INDOOR AIR QUALITY AND RISK OF RESPIRATORY INFECTIONS AMONG UNDER-FIVE CHILDREN PRESENTING IN TWO HOSPITALS IN IBADAN, NIGERIA

BY

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CERTIFICATION

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DEDICATION

This research work is dedicated to the Alpha and Omega, the beginning and the end in whose hand is the power and strength to do all things. I also want to dedicate this research work to Pastor and Mrs. G. A. Fakunle for their endless love and sacrifice for me. May the Almighty God grant you long life to reap the fruit of your labour. Amen.

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ABSTRACT

Acute Respiratory Infection (ARI) is a major cause of morbidity and mortality among under-five children in developing countries. In Nigeria, studies on indoor air quality, particularly, the microflora that are associated with respiratory infections are scanty. This study was therefore designed to determine risk factors in the indoor environment that could predispose under-five children in Ibadan to respiratory infections.

A prospective hospital-based case-control study of 220 under-five children each with ARIs (cases) and without ARIs (controls) presenting consecutively in two major hospitals in Ibadan; Oni-memorial Children Hospital and University College Hospital, was carried out. Cases and controls were recruited from January to April, 2010 and matched for age, sex and parent's education. A community-based follow-up of cases and controls was carried out using a checklist to assess indoor housing indicators such as ventilation, temperature and relative humidity. Interviewer-administered four hundred and forty questionnaires were used to elicit information from mothers of under-five children among cases and controls on risk factors for ARIs. Temperature and Relative Humidity (RH) of the livingroom, bedroom and Kitchen were measured between 8-11am using multi-tester N21FR. Airborne microbial samples were collected using non-volumetric method. The total bacterial and fungal counts per cubic metre were determined and compared with the American Industrial Hygiene Association (AIHA) guideline for residential buildings. Data were analysed using descriptive statistics, Chi-square, t-test and logistic regression at p=0.05.

Mean ages of cases and controls were 20.4 ± 2.5 and 20.9 ± 2.4 months respectively. Mean number of occupants per room among cases was 3.0 ± 1.1 compared to 2.0 ± 0.7 among controls ($p<0.05$). Forty percent of houses among cases had a minimum of two windows per room compared to 60% among controls (OR=3.3, CI:1.4-10.0). Mean indoor temperature and RH was significantly higher among cases (33.7 ± 1.6ºC and 66.3 ± 5.6%) than controls (31.6 ± 1.8ºC and 61.9 ± 6.3%). *Streptococcus spp.* (33.0%, 12.0%), *Staphylococcus spp.* (35.0%, 22.0%) *and Aspergillus spp.* (28.0%, 29.0%) were isolated from the indoor air environment among cases and controls respectively. Indoor total bacterial count among cases ($9.6x10^2cfu/m^3$) was higher than among controls ($3.5x10^2cfu/m^3$) and the AIHA guideline ($\leq 5.0x10^2cfu/m^3$) ($p<0.05$). Indoor fungal count was similar among cases and controls ($0.2x10^2cfu/m^3$). The livingroom recorded the highest bacterial count of $5.4x10^2cfu/m^3$ and $1.4x10^2cfu/m^3$ for cases and controls

respectively ($p<0.05$). Under-five children sleeping in same room with more than two adults were found to be twice more likely to develop respiratory infections than those who slept with less than two adults (OR=2.7, CI:1.7-3.6). The use of mosquito coil (OR=1.6, CI:1.0-2.3), lantern (OR=4.1, CI:2.4-6.9) and firewood for cooking (OR=9.3, CI:3.6-24.1) were found to be risk factors for ARIs.

Environmental risk factors were higher among cases than controls. These may have contributed to an increased vulnerability to respiratory infections among cases. Health education on adequate ventilation, personal hygiene and good housing conditions are therefore advocated to minimise the risk of respiratory infections associated with poor indoor air quality.

