica*, but then it requires various techniques such as ELISA and PCR (Pillai *et al.,* 1999; Verweij *et al.,* 2000), as this species cannot be differentiated by mere microscopy which is the most commonly used diagnostic method particularly in tropical countries where resources are limited (Samie and Ra'ed, 2012). This is the reason why *E. histolytica* and *E. dispar* are most times reported as *E. histolytica*/*dispar* when its identification was conducted with just microscopy. The species are found throughout the world, but like many other intestinal protozoa, they are more common in tropical countries or other areas with poor sanitary conditions (Samie and Ra'ed, 2012).

Entamoeba histolytica is a tissue-lysing luminal protozoan parasite of the family *Entamoebae*. It is the most prevalent of the intestinal protozoa pathogens found throughout the world (McLaughlin and Aley, 1985). *Entamoeba histolytica was* recognized since 1875 by Losch in the dysenteric faeces of a patient in St. Petersburg, Russia (Jayaram, 2002; Obadiah, 2012). The name *E. histolytica (*first used by Schandinn in 1903 and amended by Walker in 1911) has been retained for the protozoan parasite that causes invasive intestinal and extra intestinal ameobiasis (Atu, 2008). This invasive protozoal infection by the pathogenic parasite *E. histolytica* is the most aggressive protozoal disease that affects the human bowel and is considered as the second or third leading cause of death amongst the parasitic diseases (WHO, 1997), killing about 100,000 people per year and infecting about 50,000,000 or more (Roberts and Janovy, 2009). About 85% of people infected with this parasite are healthy carriers (Noble *et al.*, 1989).

The life cycle of *E. histolytica is* simple, it includes two stages, the infectious (cyst) stage and the pathogenic (trophozoite) stage. Infection is through the ingestion of the infective microscopic cysts, where infected food handlers with poor sanitation habits can easily pass cysts on to others and fomites. Contaminated drinking water and mechanical vectors such as cockroaches and flies are also potential sources of infection. A significant portion of the homosexual population is infected through faecal/oral contamination (Noble *et al.*, 1989), where it can reach epidemic levels. Mature cysts (10 to 15 µm in diameter) in the large intestine are excreted from the host in large numbers and remain viable and infective in a moist, cool environment for at least 12 days and are also resistant to chlorine levels normally used to disinfect water (Samie and Ra'ed, 2012) and other contaminated surfaces.

2.1.1.3 *Giardia intestinalis*

Giardia is a flagellate, bi-nucleated protozoan parasite discovered by Van Leeuwenhoek in 1681 (Ali and Hill, 2003). The genus *Giardia* belongs to the phylum Sarcomastigophora, class Zoomastigophorasida, order Giardiida and family Giardiidae. It contains at least six species that infect animals and/or humans. In most mammals, giardiasis is caused by *G. duodenalis*, which is also called *G. intestinalis*. Two older names for the organism, *Giardia lamblia* and *Lamblia intestinalis,* are no longer considered to be taxonomically valid (USEPA, 1999; CDC, 2010).

Giardia is distributed globally and has been detected in nearly all classes of vertebrates, including domestic animals and wildlife (Thompson, 2004). It causes infection by attaching to the wall of the small intestine in the upper gastrointestinal tract of humans and other vertebrates (USEPA, 1999; CDC, 2010).

Giardia spp. have two stages, cysts and trophozoites. It is transmitted by the cyst form of about 10–12 mm long and infectious immediately upon excreted in faeces. The infectious dose is low and ingestion of 10 cysts has been reported to cause infection. In the encysted stage the organism is relatively resistant to chlorination and ozonolysis and can remain viable for several weeks especially in cold surface water. The acquisition of *Giardia* occurs most commonly through ingestion of the cyst in contaminated water, but person-to-person spread is common, particularly in settings of poor faecal–oral hygiene. Filth flies can carry potentially viable *G. intestinalis* cysts on their exoskeleton, which they have acquired naturally from unhygienic sources to contaminate other vulnerable surfaces (Graczyk *et al*., 2003).

2.1.2 Helminths

The word 'helminth' is a general term meaning 'worm'. Helminths are multicellular eukaryotic invertebrates with tube-like or flattened bodies exhibiting bilateral symmetry. Many helminths are free-living organisms in aquatic and terrestrial environments, others occur as parasites in most animals and some plants. Parasitic helminths are almost universal feature of vertebrate animals with most organisms having worms in them somewhere. According to Ojha *et al.* (2014), the major groups of parasitic helminths include nematohelminths (nematodes) and platyhelminths (flatworms), the latter subdivided into trematodes (flukes) and cestodes (tapeworms). Helminths are a group of intestinal parasites causing human infection through contact with parasite eggs or larvae that thrive in warm and moist soils of the world's tropical and subtropical countries. Helminths belonging to the phylum Nematoda that are of particular worldwide importance are the roundworms (*A. lumbricoides*), whipworms (*T. trichiura)*, and two hookworms (*A. duodenale* and *N. americanus)*, which are morphologically indistinguishable by mere microscopic observation (CDC, 2013; Ojha *et al.,* 2014). As adult worms, soil-transmitted helminths live for years in the human gastrointestinal tract with more than a billion people infected with at least one species (Bethony *et al*., 2002).

2.1.2.1 *Ascaris lumbricoides*

Ascaris lumbricoides, also known as roundworm, is one of the largest (measuring 30 to 50 cm in length and 3 to 6 mm in diameter) of the parasites that infest the human bowel and is common in regions with poor faecal sanitation, particularly in developing countries in the tropics and subtropics (Ping, 2012 and Raina *et al*, 2013).

Ascaris has a direct life-cycle where mature male and female adult worms reside in the lumen of the small intestine infecting humans that ate food contaminated with matured ova (Raina *et al*, 2013).Transmission of these infective ova occurs by an infected person defecating outside indiscriminately and or if the faeces of an infected person are used as fertilizer, the eggs are then deposited on the soil where they can then mature into a form that is infective.

Ascariasis is caused by ingesting the infective eggs when hands or fingers that have contaminated dirt on them are put in the mouth or by consuming contaminated vegetables or fruits that have not been carefully cooked, washed or peeled (Raina *et al.*, 2013; CDC, 2013). Larvae hatch in the small intestine, penetrate the intestinal wall, migrate to the lungs to become fourth-stage larvae, and then migrate up the trachea back into the oesophagus and ultimately the small intestine. In about 60 days from the point of infection, females will start to produce up to 200,000 fertilized eggs a day (Kathleen and Arthur, 2002).

2.1.2.2 *Trichuris trichiura*

Trichuris trichiura is a soil-transmitted roundworm commonly called the human whipworm due to its characteristic thin, long, whip-like appearance. Of the roundworms that infect humans, the whipworm is the third most common soil transmitted helminths, with a cosmopolitan distribution, more common in tropical climates (Anon, 2007, CDC, 2010). It has been estimated to infect 604 – 795 million people worldwide resulting in an expected 6.4 million disability adjusted life-years lost globally (Hansen *et al.,* 2013).

Trichuriasis is transmitted when the infective eggs of the whipworm are unintentionally ingested, usually through consuming soil that has been contaminated with human faeces via dirt covered foods or hands. The spread of the barreled shaped eggs, measuring 50µm to 54µm, of human whipworm usually occurs in areas where outside defecation takes place or human faeces is used as fertilizer (CDC, 2010). After the eggs are ingested, they move to the small intestine where they hatch and grow into juveniles. Then they migrate to the large intestine and burrow their anterior ends into the wall of the intestine. The worms become sexually mature adults after about three months and the female worm starts producing eggs, up to 10,000 a day. The eggs are dispersed into the human's faeces and exit along with it. If humans defecate outside, the faecal matter mixes with the soil where the eggs are incubated in the warm, moist environment allowing them to survive and become infective. The worms cannot multiply inside the host, so each worm is considered a separate case of infection (CDC, 2010).

2.1.2.3 Hookworm

Hookworms are blood sucking roundworms living in the small intestine and the second most common human worms (parasitesinhumans.org). They are prevalent throughout the tropics and subtropics, wherever there is faecal contamination of the environment (WHO, 1991). Taxonomically, hookworms are nematodes belonging to the family Ancylostomatidae, a part of the superfamily Strongyloidea. There are thousands of hookworm species but the two major genera that affect humans are *N. americanus* (causing necatoriasis) and *A. duodenale* (causing ancylostomiasis) (WHO, 1991, Simon *et al*., 2004) which are characterized by the presence of either teeth or cutting plates that line the adult parasites buccal capsule (Hotez, 1995) whose geographical distributions overlap (WHO, 1991).

Necator americanus is gray-pink in colour. Male is 5–9 mm and female 10 mm long and about 0.5 mm thick. Usually they live a few years but can live for up to 15 years. Females produce up to 10,000 eggs per day. *Necator americanus* is very similar to *A. duodenale*. *A. duodenale* males are 5–10 mm and females 10 mm or more in length and 0.5 mm thick. They live for only about six months with females producing up to 30 000 eggs per day more than that of *N. americanus* (Simon *et al.*, 2004). Both species cannot be distinguished by microscopic examination of their eggs due to their similarities (WHO, 1991).

Hookworm infections occur in approximately 700 million people, primarily in disadvantaged communities causing a disease burden of 1.5–22.1 million disability-adjusted life years (Hotez *et al.,* 2010). *Necator americanus* represents about 85% of all hookworm infections and causes necatoriasis, characterized clinically by anaemia, malnutrition in pregnant women and an impairment of cognitive and/or physical development in children (Diemert *et al.,* 2008).

The life cycle of *N. americanus* commences with eggs being shed in the faeces of infected people deposited indiscriminately in open places or used as fertilizers in the soil. Eggs embryonate in soil under favourable conditions and the first-stage larvae hatch afterwards, feeding on environmental microbes and molt twice to become infective third-stage larvae (iL3). Unlike other intestinal worms infectious hookworm larva hatches outside the body and infect by penetrating the skin, mainly acquired by walking barefooted on contaminated soil (Kathleen and Arthur, 2002). Although, other possible modes of infections for *A. duodenale* larvae are orally by ingesting infective larvae and from mother to child through breast milk (lactogenic transmission) (Loukas and Prociv, 2001; Bethony *et al.,* 2006).

2.2 Prevalence of Parasites' Cysts, Oocysts and Ova

2.2.1 Protozoa

Several protozoans with cysts and oocysts have been isolated from human subjects from various parts of the world. The intestinal protozoan parasites that remain prevalent in human subjects include *B. coli, B. hominis, C. mesnili, E. coli, E. dispar, E. hartmanni, E. histolytica, E. nana, G. intestinalis , I. butschlii, I. belli, Mierosporidia species.*

Oubreaks of Cryptosporidiosis have been reported in Canada and the United State of America (Frost *et al.*, 2000).

Budu-Amoako *et al*. (2012) reported a prevalence of 95% for *G. intestinalis* and 14% for *C. parvum* in Prince Edward Island, Canada. Cryptosporidiosis epidemic was detected at two nursing homes in Collingwood, Ontario, Canada with approximately 121 cases, making cryptosporidiosis a reportable disease (Frost *et al.*, 2000).

In Central America, a study conducted on 10,586 school children aged 5-15years over a four year period (2004-2007) showed an average overall prevalence of infection for specific parasites to be *E. histolytica* 16.1%, *G. intestinalis* 10.9%, in Guatamala (Cook *et al.*, 2009). In Belize, *E. coli* (21%), *G. intestinalis* (12%), *I. butschlii* (9%), and *E. histolytica*/*dispar* (6%) were reported by Pote and Paul (2004) on a stool survey carried out in 5 villages in the Toledo district. Other protozoan parasites found during this study were *E. hartmani, E. nana, I. belli*, and *C. mesnili*. The study observed the presence of garbage pit near houses and consumption of stream water as risk factors for protozoan infections (Pote and Paul, 2004).Comparative studies in Latin America have led to the reported that parasitic infections is serious threat to child survival among the children under the age of five worldwide, as they cause 19% of under-five mortality in Honduras, 23% in Nicaragua, 20% in El Salvador and 43% in Guatemala (Erica, 2008). In Mexico, One hundred and twenty-one (44%) of the children examined tested positive for such protozoans as *G. intestinalis* (18%), *E. histolytica/E.dispar* (10%), *B. hominis* (7%), *C. parvum* (4%) and *Cyclospora cayetanensis* (3%) (Elvia *et al.*, 2003).

In South America, studies on enteric parasitic infections showed an overall high prevalence among the young subjects with most of those infected harbouring at least one species of protozoa in their intestines in the northern region of Brazil (Maia *et al.*, 2009). Of the 451 children tested, 58.7% were found to have intestinal parasitic infection, the most prevalent of the protozoan parasites include *G. intestinalis* (21.5%), *E. nana* (17.9%), *and E. histolytica*/*E. dispar* (13.7%) (Maia *et al.*, 2009).While 5.8% and 9.3% of *Cryptosporidium* has also been reported (Ribeiro *et al.,* 2004). Such high prevalence of intestinal parasitic infections have been detected in several earlier studies based in Manaus, Brazil (Hurtado-Guerrero *et al.*, 2005). Also in rural Amazona, Acre State in Brazil, while *G. duodenalis* has also been reported as the most prevalent of protozoan parasites with 19.6% prevalence rate with most frequent protozoan species combinations to be (1) *E. coli* and *E. nana* (10.7% of the subjects examined), (2) *G. duodenalis* and *Escherichia coli* (6.5%), (3) *G. duodenalis* and *E. nana* in 429 stool samples. In Argentina, there is a high shedding of environmentally resistant oocysts of *Cryptosporidium* by calves which promotes contamination of drinking water and facilitates outbreaks of cryptosporidiosis in humans (Mariela *et al.,* 2013).

In Asia, survey of intestinal parasitic infections in people from low socioeconomic communities in Bangladesh and India have revealed that 113 (38%) of the stool samples examined from Kolkata, India and 267 (40%) of stool samples examined from Dhaka, Bangladesh were positive for parasitic cysts and oocysts of protozoans. When the corresponding hand wash samples were analyzed *G. intestinalis* cysts predominated from both surveyed sites with prevalence of cysts being 31% for India and 19% from Bangladesh (Ijaz *et al.*, 2013). People living in these communities who were involved in working in food shops and other settings (e.g., schools, hospitals and service industries), revealed that natural contamination of hands of infected people could be a potential source of transmission of all enteric parasites in hygienically-compromised communities (Ijaz *et al.,* 2013).

In India, intestinal parasitic infection is a major public health problem in children as a result of poor socio‑economic conditions and lack of good hygienic living (Sah *et al.,* 2013). Out of the overall intestinal parasitic infestation found to be 31.5% in a cross‑sectional study conducted in Grade VI, VII and VIII in Government and private schools of Itahari municipality, eastern region of Nepal, 18.5% of the study population was protozoa infected. The study revealed the habit of not using soap to wash hands after defecation, not wearing sandals, habit of nail biting and thumb sucking were significantly associated with parasitic infection (Sah *et al.,* 2013). Elsewhere in the far western region of Nepal a similar study has shown high prevalence of (7.47%) of *G. intestinalis (*Tiwari *et al.,* 2013). According to Dash, *et al.* (2013), intestinal parasitic pathogens were detected in 46.1% out of 115 samples from HIV-infected patients examined in Odisha State, India and the major pathogens were opportunistic protozoans (37/115) 32.2%, with the most common protozoa to be *I. belli* (19/115)16.5% followed by *C. parvum* (14/115)12.2%. Various other studies from India and other countries have reported low, similar or higher prevalence of intestinal parasites, ranging from 15.3% to 77.14% (Daryani *et al.,* 2009). The opportunistic protozoans of 69.8% predominated among all intestinal parasites with *I. belli* (51.3%) as the most commonly detected parasite followed by *C. parvum* (37.8%), Microsporidia (8.1%), and *C. cayetanensis* (2.8%) (Dash, *et al.,* 2013). Also, *Cryptosporidium* species was reported as the most common enteric opportunistic parasite accounting for 37.93 % of the total parasites, followed by *Isospora belli* (31.03 %) in HIV/AIDS infected people with diarrhoea in Jaipur City (Nitya *et al.*, 2013).

In Iran, Homeira *et al.* (2013) reported a total prevalence of 25.7% for parasitic infections in HIV-positive patients in Sanandaj, Iran in the years 2007-2008. The Prevalence of the specific parasites identified were *B. hominis* (6.8%), *E. coli* (6.8%), *G. intestinalis* (1.4%), *C. parvum* (8%) and *C. cayetanensis* (2.7%). In addition, the Prevalence of intestinal parasites' contamination of some raw vegetables (leek, green onion, radish, garden cress) in Khorramabad, Iran was 52.7% and the highest contaminated vegetable being leek with 80% prevalence in spring and 43.6% prevalence in winter. However, the least contaminated vegetables were green onion (34.5%) in spring and garden cress (10.9%) in winter out of a total of 550 fresh vegetables sampled during spring and winter. The investigation revealed the cysts of *Giardia* spp. in 6.9% and *E. coli* in 11.3% of the total vegetables sampled. The findings from this study were almost similar with previous reports in parts of Iran which were 8.2% in Shahrekord (Fallah *et al.*, 2011), 14% in Jiruft (Zohour and Molazadeh, 2001), 6.5% in Tehran (Gharavi, *et al.*, 2002), 9% in Ardabil (Daryani *et al.*, 2008) and 4% in Qazvin (Shahnazi and Jafari-Sabet, 2010). It has been determined that the excretion of parasite eggs to environment by human or animals is higher in warm seasons when compared to cold seasons (Eslami *et al.*, 2003). In Pakistan, *G. intestinalis* has been reported as the most common intestinal protozoan parasites present in 63 samples (28.9%) with *Blastocystis hominis* in 22 samples (10.1%), *E. coli* in 5 samples (2.3%) and *I. butschlii* in 7 samples (3.2%) obtained from children in urban slum of Karachi (Mehraj *et al.*, 2008).

In South Africa, infection prevalence of (16/162)9.9% was obtained for *G. intestinalis*, (11/162)6.8% for *E. histolytica/dispar* (5/162)3.1% for *I. butschlii* and (2/162)1.2% for *C. mesnili* among 162 learners analyzed for parasitic protozoans (Nxasana *et al.*, 2014).

In North Africa, the ingestion of raw vegetables was found as an important means of the transmission of several infectious diseases. A study conducted to detect the parasitic contamination of some common raw vegetables in Alexandria, Egypt revealed infestation of *Giardia* spp. oocysts of *Cryptosporidium* spp., Oocysts of *Cyclospora* spp. and spores of *Microsporidium* spp. The highest contamination was detected in rocket (46.7%) and the least was detected in green onion (13.3%). Oocysts of *Cryptosporidium* spp. were the highest prevalent parasite detected in raw vegetables (29.3%) with the highest score density in rocket samples. It was followed in that order by *Microsporidium* spp. spores (25.3%), *Cyclospora* spp. oocysts (21.3%) and *Giardia* spp. cysts (6.7%). The study showed no significant difference between the number of contaminated samples obtained in spring and summer or autumn and winter (Doaa, 2012). These results were in agreement with 36% contamination in Ghana and 36% reported in Nigeria (Damen *et al.*, 2007).

In Libya, the occurrence and prevalence of intestinal protozoan parasites in male and female Libyan nationals residing in Benghazi, Libya was investigated by El-Ammari and Nair (2003). The study revealed that 18.3% males (156 out of a total of 852 males) and 14.2% women (86 out of a total of 606 females) had cysts and /or trophozoites of seven intestinal parasites which included the pathogenic *E. histolytica* and *G. intestinalis* and the non-pathogenic *E. dispar, E. coli, E. nana, Chilomastix* and *Blastocystis hominis.*

Higher overall and group –wise percentages of both sexes had the cysts of *E. histolytica/dispar* and *E. coli* followed by the cysts and /or trophozoites of *G. intestinalis* in their stools (El-Ammari and Nair, 2003).

In Eastern Africa, a 6-year (2005-2010) retrospective study conducted at the Mojo Health Centre in eastern Ethiopia gave the total prevalence of protozoan infection as 8.8% of the 5007 samples (Chala, 2013). There was a statistically significant difference with the total prevalence in helminths infection of 0.5% out of 9.3% overall prevalence (Chala, 2013). Of these positive samples, 4.4% and 4.9% were males and females and multi-infection was common, especially with the two most prevalent protozoan parasites, *E. histolytica* and *G. intestinalis* (Chala, 2013). Another Cross-Sectional Study conducted in Northwest Ethiopia has shown the prevalence of *G. intestinalis* to be 12.4% and *E. histolytica/dispar* 4.6% (Abate *et al.*, 2013). Furthermore, an overall prevalence of 60.7% (58.2% in males and 62.8% in females) for intestinal parasites was obtained in stool samples of 384 primary school children at Wukro town, Ethiopia (Kidane *et al.*, 2013). *Entamoeba histolytica, G. intestinalis* and *I. beli* were the major protozoan parasites identified from the school- children with the prevalence of 23.2%, 16.9% and 4.4%, respectively (Kidane *et al.*, 2013). The varied results were due to variations in climatic and geographic zones in Ethiopia, as it was evident that there are macro and micro-environmental factors contributing to the differences in prevalence of intestinal parasites. The prevalence of pathogenic protozoans among school aged children in Tanzania was 18.0% for *E. histolytica*/*E. dispar*, 16.4% for *G. intestinalis* , 28.0% for *B. hominis*, 51.5% for *E. coli*, 19.5% for *E. nana*, 13.3% for *E. hartmanni*, 8.2% for *C. mesnili* and 6.7% for *I. bütschlii* (Speich *et al.*, 2013). In Kigali, Rwanda prevalence of *Entamoeba histolytica* was 54.5%

and *Giardia duodenalis* was 3.6% which were strongly associated with drinking any kind of water and eating outside of the Kigali Institute of Education (KIE) cafeteria and significantly related to living outside of the KIE campus, (Emile *et al.,* 2013).