Keywords: Acute respiratory infections, Under-five children, Indoor air quality, Microbial load

Word Count: 485

TABLE OF CONTENT

CHAPTER FOUR

LIST OF TABLES

LIST OF FIGURES

LIST OF PLATES

GLOSSARY OF TECHNICAL TERMS AND ABBREVIATIONS

AFP	Academy of Family Physician
ARI	Acute Respiratory Infection
AIHA	American Industrial Hygiene Association
ACGIH	American Conference of Governmental Industrial Hygienist
CDCP	Centre for Disease Control and Prevention
CMHC	Canada Mortgage and Housing Corporation
CVD	Cerebrovascular Disease
COPD	Chronic Obstructive Pulmonary Disease
DALYs	Disability Adjusted Life Year
ECRHS	European Community Respiratory Health Survey
ETS	Environmental Tobacco Smoke
GPS	Geographical Positioning System
HVAC	Heating, Ventilation and Air Conditioning
HDM	House Dust Mites
IIPS	International Institute of Population Sciences
IOM	Institute of Medicine
ICCARI	International Consultation on the Control of Acute Respiratory Infections
IHD	Ischemic Heart Disease
LRTI	Lower Respiratory Tract Infections
MDG	Millennium Development Goal
NAAQS	National Ambient Air Quality Standard
NFHS	National Family Health Survey
NIOSH	National Institute for Occupational Safety and Health

NHMRC	National Health and Medical Research Council
OMCH	Oni-Memorial Children Hospital
PM	Particulate Matter
SFU	Solid Fuel Use
SPSS	Statistical Package For Social Science
USEPA	United States Environmental Protection Agency
UCH	University College Hospital
URTI	Upper Respiratory Tract Infection
VOC	Volatile Organic Compounds
VPD	Vaccine Preventable Diseases
WHO	World Health Organization

CHAPTER ONE

INTRODUCTION

1.1 BACKGROUND INFORMATION

Acute respiratory infections are responsible for 8.2% of the world's total burden of disability and premature mortality and are the leading cause of childhood morbidity (WHO, 2002). They account for 19% of all deaths in children under the age of five. Each year, pneumonia alone kills 3 million children, while other acute respiratory infections cause another 1 million children to die (WHO, 2002).

The common acute infections of the upper and lower respiratory tract range from a simple cold or cough, otitis media, sore throat, laryngitis to bronchitis, bronchiolitis, and pneumonia. Diphtheria, measles, and pertussis (whooping cough) are also inclusive. On the average, children under the age of five experience between five and eight ARI episodes a year, which translates into at least 2,000 million episodes each year in the developing world (WHO, 1999). The majority of ARI episodes are mild and self-limiting, as in the case of coughs and colds. However, about one in every 30 to 50 episodes of cough will develop into pneumonia. Without treatment, 10% to 20% of pneumonia cases will result in death (WHO, 1999). ARI have received far less attention in humanitarian relief policies and programmes, despite being the largest baseline contributor to disability-adjusted life-years (DALYs) lost and the leading single cause of mortality among children under-five worldwide (Mizgerd, 2006).

ARI cause a greater burden of disease worldwide than human immunodeficiency virus infection, malaria, cancer, or heart attacks. In the United States, they cause more disease and death than any other infection in children, and there has been little change in mortality due to respiratory tract infection for more than five decade (Mizgerd, 2006). The outcome of an acute lower respiratory infection depends on the virulence of the organism and the

inflammatory response in the lung. When small numbers of low-virulence microbes are deposited in the lungs, an effective defense can be mounted by resident innate immune defenses, such as the mucociliary escalator, antimicrobial proteins in airway surface liquid and alveolar macrophages. In contrast, numerous or more virulent microbes elicit an inflammatory response. Although this response serves to reinforce innate immunity and is essential to rid the lungs of microbes, it contributes directly to lung injury and abnormal pulmonary function. The presence of high concentration of aerosols which include particulate matter, gases, and airborne microorganisms within the indoor environment is of increasing concern with respect to acute respiratory infections and other infectious diseases.