In West Africa, in a study conducted to accurately diagnose human infection in cote d' Ivoire, Becker *et al.* (2011) found higher prevalence of *E. coli* (77.8% versus 71.3%), *B. hominis* (20.4% versus 13.0%) and *G. intestinalis* (8.3% versus 6.5%, P < 0.001) using the Flotac-400 dual technique while the formalin-ether concentration technique (FECT) detected higher prevalence of *E. histolytica/E. dispar* (27.8% versus 20.4%), Ouattara *et al.* (2010) have also reported prevalence of *Entamoeba histolytica*/*dispar* and *Giardia intestinalis* as 18.8% and 13.9% respectively, among School children in Agboville Area of Coˆte d'Ivoire. In addition to these pathogenic species, six nonpathogenic species were found among the samples: *E. hartmanni, E. coli, E. nana, I. butschlii, C. mesnili* and *B. hominis*. The most common species were *E. nana* and *E. coli*, with respective prevalence of 65.5% and 62.3%. Other previous studies reported 11.3% *E. histolytica*/*dispar* in west Coˆte d'Ivoire (Ouattara *et al.,* 2008), 10.8% *G. intestinalis* in Agboville in the Man area (Raso *et al.,* 2004) and 1.4% for *G.intestinalis* in Toumodi in central Coˆte d'Ivoire (Adou *et al.,* 2001). In Ghana, Ayeh-Kumi *et al.* (2009) reported prevalence of 2.5%, 2.0%, and 2.0% for *C. parvum*, *G. intestinalis* and *E. histolytica* respectively among food vendors.

In Nigeria, studies conducted by Wellington *et al*. (2008) in Lagos showed that parasitic protozoans were detected more in watery stools with mucus with 23.0% positivity compared with watery stools alone 14.3% positivity. The overall prevalence of parasitic protozoan infection was 27.6% with *E. histolytica/dispar* and *Cryptosporidium* species having the highest prevalence of 9.5% and 17.1% respectively. In Abeokuta, Ogun State, Nigeria, Akingbade *et al.* (2013) obtained prevalence of 25.8% and 19.4% for *E. coli and E. histolytica* respectively among children with diarrhoeal stools. An earlier report by Egwari *et al.* (2005) in Lagos southwest Nigeria who worked on sachet water found no cyst of *E. coli* but Okonko *et al.* (2009) reported a far higher prevalence of 51.7% for *E. histolytica*.

In south eastern Nigeria, a study carried out by Ezeagwuna *et al.* (2009) at a tertiary institution in Anambra State showed that out of 492 subjects examined, *E. histolytica* was the most prevalent parasite amongst the population with 43.9% prevalence while *G. intestinalis* (*G.lamblia*) had the least prevalence of 12.4%. In Awka Anambra State, Nigeria, sachet drinking water were contaminated with the cysts of *E. histolytica* and *G. intestinalis* with respective prevalence of 4.6% and 1.9% (Ekwunife *et al.*, 2010). Orji *et al.* (2012) isolated protozoan cysts from assorted dirty and mutilated bank notes which belonged to flagellates and *E. histolytica* with respective prevalence of 3.5% and 9%. A prevalence of 9.3% for *E. histolytica* among undergraduate student of Michael Okpara University of Agriculture in Umudike, Abia State, Nigeria was reported by Ohaeri and Orji (2013).

Biu and Dauda (2008) examined 150 stool samples in Maiduguri, and observed a high prevalence of enteric protozoa to a tune of 72.0%. Parasite specific prevalence were 75%, 17.6% and 7.45% *G. intestinalis, E. histolytica* and *B. coli* respectively. The high prevalence of parasites was attributed to poverty, poor personal and environmental hygiene, impoverished health services and endemicity of enteric protozoans parasites as previously highlighted by several workers (Fashuyi, 1983; Adeyeba and Akinlabi, 2002; Biu and Adam, 2004).

In Kaduna State Nigeria, Inabo *et al.* (2012) isolated cysts and oocysts of five parasitic protozoans from diarrhoeic stools of HIV/AIDS patients in a tertiary hospital in Zaria. The prevalence of the parasites encountered were 7.8% for *E. histolytica*, 3.9% for *G. intestinalis,* 23.55% for *C. parvum*, 9.8% for *I. belli* and 23.5% for *C. cayetanensis*. Other environmental parasitological studies included those of Nock and Tanko (2000) who reported prevalence of 14% for protozoan oocysts on the soles of shoes and Ademola (2012) obtained a prevalence of 38.30% for *Cryptosporidium*, 0.13% for *Isospora* sp. from the hands of primary school children pupils. A high prevalence of 64% oocysts was obtained for the Coccidia and 16% for the cysts of *E. histolytica* on the handles of water closets in toilets of staffs and students in the University (Nock and Geneve, 2002). Ndams and Jimoh, (2006) reported a prevalence of 12.5% for *E. histolytica* on computer mouse and keyboards. From twenty four bunches of assorted dirty naira notes in Zaria were recovered the oocysts of *Isospora* sp. (Awodi *et al.*, 2000). From these studies it was evident that the soles of shoes, door handles, and computer accessories (Keyboard and mouse) were potential surfaces for the contamination of protozoan parasites.

In the north central part of Nigeria, Omowaye and Audu (2012) observed that 2.5% of the fruits and 2.8% of the vegetables on sale in the major markets in Kogi State were contaminated with protozoan cysts. Also some of the naira notes in circulation within the

Federal Capital Territory (FCT), Abuja, were contaminated with flagellates and *E. histolytica* cysts with prevalence of 1.5% and 12.5% respectively (Matur *et al.,* 2009).

In Benue State, Jombo *et al.* (2007) worked in Tyogbenda, Jato-Aka and Adikpo communities and reported respective prevalence of 6.5%, 8.5% and 8.0% for *E. histolytica* and 10.5%, 8.0% and 2.5% for *E. coli*. These varied reports indicate that protozoans constitute a very formidable and cosmopolitan parasitic scourge infecting all categories of individuals through contaminated food items and surfaces and of animate or inanimate nature.

2.2.2 Helminths

Soil transmitted helminths (STH) have been known to constitute horrendous global burdens on human health (Emile *et al.,* 2013). Helminths have also imposed a great burden on poor populations in the developing world despite the robust, low-cost and effective public health interventions available to relieve that burden and provide a better quality of life for people in poor settings (Saboyá *et al.,* 2011).

The four most common soil-transmitted helminths (STH) are roundworm (*A. lumbricoides*), whipworm (*T. trichiura)* and the anthropophilic hookworms (*Necator americanus* and *Ancylostoma duodenale*). Recent worldwide estimates suggest that *A. lumbricoides* infects 1.221 billion people, *T. trichiura* 795 million and hookworms 740 million (Saboyá *et al.,* 2011). The greatest numbers of STH infections occur in the Americas, China, East Asia and Sub-Saharan Africa (Brooker *et al.,* 2006; Hotez and Kamath, 2009). *S. stercoralis* is also a common STH in some of these regions, although detailed information on the prevalence of strongyloidiasis is lacking because of the difficulties in diagnosing human infections (Saboyá *et al.*, 2011).

In Central America, helminths such as *H. nana* (10%), *T. trichiura* (6%), and *A. lumbricoides* (6%) and two cases of infection with *E. vermicularis* were identified among 202 children with age ranging between 2-14 years in Mexico (Elvia *et al.*, 2003). In Belize, a stool survey showed prevalence of hookworm infection as 55% and was the most common infection followed by 30% prevalence of *A. lumbricoides* and a low prevalence of 1% for *S. stercoralis* (Pote and Paul 2004). This was however different from earlier studies conducted in West-Central Belize by Petana (1968) who reported prevalence rate of 43%, 40%,7%,6%,2% and >1% for the ova of *A. lumbricoides*, *T. trichiura*, *E. histolytica*, hookworms, *H. nana*, *S. stercoralis*, and *E. vermicularis* (Pote and Paul, 2004). Cook *et al.* (2009) obtained prevalence of 17.7%, 5.4%, and 2.8% for *A. lumbricoides, H. nana,* and *B. hominis* respectively, among young Guatemalan children.

In South America, Maia *et al.*, (2009) obtained 13.5% and 4.9% prevalence for *A. lumbricoides* and *T. trichiura* respectively as the two important public health problems in northern region of Brazil. Elsewhere in Brazil, *A. lumbricoides* has been identified as a more common parasite in young children with approximately 35% prevalence (Arau´jo and Fernandez; 2005; Hurtado Guerrero *et al.*, 2005).

In Asia, a study by Mehraj *et al.* (2008) identified the proportions of wasted, stunted and underweight children to be 10.4%, 58.9% and 32.7% respectively and that prevalence of helminths such as *A. lumbricoides* to be 16.5% while that of *H. nana* was 0.9%. A study conducted in Nepal, 13% of the study population was found to be infested with helminths with *Taenia* species been the most prevalent among the helminth infestation (Sah *et al.*, 2013). Also, studies conducted among different age groups gave 46.56% prevalence of *H. nana,* 27.58% for Hookworm, 17.82% *A. lumbricoides*, and 0.57% *T. trichiura* (Tiwari *et al., 2013*). A study on the natural contamination of human hands with eggs of enteric parasites in the Indian subcontinent has indicated that eggs of *A. lumbricoides* was the most prevalent with 43% and 37% prevalence in Kolkata and Dhaka respectively. Other helminths parasites encountered and their prevalence include 20% for *Trichuris* spp. in Dhaka and 2% for both *Taenia* spp. and *H. nana* infections in Kolkata and 0.5% for Hookworm in Dhaka (Ijaz *et al.*, 2013). In addition, school children from a slum in Visakhapatnam, South India were surveyed for intestinal parasitic load and were found to have 73%-75% prevalence of *A. lumbricoides* followed by 66% for *T. trichiura* and 9% for Hookworm (Ijaz *et al.,* 2013). In Iran, it was well known that raw vegetables were agents for the transmission of intestinal parasites and a study designed to detect the contamination of helminths eggs in many common raw vegetables in Khorramabad gave prevalence of *A. lumbricoides* as 4.7%, *E. vermicularis* as 4%, *S. stercoralis* as 1.8% and *Fasciola hepatica* as 1.1% on the vegetables in spring, while in winter they all showed prevalence of 1.1% (Ezatpoura *et al.,* 2013). Other studies in Iran gave the prevalence of *A. lumbricoides* as 2% in Ardabil (Daryani *et al.,* 2008), 2.5% in Jiruft (Zohour and Molazadeh, 2001) and 2.3% in Qazvin (Shahnazi and Jafari-Sabet, 2010).

In Southern Africa, *A. lumbricoides* accounted for 29.0% and it was the most common helminths pathogen found in Eastern Cape Province, South Africa (Nxasana *et al.*, 2014). Prevalence of the other helminths isolated, though in lower numbers, were 3.7% *T. trichiura*, and 1.6% for *Taenia* spp. (Nxasana *et al.,* 2014). In a study conducted in

Lesotho, a neighbouring country to South Africa, in the northern part of Mthatha, a high prevalence rate of *A. lumbricoides* was reported among patients attending Tebellong hospital, in Qacha's Nek (Oguntibeju, 2003; Nxasana, *et al.*, 2014). Samie *et al.* (2009) also reported higher rates of infection by *Ascaris* in Cape Town, South Africa. Ekpo *et al.*, (2008) found that *A. lumbricoides* was the most common infecting helminthic species in the three schools they surveyed.

In East Africa, intestinal parasitic infections were identified as the major causes of mortality and morbidity and a series of public health problems in Ethiopia (Abate *et al.*, 2013). *A. lumbricoides* was the most predominant pathogenic helminth parasite accounting for 23.2% of cases in Teda Health Centre, Northwest Ethiopia with others being 0.4% *E. vermicularis* and 0.2% for *S. stercoralis* (Abate *et al.*, 2013). Furthermore, studies conducted in Gondar and Southeast of Lake Langano also reported 5.9% and 6.2% prevalence of *A. lumbricoides* respectively (Abate *et al.*, 2013). However, the demonstration of 7.30% and 0.50%, prevalence of hookworm species and *S. stercoralis* were not in agreement with previous studies conducted in Ethiopia (Mengistu, 2007 and Gelaw *et al.*, 2013). In Rwanda, six species of intestinal helminths with an overall prevalence of 65.8% have been identified among school children aged 10-16 years from 136 primary schools in 2008. The predominant parasites were *A. lumbricoides* observed in 38.6% of the children, followed by *A. duodenale* in 31.6% of the children (Mupfasoni *et al.*, 2009).

In North Africa, ingestion of raw vegetables represents an important means of transmission of several infectious diseases and studies conducted have revealed prevalence of *A. lumbricoides* eggs to be 20.3% while eggs of *Toxocara* spp. was reported to be 19% in Alexandria, Egypt (Doaa, 2012). In Tripoli, Libya a higher rate of contamination with 68% of fresh salad vegetables with *Ascaris* eggs have been reported (Abougraina *et al.,* 2010). They were detected in tomato with 19%, cucumber 75%, lettuce 96% and cress 96%. *Toxocara* eggs on the other hand were detected in 11%, 14%, 48% and 41% of the tomato, cucumber, lettuce, and cress samples respectively (Abougraina *et al.,* 2010).

In West Africa, the operation and patronage of fast-food facilities, restaurants and chop bars have increased and was common within the Ghanaian communities. Ayeh-Kumi *et al.* (2009) found an overall prevalence of helminth infections among food vendors to be 15.2% with specific prevalence for *A. lumbricoides* as 5.0%, *S. stercoralis* as 4.4%, *E. vermicularis* as 4.1% and *A. duodenale* 2.0% out of a total of 204 food vendors examined in seven metropolitan areas of Accra- Ablekuma –South. Other studies identified prevalence of *A. lumbricoides* to be 45.5%, *Ancylostoma* sp. to be 37%, *T. trichiura* to be 9%, and *Trichostrongylus* spp. 8.5% in stabilization ponds sludge in Burkina Faso (Konate *et al.,* (2013). Yapi *et al.* (2006) obtained from the savannah areas of Cote d' Ivoire a prevalence of 0.7% for *A. lumbricoides,* while they got prevalence of 18.9%, 2% and 0.1% *A. lumbricoides, T. trichiura* and *S. stercoralis* respectively from the forest areas.

In Nigeria, a study carried out among undergraduate students of the Michael Okpara University of Agriculture, Umudike in Abia State, observed prevalence of *A. lumbricoides* to be 25.2%, Hookworm spp. 20.4%, *T. trichiura* 3.0%, *Taenia* species

7.5% and *S. stercoralis* 6.6% (Ohaeri and Orji.2013). Amaechi *et al.* (2013) have also reported the prevalence of 8.2% *A. lumbricoides*, 5.1% for Hookworm and 3.9% for *T. trichiura* among children in three selected schools at the Ukwa East Local Government Area of Abia State. The result showed a high prevalence of 75.7% out of 338 stool samples examined. Risk factors identified with infections were in the month of July (peak of the rainy season) which had the highest prevalence rate (92.9%), highest prevalence of 89.9% for those who defecated in bushes and other unhygienic places and those that used wells and streams as their main sources of water had prevalence of 96.9% (Amaechi *et al.,* 2013). Inadequate basic social amenities have contributed to the spread of parasites in the area (Ohaeri and Orji, 2013).

In Enugu, South eastern Nigeria, Out of 1,296 school children examined for helminth parasites, were infected. Prevalence of 4.9% was recorded for *A. lumbricoides*, 2.5% for hookworm and 0.7 % for *T. trichiura* (Edelduok *et al.,* 2013). High prevalence of STHs among school age pupils have been consistently reported in other studies (Nock *et al.,* 2003; Edelduok *et al.,* 2013). Overall prevalence of hookworm (*A. duodenale* and *N. americanus*) infection of 50.0% in males and 55.0% in females as well as ascariasis prevalence of 69.5% in males and 71.9% in females have also been reported at Nsukka zone, eastern Nigeria (Onuoha *et al.,* 2010). Overall prevalence of 4.9% for *A. lumbricoides*, 2.5% for Hookworm and 0.7% for *T. trichiura* infections was recorded among school children in Igbo-Eze South Local Government Area of Enugu State (Ekpenyong and Eyo, 2008). In Awka, Anambra State, Ekwunife *et al.,* (2010) reported that the surfaces of the sachets of packaged water purchased from hawkers had the highest prevalence of 41.7% of parasites. Identified isolated helminths ova included those of *A. lumbricoides* (5.6%), Hookworm (2.8%) and *T. trichuria* (2.8%) (Ekwunife *et al.*, 2010).

In the north west of Nigeria, *A. lumbricoides* with prevalence of 30.7%, *Taenia* spp. 23.0%, Hookworm 6.4%, *T. trichiura* 4.9%, *E. vermicularis* 4.6% and *S. stercoralis* (4.2%) were obtained among primary school chidren of Gwagwada in Kaduna State (Auta *et al.,* 2013). Studies in Zaria have reported that 88.3% of vegetables eaten raw had helminth ova on them. Helminth ova detected were those of *A. lumbricoides* (73.3%), *T. trichiura* (13.3%) and hookworm (1.66%) (Inabo and Gana, 2011). A total of 69% of assayed stools obtained from human preidomestic environment around Zaria were positive for ova and larvae of five helminth parasites (Adebote *et al.,* 2005). The respective number and prevalence of helminths positive stools were 69 (34.5%) *A. lumbricoides*, 30(15.0%), Hookworm, 3(1.5%) *Schistosoma mansoni*, 32(16%) *S. stercoralis* and 5(2.5%) *T. trichiura* (Adebote *et al.,* 2005). Ova of such helminths as *A. lumbricoides,* (62.50%), *E. vermicularis* (12.50%), *T. trichiura* (8.33%) and *Taenia* spp. (4.17%) have also been isolated from computer mouse, keyboards and users of internet cafes in Samaru, Zaria (Ndams and Jimoh 2006).

In north central Nigeria, dirty naira notes have been identified as potential vehicles for pathogens and parasitic infections to man during handling. It has been identified that 32% of the naira notes in circulation in the Federal capital territory (FCT) Abuja were contaminated with the ova of various species of helminths, *A. lumbricoides* eggs accounted for 4.5%, Hookworm eggs 8.5%, and *E. vermicularis* eggs (0.5%) while the mints harbor no contamination (Malau *et al.,* 2009). Parasites that have been observed to be contaminants of the naira notes or other surfaces are those of high social-economic importance and mainly of faecal origin (Awodi *et al.,* 2000). In Kogi State, 4.3% and 4.6% helminths ova contamination has been identified of 1755 fruits and 761 vegetables respectively. *S. stercoralis*, *T. trachiura* and *A. lumbricoides* were predominant in that order with highest contamination in Anyigba market with rate of 15.07% followed by Dekina market with 11.93% (Omowaye and Toluhi, 2011).

In Benue State, Nigeria, a study by Jombo *et al*. (2007) to assess the level of parasite burden has revealed the prevalence of intestinal parasites at Tyogbenda to be 76.5% (153 out of 200), Jato-Aka 71.0% (142 out of 200) and that of Adikpo 44.0% (88 out of 200). *A. lumbricoides* accounted for 34.5%, 28.5% and 19.0% in Tyogbenda, Jato-Aka and Adikpo communities respectively. Other helminths identified in this study were *T. trichiura, S. stercoralis, E. vermicularis, Taenia* species and Hookworm (Jombo *et al.,* 2007). Overall prevalence of 83.6% for helminth parasites has been reported in slaughtered pigs in Makurdi, a possible route through which human Taeniasis may occur (Aernan *et al.,* 2011). In addition *Ascaris suum* (22.8 %), *T. vitulorum* (13.2 %), *Toxocara canis* (19.8 %) and *T. cati* (9.5 %) were identified among soil samples collected from Makurdi metropolis. Filthy environment and refuse heaps has been identified as means of contamination and flies can mechanically transfer parasites' ova from dirt to openly displayed products and or surfaces (Omowaye and Toluhi, 2011).

2.3 Factors Promoting the Occurrence and Viability of Parasites' Cysts and Ova in the Environment

Intestinal protozoan and helminthic infections are endemic worldwide and have been described as constituting the greatest single worldwide cause of illness and disease

(Steketee, 2003). These infections have a worldwide distribution, especially in developing countries with low socio-economic status and poor living conditions (Adamu *et al.,* 2006).

The prevalence of intestinal parasitic infections is one of the most accurate indicators of socioeconomic living conditions of a population (Astal, 2004), and are associated with several determinant factors, such as inadequate sanitation, faecal pollution of water and foods, sociocultural factors, contact with animals, as well as host age and type of infecting parasite (Gamboa *et al.,* 2003). Some of the stringent factors promoting the occurrence and viability of parasites' cysts and ova in the environment are discussed below.

2.3.1 Environmental insanitation

Environmental insanitation plays a key role in the distribution of parasitic infections. It provides the varied and favourable medium for occurrence and viability of parasite cysts and ova. This becomes most important when it is associated with other co-factors like poor personal hygiene and limited access to clean water in the transmission and contamination processes especially of vulnerable contact surfaces where eggs and cysts are easily picked and ingested thereby causing serious deleterious intestinal parasitic infections to host organisms (Gabbad and Elawad 2014).

Many epidemiological researches carried out in different countries have shown that poor sanitary and environmental conditions are associated with intestinal parasitic infections (Pinar *et al.,* 2004). This finding was also observed by Al-Shammari *et al.* (2001), in Riyadh, Saudi Arabia where water storage and open sewage disposal in the environment were statistically associated with parasitic infections ($P < 0.05$). Self-latrine care, lack of solid waste collection and visible sewage near the houses were found as significant risk factors for intestinal parasitic infections (Manisha *et al.*, 2014).

A cross sectional study conducted by Gabbad and Elawad (2014) on environmental sanitation factors associated with intestinal parasitic infections in primary school children in Elengaz, Khartoum, Sudan showed statistical significance between access to potable water in family house and intestinal parasite infection among primary school children (Odds ratio = 5.8 and 95% Confidence Interval (CI) = 3.8 to 8.9). In addition, unsanitary solid waste disposal was statistically significantly associated with intestinal parasitic infections among primary school children (Odds ratio = 1.6 and 95% Confidence Interval = 1.1 to 2.3). Also the presence of latrine in the family house as well as number of house rooms were significantly associated with intestinal parasitic infections (Relative risk = 3.9, 95% Confidence Interval = 2.7 to 4.3) (Gabbad and Elawad, 2014).Gabbad and Elawad (2014) in their study concluded that improvement of water supply and sanitation are fundamental issues in controlling intestinal parasitic infections.
Similarly, Shadma *et al.*, (2009) associated the drinking of impure water with intestinal parasitic infections among children. Asrat *et al.* (2011) in Ethiopia also found that unsafe drinking water was statistically significantly associated with these infections in school children.

Ezeagwuna *et al.* (2009) in a study in Ozubulu, Anambra State, Nigeria attributed the spread of intestinal parasitic infections to the state of the environment and the socio-cultural habits of the people. Adebote *et al.* (2005) has also demonstrated a high prevalence of 69.5% for helminths ova in human faeces deposited in the peri-domestic environment of a suburb village in Zaria, northern Nigeria. This study has demonstrated the existence of infective stages of some soil-transmitted helminths in human peri-domestic environment contaminated with faeces that could ensure the transmission of infection to individuals that make skin contact with soil.

Spread of intestinal parasitic infections in a population is generally associated with water supply and sanitation beside other factors in the environment (Zahid *et al.*, 2004). People that drank contaminated water were exposed to the risk of infection with intestinal parasites (Shadma *et al.*, 2009). Children using tube wells as sources of drinking water had significantly higher prevalence of parasitic infestation than those using tap water (Ram *et al.*, 2013).

The significance of unsanitary disposal of solid waste in association with the spread of intestinal parasites has been revealed (Gabbad and Elawad 2014). Undisposed or unsafe disposal of solid waste provides an unsanitized environment for the lodging, favourable life cycle completion and transmission of (oo)cysts, ova, larvae and even trophozoites of parasitic pathogens. Such environments are also ideal breeding of house flies and cockroaches, which are vectors of some intestinal parasites, in addition to the risk of cross contamination of water and food by infective stages of these parasites. House flies and cockroaches which are indicators of insanitary environments, are increasing in houses with no hygienic means of human excreta disposal i.e. sanitary latrines (Gabbad and Elawad 2014). In India, Manisha *et al.* (2014) have indicated latrines as significant risk factor for intestinal parasitic infections. Gastro-intestinal parasitic infections, including soil-transmitted helminths are widespread in crowded urban environments with poor sanitation (Gabbad and Elawad 2014).

Parasitic diseases associated with low standard of sanitation in the environment remain the leading cause of morbidity and mortality in many developing countries. The prevalence of amoebiasis varies from as low as 2 percent to 60 percent or more in areas devoid of sanitation. The severities of enteric diseases in tropical areas are due to widespread poverty, lack of good drinking water and poor sanitation as well as climatic influence (Encarta, 2004). Amuta *et al.* (2004) also observed a positive correlation between faecal contamination of school compounds and the availability of sanitary facilities in Makurdi, Nigeria.

In Nigeria, the interplay of these factors are due to lack of relevant and effective policy on environmental sanitation, inadequate implementation of health, housing and other related policies, lack of community awareness and concerns on environmental issues as well as inadequate knowledge and access to low cost sanitation technologies, high level of poverty and low level of rural development (FEPA, 2000; Ademola, 2012).

2.3.2 Poor personal hygiene

Poor hygienic practices and inadequate sanitary conditions play major role in increasing burdens of communicable diseases especially within developing countries (Vivas *et al.*, 2010). These account for the presence of parasitic immature stages of protozoans and helminths in the soil and air (Lawande, 1983; Mahdi and Ali, 1993), on fomites and other contact surfaces, acting as vectors for the transmission of infective stages of parasites and subsequent spread of infections (Awodi *et al*., 2000; Oluwafemi and Ajibade 2012).

For instance, amoebiasis can be spread when infected people do not dispose their faeces in a sanitary manner (Ademola, 2012). The existence of toilets in houses was associated with fewer helminthic infections, and helminth transmission mode was closely associated with ground contamination (Vinícius *et al.,* 2012). Lack of portable water supply and poor environmental sanitation are the reasons why diseases associated with unhygienic disposal of human faeces and refuse are so common in developing countries (OECD, 2005). Parasites observed to be contaminants of the naira notes are mainly from faecal sources (Awodi, *et al.,* 2000), especially when hands used in cleaning up the anus after passing out faeces are not properly washed or when hands from contaminated contact points are used to touch surfaces, thus exposing those surfaces to contamination with the trophozoite, eggs, cysts or even the oocysts of the parasites.

Other attitudes such as wetting of hands or fingers with saliva or use of contaminated water to lubricate the hand while counting money are unhygienic behaviors that leads to possible transfer of parasite cysts and ova from such medium to the notes and to humans (Ameh and Balogun, 1997). People are not always conscious of washing their hands especially with cleansing agents as previous hand hygiene studies have indicated (Global Handwashing Day, 2009).

A study conducted by the United Nations Children's Fund (UNICEF) and the Ethiopian Ministry of Health found that study participants in rural Ethiopia had poor status regarding knowledge, attitudes and practices (KAP) of hygiene (Kumie and Ali, 2005). Out of 99.0% of individuals that practiced hand washing before meals, only 36.2% actually used soap. While of the 76.7% of students who agreed that washing hands after defecation was important, only 14.8% actually followed this practice (Vivas *et al.,* 2010). A study conducted by the Global Public–Private Partnership for Hand Washing (PPPHW) which included several sub-Saharan African countries reported that only 17% of participants washed their hands with soap after using the toilet, while 45% used only water (Curtis *et al.,* 2009).

It was noted by Ejemot *et al.* (2008) and Snow *et al.* (2008) that individuals that observed proper hand washing practices were less likely to report gastrointestinal and respiratory disease symptoms. Also, hand washing with soap has been reported to reduce diarrhoeal morbidity (Curtis *et al.,* 2009). These indicate that unhygienic hands play key roles in supporting the entrance of infective stages of parasites into humans. This is an important point to note as lack of resources such as soap and water, as well as inadequate sanitation facilities are two of the main reasons why people do not wash their hands (Oswald *et al.*, 2008). Lack of these resources could also have been responsible for high poor personal and sanitary conditions especially in developing countries such as Nigeria where the state of personal and environmental hygiene have been described as generally poor, with soil in the environment infested with faecal matter which results to poor state of hygiene arising from improper disposal of faeces (Ademola, 2012).

2.3.3 Socio-economic factors

Diseases that are human induced or self-inflicted, mostly brought by other humans, either as individuals or collectively as a society are described as social diseases (Taylor *et al*., 1997). Several socio-economic factors have been identified for the continual propensity of intestinal parasites (Samba, 2005). Human behaviour, cultural practices, customs and traditions, socio-economic conditions and educational status of the population are all socio economic factors that aggravate the spread of tropical diseases.

Most diseases caused by micro-organisms in tropical Africa are as a result of poverty and its accompanying features (Sulaiman, 2005). These features include lack of sanitation, malnutrition, illiteracy and overcrowding which play key roles in the transmission of both the infectious and non-infectious diseases in tropical Africa (Encarta, 2004).

For instance, the growing urbanization of most societies has created dense population centres which help to aggravate the spread of tropical diseases (Sulaiman, 2005). The banking system provides such centres where constant human traffic could lead to contamination of bank facilities. Contamination of the naira notes, computer keyboards and mouse and other vulnerable surfaces has long been discovered to be through socio-economic pressures and poor handling practices with hands inadvertently contaminated with human and or animal faecal matters (Fashuyi, 1983). It has been found that movements from place to place especially for social gatherings are potential means for the transmission of parasites as was the case incriminating soles of foot-wears harbouring parasites' cysts and eggs from contaminated soils (Nock and Tanko, 2000). Adebote *et al.* (2005) also observed that playing with contaminated soil, people walking and working barefooted on peridomestic farmlands could also succumb to geohelminth infections. Pathogenic organisms are widely distributed in the environment and so are much associated with human behaviour and their metabolic wastes, which boils down to the level of personal hygiene and other human social practices.

Studies have demonstrated a common relationship between parasitic infections and lower socioeconomic status (Otkun *et al.,* 2000). Living in rented houses as a proxy measure of socio-economic-status revealed that lower socio economic status is positively associated with inter-parasitic infections (Mehraj *et al.,* 2008). The hometown of parents as the place of birth for children and in-house animal breeding were also found to be associated with higher risk for parasitic infections. However, the effect of socioeconomic status on the risk of infectious diseases in general, and parasitic infections in particular is complex in nature and observed infections could be attributed to several other factors (Harpham *et al.,* 2002; Houweling *et al.,* 2003).

Parasitic infections cause human suffering and economic loss worldwide, however the burden is greatest in the underdeveloped countries. This is because basic amenities such as good drinking water, good toilet system and other cleansing agents are lacking in underdeveloped nations with increased low level of personal hygiene and poor sanitation (Schimunis and Lopez, 1999; Mehraj *et al.*, 2008; Ademola, 2012).

Parasites cause social problems and their effects are increased by the conditions in disordered societies. Their presence hampers educational, political and economic development, imposing a tremendous burden on an already pre-carious health services in the poor areas of the world (Schimunis and Lopez, 1999).

More efficient control measures directed at susceptible populations and those which take into consideration the associations and interplay of factors, should be a priority, as they are not only useful to decrease inequalities among associated factors, the prevalence and the incidence of intestinal parasitic infections, but also improve quality of life and the public health system as a whole (Vinicius *et al*., 2012).

2.3.4 Age of host

Intestinal infections by protozoans and helminths are estimated to affect 3.5 billion people and causes diseases in 450 million individuals, most of them children, around the world (WHO, 2008). This shows that age is an important determinant and risk factor for IPIs especially as increasing dose response association between age and IPIs has been identified (Mehraj *et al.,* 2008).

School children belong to the age group with the highest prevalence of parasitic infection in most communities of low economic backgrounds (Hoeprich, 1975). The prevalence of diarrhoea in Nigeria is widely reported showing 18% and 10% rates among infants and under five respectively (Anonymous, 2003; Gundiri and Akogun, 2000). It has also been identified that parasitic infections were more common in younger children and children sharing rooms, due to weaker hygienic attitudes of younger children (Otkun *et al.,* 2000). In addition, *E. histolytica* and *E. disper* infections increase with age from 2-14 years old children, which are probably person to person transmission (Roche and Benito, 1999). Young children are most vulnerable to chronic blood loss due to hookworm infections because they have the lowest iron stores, and pinworm typically affects children between the ages of 5-15 years old (Franchot and Nicky, 2000). Omudu and Samba (2005) reported a high prevalence of intestinal parasites in selected pupils in Benue State, where out of 350 samples, 202 (56.1%) were positive for various helminth infections.

One major factor that accounts for school children being at high risk of intestinal parasitic infections is their behavioral habit when it comes to playing with contaminated sands in schools and even at home as Dyek (2001) reported a total of 7.9% prevalence of parasites cysts and eggs on the fingernails of primary school children (public and private schools) in Zaria. This is in line with the observation by Nock and Tanko (2000), indicating that the soil in our environment is contaminated with faecal matter. Adebote *et al.,* (2005) also noticed babies and toddlers crawing on bare soil and playing with faecal contaminated soil, with the obvious danger of contaminating their hands and or pick the oocysts and eggs from such floors and pass them directly to their mouth or contaminate food. This transfer process is further facilitated by geophagy (Nock and Tanko, 2000), and playing on soils contaminated with dog and cat faeces (Uga and Kataoka, 1995). Furthermore, the presence of parasites' cysts and eggs underneath of shoes ensures disease spread, as children often put shoes in their mouths and potential transmission during the process of putting on and removing shoes (Nock and Tanko, 2000).

2.4 Prevalence, Intensity and Distribution of Parasites' Cysts and Ova in Diverse Environmental Surfaces

2.4.1 Fruits and vegetables

Vegetable in its broadest sense commonly refers to the fresh edible portion of an herbaceous plant's roots, stems, leaves or fruits (Damen *et al.,* 2007). Vegetables are essential parts of a healthy human diet owing to their nutritional values. Raw vegetables are great sources of vitamins, dietary fibre and minerals, and their regular consumption are associated with a reduced risk of cardiovascular diseases, stroke and certain cancers (Van and Pivonka, 2000). However, the consumption of poorly washed vegetables is a major way for transmission of parasitic infections (Van and Pivonka, 2000). Various studies have reported diverse prevalence and intensities of parasitic contamination of fruits and raw vegetables (Abougrain *et al.*, 2010).

For instance, 79% contamination rate of green vegetables has been reported as being high in Asia (Ezatpour *et al.*, 2013) compared to other studies that got 19.4% and 31.7% in Egypt (El- Said, 2012; Hassan and Abdul-Ghani, 2012), 32.6% and 71% in Iran (Daryani *et al.*, 2008; Fallah *et al.*, 2011), 58% in Libya (Abougrain, *et al.*, 2010), 16.4% in Saudi Arabia (Al-Megrm, 2010). Examination of vegetable samples in Kenya also revealed high rate of contamination of 75.9% (Nyarango *et al.*, 2008). Another study noted that the excretion of parasite eggs to environment by humans or animals and contamination of vegetables were higher in warm seasons on vegetables when compared to cold seasons (Eslami *et al.*, 2003).

Vegetables and fruits have been reported to be heavily contaminated with parasites' cysts and eggs in Jos, Plateau State, Nigeria, with cabbage having the highest contamination rate of 64%, lettuce 40%, carrot 32%, green leafy vegetables 24.0% and tomatoes 20.0% (Damen *et al.*, 2007). The overall parasitic contamination of the vegetables was 450/1250 (36%) (Damen *et al.*, 2007). The report showed that *Trichomonas hominis* had the highest contamination prevalence of 24.9%, Hookworms 19.8%, *A. lumbricoides* 17.1%, *S. stercoralis* 16.7%, *E. histolytica* 14.0%, *T. trichiura* 5.1% and *H. nana* 2.4% (Damen *et al.*, 2007). In Bassa, Kogi State, Nigeria, *Vernonia* species (Bitter leaf) had 43.33% prevalence and *Allium cepa* had 32.5% and were the most contaminated vegetables (Omowaye and Toluhi, 2011). *Citrus sinensis* was the most contaminated of the fruits with 40.0% followed by *Piper nigrum* 27.94% and eggplant 29.89 and were the highest contaminated among other fruits (Omowaye and Toluhi, 2011). Filthy environment and refuse heaps constituted sources of contamination of fruits and vegetables even at the point of sale where these edible products are displayed. Flies constitutes significant potential hazards as they can mechanically transfer parasites' cysts and ova from dirts to already displayed products (Omowaye and Toluhi, 2011).

2.4.2 Sachet water

Sachet drinking water popularly called "pure water" in Nigeria is presently a lucrative business, with many people involved in the production and marketing of the product (Ekwunife *et al.,* 2010; Alli *et al.,* 2011), and are highly patronized by several individuals due to their cheapness. Sachet water is presently a major source of drinking water for both poor and rich and is easily available and affordable. As a result it is very common to see children and adults especially from poor background hawking sachet water on the streets in Nigeria (Egwari *et al.,* 2005) and elsewhere in Ghana (Kwakye *et al.,* 2007). These sachet drinking water and other food – drinks, though beautifully packaged, well labelled and advertised are not necessarily free of contaminants, to which they are exposed (Ekwunife *et al.,* 2010; Alli *et al.,* 2011), as their contamination are well documented (Omemu *et al.,* 2005).

In Accra Ghana, 77% of sachet drinking water have been found contaminated with infective stages of pathogenic parasitic organisms (Kwakye *et al.,* 2007).The prevalence of infective stages of four common protozoan pathogens identified included *Microsporidia* sp. 51.2%, *Cryptosporidium parvum* 63.0%, *Cyclospora cayetenensis*

59.3%, *Sarcocystis* spp. 66.7% (Kwakye *et al.,* 2007). Rotifers with prevalence of 18.5% and Charcot-Leyden crystals with prevalence of 44.4% were also identified in the water (Kwakye *et al.,* 2007).

In south western, Nigeria, 100 brands of 500ml sachet water samples purchased from roadside and market hawkers were found to be infested with developmental stages of six common protozoan and helminths pathogens (Alli *et al.,* 2011). Of the 6 parasites incriminated, *Entamoeba* species with prevalence of 31.8% was the most predominant followed by *Isospora belli* and *B. coli* both with prevalence of 27.2% each while *Cryptosporidium parvum*, Hookworm and *Taenia* species had prevalence of 4.5% (Alli *et al.,* 2011). Ekwunife *et al.* (2010) examined the surfaces of sachet water in Awka, Anambra State, Southeast Nigeria and isolated the cysts and ova of the following protozoans and helminths parasites and the associated prevalence: *A. lumbricoides* (5.6%), *E. histolytica* (4.6%), hookworm (2.8%), *T. trichiura* (2.8%) and *G intestinalis* (1.9%). Hawkers of the sachet water possibly played a very significant role in the dissemination of the parasites through improper handling and surface contamination of the sachets as packaged water purchased from hawkers had the highest number of parasites 15 (41.7 %) (Ekwunife *et al.,* 2010).

This shows that contamination of surfaces by contacts plays significant role in the transmission of cysts and ova of pathogenic parasites and poses significant risk to public health (Alli *et al.,* 2011). Stages of the organisms detected in these sachets samples were mainly those of pathogens of faecal and zoonotic origin. This observation made by Alli *et al.* (2011) suggests the existence of significant level of faecal contaminants in some of our sachet water and corroborated the findings of Kwakye-Nuako *et al.,* (2007) who worked in Ghana.

2.4.3 Paper currency

Paper currency is widely exchanged for goods and services in countries worldwide. It is used for every type of commerce (Lamichhane *et al.,* 2009), presenting a particular risk to public health, since communicable diseases can be imposed and spread through contact with fomites (Pope *et al.*, 2002; Xu and Moore 2005). The contamination is enhanced as paper currency provides a large surface area for the adherence of pathogens (Podhajny, 2004).

Over the last two decades, the published data shows that simultaneous handling indeed was a cause of sporadic food borne-illness and survival of pathogens on currency notes in Turkey (Goktas and Oktay 1992), United States (Jiang and Doyle 1999; Pope *et al.*, 2002), Australia (FSA, 2000), India (Singh *et al.,* 2002), Egypt (El-Dars and Hassan 2005) and China (Xu and Moore 2005).

In the United State of America, 13% of coins and 42% of paper money were found contaminated with potential pathogens (Abrams and Waterman 1972) with 18% of the coins and 7% of the paper money showed potential disease producing organisms (Gadsby 1998).

In Tanzania, intestinal parasites were prevalent in market places at Korogwe and Mombo towns where ova of *A. lumbricoides* and *E. hystolytica* cysts occurred on 500 Tshs, 1000 Tanzanian shillings (Tshs) also had *E.coli* cysts (11.53%). The 2000Tsh were contaminated by *E. coli* (7.14%), while 5000Tshs were contaminated with *E. coli*

(4.34%) (Neel, 2012). The 3.70% prevalence of *E. hystolytica, A. lumbricoides* and 37.03% of *E. coli* in the study were similar to those obtained elsewhere by other workers (Ekejindu, 2005; Uneke 2007; Orji *et al.,* 2012). The 37.03% prevalence of *E. coli* was similar to reports by Ahmed and Shakir, (2010).

In Nigeria, daily economic transactions have made the Naira bank notes to pass through many hands whereby cysts and ova of pathogens have been imposed on them (Ogo *et al.*, 2004). A prevalence of 64% was recorded for cysts and ova of parasites on dirty naira notes (Matur *et al.,* 2009). This was in agreement with the findings of Jolaoso (1991) as well as Ameh and Balogun (1997) that dirty naira notes are potential sources of contracting disease agents. Matur *et al.,* (2009) isolated cysts and ova of six parasites from bank notes in Abuja, Nigeria including those of *A. lumbricoides* with prevalence of 4%, hook worm 8.5%, *E. vermicularis* 0.5%, flagellates 1.5%, and *E. histolytica* 2.5%. Orji *et al.* (2012) obtained an overall prevalence of 33.3% for cysts and ova of 5 species of parasites on dirty and mutilated Naira notes in Anambra State, Nigeria. The eggs and cysts of parasites discovered and their respective prevalence were *A. lumbricoides* 7.5%, hookworm ova 4%, *T. trichiura* 3.5%, *E. vermicularis* 2.0%, *E. histolytica* 6.5% and flagellate 3.5%.

The contamination of naira notes with the cysts and eggs of parasites poses significant risk to public health (Pope *et al.,* 2002; Xu and Moore 2005). The currencies are usually contaminated from different sources (Awodi *et al.,* 2000; Oyero, 2007). This has become very worrisome when in Nigeria many people tongue-wet their fingers when counting money, thereby contaminating such fingers which are eventually used to handle or eat food without washing (Matur, *et al.*, 2009).