National Health and Medical Research Council (NHMRC) defined indoor air as 'air within a building occupied for a period of at least one hour by people of varying states of health' (NHMRC, 1996). Buildings covered by this definition were homes, schools, restaurants, public buildings, residential institutions and offices, but not premises (e.g. workplaces) or parts of premises otherwise covered by occupational health standards. Modern populations typically spend 80–90% of their time indoors, whether at home, work or elsewhere (U.S EPA, 2001). Coupled with the common research finding that pollutants in indoor air occur more frequently and at higher concentrations than in outdoor air, it is clear that indoor air is a major source for environmental exposure to air pollutants.

The quality of indoor air in homes may be influenced by many biological, chemical and physical agents, e.g. viruses, bacteria, mites, actinomycetes, fungal spores, arthropod fragments and droppings, animal and human dander, tobacco smoke, chemicals (Samet *et al*., 1996), temperature, humidity and poor ventilation (Pekkanen *et al*., 2007). The impact of the quality of indoor air on the health and well-being of people that use or work in artificially climatized buildings has been the theme of research in the Public Health area since 1970 (WHO, 2000). Modern, artificially climatized buildings, planned to offer the maximum comfort to their occupants, and often with bold architectural projects, may be creating an environment that is a threat to human health. Various studies have attributed the poor quality of indoor air to the high incidence of complaint relating to health and environmental discomfort received from the occupants of these places, as well as to the

high level of absenteeism, mood changes, dissatisfaction and poor work performance (Gioda and Neto, 2002).

Bioaerosols represent, roughly, all biologically originated aerosols and can be found both indoors and outdoors. The most studied bioaerosols are the airborne bacteria and fungi. Health impacts of certain fungi species, such as *Penicillium spp*., *Aspergillus spp*., *Mucor spp*., and *Rhizopus spp*., are commonly related with allergy, infection, irritation, and toxicity (Stetzenbach *et al*., 2004). Among these fungi, species of *Aspergillus*, *Cladosporium* and *Penicillium* were shown to be the most frequently found genera associated with allergy and exist in both indoor and outdoor environments (Sibel, 2009). Since most of the fungi species occur in the presence of special substrates, they are often found indoors rather than outdoors or vice versa (Godish, 1996). Humidity, human presence, type of activities, and air circulation affect the levels and species of bacteria (Kalogerakis *et al*., 2005). In conventional indoor environments, human presence is the most important source of airborne bacteria.

1.2 Problem Statement

Acute Respiratory Infections (ARIs) are one of the leading causes of childhood morbidity and mortality in developing countries. The World Health Organization (WHO) estimates that approximately three million children under-five died from ARI in 1993, exclusive of measles, pertussis, and diphtheria, and another 1.1 million died from conditions in association with these diseases. It is now a widely recognized fact that about 15 million premature deaths occur each year in developing countries among children under five years of age (WHO, 2002). Nearly one-third of these deaths are caused by acute respiratory infection (ARI), an illness that is both preventable and treatable (WHO, 2002).

Acute respiratory infections are responsible for 8.2% of the world's total burden of disability and premature mortality and are the leading cause of childhood morbidity (WHO, 2005). They account for 19% of all deaths in children under the age of five. Each year pneumonia alone kills 3 million children, while other acute respiratory infections cause another 1 million children to die (WHO, 2002). Yet even with such a high prevalence, ARI receives only 0.15% of the research and development budget for health

globally (WHO, 2002). ARI have received far less attention in humanitarian relief policies and programmes, despite being the largest baseline contributor to disability-adjusted life-years (DALYs) lost and the leading single cause of mortality among children under 5year worldwide (Mizgard, 2006).

Majority of ARI cases occur in India (43 million), China (21 million), Pakistan (10 million), Bangladesh, Indonesia and Nigeria (56 million) (WHO, 2005). Around 90% of ARI deaths in Nigeria are generally due to pneumonia (World Bank, 1993). It was estimated that in 2000-2003, pneumonia accounted for 19% of the 10.6 million yearly global deaths in children under-five (Jennifer *et al*., 2005). The World Bank (1993) highlights that Nigeria lost 41 healthy years of life per 1,000 due to ARI. About 1 million Nigerian children under five years old die each year (NAS, 2009). One-fourth of these children die in their first month of life. The record for males is 100.87 deaths per 1,000 live births while females is 86.79 deaths per 1,000 live births (World Bank, 1993).

Almost all West African countries have achieved a lower under-five mortality rates including Benin (150 per 1000), Togo (139 per 1000), Cameroon (149 per 1000) and Ghana (112 per 1000) but a reverse is the case for Nigeria where the rate of hospitalization and under-five mortality is on the increase (194 per 1000) (NAS, 2009).

Poor indoor air quality has been found to be responsible for more than 900 000 of the 2 million annual deaths from pneumonia (WHO, 2005). World Health Organization has estimated that around three quarters of the total global burden of exposure to particulate air pollution is experienced indoors in developing countries (WHO, 1997) and young children particularly children under-five are at high risk of exposure, because they are usually with their mothers in the kitchen. About 56% of all indoor air pollution-attributable deaths occur in children under five years of age.

Most rural areas in Nigeria depend on woodfuel which is a major source of indoor air pollution (Energy Commission of Nigeria, 1998). About 95% of the total woodfuel consumption is been used in households for cooking (Energy Commission of Nigeria, 1998). Exposure to smoke from traditional cookstoves and open fires has been identified as the fifth worst health risk factor in poor countries such as Nigeria and leads to nearly 2

million premature deaths of mostly women and young children under-five each year (more than twice the mortality from malaria) (WHO, 1994).

1.3 Rationale for the Study

The fourth Millennium Development Goal (MDG-4) aims to "reduce by two-thirds, between 1990 and 2015, the under-five mortality rate". In this respect, considering the current rate of under-five mortality in Nigeria and with three years left to the 2015 deadline for the achievement of this goal, it was estimated that, it will take Nigeria an additional 70 years to meet the MDG-4. There is therefore a need to investigate and collect vital information as regards risk factors that could contribute to ARIs – a major cause of under-five mortality in Nigeria. This is expected to provide measures of reduction in under-five mortality and invariably propel Nigeria to meets the MDG-4 before the 2015 deadline.

In addition, people particularly children under-five years of age spend most of their time indoors (Klepeis *et al*., 2001), stressing the need for studies on indoor air quality in this part of the world. Studies on how the quality of the indoor environment particularly, the microflora predisposes children under-five to respiratory infections have not been extensively carried out in Nigeria. There is therefore a need to generate baseline data on the extent to which the quality of the indoor environment predisposes children under-five to respiratory infections.

The study would provide information on knowledge of risk factors for respiratory infections in the indoor air environment and the perception of mothers to the different indoor practices, which would be systematically documented. Thus, information gathered in this research would create awareness amongst mothers on the risk factors in the indoor environment that predispose under-five children in Ibadan to respiratory infections.

1.4 Research Questions

1. What are the housing characteristics that contribute to the acquisition of ARIs among under-five children in Ibadan?
2. What are the indoor environmental factors that predisposes children under-five to ARI?

3. What are the indoor meteorological conditions of selected houses in the study area?
4. What is the level and characteristics of airborne bacteria and fungi in different indoor environments (living room, bedroom and bathroom) in the study area?
5. What is the relationship between indoor environmental factors and the microbial load?
6. What is the respondent level of knowledge and toward the risk associated with ARIs among children under-five?
7. How could an ARI Risk map be developed in the study area?

1.5 Hypothesis of the study

In confirming the impact of the different indoor environmental risk factors on the acquisition of Acute Respiratory Infections among children under-five, the hypothesis to be tested and analyzed using the data collected is that:

- There is no significant relationship between residential housing characteristics and acquisition of ARIs among children under-five.
- There is no significant relationship between indoor environmental factors and acquisition of ARIs among children under-five.
- There is no significant relationship between environmental conditions and level of bacteria and fungi in the indoor air..