2.4.4 Computer accessories

Computer keyboards and mouse are accessories frequently used for input of commands with fingers of the human hands acting as points of contacts between the users and internet services. World Health Organization (1994) has posited that parasites are just about everywhere in the environment. The surfaces of computer keyboards and mouse are not exempted from contamination by cysts and eggs of parasites as reports from Nigeria have shown.

In Kaduna State, Ndams and Jimoh (2006) have isolated eggs and or cysts of *A. lumbricoides, E. vermicularis, E. histolytica, T. trichiura* and *Taenia* spp. with respective prevalence of 62.50% 12.50%, 12.50%, 8.33% and 4.17% from computer mouse and keyboards in internet cafes in Zaria, Nigeria.

Human attitudes and other behavioural habits like touching of the mouth or the nose while operating the keyboard apart from eating while working could contribute greatly to the contamination of surfaces as humans could transport cysts and eggs from the nasal passages making it an important entry point. As results from previouse study have revealed that mouse and keyboards of computers are not free of parasites' cysts and eggs thus could be foci of transmission (Ndams and Jimoh, 2006).

2.4.5 Human peri-domestic environment

Human immediate environment has been seen as a reservoir for high prevalence and intensity of parasite cysts and ova due to indiscriminate defecation out-of toilets, especially in areas with poor sanitation (Adebote *et al.,* 2005). A high prevalence of helminth ova was observed in human faeces promiscuously deposited among homes in northern Nigeria (Adebote *et al.,* 2005). An earlier review by Cook (1986) mentioned indirect or direct deposition of faecal material on the ground as a major factor responsible for gastrointestinal infections and the often higher infection rates in tropical than non-tropical countries. Other studies by Fashuyi (1983) in Lagos and Onwuliri *et al.* (1993) in Jos, Nigeria captured the problem of human defecation out of toilet and the associated high prevalence of gastrointestinal parasites' infective stages in such stools. The prevalence and intensity of parasite cysts and ova around human environment varies considerably according to regions and locations depending on predisposing factors of sanitation, hygiene and poor socioeconomic conditions (Okpala, 1961; Feachem *et al.,* 1983).

In their study, Adebote *et al.* (2005) got an overall prevalence of 69.5% for helminth ova in human peridomestic excrements in northern Nigeria. *A. lumbricoides* ova had the highest prevalence of 34.5% followed by hookworm 15% while *T. trichiura* had the least ova prevalence of 2.50%.The prevalence of *S. stercoralis* larvae in the stool was 16.0%. The prevalence of helminth ova of 69.5% in the same report was in concordance with that of Onwuliri *et al.,* (1993) who got 68.9%, but lower than that of Fashuyi (1983) who reported prevalence of 90.2%-96.3% for ova. Furthermore, faecal sample picked from five selected popular refuse dump sites in Ado-Ekiti has documented *E. histolytica, G.*

intestinalis and *B. coli* as the most prevalent protozoan cysts. *E. histolytica* had a prevalence of 65.5%, followed by *G. intestinalis* with 42.5% while *B. coli* had 1.9% (Adewole and Ajayi, 2010). This was similar to the findings of Gundiri and Okwuosa (2006).

According to Ejima and Ajogun (2011), eighty percent (80%) of faeces deposited around students' hostels at the FPI, Kogi State Nigeria were found to have eight helminth parasites at the oval and/or larval stages. Whereas the overall geometric mean intensity (gmi) of *A. lumbricoides* of 7.75 eggs per gram (epg) and prevalence of 22. 0%, *T. trichiura* had the least intensity of infection of 3.02 epg with prevalence of 3.0%.

The prevalence of cysts and ova of parasites in these human peridomestic environments is alarming as highlighted by previous epidemiological studies (Adebote *et al*., 2005). It has been clearly shown that human peridomestic environment is highly infectious and signifies the role it could play in the transmission and contamination of other contact surfaces with cysts and ova of parasites. Thus human insanitary attitudes and behaviours especially that of indiscriminate out of toilet defaecation have serious health implications on the entire public.

2.5 Pathogenicity and Medical Importance of Parasites with Cysts and Ova

2.5.1 Protozoa

Protozoans are a group of parasites causing human infection partly through contact with parasite cysts and oocysts. Protozoans infect people of all ages (Smith and Paget, 2007) with low levels of hygiene and sanitation to cause diarrhoea by direct cytotoxic effects or by their ability to invade the intestinal epithelium and or effects of the immune response on the intestinal epithelium (Monkemuller and Wilcox, 2000).

The hypothesized sequence of events is such that, after invasion of the enterocytes by the parasite, the epithelial cells release cytokines. These cytokines activate phagocytes and recruit new leukocytes, which in turn, release soluble factors (resulting in intestinal secretion of chloride and water) and inhibit absorption (Atu, 2008). Enterocyte damage may be a direct consequence of parasitic invasion, multiplication and extrusion. Regardless of the specific mechanism, marked distortion of the villus architecture is accompanied by nutrient malabsorption and osmotic diarrhoea (Atu, 2008).

Although many intestinal protozoan parasites inhabit the gastrointestinal tracts of humans (Baqui *et al.,* 1992), but majority of them are non-pathogenic commensals or only result in mild disease while a few of them like *C. parvum*, *E. histolytica* and *G. intestinalis* are pathogenic and have been associated with human gastrointestinal disorders worldwide (Fontanet *et al.,* 2000; Apichai *et al.,* 2005).

2.5.1.1 *Giardia intestinalis*

Human feeding studies with *G. intestinalis* cysts produced a dose response relation between the probability of infection and the ingested cyst dose (Rendtorff, 1954). Upon ingestion of the cysts in contaminated water or food, emerges trophozoites in the small intestine which multiplies rapidly and attach to the villi in the small intestine by means of a disc on its posterior or ventral surface. Lectin, a protein on the trophozoite lining recognizes specific receptor on the intestinal cell and may be partly responsible for the tight attachment between the parasite and the villi, which is followed by mucosal damage, mechanical obstruction and de-conjugation of bile salts (Atu, 2008).

The specific mechanism of pathogenesis of *G. intestinalis* leading to diarrhoea and intestinal malabsorption has not been completely elucidated and no specific virulence factors have been identified (Beaver *et al.*, 1984). However, its pathogenesis is thought to be related to the number of organisms ingested, specific strains ingested and non-antibody protective factor in the gastrointestinal tract and the immune response of the host (Beaver *et al.*, 1984).

According to the most recent studies, giardiasis is a complex of pathophysiological alterations. One of them is the changed permeability of enterocytes resulting from the cytopathological effect of parasite's metabolites (Buret *et al.,* 2002), and the peripheral membrane proteins, in particular zonula occludin-1 (ZO-1) that is important for the regulation of epithelial permeability, are destroyed. As a result, enterocytic brush border is damaged and the epithelial permeability is increased, resulting in inflammation and gastrointestinal troubles (Scott *et al.,* 2002).

Giardia also triggers apoptosis causing loss of epithelium barrier function with a subsequent increase in permeability (Chin *et al.,* 2002). Apoptosis and severity of disease are determined by strain dependent virulent factors of the parasite as well as by physiological and immunological status of the host (Chin *et al.,* 2002; Scott *et al.*, 2002). It is established that the increased intestinal permeability could also result from increased luminal antigens. This could provoke the appearance of allergic reactions – a complication, often observed in humans infected with *Giardia* (Scott *et al.*, 2002).

In addition, normal villus structure is affected in some patients. For example villus atrophy (blunting) and crypt hypertrophy and an increase in crypt depth have been observed to varying degrees. The increase in crypt cells will lead to a repopulation of the intestinal epithelium by relatively immature enterocytes with reduced absorptive capacities. An increase inflammatory cell infiltration in the lamina propria has also been observed and this inflammation may be associated with the pathology (Atu, 2008).

G. intestinalis infections can also lead to lactase as well as other enzyme deficiencies in the microvilli, such as disaccharidase (Buret, 1994). This results in reduced digestion and absorption of solutes as well as cause damage to the mucosa surface thus resulting in the shortening of crypt and villi thereby causing osmotic diarrhoea which probably explains the malabsorption syndrome that is characteristic of the disease. In children, infection with giardiasis causes failure to thrive by impairing the uptake of nutrients especially fats, vitamins A and B12 (Farthing, 1994).

2.5.1.2 *Cryptosporidium* species

The pathogenic mechanisms by which *Cryptosporidium* causes diarrhoea, malabsorption and wasting are poorly understood. Whatever these mechanisms may be, the initial host–parasite interactions of attachment and invasion are critical primary events in pathogenicity (Theodos, 1998).

When the oocyst is ingested by a new host, the suture in the oocyst wall opens (excystation), triggered by the body temperature and the interaction with stomach acid and bile salts. Four motile sporozoites are then released that infect the epithelial cells of the small intestine (Medema, 1999). The rapid loss of surface epithelium causes marked shortening and fusion of the villi and lengthening of the crypts due to acceleration of cell division to compensate for the loss of cells (Tzipori, 2002).

These processes lead to the epithelial mucosa cells releasing cytokines that activate resident phagocytes (Goodgame, 1996), and recruit new phagocytes into the lamina propria from the blood (Powell, 1995). These activated leucocytes release soluble factors such as histamine, serotonin, adenosine, prostaglandins, leukotrienes and platelet activating factors that increase intestinal secretion of chloride and water and inhibit absorption (Ciacino and Chang, 1992). Some of these mediators such as histamine, serotonin and adenosine affect secretion and absorption by acting directly on epithelial cells (Powell, 1995). While the prostaglandins, leucotrienes and platelet activating factors act on the enteric nerves to induce neurotransmitter mediated intestinal secretion resulting in enterocytes and cell damages. This leads to marked distortion of villus architecture accompanied by nutrient malabsorption and osmotic diarrhoea (Goodgame, 1996). Fluid loss is often excessive, 3-6 litres of watery stool per day and as much as 17 litres of watery stool have been reported (Arora and Arora, 2009). The severe dehydration is the most prominent symptom of an intestinal infection with *C. parvum* (Fayer and Ungar, 1986), with frequent and voluminous bowel movements causing dehydration and weight loss (Arrowood, 1997). Other symptoms are nausea, abdominal cramps, vomiting and mild fever (Medema, 1999).

2.5.1.3 *Entamoeba histolytica*

Entamoeba histolytica is the parasite causing diarrhoea, dysentery, hepatitis, liver abscesses in humans. *E. histolytica* upon invasion of the host through contaminated water or food kills the immune effector cells of the body by contact dependent cytolysis (Monkemuller and Wilcox, 2000). It exhibits a wide range of pathogenicity with its possible virulence factors such as parasite surface protein (lectin), the amoebapore and the cytoproteins (cysteine, proteases) (Petri, 1996).

This begins with excystation in the intestinal lumen to produce trophozoites. The trophozoites of *E. histolytica* can bore into the intestinal wall by the help of its proteolytic enzymes (collagenase and neutral proteases). The proteolytic enzyme, histolysin attaches to the host's mucin glycoproteins that line the intestinal lumen (Eichinger, 2001) causing dissolution and necrosis of mucosa and submucosa of large intestine. These areas of destruction are called ulcers which bleed profusely.

The destruction leaves free routes and increases the possibility of the trophozoites to reach other parts of the body like liver, lungs, brain, spleen, pericardium and even the skin (Cox, 2002), through blood circulation, in the process cause destruction of these tissues and formation of abscesses.

Entamoeba histolytica trophozoites kill (in vitro) a wide variety of tissue cell lines including neutrophils, T lymphocytes and macrophages (Salata *et al.,* 1986), initiated via the galactose/GalNAc lectin (Ravdin and Guerrant, 1981). There are varieties of changes the trophozoites engage that are vital to the ability of the trophozoties to kill host cells on contact (Petri *et al.,* 2002). A pore-forming protein complex inserted into the host cell by the trophozoite when in contact, most likely enhances the pathogenicity (Leippe *et al.,* 1991). The cytolysis and calcium ion binding protein and calmodulin (Cox, 2002),and others like the cysteine proteases are known to be important to the pathogenesis of *E.*

histolytica and function by degrading extracellular proteins and through the disruption of cell monolayers (Que and Reed,1997).

In the final stages, when the host cell dies, it undergoes apoptosis as the nuclear chromatin condenses, the membrane forms blebs and the inter-nucleosomal DNA fragments (Huston *et al.,* 2000). The virulence may be directly proportional to the amoeba's ability to cause apoptosis and then phagocitize the dead cell, a process that seems to substantially limit the host inflammatory response (Huston *et al.*, 2003).
Symptoms include vomiting, mild fever, diarrhoea, blood and mucous in faeces, tenderness over the sigmoidal region of colon and hepatitis.

2.5.2 Helminths

Soil-transmitted helminths are a group of parasitic worms causing human infection through contact with parasite eggs or larvae that thrive in the warm and moist soil of the world's tropical and subtropical countries.

The hypothesized sequence of pathogenicity involves the ingestion of the infective eggs. After invasion, the ingested eggs undergo some multiple developments into motile adult stage that penetrates cellular compositions of the host. This intracellular and extracellular parasitic mobility results to series of deleterious effects on nutrition and impairment of immune functions (Silva and Assis, 2008).

The important harmful factors in helminth infections include the direct pathogenic effect by the worms and the modulatory role of the parasite on the host immune system, altering the response to other antigens or pathogens and causing additional immunopathology

(Maizels and Yazdanbakhsh, 2003). Chronic helminth infections induce T-cell hyporesponsiveness, which may affect immune responses to other pathogens (Borkow and Bentwich, 2008). Of particular worldwide importance are the roundworms (*A. lumbricoides*), whipworms (*T. trichiura*) and hookworms (*A. duodenale* and *N. americanus*).

2.5.2.1 Pathogenicity of hookworm species

Ancylostomiasis and necatoriasis are human infections caused by the nematode parasites, *Ancylostoma duodenale* and *Necator americanus* respectively. Both species share common morphology and life cycle. The larval transmission occurs either by direct penetration of the skin, usually through the feet, or by the faecal-oral route (Brown *et al.*, 1995). The larvae moult twice to become the infective third-stage larvae, which are non-feeding but motile organisms that seek out higher ground to improve their chances of contact with human skin. Several cutaneous syndromes occur from skin penetrating third-stage larvae of *N. americanus* and *A. duodenale* manifest in ground itch, a local erythematous and papular rash accompanied by pruritus on the hands and feet (Hotez *et al.*, 2004). By contrast, when the zoonotic hookworm third-stage larvae—typically of *Ancylostoma braziliense*—enter the skin, they produce cutaneous larva migrans, which is characterised by the appearance of serpiginous tracks on the feet, buttocks and abdomen (Blackwell and Vega-lopez., 2001). Oral ingestion of *A. duodenale* larvae can also occur, resulting to Wakana syndrome, which is characterized by nausea, vomiting, pharyngeal irritation, cough, dyspnoea and hoarseness (Hotez *et al.*, 2004).

After skin invasion, hookworm third-stage larvae enter subcutaneous venules and lymphatic vessels to access the host's afferent circulation. Ultimately, the larvae become trapped in pulmonary capillaries, enter the lungs, pass over the epiglottis, and migrate into the gastrointestinal tract (Hotez *et al.,* 2004). Adult worms live with their anterior ends dug deep within the mucosa of the distal duodenum and proximal jejunum (Ojha *et al.,* 2014). *Necator americanus* secretes a metalloprotease that degrades eotaxin, providing a potential strategy to prevent recruitment and activation of eosinophils at the site of infection (Culley *et al.,* 2000). The *Ancylostoma* secreted molecules inhibit host's coagulation and ensure blood flow and continuous bleeding (Ledizet *et al.,* 2005).It was reported to possess a multienzyme cascade involved in host's red-blood-cell lysis and haemoglobin digestion (Williamson *et al.,* 2004). The attachment to host's mucosae is followed by the release of active peptides that down regulate host inflammation, block the clotting of blood, prevent platelet aggregation and degrade host's connective tissue components (Brown *et al.,* 1995), resulting in continuous blood loss from capillaries and arterioles, which the parasite ruptures and degrades (Ojha *et al.,* 2014). *Ancylostoma duodenale* causes more blood loss than *N. americanus* (Hotez *et al.,* 2004) and the chronic protein loss from heavy hookworm infection can result in hypoproteinaemia and anasarca (Hotez *et al.,* 2004).

Infective larvae of *A. duodenale* arrested in pregnant women enter the colostrum and breast milk postpartum and cause infantile hookworm infection (Yu and Jiang, 1995). Pulmonary invasion by hookworm larvae can manifest with cough and transient pulmonary infiltrates. Eosinophilia begins to occur during the extraintestinal migrations of hookworm larvae. Children with chronic infections have an increased susceptibility to recurrent viral illnesses (Hotez, 1989). These children may have profoundly low haemoglobin concentrations (Ojha *et al.*, 2014).

The illness is characterized by abdominal pain, nausea, vomiting, anorexia, fatigue, dyspnea, koilonychias, pale sclera, pallor, melena and poor concentration. During heavy infections, each individual adult hookworm can cause up to 0.2 mL of blood loss per day, which leads to depletion of host iron and protein reserves, causing iron deficiency anaemia and protein malnutrition. Plasma protein loss can impart kwashiorkor-like appearance in children. The processes of growth retardation and deficits in attention and intellectual development that occur during chronic heavy hookworm infections in childhood could be due to the development of a clinical iron deficiency. Iron is considered essential for the biosynthesis of dopaminergic neurons and for the biosynthesis of iron-containing metallo-enzymes such as monoamine oxidase (Hotez, 1989; Hotez and Pritchard 1995).

2.5.2.2 Pathogenicity of *Ascaris lumbricoides*

Upon ingestion of infective eggs and subsequently hatching into larvae in the small intestine, they penetrate blood vessels in the wall of the intestine. Minimal damage is produced by larval intestinal invasion, although some hepatic inflammation and granulomata formation have been described (Hotez and Pritchard, 1995). The extraintestinal migrations in the lungs are associated with a vigorous host inflammatory response that includes elevated serum IgE levels and eosinophilia (Hotez, 2000). Subsequent migration of the larvae results to Loeffler's pneumonitis, characterized by fever, dry cough, mild chest pain, pulmonary infiltrates, dyspnea and breathlessness on exertion. Allergic reactions such as urticaria and asthma may develop in hypersensitive people (Ojha *et al.,* 2014). The larvae then develop into adult worms following a heart-lung migration. Migrating worms may result to cholecystitis in the common bile duct, where the worms can cause cystic duct obstruction directly or serve as a nidus for stone formation (Seltzer and Barry, 1999).It may also cause liver abscesses and appendicitis and may occasionally enter the stomach and be vomited out. Adult worms also elicit mechanical damage and lumen obstruction if wandering in the biliary tree or become entangled and matted into a bolus of worms (Ojha *et al.,* 2014). The presence of adult worms in the intestine may result in nausea, vomiting, abdominal discomfort, epigastric pain, and in some cases, steatorrhea will occur. Moderate to heavy infections may result in impaired digestion and malabsorption of protein, lactose, and some fat-soluble vitamins (Hotez and Pritchard, 1995). *Ascaris lumbricoides* is the largest of the intestinal nematodes, its size ranges from 15-45 cm long and 2-6 mm in diameter characterized by fluid production. The body fluid of *Ascaris* when absorbed in the blood causes toxic effects and gives rise to typhoid-like fever (Ojha *et al.,* 2014). In young children with small intestinal lumen, adult worms can aggregate in the ileum and cause partial obstruction (Khuroo *et al.,* 1990; Villamizar *et al.,* 1996). Various grave consequences can ensue, including intussusception, volvulus, and complete obstruction (Khuroo *et al.*, 1990) leading to bowel infarction and intestinal perforation. The resulting peritonitis can be fatal, although if the child survives, the wandering adult worms can die and cause a chronic granulomatous peritonitis. Typically, a child with obstruction because of *Ascaris* has a toxic appearance with signs and symptoms of peritonitis (Bethony, 2006). In some cases, a mass can be felt in the right lower quadrant (Khuroo *et al.*, 1990). Adult worms can enter the lumen of the appendix, leading to acute appendicular colic and gangrene of the appendix tip, resulting in a clinical picture indistinguishable from appendicitis. Adult *Ascaris* worms also tend to move in children with high fever, resulting in the emergence of worms from the nasopharynx or anus. Hepatobiliary and pancreatic ascariasis results when adult worms in the duodenum enter and block the ampullary orifice of the common bile duct, leading to biliary colic, cholecystitis, cholangitis, pancreatitis and hepatic abscess (Khuroo *et al.,* 1990). By contrast with intestinal obstruction, hepatobiliary and pancreatic ascariasis occurs more commonly in adults— especially women—than in children, presumably because the adult biliary tree is large enough to accommodate an adult worm (Khuroo *et al.*, 1990; Bethony, 2006; Ojha *et al.*, 2014).

The growth retardation associated with ascariasis may have a nutritional basis (Crompton, 1992). It may be due to the parasite impairing host nutrition by causing malabsorption through a process of villous atrophy. Lactase deficiency also has been described. Although *Ascaris* worms produce a battery of peptide serine protease inhibitors that, in vitro, can block the action of pancreatic trypsin, chymotrypsin and elastase (Grasberger *et al.,* 1994), whether these peptide inhibitors are actually released by the parasite and whether they have a physiologic role in the parasite-host relationship remains unclear (Ojha *et al.,* 2014).

2.5.2.3 Pathogenicity of *Trichuris trichiura*

Upon ingestion of fully developed eggs of *Trichuris trichiura* into the small intestine, the first-stage larvae of *T. trichiura* are liberated and undergo multiple moulting processes of maturation into adult stage within about 12 weeks of infection. In the caecum, the anterior part of the worm burrows into the mucosal epithelium, but in heavy infections they may be present throughout the intestinal tract (Bethony, 2006; Ojha *et al.,* 2014) where they remain in the large intestine and live both an intracellular and extracellular parasitic existence. Here, they survive by creating epithelial tunnels by a process of host cell fusion in response to parasite-derived secreted proteins (Bethon, 2006; Ojha *et al.*, 2014). These protein known as TT47 forms ion-conducting pores in lipid bilayers, allowing the parasite to invade the host gut and maintain its anterior end in a syncytial environment in the caecal epithelium and the thickened posterior portion of the worm rupturing out of the epithelial tunnel to protrude into the lumen (Hotez and Pritchard, 1995; Bethony, 2006; Ojha *et al.*, 2014).

In these circumstances, adult worms have the capability to disrupt the normal architecture of the colonic mucosa, which is further affected by host inflammation (Ojha *et al.*, 2014). Inflammation at the site of attachment from large numbers of whipworms results in colitis. Longstanding colitis produces a clinical disorder that resembles inflammatory bowel disease, including chronic abdominal pain and diarrhoea, as well as the sequelae of impaired growth, anaemia of chronic disease, and finger clubbing (Bundy and Cooper, 1989).

Anaemia from severe trichuriasis in microcytic, hypochromic direct blood loss from the friable colon due to the special mode of attachment of *Trichuris* may be sufficient in massive infections, to unbalance iron metabolism and induce iron deficiency anaemia (WHO, 1986).

Trichuris dysentery syndrome is an even more serious manifestation of heavy whipworm infection, resulting in chronic dysentery and rectal prolapse (Bundy and Cooper 1989;

Bethony, 2006), especially children with longstanding massive infections, have dysenteric syndrome presenting with chronic mucous diarrhoea, rectal prolapse, anaemia from chronic blood loss and iron deficiency, protein-energy malnutrition and growth retardation (Ojha *et al.,* 2014). The most intense infections are in children aged 5-15 years with a decline in intensity and frequency in adulthood. Whether such age dependency indicates changes in exposure, acquired immunity, or a combination of both, remains controversial (Anderson and May, 1985).

In addition, whipworm impairs serious physical growth in children, although the basis by which this is done is unknown. Among the mechanisms proposed are direct intestinal protein losses, anorexia, increased catabolism resulting from host tumour necrosis factor production, and reduced host circulating levels of insulin-like growth factor I. Even less well-known are the mechanisms by which *T. trichiura* impairs cognition and school performance (Ojha *et al.,* 2014).

2.6 Intensity of Parasite's Cysts and Ova in Human

Intensity of parasitic infection is usually measured by the number of eggs per gram (epg) of faeces, generally by the Kato-Katz faecal thick-smear technique (Bethony, 2006). In study conducted in China, among people of Hainan Province, revealed that the peak mean intensity for *Ascaris* infection was 665 epg (95% CI=109–1220) and for *Trichuris* infection was 242 epg (95% CI=242–363) which occurred during the first decade of life for the age range of 1–9 years (Bethony *et al*., 2002). Earlier workers also presented similar findings (Anderson, 1985; Labiano *et al.,* 1999). The mean egg count per gram of stool for *Necator* infection in the sample was 971 epg (95% CI=639–1304). The range of egg count was 24–66,432 epg while peak egg counts occurred among persons in the oldest age intervals. Female subjects (1332 epg, 95% CI=724–1939 epg) had significantly higher egg counts than did male subjects (615 epg, 95% CI=340–890 epg) (Bethony *et al*., 2002).

In Ecuador, in the city of Portoviejo, a study that examined stool samples of 151 school children revealed that seven (7.8%) of the children had high intensity of *A. lumbricoides* out of mean egg value of 13217 (± 1540). The respective high intensities of *T. trichiura* occurred in five (3.3%) of the children with mean egg value of 7168 (± 1074). Hookworm was reported to be of low intensity with mean egg value of 4800 (± 960) (Andrade *et al.,* 2001).

In Côte d'Ivoire, infection intensities expressed as group arithmetic mean faecal egg counts among school children in rural Azaguié M'Bromé/Azaguié Makouguié for hookworm, *T. trichiura* and *A. lumbricoides* were mainly light (Coulibaly *et al.,* 2012). Most of the children were heavily infected with intestinal protozoa. In peri-urban Abbé-Bégnini, 97.0% of the infected school children showed light helminth infection intensities. In urban Azaguié Gare, all helminth infections were of light intensities. Intestinal protozoan infections were light (58.4%) or moderate (36.5%) and only 13 children showed heavy infection (Coulibaly *et al.,* 2012). In Ethiopia, stool samples obtained from children attending 14 primary schools in Jimma have shown infection intensity of soil transmitted helminths to be of mean arithmetic means of 2,411epg (0–176,000), 295 epg (0–19,350) and 35 epg (0–950) for *A. lumbricoides, T. trichiura* and hookworm respectively.

In Nigeria, a study carried out among residents of Era-Awori village located in a Lagos suburb showed highest mean parasite egg count (epg) for people aged 11 – 20 years as 2841.12 followed by those aged with 1 – 10 years with 1893.1 epg (Ibidapo and Okwa 2008). There was a drop in the mean epg value from age group of 21 – 30 years (860.66 epg) down to the 51 – 60 years age group (392.64 epg). For males, there was no significant difference in egg counts among all the age groups except for the 51 – 60 years group, which was significantly lowest ($P < 0.05$). Adeyeba and Akinlabi (2002) have also reported high prevalence and intensity of soil transmitted helminths (STHs) among rural school age children in Nigeria. Awolaju and Morenikeji (2009) reported intensity of *A. lumbricoides* as light (100 - 3,000 epg) among school children in both primary and post–primary schools, although those aged 13-15 years recorded moderate intensity of 5000-6000 epg. The differences recorded in the prevalence and intensities of the intestinal parasites in all the study locations were attributable to the level of sanitation prevailing in these areas.

CHAPTER THREE

3.0 MATERIALS AND METHODS

3.1 Study Area

The study was conducted among commercial banks in Gboko, Makurdi and Otukpo in Benue State, Northcentral Nigeria (Figure 3.1). Benue State lies between latitudes 6°25'N and 8°8'N and longitudes 7°47'E and 10°E'. Benue State is surrounded by five other States, namely Nasarawa to the north, Taraba to the northeast, Cross River to the south, Anambra to the southwest and Kogi to the west. There is also a short international boundary between the State and the Republic of Cameroun along Nigeria's southeast border. The State had a population of 5,181,642 (NPC, 2006) with a land mass of 34,059 square kilometres. Benue State has no problem of capital city primacy. Rather, three towns stand out very clearly as important urban centres which together account for more than 70 per cent of the amenities provided in the state and almost all the industrial establishments. These centres are Makurdi, Gboko and Otukpo. They are amongst the oldest towns in the state and are growing at a much faster rate than the smaller younger towns such as Apir, Gwe west, Oshongo, Taraku, Aliade, Ohimini, Okpokwu among many others.

Makurdi doubles as the capital of the state and the headquarters of Makurdi Local Government Area, while Gboko and Otukpo double as local government and ethnic headquarters (i.e. for the Tiv and Idoma tribes respectively). All the roads in the state radiate from these three centres. Amenities such as electricity, telephone, pipeborne water, hospitals, schools, colleges, sporting facilities, hotels, banks, insurance houses,

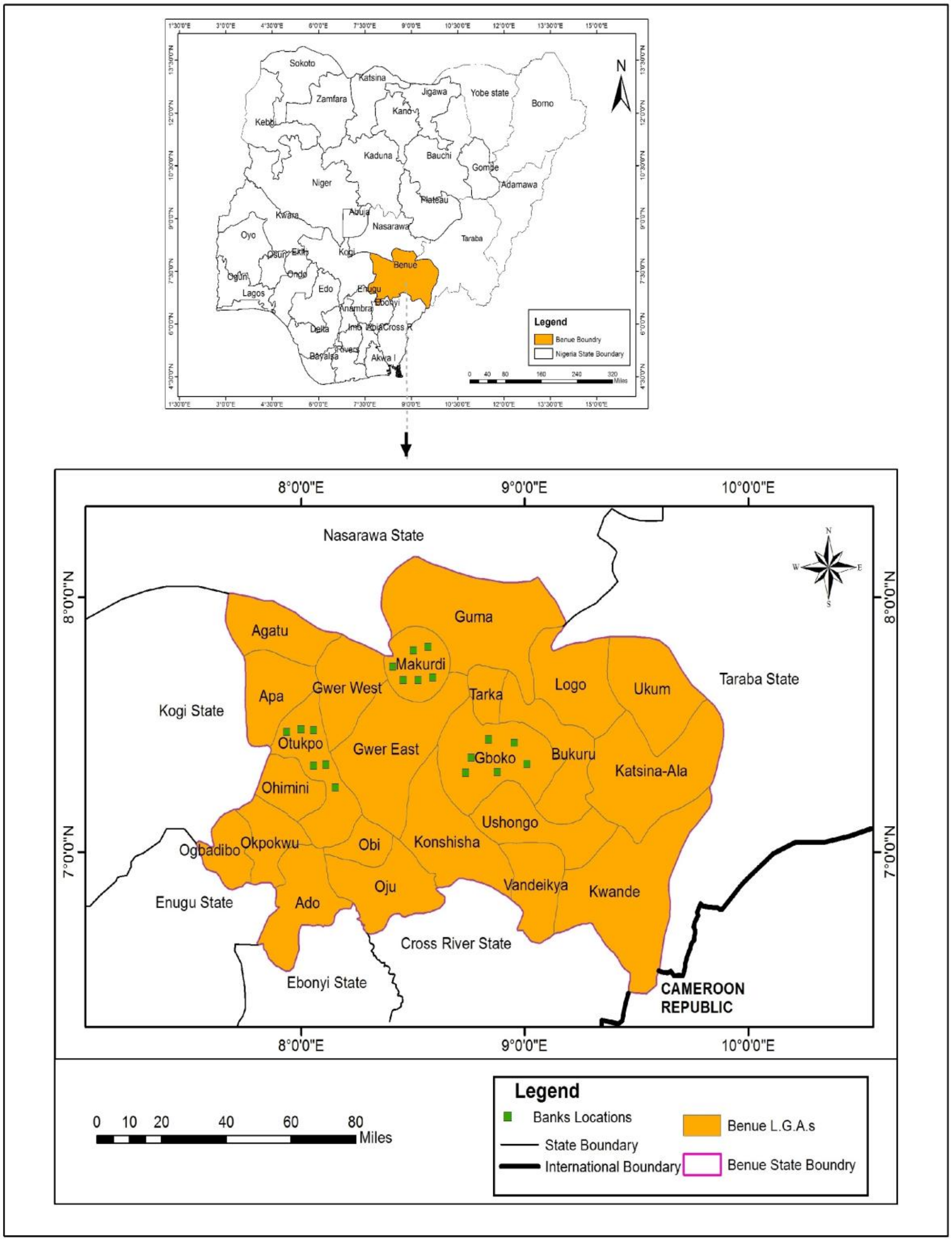

Figure 3.1: Benue State Showing the Distributions of Selected Banks
Source: Modified from the Administrative Map of Benue State 2013.

night clubs, cinema halls, etc. are disproportionately concentrated in these three towns at the expense of the smaller younger towns and the rural areas; Apir, Gwe west, Oshongo, Taraku, Aliade, Ohimini, Okpokwu.

3.2 Selection of Banks for the Study

Branch networks of available banks at the three towns in Benue State, Nigeria were ascertained via the internet. Identified banks with wide networks were approached with official letters from the Head, Department of Biological Sciences, Ahmadu Bello University Zaria intimating them of the study and seeking permission to conduct the study.

Final selection of participating banks was based on their individual permission, willingness to volunteer and successful outcome of balloting. A total of 18 common banks were selected as six common banks per town constituted the sampling units for the study.

3.3 Sampling Points (Bank facilities)

At each selected bank, surfaces of such facilities such as door handles (inner and outer handles), automated teller machines (ATMs)(down and upper instruction knobs), computer accessories (keyboards and mouse), currency (paper and polymer notes), counting machines (cash loader and cash receiver) and counter/slab surfaces (banking hall and bulk room) constituted the sampling points where eggs and cysts of parasites (if any) were isolated from. These are bank facilities frequently utilized by customers and common to the selected banks identified for the study in the three towns in Benue State.

3.4 Sample Size Determination

The sample size used for this study was determined from the formula of Sarmukaddam and Gerald (2006) given as:

$$N = \frac{Z^2PQ}{d^2}$$

Where, Z= the critical value of standard normal distribution, which is 1.96 % confidence interval.

P= estimated prevalence, which was fixed as 7.1% (Dyke, 2001).

Q=1-P.

d= absolute precision or tolerated sampling error, which is 5%.

N = 254.9, Implying that approximately a minimum of 255 samples should be collected. However, 432 samples were collected. One sample each was obtained from the surfaces of each of the twelve (12) bank facilities at each of the six (6) common banks per town. This translated to a total of seventy two (72) samples per bank, one hundred and forty four (144) samples per town and four hundred and thirty two samples in the three (3) towns.

3.5 Sample Collection and Preservation

Separate sterile cotton swabs wetted with sterile normal saline was used to swab the surfaces of interest at each of the designated banks of interest (Nock and Tanko, 2000; Nock and Geneve, 2002). Swabbing was done to cover a good representative surface area as much as possible. The surface area of $100cm^2$ was swabbed on each flat surface of interest in each bank was standardized for similar surface type per bank. Several cotton buds were used for large surfaces as conditions warranted.

The cotton swabs were dropped into capped sterile universal (specimen) bottles containing 10ml of normal saline and 10ml of 4% formalin as preservatives. Each specimen bottle was labelled using masking tape glued to each bottle according to the date of collection, name and address of bank and name (type) of swabbed surface/facility.

3.6 Preliminary Processing and Storage of Samples

Each swab that was used was stored in a specimen bottle and mechanically pressed repeatedly against the wall of the bottle to dislodge any adhering cysts and eggs of parasites into the liquid preservatives (Nock and Tanko, 2000). The specimen bottles and their contents were stored in a refrigerator at 3-5˚C prior to parasitological assay.

3.7 Parasitological Assays of Samples

Parasitological assay of collected samples were conducted at the Helminthology Laboratory of the Department of Veterinary Parasitology and Entomology, Ahmadu Bello University, Zaria, Nigeria.

Both the sedimentation (using centrifuge tubes and centrifuge machines at 2000 rpm in formol saline) and simple floatation (using Zinc sulphate solution of 1.18-1.20 specific gravity) techniques were performed on each sample to isolate and identify parasites' cysts, oocysts and ova (Neva and Brown, 1994).

Preserved samples were subjected to centrifugation in formol saline in sterile centrifuge tubes at 2000 rpm (revolutions per minute) for 3 minutes twice. The resultant supernatants were discarded and sediments at the bases of the tubes were mixed in the small volumes of formol saline that drained back from the sides of the tubes. The sediments were stirred with parasitologically sterile applicator sticks and a drop each was deposited on a clean microscope slide, covered with cover slip stained with a drop of Lugol's iodine solution from the side of the cover slip and examined microscopically under ×100 objective lens magnification of a research microscope for the cysts, oocysts and ova of parasites.

In order to further enhance detection of parasite stages, the left over sediments were subjected to the Zinc sulphate floatation technique (Neva and Brown, 1994). Zinc sulphate fluid of specific gravity 1.18-1.20 (prepared as 336g of Zinc-sulphate in 1 litre of distilled water) was added to the sediments in each tube until a slightly bulging reverse meniscus was obtained on top of the tube. A clean cover slip was placed on top of the tube to slightly touch the meniscus but not spill over. The cover slip was left in place for an average of 15 minutes (10-20 minutes). The cover slip was removed carefully with the adhering floatation solution that may contain cysts, oocysts and ova of parasites. The cover slip was then placed faced down on a clean microscope slide (care being taken to prevent bubbles). Also, modified Ziehl Neelsen cold staining technique was used to differentiate encountered oocysts of protozoans.The entire cover slip was then examined for cysts, oocysts and ova of parasites under both ×100 and ×400 magnification of a research microscope (model: Olympus CH binocular light microscope).

3.8 Identification of Parasites' Stages

Identification of the cysts, oocysts and ova of encountered parasites was done with the aid of parasitological atlases (Jeffrey and Leach, 1975, Cheesbrough, 1992). Physical counts of encountered parasites' stages were done on microscope films and recorded appropriately. Photomicrographs of representative stages of parasites were obtained with a digital camera (Model-Samsung digital camera).

3.9 Statistical Analysis of Data

Data obtained are presented in percentiles, summarized into respective means and accompanied with standard errors. Chi-qured was used to test for significant differences in parasite distribution among facilities, banks and towns

Analysis of Variance statistic was used to test for significance among the intensities of the various stages of parasite species on the various bank facilities among the various bank branches and towns.

CHAPTER FOUR

4.0 RESULTS

4.1 Species of Parasitic Organisms with Cysts, Oocysts and Ova on Bank Facilities

The cysts or oocysts and ova of sixteen parasitic organisms made up of eight protozoans and eight helminths were recovered from the surfaces of various bank facilities in this study (Table 4.1). These, in order of magnitude, included those of *E. histolytica* (58.10%), *Cryptosporidium* sp. (35.88%), *A. lumbricoides* (24.54%), *E. coli* (10.19%), *G. intestinalis* (7.64%), unidentified coccidia (3.70%), *T. trichiura* (3.47%), *Taenia* sp. (3.24%), Hookworm (3.24%), *B. coli* (2.08%), *Cyclospora* sp. (1.62%) *Dicrocoelium dendriticum* (1.39%) *Capillaria* sp. (0.69%), *Toxocara* sp. (0.46%), *E. vermicularis* (0.46%) and *Isospora* sp. (0.46%) (Table 4.1, Plate I-Plate XVI). The helminths included one trematode - *D. dendriticum*; one cestode - *Taenia* sp. and six nematodes - *A. lumbricoides*, *T. trichiura*, hookworm, *Capillaria* sp., *E. vermicularis* and *Toxocara* sp.

4.2 Types and Diversity of Bank Facilities on which Cysts, Oocysts and Ova of Parasites were recovered

The distribution of the occurrences of the cysts, oocysts and ova of each of the sixteen parasites on each of the twelve bank facilities in Benue State, Nigeria is presented in Table 4.1. The cysts, oocysts and ova of *E. histolytica*, *E. coli*, *Cryptosporidium* sp. and *A. lumbricoides* were encountered and recovered from all the twelve bank facilities.