1.6 Objective of the Study

1.6.1 Broad Objective

The main objective of this study is to determine the indoor environmental risk factors for acute respiratory infections among children under-five years of age in Ibadan.

1.6.2 Specific Objectives

The specific objectives of this study were to:

1) describe the housing characteristics that contribute to the acquisition of ARI among under five children in Ibadan
2) determine the indoor environmental factors that predisposes children under-five to ARIs
3) determine the residential indoor meteorological conditions of selected houses in the study area
4) assess the level and characteristics of airborne bacteria and fungi in different indoor environments (livingroom, bedroom and bathroom) in the study area
5) determine the relationship between indoor meteorological conditions and microbial load
6) assess the respondent level of knowledge and attitude towards the risk factors associated with ARIs among children under-five
7) Develop an ARI Risk map for the study area

1.7 Limitation of the study

Most respondents were reluctant to grant access into their houses for indoor meteorological and airborne microbial evaluation.

CHAPTER TWO

LITERATURE REVIEW

2.1 INTRODUCTION

Acute respiratory infections (ARIs) continue to be the leading cause of acute illnesses worldwide and remain the most important cause of infant and young children mortality, accounting for about two million deaths each year (Mizgerd, 2006) and ranking first among causes of disability-adjusted life-years (DALYs) lost in developing countries (94.6 millions, 6.3% of total) (Williams *et al*., 2002). The populations most at risk for developing a fatal respiratory disease are the very young, the elderly and the immunocompromised.

While upper respiratory infections (URIs) are very frequent but seldom life-threatening, lower respiratory infections (LRIs) are responsible for more severe illnesses such as influenza, pneumonia, tuberculosis, and bronchiolitis that are the leading contributors to ARIs' mortality (Scott *et al*., 2008). Pneumonia, with a global burden of 5 000 childhood deaths every day, is a tangible threat that needs to be dealt with accordingly.

The incidence of ARIs in children aged less than 5 years is estimated to be 0.29 and 0.05 episodes per child-year in developing and industrialized countries, respectively, which translates into 151 million and 5 million new episodes each year, respectively (Rudan *et al*., 2008). Most cases occur in India (43 million), China (21 million), Pakistan (10 million), Bangladesh, Indonesia and Nigeria (56 million each). Pneumonia is responsible for about 21% of all deaths in children aged less than 5 years, leading to estimate that of every 1000 children born alive, 12-20 die from pneumonia before their fifth birthday (Williams *et al*., 2002).

The main etiological agents responsible for ARIs in children include *Streptococcus pneumoniae, Haemophilus influenzae* type b *(Hib), Staphylococcus aureus* and other

bacterial species, respiratory syncytial virus (RSV), measles virus, human parainfluenza viruses type 1, 2, and 3 (PIV-1, PIV-2 and PIV-3), influenza virus and varicella virus.

However, the proportion of mild to severe disease varies between high- and low income countries, and because of differences in specific etiologies and risk factors, the severity of LRIs in children under-five is worse in developing countries, resulting in a higher case fatality rate. Although medical care can to some extent mitigate both severity and fatality, many severe LRIs do not respond to therapy, largely because of the lack of highly effective antiviral drugs. Some 10.8 million children die each year (Black *et al*., 2003). Estimates indicate that in 2000, 1.9 million of them died because of ARIs, 70 percent of them in Africa and Southeast Asia (Williams *et al*., 2002). The World Health Organization (WHO) estimates that 2 million children under five die of pneumonia each year (Bryce *et al*., 2005).

Respiratory diseases offer a particularly difficult public health challenge. With food- and water-borne diseases, people can protect themselves by cooking foods properly or boiling water. With sexually transmitted diseases, people can reduce their risk by minimizing the number of sexual partners or using condoms. But with respiratory tract infections, where a person's main risk factor is breathing, it is not so easy to control exposure. Also there is considerable variation in how contagious different respiratory diseases are.