Table 4.1: Number (%) of Bank Facility Types Positive with Cysts, Oocysts and or Ova of Parasitic Protozoans and Helminths in Benue State, Northcentral Nigeria

Bank Facilities	Down instruction knob	Upper instruction knob	Outer door handle	Inner door handle	Banking Hall	Bulk Room	Key Board	Mouse	Cash Loader	Cash Receiver	Polymer Notes	Paper Notes	Total	Chisquare	df	P value
Entamoeba histolytica	22 (61.11)	9 (25.00)	25 (69.44)	28 (77.78)	20 (55.56)	14 (38.89)	21 (58.33)	10 (27.78)	28 (77.78)	33 (91.67)	8 (22.22)	33 (91.67)	251 (58.10)	101.203	11	0.000**
Cryptosporidium sp.	9 (25.00)	4 (11.11)	8 (22.22)	11 (30.56)	31 (86.11)	11 (30.56)	17 (47.22)	1 (2.78)	25 (69.44)	29 (80.56)	3 (8.33)	17 (47.22)	155 (35.88)	131.686	11	0.000**
Entamoeba coli	3 (8.33)	2 (5.56)	2 (5.56)	2 (5.56)	6 (16.67)	4 (11.11)	4 (11.11)	3 (8.33)	3 (8.33)	6 (16.67)	1 (2.78)	8 (22.22)	44 (10.19)	14.171	11	0.224ns
Giardia intestinalis	0 (0.00)	0 (0.00)	0 (0.00)	2 (5.56)	3 (8.33)	2 (5.56)	3 (8.33)	4 (11.11)	3 (8.33)	7 (19.44)	3 (8.33)	6 (16.67)	33 (7.64)	21.359	11	0.030*
Coccidia sp.	0 (0.00)	0 (0.00)	2 (5.56)	1 (2.78)	2 (5.56)	2 (5.56)	1 (2.78)	0 (0.00)	2 (5.56)	0 (0.00)	0 (0.00)	6 (16.67)	16 (3.70)	25.442	11	0.008**
Balantidium coli	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	1 (2.78)	0 (0.00)	1 (2.78)	0 (0.00)	1 (2.78)	6 (16.67)	0 (0.00)	0 (0.00)	9 (2.08)	43.915	11	0.000**
Cyclospora sp.	0 (0.00)	0 (0.00)	1 (2.78)	0 (0.00)	3 (8.33)	2 (5.56)	0 (0.00)	0 (0.00)	0 (0.00)	1 (2.78)	0 (0.00)	0 (0.00)	7 (1.62)	19.023	11	0.061ns
Isospora sp.	0 (0.00)	0 (0.00)	1 (2.78)	0 (0.00)	1 (2.78)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	2 (0.46)	10.047	11	0.526ns
Ascaris lumbricoides	16 (44.44)	4 (11.11)	11 (30.56)	3 (8.33)	8 (22.22)	8 (22.22)	5 (13.89)	2 (5.56)	7 (19.44)	14 (38.89)	3 (8.33)	25 (69.44)	106 (24.54)	75.259	11	0.000**
Trichuris trichiura	3 (8.33)	1 (2.78)	1 (2.78)	1 (2.78)	1 (2.78)	0 (0.00)	0 (0.00)	0 (0.00)	1 (2.78)	1 (2.78)	5 (13.89)	1 (2.78)	15 (3.47)	18.440	11	0.072ns
Taenia sp.	1 (2.78)	1 (2.78)	0 (0.00)	1 (2.78)	2 (5.56)	1 (2.78)	0 (0.00)	1 (2.78)	0 (0.00)	0 (0.00)	4 (11.11)	3 (8.33)	14 (3.24)	15.65	11	0.155ns
Hookworm	1 (2.78)	0 (0.00)	1 (2.78)	1 (2.78)	1 (2.78)	2 (5.56)	0 (0.00)	0 (0.00)	0 (0.00)	2 (5.56)	1 (2.78)	5 (13.89)	14 (3.24)	19,193	11	0.058ns
Dicrocoelium dendriticum	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	1 (2.78)	1 (2.78)	1 (2.78)	0 (0.00)	2 (5.56)	0 (0.00)	0 (0.00)	1 (2.78)	6 (1.39)	10.141	11	0.518ns
Capillaria sp.	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	2 (5.56)	0 (0.00)	1 (2.78)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	3 (0.69)	17.119	11	0.104ns
Toxocara sp.	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	1 (2.78)	0 (0.00)	0 (0.00)	0 (0.00)	1 (2.78)	0 (0.00)	0 (0.00)	0 (0.00)	2 (0.46)	10.047	11	0.526ns
Enterobius vermicularis	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	1 (2.78)	1 (2.78)	2 (0.46)	10.047	11	0.526ns
Total	**27 (75.0)**	**17 (47.2)**	**30 (83.3)**	**32 (88.9)**	**20 (55.6)**	**16 (44.4)**	**21 (58.3)**	**23 (63.9)**	**36 (100.0)**	**31 (86.1)**	**13 (36.1)**	**34 (94.4)**	**304 (70.4)**	**87.286**	**11**	**0.000****
No. of facilities examined	**36**	**36**	**36**	**36**	**36**	**36**	**36**	**36**	**36**	**36**	**36**	**36**	**432**			

Plate I: Cyst of *Entamoeba histolytica*

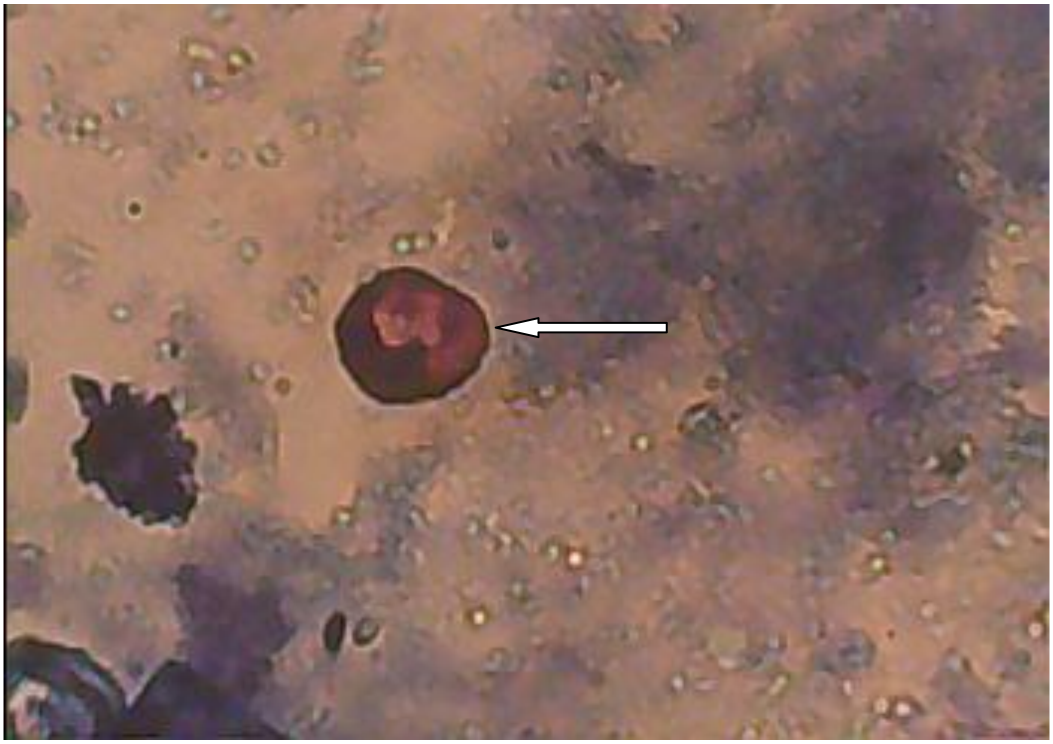

Plate II: Oocyst of *Cryptosporidium*

Plate III: Cyst of *Entamoeba coli*

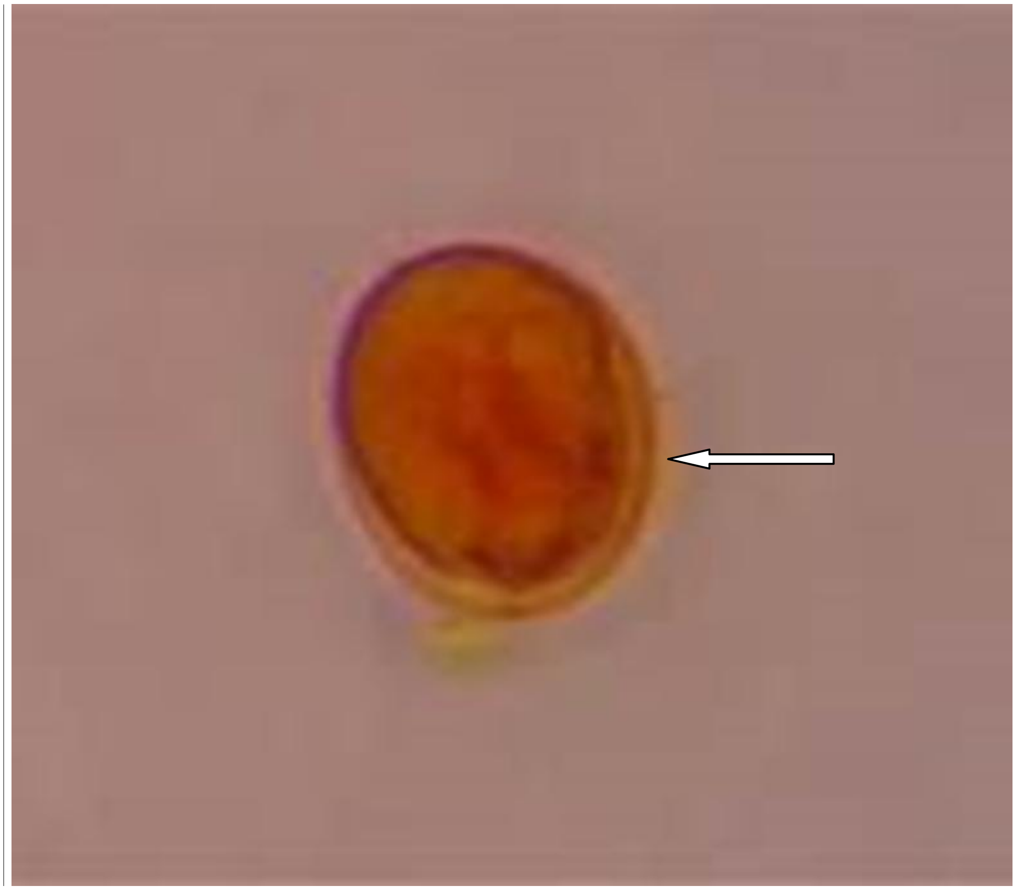

Plate IV: Cyst of *Giardia intestinalis*

Plate V: Oocyst of *Coccidia*

Plate VI: Cyst of *Balantidium coli* (x400)

Plate VII: Egg of *Dicrocoelium*

Plate VIII: Ovum of *Taenia* species

Plate IX: *Ascaris lumbricoides* Egg (x100)

Plate X: Egg of *Trichuris trichuria*

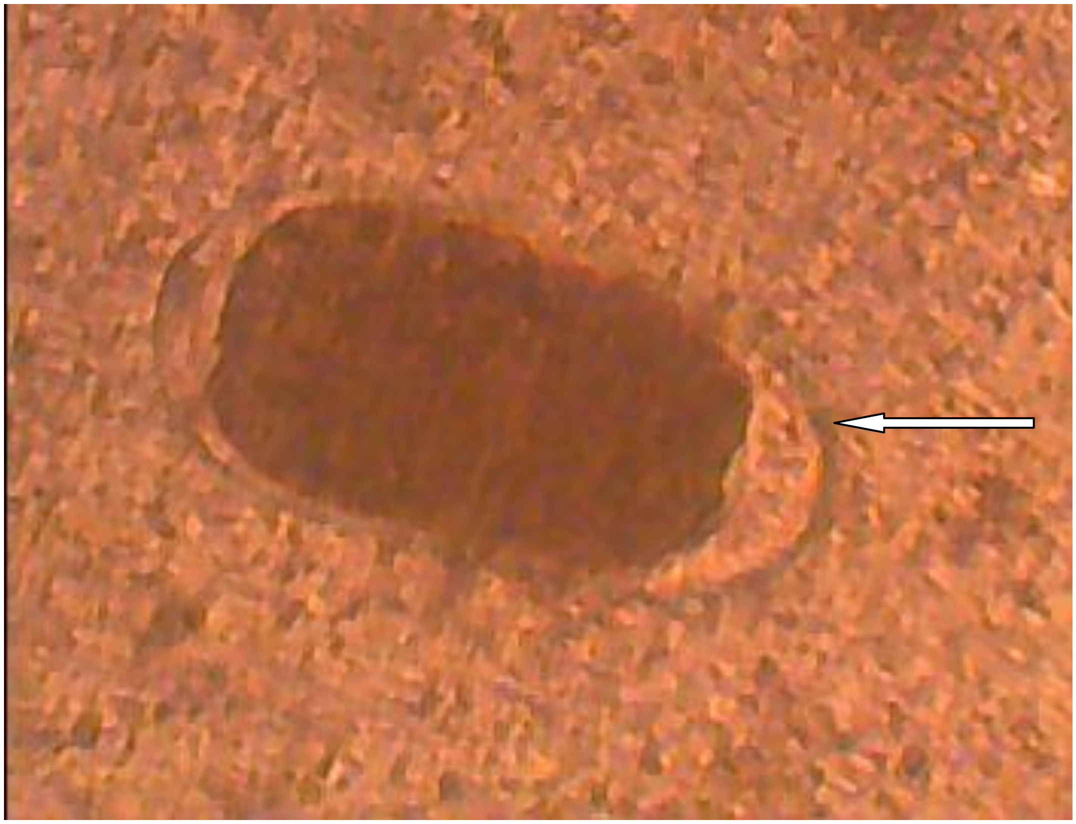

Plate XI: Ovum of Hookworm

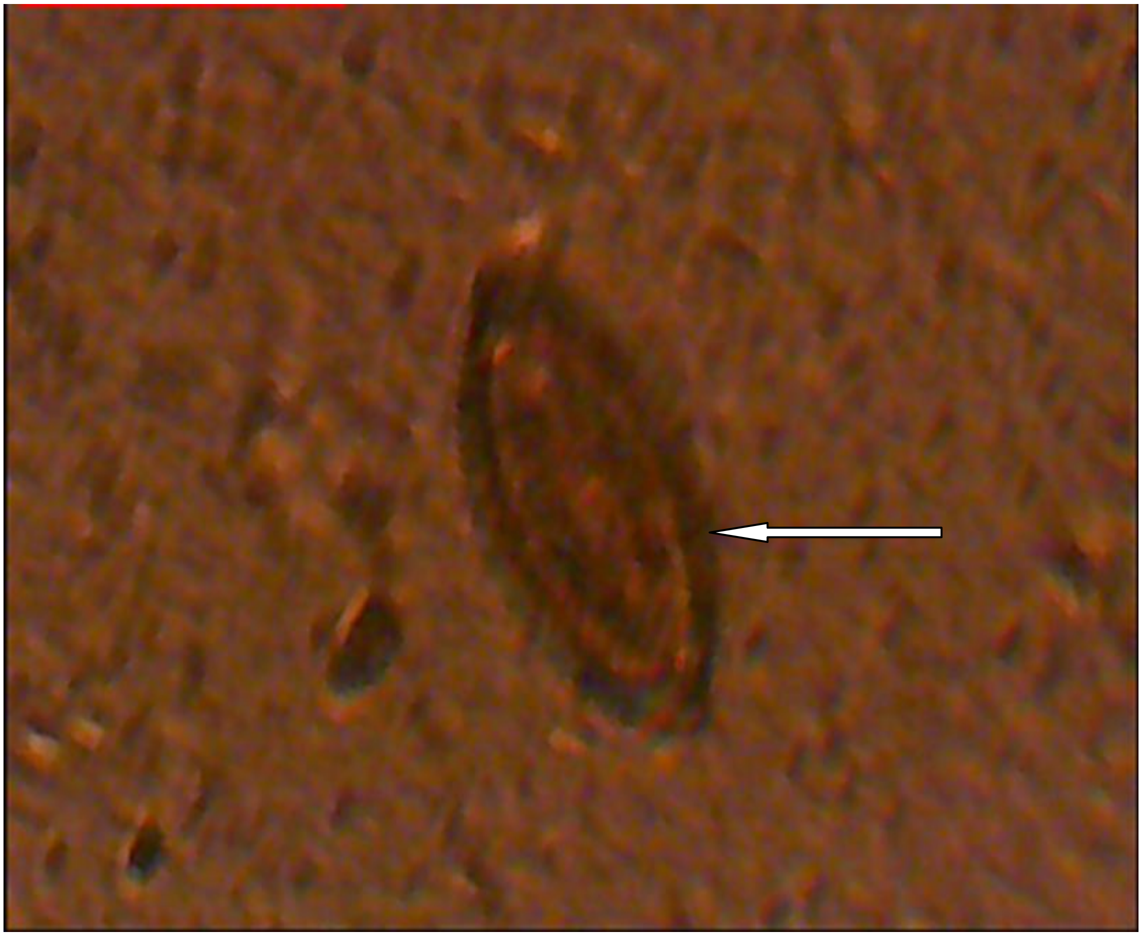

Plate XII: Egg of *Capillaria* species

Plate XIII: Egg of *Enterobius vermicularis*

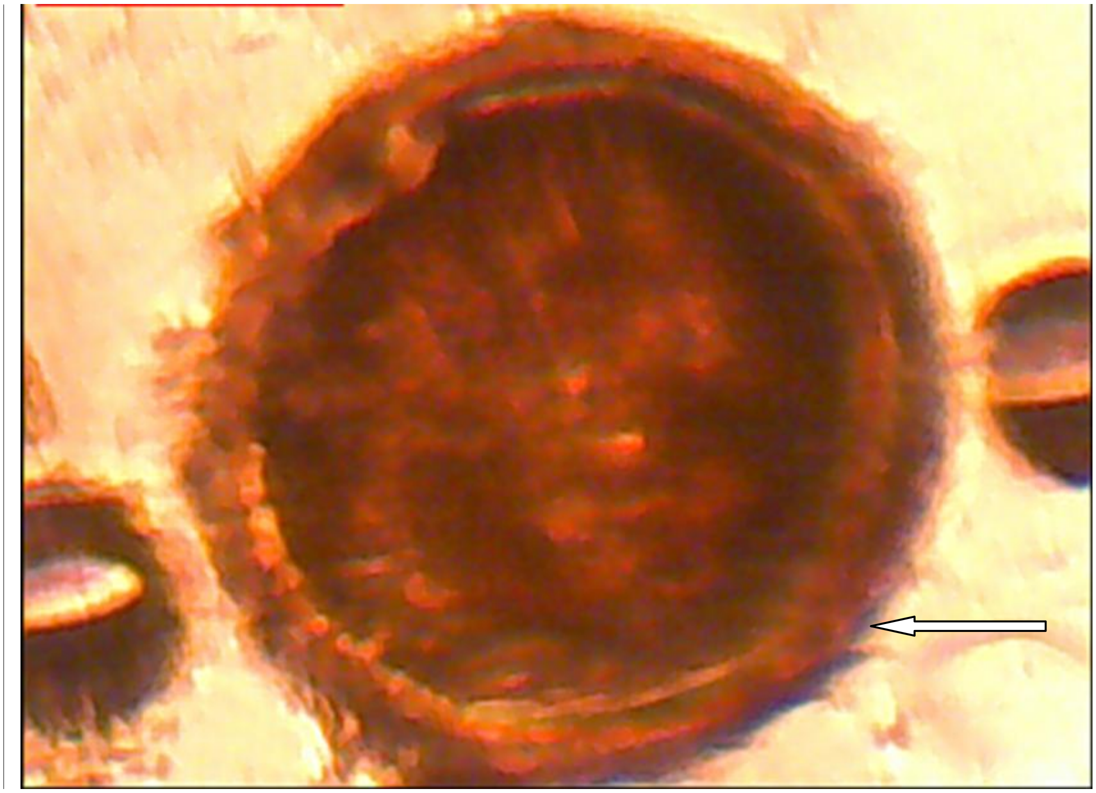

Plate XIV: Ovum of *Toxocara* species

Oocysts of *G. intestinalis* and ova of *T. trichiura* were each encountered on nine facilities while the ova of hookworm and *Taenia* sp. were each recovered from eight facilities.

Oocysts of the unidentified coccidia were recovered from seven facilities while the ova of *D. dendriticum* were obtained from five facilities. While the cysts of *B. dendriticum* and oocysts of *Cyclospora* sp. were each recovered from four facilities, the oocysts of *Isospora* sp. and the ova of *Capillaria* sp., *Toxocara* sp. and *E. vermicularis* were each recovered from two facilities (Table 4.1).

The number of the various bank facilities positive for the cysts, oocysts and ova of each of *E. histolytica*, *Cryptosporidium* sp., B. coli, *G. intestinalis* , coccidia sp. and *A. lumbricoides* differed significantly ($P < 0.05$); but the number of the bank facilities positive with cysts of *E. coli*; oocysts of *Cyclospora* sp. and *Isospora* sp.; ova of *Taenia* sp., hookworm, *T. trichiura*, D. dendriticum, *Capillaria* sp., *Toxocara* sp. and *E. vermicularis* did not differ significantly ($P > 0.05$) (Table 4.1).

Of the 432 bank facilities examined, 304 (70.0%) were found positive with the cysts, oocysts and ova of at least six parasitic organisms. Four of the parasites, including *E. histolytica*, *E. coli*, *Cryptosporidium* sp and *A. lumbricoides*, had their resistant stages on all the twelve bank facilities. A total of 251 (58.10%), 155 (35.88%), 106 (24.54%) and 44 (10.19%) and of the 432 bank facilities examined were positive with the resistant stages of *E. histolytica*, *Cryptosporidium* sp., *A. lumbricoides* and *E. coli* respectively (Table 4.1). Occurrence positivity of cysts, oocysts and or ova of the other parasitic organisms ranged from 33 (7.64%) bank facilities for *G. intestinalis* to 2 (0.46%) facilities for the trio of *Isospora* sp., *Toxocara* sp. and *E. vermicularis* (Table 4.1). The total number and percentages of each of the twelve bank facilities from which the cysts, oocysts and ova of parasites were isolated were high and ranged from 13/36 (36.1%) for polymer bank notes to 36/36 (100%) for cash loader (Table 4.1).