2.2 Epidemiology of ARIs

In 19th century Europe acute respiratory infections (ARIs) was the most important cause of childhood death. Sir William Osler wrote 'the most widespread and fatal of all acute diseases, pneumonia, is now Captain of the Men of Death' (Steven and Schmitt, 1999). Figure 2.1 shows the global distribution of acute respiratory infections. As childhood mortality levels fell in Europe so the proportion of all deaths due to ARI fell. When life expectancy was below 45 years about 25% of childhood deaths were due to ARI compared with only 4% when life expectancy was higher than 70 years (UNICEF, 2006). The fall in ARI mortality accelerated noticeably in the 1950s when antibiotics became widely available.

In 1991 there were 53 developing countries reporting mortality in children under 5 years of age of more than 100/1000 live births. Out of an estimated total of 12.9 million deaths globally in 1990 among children under 5 years of age, over 3.6 million have been attributed to ARI. This represented 28% of all deaths in young children and placed ARI as the largest single cause of childhood mortality (Archives of Disease in Childhood, 1995). Within these overall estimate respiratory complications of measles accounted for 475,000 deaths and respiratory complication of pertussis for 205,000 deaths. The remaining 2,915,000 deaths are considered to be associated mainly with pneumonia. Although these estimates are based on broad evaluations, a study of available national registration data and of 22 longitudinal communities based studies have confirmed ARI as the leading cause of childhood mortality in developing countries (Archives of Disease in Childhood, 1995).

Pneumonia is the leading cause of death among respiratory ailments in Africa and nearly 75% of these deaths occur in infants under 1 year of age (USAID, 2006). The devastating impact of pneumonia is apparent not only due to its high mortality, but its considerable rate of morbidity. The health research approach shows that every ARI death contributes to 2-3 further deaths. Pneumonia, for example, considerably worsens the morbidity associated with other diseases such as malnutrition, Vitamin A deficiency, measles, and HIV infections in children. Such co-morbidity has a synergistic effect on mortality. For example, the estimated case fatality rate of children who suffer from ARI and measles is approximately 62%. Additionally, in HIV infected children, pneumonia represents the most common deadly initial manifestation of the disease (USAID, 2006)

A longitudinal community-based study carried out on the epidemiology of acute respiratory tract infections among children under-five years of age in Idikan community, Ibadan, Nigeria, showed that the annual incidence of ARI range from 6.1 to 8.1 episode per child per year (Oyejide and Osinusi, 1990). The incidence was highest in the first 2 years of life and decrease with increasing age. The incidence was higher in boys than in girls and occurred throughout the season.

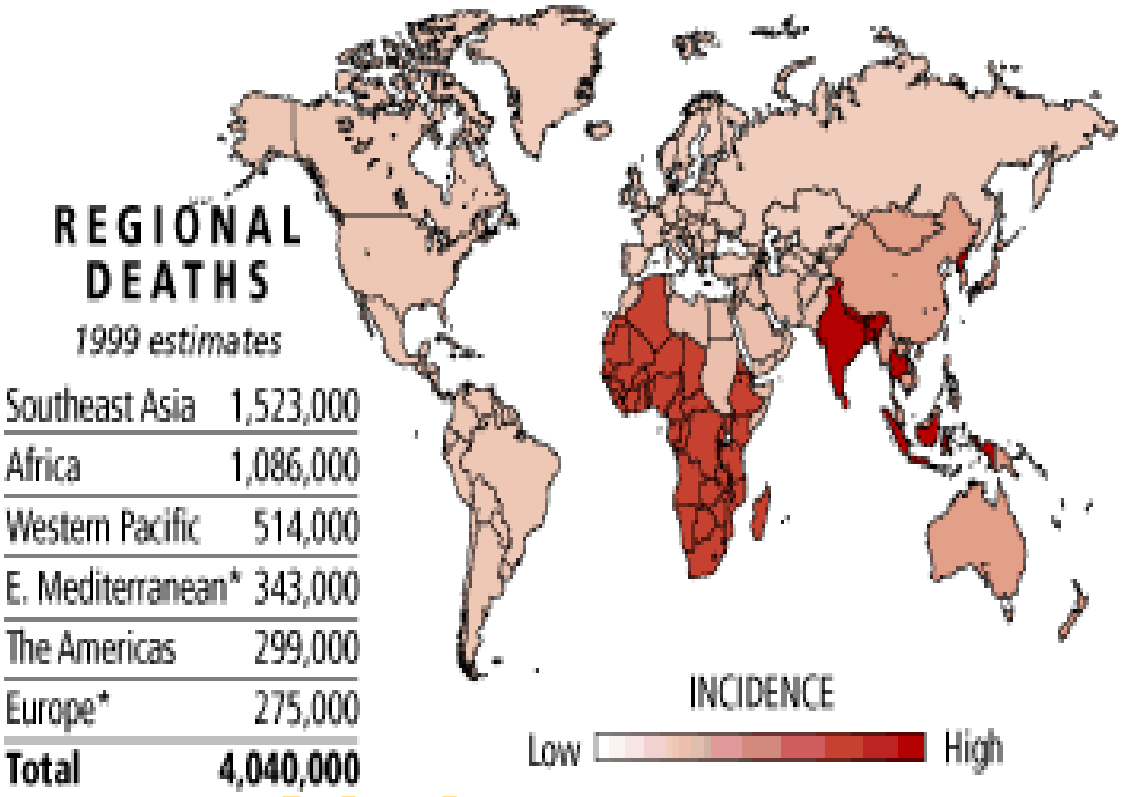


Figure 2.1: Global distribution of Acute Respiratory Infections (Including pneumonia and influenza)

Source: UNICEF/WHO, 2006. Pneumonia: The Forgotten Killer of Children.

2.3 Aetiology/classification of ARIs

Acute respiratory infections (ARIs) are classified as upper respiratory tract infections (URIs) or lower respiratory tract infections (LRIs) (WHO, 1993). The upper respiratory tract consists of the airways from the nostrils to the vocal cords in the larynx, including the paranasal sinuses and the middle ear. The lower respiratory tract covers the continuation of the airways from the trachea and bronchi to the bronchioles and the alveoli. ARIs are not confined to the respiratory tract and have systemic effects because of possible extension of infection or microbial toxins, inflammation, and reduced lung function.

2.3.1 Upper Respiratory Tract Infections (URTIs)

In terms of research and case management under field conditions in less developed countries, the WHO 1993, defines URI to include any combination of the following symptoms: cough with or without fever, blocked or runny nose, sore throat, and/or ear discharge. URIs are the most common infectious diseases. They include rhinitis (common cold), sinusitis, ear infections, acute pharyngitis or tonsillopharyngitis, epiglottitis, and laryngitis—of which ear infections and pharyngitis causes the more severe complications (deafness and acute rheumatic fever, respectively). The vast majority of URIs have a viral etiology. Rhinoviruses account for 25 to 30 percent of URIs; respiratory syncytial viruses (RSVs), parainfluenza and influenza viruses, human metapneumovirus, and adenoviruses for 25 to 35 percent; corona viruses for 10 percent; and unidentified viruses for the remainder (Denny, 1995). Because most URIs is self-limiting, their complications are more important than the infections. Acute viral infections predispose children to bacterial infections of the sinuses and middle ear (Berman, 1995), and aspiration of infected secretions and cells can result in LRIs.