Table 4.2 shows the distribution of the resistant stages of twelve parasites on bank facilities in the six bank networks within Benue State, Nigeria. The resistant stages of *E. histolytica*, *Cryptosporidium* sp., *E. coli*, *Cyclospora* sp, *G. intestinalis* and *A.* were recovered from facilities at all the six banks. Ova of *Taenia* sp. and *T. trichiura* were each recovered from five of the six banks; being absent from BNKA and BNKB respectively. Oocysts of the unidentified coccidia only occurred in four banks; being absent in BNKB and BNKF. Cysts of *B. coli* occurred in three banks. The prevalence of contamination with the cysts of *E. histolytica* among the banks differed significantly ($P < 0.05$) and ranged from 47.22% in BNKB and BNKF to 69.44% in BNKA; with an overall prevalence of 58.10%. The prevalence of contamination of the bank facilities with the oocyst of *Cryptosporidium* sp. ranged from 30.56% in BNKE to 43.06% in BNKA and BNKE; with an overall prevalence of 35.88%. Prevalence of *E. coli* contamination differed significantly ($P < 0.05$) among the banks and ranged from 2.78% in BNKB to 18.06% in BNKA; with an overall prevalence of 10.19%. Overall prevalence of contamination with *G. intestinalis* cysts was 7.64%, and did not differ significantly ($P > 0.05$) in range from 1.39% in BNKF to 13.89% in BNKC. Prevalence of contamination with oocyst of the unidentified coccidia did not differ significantly ($P > 0.05$) and ranged from nil (0%) in BNKB and BNKF to 6.94% in BNKD; and an overall prevalence of 2.31%. *Balantidium coli* contamination prevalence differed significantly ($P < 0.05$) among the banks and ranged from nil (0%) in BNKA, BNKB and BNKC to 5.56% in BNKD and BNKE; and an overall prevalence of 2.08%. Overall prevalence of

Table 4.2: Number of Bank Facilities Positive for Cysts, Oocysts and Ova of Protozoa and Helminth among Banks in Benue State, Northcentral Nigeria

Bank	BNKA	BNKB	BNKC	BNKD	BNKE	BNKF	Total	Chisquare	df	P value
Entamoeba histolytica	50 (69.44)	34 (47.22)	43 (59.72)	44 (61.11)	46 (63.89)	34 (47.22)	251 (58.10)	12.143	5	0.033*
Cryptosporidium sp.	31 (43.06)	24 (33.33)	23 (31.94)	22 (30.56)	31 (43.06)	24 (33.33)	155 (35.88)	5.001	5	0.416ns
Entamoeba coli	13 (18.06)	2 (2.78)	9 (12.50)	4 (5.56)	10 (13.89)	6 (8.33)	44 (10.19)	12.652	5	0.027*
Giardia intestinalis	6 (8.33)	5 (6.94)	10 (13.89)	5 (6.94)	6 (8.33)	1 (1.39)	33 (7.64)	8.17	5	0.147ns
Coccidia	2 (2.78)	0 (0.00)	2 (2.78)	5 (6.94)	1 (1.39)	0 (0.00)	10 (2.31)	10.646	5	0.059ns
Balantidium coli	0 (0.00)	0 (0.00)	0 (0.00)	4 (5.56)	4 (5.56)	1 (1.39)	9 (2.08)	13.277	5	0.021*
Cyclospora sp.	2 (2.78)	1 (1.39)	1 (1.39)	1 (1.39)	1 (1.39)	1 (1.39)	7 (1.62)	0.726	5	0.982ns
Isospora sp.	0 (0.00)	0 (0.00)	1 (1.39)	1 (1.39)	0 (0.00)	0 (0.00)	2 (0.46)	4.019	5	0.547ns
Ascaris lumbricoides	25 (34.72)	12 (16.67)	28 (38.89)	13 (18.06)	20 (27.78)	8 (11.11)	106 (24.54)	23.503	5	0.000**
Trichuris trichiura	3 (4.17)	0 (0.00)	3 (4.17)	3 (4.17)	5 (6.94)	1 (1.39)	15 (3.47)	6.423	5	0.267ns
Taenia sp.	5 (6.94)	1 (1.39)	0 (0.00)	3 (4.17)	4 (5.56)	1 (1.39)	14 (3.24)	8.563	5	0.128ns
Hookworm	0 (0.00)	3 (4.17)	0 (0.00)	3 (4.17)	8 (11.11)	0 (0.00)	14 (3.24)	21.851	5	0.001**
Dicrocoelium dendriticum	1 (1.39)	0 (0.00)	0 (0.00)	3 (4.17)	2 (2.78)	0 (0.00)	6 (1.39)	8.113	5	0.150ns
Toxocara sp.	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	1 (1.39)	1 (1.39)	2 (0.46)	4.019	5	0.547ns
Enterobius vermicularis	0 (0.00)	0 (0.00)	0 (0.00)	2 (2.78)	0 (0.00)	0 (0.00)	2 (0.46)	10.047	5	0.074ns
Capillaria sp.	0 (0.00)	1 (1.39)	2 (2.78)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.69)	7.049	5	0.217ns
Total	58 (80.6)	44 (61.1)	53 (73.6)	55 (76.4)	50 (69.4)	44 (61.1)	304 (70.4)	11.146	5	0.049*
No. of facilities examined	72	72	72	72	72	72	432			

contamination with oocyst of *Cyclospora* sp. was 1.62%, which did not differ significantly (P > 0.05) amongst the banks but ranged from 1.39% in BNKB, BNKC, BNKD, BNKE and BNKF to 2.78% in BNKA. Overall prevalence of contamination with oocyst of *Isospora* sp. was 0.46% and did not differ significantly (P > 0.05) amongst the banks in range from nil (0%) in BNKA, BNKB, BNKE and BNKF to 1.39% in BNKC and BNKD. The prevalence of *A. lumbricoides* ova contamination amongst the banks differed significantly (P < 0.05) and ranged from 11.11% in BNKF to 38.89% in BNKC; with an overall prevalence of 24.54%. The overall contamination prevalence of *T. trichiura* ova was 3.47% and ranged from nil (0%) in BNKB to 6.94% in BNKE: but these did not differ significantly (P > 0.05). Prevalence of *Taenia* sp. contamination did not differ significantly (P > 0.05) amongst the banks and ranged from nil (0%) in BNKC to 6.94% in BNKA; with an overall prevalence of 3.24%. Prevalence of contamination with ova of hookworm differed significantly (P > 0.05) amongst the banks and ranged from nil (0%) in BNKA, BNKC and BNKF to 11.11% in BNKE; and overall prevalence of 3.24%. For D. dendriticum, contamination prevalence totalled 1.39% and ranged from nil (0%) in BNKB, BNKC and BNKF to 4.17% in BNKD and these did not differ significantly (P > 0.05). Total prevalence of contamination with the ova of *Capillaria* sp. was 0.69%, with 1.39% and 2.78% prevalence in BNKB and BNKC respectively; its prevalence in the other four banks was nil (0%). Prevalence of contamination with ova of *Toxocara* sp. was 1.39% in both BNKE and BNKF where it occurred; with an overall prevalence of 0.46%. Overall prevalence of contamination with *E. vermicularis* ova was 0.46%; did not differ significantly (P > 0.05), and ranged from nil (0%) in five banks to 2.78% in BNKD where it was only encountered (Table 4.2).

On Table 4.3 Shows the number of contaminated facilities and prevalence of cysts, oocysts and ova of parasites on bank facilities in each of the three towns within Benue State, Nigeria. A total of 304 (70.40%) of the 432 facilities in the three towns were contaminated with resistant stages of parasites. A total of 100 (69.40%) of the 144 facilities examined in Otukpo were contaminated while 102 (70.80%) facilities were each contaminated in Gboko and Makurdi. The number of bank facilities contaminated among the three towns did not differ significantly ($P > 0.05$). Prevalence of contamination with *E. histolytica* cysts totalled 58.10% but did not differ significantly ($P > 0.05$) amongst the towns and ranged from 54.17% in banks in Makurdi to 61.81% in Gboko. Prevalence of contamination with oocyst of *Cryptosporidium* sp. totalled 35.88% but did not differ significantly ($P > 0.05$) amongst the towns and ranged from 34.72% in Makurdi to 37.50% in Otukpo. Overall prevalence of contamination with *E. coli* cysts was 10.19% and ranged from 2.08% in Makurdi to 14.58% in Gboko. Prevalence of *E. coli* contamination was significantly higher ($P < 0.05$) in banks in Gboko and Otukpo than Makurdi. Overall prevalence of contamination with *G. intestinalis* cysts was 7.64% and ranged insignificantly ($P > 0.05$) from 4.86% in banks at Gboko to 11.81% in Makurdi. The overall prevalence of contamination with oocysts of the unidentified coccidia was 3.70%, it did not differ significantly ($P > 0.05$) amongst towns but ranged from 2.78% in Gboko and Makurdi to 5.56% in Otukpo. Overall prevalence of contamination with cysts of B. coli was 2.08%; did not differ significantly ($P > 0.05$) amongst towns but ranged from 1.39% in Otukpo to 2.78% in Gboko. The overall prevalence of *Cyclospora* sp. contamination was 1.62% and ranged insignificantly ($P > 0.05$) from nil (0%) in

Table 4.3: Number (%) of Bank facilities Contaminated with the Oocysts, Cysts and Ova of Parasitic Protozoans and Helminths in Towns within Benue State, Northcentral Nigeria

Parasites	Gboko	Makurdi	Otukpo	Total	Chisquare	df	P value
Entamoeba histolytica	89 (61.81)	78 (54.17)	84 (58.33)	251 (58.10)	1.731	2	0.421ns
Cryptosporidium sp.	51 (35.42)	50 (34.72)	54 (37.50)	155 (35.88)	0.262	2	0.877ns
Entamoeba coli	21 (14.58)	3 (2..08)	20 (13.89)	44 (10.19)	15.537	2	0.000**
Coccidia sp.	4 (2.78)	4 (2.78)	8 (5.56)	16 (3.70)	2.077	2	0.354ns
Balantidiumcoli	4 (2.78)	3 (2.08)	2 (1.39)	9 (2.08)	0.681	2	0.711ns
Cyclospora sp.	3 (2.08)	4 (2.78)	0 (0.00)	7 (1.62)	3.775	2	0.151ns
Isospora sp.	1 (0.69)	1 (0.69)	0 (0.00)	2 (0.46)	1.005	2	0.605ns
Giardia intestinalis	7 (4.86)	17 (11.81)	9 (6.25)	33 (7.64)	5.512	2	0.064ns
Ascaris lumbricoides	30 (20.83)	41 (28.47)	35 (24.31)	106 (24.54)	2.275	2	0.321ns
Toxocara sp.	1 (0.69)	0 (0.00)	1 (0.69)	2 (0.46)	1.005	2	0.605ns
Taenia sp.	2 (1.39)	2 (1.39)	10 (6.94)	14 (3.24)	9.449	2	0.009**
Hookworm	3 (2.08)	6 (4.17)	5 (3.47)	14 (3.24)	1.033	2	0.596ns
Trichuris trichiura	8 (5.56)	5 (3.47)	2 (1.39)	15 (3.47)	3.729	2	0.155ns
Enterobius vermicularis	2 (1.39)	0 (0.00)	0 (0.00)	2 (0.46)	4.019	2	0.134ns
Capillaria sp.	2 (1.39)	1 (0.69)	0 (0.00)	3 (0.69)	2.014	2	0.365ns
Dicrocoelium dendriticum.	5 (3.47)	1 (0.69)	0 (0.00)	6 (1.39)	7.099	2	0.029*
Total Positive	102 (70.8)	102 (70.80	100 (69.4)	304 (70.40)	0.089	2	0.957ns
No. of facilitiesexamined	144	144	144	432			

Otukpo to 5.56% in Gboko. *Taenia* sp. ova contamination of the banks' facilities totalled 3.24% prevalence and was significantly ($P < 0.05$) higher in Otukpo (6.94%) than in Gboko (1.39%) and Makurdi (1.39%). Total prevalence of contamination of the bank facilities with the ova of hookworm was 3.24% and ranged insignificantly ($P > 0.05$) from 2.08% in Gboko to 4.17% in Makurdi. Overall prevalence of contamination with ova of *D. dendriticum* was 1.39% and ranged insignificantly ($P < 0.05$) from nil (0%) in Otukpo to 3.47% in Gboko. Overall prevalence of contamination of bank facilities with the ova of *Capillaria* sp. totalled 0.69% and ranged insignificantly ($P > 0.05$) from nil (0%) in Otukpo to 1.39% in Gboko. The overall prevalence of contamination with ova of *Toxocara* sp. was 0.46% and ranged insignificantly ($P > 0.05$) from nil (0%) in banks in Makurdi to 0.69% in both Gboko and Otukpo. *Enterobius vermicularis* ova contamination only occurred in banks at Gboko, with a prevalence of 1.39% and a total prevalence of 0.46% ($P > 0.05$). (Table 4.3).

4.3 Intensities of Cysts, Oocyst and Ova of Parasites Among Bank Facilities and Banks

The intensities (mean cysts/oocysts/ova count per facility) of contamination of bank facilities with the cysts, oocysts and or ova of each of the sixteen parasites are shown in Table 4.4. *Isospora* sp., *Toxocara* sp. and *E. vermicularis* had the least intensity of 0.005 mean oocyst/ova count (MOC/MOvC) while *E. histolytica* had the highest intensity of 1.89 mean cyst count (MCC). The intensity of *E. histolytica* ranged significantly ($P > 0.05$) from 0.25 MCC on polymer bank notes to 6.31 MCC on slabs/counters in banking hall. Intensity of oocysts of *Cryptosporidium* sp. totalled 1.27 MOC and ranged significantly ($P < 0.05$) from 0.03 MOC on computer mouse to 4.72 MOC on

Table 4.4: Intensity (Mean±SE) of Cysts, Oocysts and Ova of Protozoans and Helminth on Bank Facilities in Benue State, Northcentral Nigeria

Bank facilities	Down Instruction Knot	Upper Instruction Knot	Outside Door Handle	Inside Door Handle	Banking Hall	Bulking Hall	Keyboard	Mouse	Loader	Cash receiver	Polymer Note	Paper note	Total	P value
Entamoeba histolytica	1.11±0.20	0.28±0.09	1.08±0.15	1.41±0.18	6.31±0.81	2.03±0.24	1.25±0.23	0.31±0.09	2.03±0.24	3.83±0.56	0.25±0.08	2.94±0.40	1.89±1.37	0.000**
Cryptosporidium sp.	0.44±0.16	0.11±0.05	0.31±0.11	0.42±0.13	4.72±0.74	2.94±0.40	0.67±0.16	0.03±0.03	1.92±0.03	4.12±0.87	0.08±0.05	1.11±0.32	1.27±1.38	0.000**
Entamoeba coli	0.19±0.12	0.06±0.04	0.08±0.06	0.08±0.06	0.83±0.26	0.31±0.12	0.14±0.07	0.08±0.05	0.11±0.07	0.39±0.19	0.03±0.03	0.42±0.15	0.22±0.04	0.000**
Coccidia sp.	0.00±0.00	0.00±0.00	0.14±0.10	0.03±0.03	0.22±0.11	0.06±0.06	0.03±0.03	0.00±0.00	0.14±0.11	0.00±0.00	0.00±0.00	0.19±0.08	0.07±0.02	0.039*
Balantidium coli	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.03±0.03	0.00±0.00	0.03±0.03	0.00±0.00	0.06±0.06	0.31±0.12	0.00±0.00	0.00±0.00	0.04±0.01	0.000**
Cyclospora sp.	0.00±0.00	0.00±0.00	0.03±0.03	0.00±0.00	0.19±0.09	0.42±0.16	0.00±0.00	0.00±0.00	0.00±0.00	0.06±0.06	0.00±0.00	0.00±0.00	0.03±0.01	0.000**
Isospora sp.	0.00±0.00	0.00±0.00	0.03±0.03	0.00±0.00	0.03±0.03	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.005±0.004	0.533ns
Giardia intestinalis	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.25±0.13	0.22±0.11	0.08±0.05	0.11±0.053	0.19±0.10	0.42±0.16	0.08±0.05	0.36±0.15	0.14±0.03	0.001**
Ascaris lumbricoides	0.67±0.15	0.14±0.07	0.39±0.11	0.17±0.12	0.69±0.17	0.11±0.05	0.14±0.06	0.06±0.04	0.25±0.09	0.61±0.16	0.08±0.05	1.22±0.23	0.40±0.41	0.000**
Toxocara	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.03±0.03	0.00±0.00	0.00±0.00	0.00±0.00	0.03±0.03	0.00±0.00	0.00±0.00	0.00±0.00	0.005±0.004	0.533ns
Taenia spp	0.03±0.03	0.03±0.03	0.00±0.00	0.03±0.03	0.14±0.09	0.03±0.03	0.00±0.00	0.03±0.03	0.00±0.00	0.00±0.00	0.11±0.05	0.08±0.05	0.04±0.01	0.103ns
Hookworm	0.03±0.03	0.00±0.00	0.03±0.03	0.03±0.03	0.08±0.05	0.25±0.09	0.00±0.00	0.00±0.00	0.00±0.00	0.06±0.04	0.03±0.03	0.17±0.07	0.04±0.01	0.015*
Trichuris	0.08±0.05	0.03±0.03	0.03±0.03	0.03±0.03	0.03±0.03	0.00±0.00	0.00±0.00	0.00±0.00	0.03±0.03	0.03±0.03	0.17±0.07	0.06±0.06	0.04±0.01	0.111ns
Enterobius vermicularis	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.03±0.03	0.03±0.03	0.005±0.004	0.533ns
Capillaria	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.06±0.04	0.00±0.00	0.03±0.03	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.008±0.004	0.116ns
Dicroecium spp	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.06±0.04	0.06±0.04	0.03±0.03	0.00±0.00	0.06±0.04	0.00±0.00	0.00±0.00	0.03±0.03	0.02±0.006	0.253ns
No. of facilities examined	**36**	**36**	**36**	**36**	**36**	**36**	**36**	**36**	**36**	**36**	**36**	**36**	**432**	

slabs/counters in banking hall. Intensity of *E. coli* cysts totalled 0.22 MCC and ranged significantly ($P < 0.05$) from 0.03 MCC on polymer bank notes to 0.83 MCC on slabs/counters in banking hall. Intensities of the cysts of *G. intestinalis* differed significantly ($P < 0.05$) amongst the facilities; with total intensity of 0.14 MCC and the highest intensity of 0.42 MCC on cash receivers of counting machines, but was not encountered on four of the twelve facilities.

Intensity of the unidentified coccidia on the facilities totalled 0.07 MOC and ranged insignificantly ($P > 0.05$) from nil (0.00) on the down and upper instruction knobs of ATMs, mouse, cash receiver and polymer bank notes to 0.22 MOC on slabs/counters in banking hall. The total mean intensity of B. coli cysts was 0.04MCC and was not found on eight of the twelve surfaces, but was highest (0.31 MCC) on cash receivers of counting machines. Oocysts of *Cyclospora* sp. were not found on eight of the twelve facilities but had total intensity of 0.03 MOC and highest intensity of 0.42 MOC on slabs/counters in the bulk rooms. *Isospora* sp. occurred only on outside door handles and slabs/counters in banking halls with respective intensities of 0.03 MOC each; which did not differ significantly ($P > 0.05$). The intensity of *A. lumbricoides* ranged significantly ($P < 0.05$) from 0.06 MOvC on computer mouse to 1.22 MOvC on paper bank notes. Ova of *T. trichiura* were not encountered on three of the facilities but its intensity ranged insignificantly ($P > 0.05$) from 0.03 MOvC on six facilities to 0.17 MOvC on polymer bank notes. Ova of *Taenia* sp. were not encountered on four facilities (0.00 intensity) but its intensities ranged significantly ($P < 0.05$) from 0.03 MOvC on five facilities, to 0.14 MOvC on slabs/counters in bank halls. Hookworm ova were not encountered on four facilities (0.00 intensity) but its intensities ranged significantly ($P < 0.05$) from 0.03

MOvC on four facilities to 0.25 MOvC on slabs/counters in bulk rooms. Dicrocoelium dendriticum ova were not encountered on seven facilities (0.00 intensity) but its intensities ranged insignificantly ($P > 0.05$) from 0.03 MOvC on two facilities to 0.06 MOvC on three facilities. Ova of *Capillaria* sp. occurred on computer keyboards and slabs/counters within bank halls with respective intensities of 0.03 MOvC and 0.06 MOvC, which differed significantly ($P < 0.05$). Ova of *Toxocara* sp. were not encountered on ten facilities (all with 0.00 intensity) but the intensities were same (0.03 MOvC) on cash loaders of counting machines and slabs/counters in bank halls. Enterobius vermicularis ova were only encountered on paper and polymer bank notes, each with an intensity of 0.03 MOvC (Table 4.4).

On Table 4.5 are shown the intensities of the cysts, oocysts and ova of sixteen parasitic organisms in the six bank examined in this study. The intensities of *E. histolytica* cysts was least (1.26 MCC) in BNKF and highest (2.53 MCC) in BNKE, and the differences were not statistically significant ($P > 0.05$). Intensities of the oocysts of *Cryptosporidium* sp. was least (0.83 MOC) in BNKF and highest (2.53 MOC) in BNKE; the differences were statistically significant ($P < 0.05$). The intensities of *E. coli* cysts was least (0.05 MCC) in BNKB and highest (0.38 MCC) in BNKA, and these differences were not statistically significant ($P > 0.05$). Intensities of the oocysts of the unidentified coccidia was nil (0.00 MCC) in BNKB and ranged insignificantly ($P > 0.05$) from 0.03 MOC in BNKA and BNKC to 0.15 MOC in BNKD. Intensities of the cysts of B. coli were nil (0.00 MCC) in BNKA, BNKB and BNKC and ranged significantly ($P < 0.05$) from 0.03 MCC in BNKF to 0.11 MCC in BNKE. Intensities of *Cyclospora* sp. oocysts were least (0.02 MOC) in BNKB and BNKC and highest (0.03 MOC) in BNKA, BNKD, BNKB

Table 4.5: Intensity (Mean±SE) of Cysts, Oocysts and Ova of Protozoan and Helminths on Bank facilities among banks in Benue State, Northcentral Nigeria

Bank	BNKA	BNKB	BNKC	BNKD	BNKE	BNKF	Total	P value
Entamoeba Histolytica	2.42±0.34	1.34±0.26	2.03±0.33	1.76±0.36	2.53±0.42	1.26±0.25	1.89±0.14	0.026*
Cryptosporidium parvum	1.55±0.36	0.91±0.18	0.95±0.23	0.85±0.22	2.53±0.60	0.83±1.88	1.27±0.14	0.001**
Entamoeba coli	0.38±0.11	0.05±0.03	0.30±0.12	0.18±0.11	0.27±0.10	0.14±0.06	0.22±0.04	0.126ns
Coccidia	0.03±0.02	0.00±0.00	0.03±0.021	0.15±0.81	0.14±0.06	0.06±0.04	0.07±0.02	0.119ns
B. Coli	0.00±0.00	0.00±0.00	0.00±0.00	0.09±0.05	0.11±0.05	0.03±0.03	0.04±0.01	0.039*
Cyclospora	0.03±0.02	0.02±0.02	0.02±0.02	0.03±0.03	0.03±0.03	0.03±0.03	0.03±0.01	0.992ns
Isospora	0.00±0.00	0.00±0.00	0.02±0.02	0.02±0.02	0.00±0.00	0.00±0.00	0.005±0.004	0.550ns
Giardia spp	0.15±0.07	0.11±0.05	0.29±0.10	0.11±0.05	0.17±0.07	0.00±0.00	0.14±0.03	0.066ns
Ascaris lumbricoides	0.52±0.10	0.24±0.07	0.53±0.09	0.36±0.13	0.64±0.14	0.12±0.04	0.40±0.04	0.002**
Toxocara	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.02±0.02	0.02±0.02	0.005±0.004	0.550ns
Taenia spp	0.08±0.03	0.02±0.02	0.00±0.00	0.05±0.03	0.09±0.05	0.02±0.02	0.04±0.01	0.144ns
Hookworm	0.00±0.00	0.05±0.03	0.00±0.00	0.06±0.04	0.12±0.04	0.00±0.00	0.04±0.01	0.002**
Trichuris	0.05±0.03	0.00±0.00	0.06±0.04	0.06±0.04	0.08±0.03	0.02±0.02	0.04±0.01	0.352ns
Enterobius vermicularis	0.00±0.00	0.00±0.00	0.00±0.00	0.03±0.02	0.00±0.00	0.00±0.00	0.005±0.004	0.073ns
Capillaria	0.00±0.00	0.02±0.02	0.03±0.021	0.00±0.00	0.00±0.00	0.00±0.00	0.008±0.004	0.218ns
Dicroecium spp	0.02±0.02	0.00±0.00	0.00±0.00	0.05±0.03	0.03±0.02	0.00±0.00	0.02±0.006	0.150ns
No. Of Sample Examined	72	72	72	72	72	72	432	

and BNKF; the differences were not statistically significant ($P > 0.05$). The intensities of *G. intestinalis* cysts were nil (0.00 MCC) in BNKF and ranged insignificantly ($P > 0.05$) from 0.11 MCC in BNKB and BNKD to 0.29 MCC in BNKC. Intensities of the oocysts of *Isospora* sp. were nil (0.00 MOC) in BNKA, BNKB, BNKE and BNKF and ranged insignificantly ($P > 0.05$) to 0.02 MOC in BNKC and BNKD. Intensities of *A. lumbricoides* ova were least (0.12 MOvC) in BNKF and highest (0.64 MOvC) in BNKD; the differences were statistically significant ($P < 0.05$). Intensities of *T. trichiura* ova were nil (0.00 MOvC) in BNKB and ranged insignificantly ($P > 0.05$) from 0.02 MOvC in BNKF to 0.08 MOvC in BNKE. Intensities of ova of *Taenia* sp were nil (0.00MOvC) in BNKC and ranged insignificantly ($P > 0.05$) from 0.02 MOvC in BNKB and BNKF to 0.09 BNKE. Ova of hookworm ranged significantly ($P < 0.05$) in intensities from nil (0.00 MOvC) in BNKA, BNKC and BNKF to 0.05 MOvC in BNKB and peaked at 0.12 MOvC in BNKE. Dicrocoelium dendriticum ova intensities were nil (0.00 MOvC) in BNKB, BNKC and BNKF and ranged insignificantly ($P > 0.05$) from 0.02 MOvC in BNKA to 0.05 MOvC in BNKD. Intensities of ova of *Capillaria* sp. were nil (0.00 MOvC) in BNKA, BNKD, BNKE and BNKF and ranged insignificantly ($P > 0.05$) from 0.02 MOvC in BNKB to 0.03 MOvC in BNKC. Ova of *Toxocara* sp. ranged insignificantly ($P > 0.05$) in intensities from nil (0.00 MOvC) in BNKA, BNKB, BNKC and BNKD to 0.02 MOvC at both BNKE and BNKF. Ova of *E. vermicularis* were of nil (0.00 MOvC) intensities in five banks and at 0.03 MOvC in BNKD (Table 4.5).

On Table 4.6 are represented the intensities of the cysts, oocysts and ova of sixteen parasitic organisms on banks amongst the three towns in Benue State, Nigeria, where this study was conducted. The intensities of *E. histolytica* cysts was least (1.63 MCC) in

Table 4.6: Comparative Intensity (Mean±SE) of Cysts, Oocysts and Ova of Protozoa and Helminth on Bank Facilities in Benue State, Northcentral Nigeria

Towns	Gboko	Makurdi	Otukpo	Total	P value
Entamoeba histolytica	2.14±0.27	1.63±0.22	1.89±0.22	1.89±0.13	0.32ns
Cryptosporidium sp.	1.36±0.22	1.23±0.28	1.21±0.20	1.27±0.14	0.907ns
Entamoeba coli	0.32±0.08	0.03±0.02	0.31±0.07	0.22±0.04	0.002**
Coccidia	0.04±0.02	0.08±0.04	0.09±0.35	0.07±0.02	0.507ns
Balantidium coli	0.05±0.03	0.05±0.03	0.02±0.01	0.04±0.01	0.454ns
Cyclospora sp.	0.03±0.02	0.05±0.02	0.00±0.00	0.03±0.01	0.170ns
Isospora sp.	0.008±0.008	0.008±0.008	0.00±0.00	0.005±0.004	0.607ns
Giardia intestinalis	0.08±0.04	0.20±0.05	0.13±0.05	0.14±0.03	0.220ns
Ascaris lumbricoides	0.34±0.07	0.51±0.08	0.36±0.06	0.40±0.04	0.191ns
*Toxocara*sp.	0.008±0.008	0.00±0.00	0.008±0.008	0.005±0.004	0.607ns
Taenia sp.	0.02±0.01	0.01±0.01	0.09±0.03	0.04±0.01	0.009**
Hookworm	0.02±0.01	0.05±0.02	0.05±0.02	0.04±0.01	0.580ns
Trichuris trichiura	0.08±0.03	0.04±0.02	0.02±0.01	0.04±0.01	0.089ns
Enterobius vermicularis	0.02±0.01	0.00±0.00	0.00±0.00	0.005±0.004	0.135ns
*Capillaria*sp.	0.02±0.01	0.008±0.008	0.00±0.00	0.008±0.004	0.367ns
Dicrocoelium dendriticum	0.04±0.02	0.008±0.008	0.00±0.00	0.02±0.006	0.028*
No. of facilities examined	144	144	144	432	

banks in Makurdi and highest (2.14 MCC) in banks in Gboko; but the differences were not statistically significant (P >0.05). Intensities of the oocysts of *Cryptosporidium* sp. was least (1.21 MOC) in banks in Otukpo and highest (1.36 MOC) in banks in Gboko; but the differences were not statistically significant (P > 0.05). The intensities of *E. coli* cysts were 0.31 MCC and 0.32 MCC in Otukpo and Gboko banks respectively, and these were significantly higher (P < 0.05) than the intensity (0.03 MCC) in Makurdi banks. Intensities of the oocysts of the unidentified coccidia ranged insignificantly (P > 0.05) from 0.04 MOC in Gboko banks to 0.09 MOC in Otukpo banks. Intensities of the cysts of B. coli were least (0.02 MCC) in Otukpo banks and highest (0.05 MCC) in both Gboko and Makurdi banks; but these differences were not statistically significant (P > 0.05). *Cyclospora* sp. oocysts were not encountered in banks in Otukpo but the intensities was lower (0.03 MOC) in Gboko banks and higher (0.05 MOC) insignificantly (P > 0.05) in Makurdi banks. The intensities of *G. intestinalis* cysts ranged insignificantly (P > 0.05) from 0.08 MCC in Gboko banks to 0.20 MCC in Makurdi banks. Intensities of the oocysts of *Isospora* sp. were similar (0.008 MOC) in Gboko and Makurdi banks where they were encountered; but the oocyst was not found in Otukpo banks. Intensities of *A. lumbricoides* ova ranged insignificantly (P > 0.05) from 0.34 MOvC in banks in Gboko to 0.51 MOvC in Makurdi. . Intensities of *T. trichiura* ova ranged insignificantly (P > 0.05) from 0.02 MOvC in Otukpo banks to 0.08 MOvC in Gboko banks. Intensities of ova of *Taenia* sp. ranged significantly (P < 0.05) from 0.01 MOvC in Makurdi banks to 0.09 MOvC in Otukpo banks. Ova of hookworm ranged insignificantly (P > 0.05) in intensities from 0.02 MOvC in Gboko banks to 0.05 MOvC in both Makurdi and Otukpo banks. Dicrocoelium dendriticum ova were not encountered in banks in Otukpo but its intensities were significantly higher ($P < 0.05$) in Gboko banks (0.04 MOvC) than Makurdi banks (0.008 MOvC). . Ova of *Capillaria* sp. were not encountered in Otukpo banks but its intensities ranged insignificantly ($P > 0.05$) from 0.008 MOvC in Makurdi banks to 0.02 MOvC in Gboko banks. Ova of *Toxocara* sp. were not encountered in banks in Makurdi and there were similar intensities (0.008 MOvC) between Gboko and Otukpo banks. Ova of *E. vermicularis* were only encountered in banks in Gboko with intensity of 0.02 MOvC (Table 4.6).

CHAPTER FIVE

5.0 DISCUSSION

This study has revealed the occurrence of the cysts, oocysts and ova of several parasitic protozoans and helminths on bank facilities in parts of Benue State, Nigeria. The study appears to be pioneering to have focused on extensive parasitological audit of bank environments. The only other similar study of this nature cited was not as extensive and only focused on microbial (bacteria and fungi) contamination of currency counting machines and counting room environment in banks (Enemuor *et al.*, 2012).

However, several studies from various countries have consistently isolated parasites' cysts and ova from currency notes, which are the major exchange materials emanating from banks, although some of the notes were those in circulation and were not obtained directly from bank environments (Awodi *et al.,* 2000; Basavarajappa and Suaresh, 2005; Ekejindu, 2005; Ogbu and Uneke, 2007; Matur *et al.,* 2010; Orji *et al.*, 2012). These bank notes would however circulated in, out, through and among banks in one way or the other. Fourteen of the sixteen parasites whose resistant stages were isolated from banks in this study, including *E. histolytica, E. coli, Cryptosporidium* sp.*, B. coli, Isospora* sp., *Cyclospora* sp. *G. intestinalis, A. lumbricoides*, *Toxocara* sp., *Taenia* sp., hookworm, *T. trichiura, Capillaria* sp. and *E. vermicularis,* are infective to humans and cause varying pathogenic conditions such as in intestinal and extra intestinal sites. Such diseases as amoebiasis, cryptosporidiosis, giardiasis, ascariasis, visceral and ocular larval migrans, *Capillaria*sis, and several more caused by the listed parasites, could be contracted from bank environments. These are amongst the leading enteric parasitic diseases (WHO, 1997), killing about 100,000 people yearly and infecting about 50 million more (Robert and Janovy, 2009). About 85% of people infected with these parasites are healthy carriers (Noble *et al.*, 1989), with consequences of more transmission by faecal - oral route or human - to -human (Hojlyng, 1987; Current and Garcia, 1991). Few of the parasitic species, including *Capillaria* sp., *D. dendriticum* and *Toxocara* sp., parasitize domesticated animals and wildlife; and could also be zoonotic (Despommier, 2003; Alli *et al*., 2011; Omowaye and Toluhi, 2011). This indicates that banks are repositories of resistant stages of important medical and veterinary parasites. The presence and isolation of resistant stages of such a high diversity of mainly gastrointestinal parasites from banks' facilities reflect the unhygienic nature of some of the large number of humans that make daily visits to banks for various financial transactions.

Awodi *et al.* (2000) also observed that parasitic contaminants of the Nigerian currency notes are mainly of faecal origin. It is therefore plausible that the heavy contaminations observed in banks in this study could be traced to very poor personal hygiene of such persons. This implies that hand washing after toilet usage is not being done properly leading to adherence of cysts, oocysts and ova of enteric parasite on human hands which are eventually deposited on bank facilities. Hands appear to be the most vulnerable parts of the human body that are used to operate and or in contact virtually with all the bank facilities in this study. Thus humans who work in and or transact businesses in these contaminated bank environments could be at the risk of being infected by some of the encountered parasites, especially those whose cysts, oocyst and ova are infective. These included *B. coli, E. histolytica, E. coli, G. intestinalis, Cryptosporidium* sp., *Cyclospora* sp., *Isospora* sp., *Toxocara* sp., *Capillaria* sp., *Taenia solium, A. lumbricoides,* *E. vermicularis*. Most of the parasite species whose cysts, oocysts and ova were encountered in this study have also been reported in one study or the other especially from shoe soles (Nock and Tanko, 2000), door handles, toilet closet handles (Nock and Geneve, 2002), computer accessories in internet cafes (Ndams and Jimoh, 2006), sachet drinking water (Ekwunife *et al.,* 2010) and bank notes (Ogbu and Uneke, 1997; Awodi *et al.,* 2000; Ogo *et al.,* 2004; Matur *et al.,* 2009 and Orji *et al.,* 2012). These previous studies did not isolate the oocysts of *Cryptosporidium* sp., *Cyclospora* sp. and *Isospora* sp. and the ova of *Capillaria* sp. and *D. dendriticum*, which were encountered in this study. This higher diversity of parasite types found in this study could be due to diverse nature of bank facilities that were explored and the higher density of human traffic to banks that are capable of contaminating bank facilities.

Furthermore, Benue State where this study was conducted is the agricultural hob of Nigeria where majority of its residents are illiterates that are engaged in subsistence farming occupation. Subsistence farming in Nigeria is associated with low level of hygiene and sanitation, lack of potable water supply and effective faecal disposal systems (Atu, 2008). These infrastructural deficits could encourage the transmission of enteric parasites capable of supporting the heavy contamination of bank environments witnessed in this study. The occurrence of ova of such classical veterinary helminth parasites as *Capillaria* sp., *D. dendriticum* and *Toxocara* sp. in banks could be an indication of cross contamination of human hands with resistant stages of parasites of domesticated animals. *Toxocara canis* and *T. cati* are the two dominant species in the genus *Toxocara* with dogs and cats as their respective definitive hosts (Despommier, 2003). Eggs from these ascarids are common environmental contaminants of human habitations, due largely to the fact that many kinds of dogs and cats serve as pets, while countless others run wild in streets of most urban centres (Despommier, 2003).

Dicrocoelium dendriticum is a common hepatic parasite of small (sheep, goats) and large (cattle) ruminants and its eggs, apart from being voided in the hosts' faeces. It is often encountered in bile samples of these animals in slaughter houses in parts of Nigeria (Hassan and Anwo, 2011; Oke *et al.*, 2014). Thus, ruminant farmers, butchers and other abattoir workers who are daily exposed to and handle infected gall bladders, bile, currencies and also visit banks for financial transactions could serve as vehicles for the contamination of bank facilities. *Capillaria* species are diverse, have low host specificity and thus infective in a wide range of domestic (chicken, dogs, cats, cattle, sheep, goats) as well as wild (wild carnivores, rodents, monkeys) animals including humans. Although most species parasitize animals, three species (*Capillaria philippinensis, C. aerophila* and *C. hepatica*) are infective in humans (Fuehrer, 2014). Unsanitary and poor hygienic conditions (e.g. drinking water from rivers, consumption of unembryonated eggs in soil or infected game) and the presence of rodents (e.g. rats) and domestic animals increase the risk of human infections with *Capillaria hepatica* (Fuehrer *et al.*, 2011). It will be highly speculative to hypothesize the origin (whether human or animal) of the ova of *Capillaria* sp. found on slabs/counters and computer keyboards in this study, since the ova are not identified to species.

It is pertinent to discuss two species of parasites that stood out amongst the parasites encountered in this study. They are *E. histolytica* and *A. lumbricoides. E. histolytica* was by far the most dominant protozoan whose cysts were encountered in banks in this study with the highest prevalence, the next closest in prevalence was *Cryptosporidium* sp.

prevalence of the other protozoans was low. Cysts of *E. histolytica* together with those of *E. coli* and oocysts of *Cryptosporidium* sp. occurred on all the bank facilities examined in this study. The cysts of *E. histolytica, E. coli* and *G. intestinalis* as well as oocysts of *Cryptosporidium* sp. and *Cyclospora* sp. occurred in all the banks investigated.

The ova of *A. lumbricoides* were by far the most dominant amongst helminth parasites in terms of prevalence. Other helminths occurred at low prevalence. Ova of *A. lumbricoides* occurred on all the bank facilities and in all the banks; being the only helminth parasite to have so occurred. Incidentally, the cysts of *E. histolytica* and ova of *A. lumbricoides* are infective and these two parasites are most likely to be contracted in bank environments. Cysts of *E. coli,* oocysts of *Cryptosporidium* sp. and ova of *A. lumbricoides* are endowed with hard and thickened outer coverings capable of protecting from and withstanding disinfectants used on contact surfaces (Ajero *et al.*, 2008). Ibidapo and Okwa (2008) attributed the ubiquity of *Ascaris lumbricoides* to high resistance of its ova to harsh environmental conditions. Cysts of *E. histolytica, Giardia* spp. and oocysts of *Cryptosporidium* spp. have thick walls that could withstand desiccation and preserve their infectivity (CDC, 2010). The use of air conditioners by banks could also aid the infectivity of the resistant stages encountered in banks in view of their humidifying and temperature reduction effects and attendant prospect of eliminating desiccation.

This study indicates that cysts, oocysts and ova of parasitic protozoans and helminths occurred on all the bank facilities examined in this study. The overall prevalence of contamination with resistant stages of protozoan was higher than that of helminths. These high contamination rates, especially for protozoans and also for helminths, were higher than the overall prevalence of 8.11% for water closet handles (Nock and Geneve, 2002);

8.8% for computer keyboards and mouse in internet cafes (Ndams and Jimoh, 2006); 33.3% on dirty currency notes (Orji *et al.,* 2012) and 41.7% on sachet drinking water (Ekwunife *et al.,* 2010). The very high contamination profile associated with slabs/counters within the banking halls and bulk rooms could be due to their larger surface areas that made them amenable to greater contamination as virtually all bank customers make contact (for writing, signature, cash confirmation etc) with them for various transactions. The high contamination profile of the counting machines (loaders and cash receivers) could be attributed to cumulative accumulation of parasites' stages following repeated usages of the often inadequate facilities for counting currencies by bank workers. Door handles (outer and inner handles) also had such a high contamination rates and diversity of parasite types due to the compulsive contacts made with them by every bank worker, customer and visitor for entrances and exits.

There was no significant difference in the overall contamination profiles for the parasites among the banks even in the face of significant differences in the specific contamination of five (*E. histolytica, E. coli, B. coli, A. lumbricoides* and hookworm) of the sixteen parasites. This could be due to the fact that the banks were patronized by the same set of individuals for similar financial transactions and some of the bank facilities (e.g. paper and polymer notes) circulate among the banks. This is not unmindful of the fact that the total customer base of the banks and hence the human density among the banks could be different. Several Nigerians maintain multiple bank accounts with several bank networks and the various banks share a common database of accounts holders that make transactions (e.g. use of ATMs) interchangeable among banks.

This study also investigated parasitic contamination of banks that were located in various towns. The data that emanated therein showed that banks that were domiciled in the various towns had very high contamination indices but with no significant differences amongst the towns. Thus the contamination of banks with cysts, oocysts and ova of parasites were not dependent on the location of the banks. This could be due to the fact that humans at the various towns where these banks are located were infected by the same parasite types, shared similar post-toilet insanitary habits and similar financial needs from the various banks that led to similarities in contamination pattern with resistant stages of parasites. Again, the banks may have similar sanitary measures put in place to effect cleanliness and these measures were obviously not that effective against parasites' stages.

Resistant stages of parasites encountered on bank facilities in this study were generally very low in intensities and often less than unit for protozoans (except *E. histolytica* and *Cryptosporidium* sp.) and all the helminth species. In instances where intensities of parasites' cysts, oocysts and ova were above unit, they occurred on slabs/counters in the banking halls and bulk rooms, bank notes as well as on the cash loaders and cash receivers of counting machines. This again has further brought the positions of slabs/counters, counting machines and currency notes to the fore as the major facilities in banks that harbour most of the resistant stages of parasites. Enemuor *et al.* (2012) also isolated most bacteria and fungi species from counting machines and currency in banks in Kogi State, Nigeria. Intensities of contamination of bank facilities with resistant stages of most of the parasites, be it protozoans or helminths, did not differ significantly amongst the towns. However, certain parasites showed outright differences as well as non existence in some towns. These location specific differences could be a reflection of disimilarities in sources of the contaminants amongst residents of the various towns that used bank facilities.

CHAPTER SIX

6.0 CONCLUSIONS AND RECOMMENDATIONS

6.1 Conclusions

- Cysts, oocysts and ova of all the parasitic protozoans and helminths occurred on and were isolated from Automated teller machines, slabs/counters, door handles, counting machines, currency notes and computer keyboards. Slabs/counters, counting machines, door handles and currency notes being the most important facilities with high contamination rates.

- Cysts, oocysts and ova of eight parasitic protozoans and eight parasitic helminths (trematodes, cestodes and nematodes) of medical, veterinary and zoonotic importance were isolated from bank facilities in three towns within Benue State, Northcentral Nigeria. The protozoan, *Entamoeba histolytica*, *Cryptosporidium* sp. *Ascaris lumbricoides* and *Entamoeba coli* were the most dorminant parasites encountered in this study.

- Intensities of cysts, oocysts and ova of the parasites are generally low, did not differ significantly ($P < 0.05$) amongst the banks and amongst the towns where the banks are located.

6.2 Recommendations

- Improved sanitary measures should be put in place in banks to reduce and or eliminate the occurrence of resistant stages of parasitic organisms on their facilities. Persons entering and leaving the bank should wash their hands. Other control measures such as internal control policy for routine disinfection and the choice of disinfectants as well as treating contaminated facilities by installing secondary disinfection systems (ultraviolet lamps or ozone disinfection systems) is important.

- Given the potential of transmission of enteric parasites amongst human subjects in banks, extra personal hygienic measures should be adopted by bank users.

- Further studies should be conducted on bank workers to determine their enteric parasitic profile as a way to determining occupational hazards in bank environments.

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