2.3.1.1 Acute Pharyngitis

Acute pharyngitis is caused by viruses in more than 70 percent of cases in young children. Mild pharyngeal redness and swelling and tonsil enlargement are typical. Streptococcal infection is rare in children under five and more common in older children. In countries with crowded living conditions and populations that may have a genetic predisposition, post streptococcal sequelae such as acute rheumatic fever and carditis are common in

school-age children but may also occur in those under five. Acute pharyngitis in conjunction with the development of a membrane on the throat is nearly always caused by *Corynebacterium diphtheriae* in developing countries. However, with the almost universal vaccination of infants with the DTP (diphtheria-tetanus-pertussis) vaccine, diphtheria is rare (Bisgard *et al*., 1998)

2.3.1.2 Acute Ear Infection

Acute ear infection occurs with up to 30 percent of URIs. In developing countries with inadequate medical care, it may lead to perforated eardrums and chronic ear discharge in later childhood and ultimately to hearing impairment or deafness (Berman, 1995). Chronic ear infection following repeated episodes of acute ear infection is common in developing countries, affecting 2 to 6 percent of school-age children. The associated hearing loss may be disabling and may affect learning. Repeated ear infections may lead to mastoiditis, which in turn may spread infection to the meninges. Mastoiditis and other complications of URIs account for nearly 5 percent of all ARI deaths worldwide (Williams *et al*., 2002).

2.3.2 Lower Respiratory Tract Infections (LRTIs)

The common LRIs in children are pneumonia and bronchiolitis. The respiratory rate is a valuable clinical sign for diagnosing acute LRI in children who are coughing and breathing rapidly. The presence of lower chest wall indrawing identifies more severe disease (Mulholland *et al*., 1992).

2.3.2.1 Pneumonia

Both bacteria and viruses can cause pneumonia. Bacterial pneumonia is often caused by *Streptococcus pneumoniae* (pneumococcus) or *Haemophilus influenzae*, mostly type b (Hib), and occasionally by *Staphylococcus aureus* or other streptococci. About 8 to 12 of the many types of pneumococcus are responsible for most cases of bacterial pneumonia, although the specific types may vary between adults and children and between geographic locations. Other pathogens, such as *Mycoplasma pneumoniae* and *Chlamydia pneumoniae*, cause atypical pneumonias. Their role as a cause of severe disease in children under five in developing countries is unclear (Cutts *et al*., 2005).

Vuori-Holopainen and Peltola's (2001) review of several studies indicated that *S. pneumoniae* and Hib account for 13 to 34% and 1.4 to 42.0% of bacterial pneumonia, respectively. Entry of bacteria from the gut which eventually spread through the bloodstream to the lungs has also been proposed for the pathogenesis of Gram-negative organisms (Fiddian-Green and Baker, 1991), but such bacteria are uncommon etiological agents of pneumonia in immune-competent children. However, in neonates and young infants, Gram-negative pneumonia is not uncommon.

In developing countries, the case-fatality rate in children with viral pneumonia ranges from 1.0 to 7.3 percent (John *et al*., 1991), with bacterial pneumonia from 10 to 14 percent and with mixed viral and bacterial infections from 16 to 18 percent (Ghafoor *et al.,* 1990).

2.3.2.2 Bronchiolitis

Bronchiolitis occurs predominantly in the first year of life and with decreasing frequency in the second and third years. The clinical features are rapid breathing and lower chest wall indrawing, fever in one-third of cases, and wheezing (Cherian *et al*., 1990). Inflammatory obstruction of the small airway, which leads to hyperinflation of the lungs and collapse of segments of the lung also take place. As a result of the signs and symptoms which are also characteristic of pneumonia, health workers may find it difficult to differentiate between bronchiolitis and pneumonia. Two features that may help are a definition of the seasonality of Respiratory Syncytial Viruses (RSV) in the locality and the skill to detect wheezing. RSVs are the main cause of bronchiolitis worldwide and can cause up to 70 or 80% of LRIs during high seasons (Simoes, 1999). The recently discovered human metapneumovirus also causes bronchiolitis (Van den Hoogen *et al*., 2001) that is indistinguishable from RSV disease. Other viruses that cause bronchiolitis include parainfluenza virus type 3 and influenza viruses.

2.3.2.3 Influenza

Even though influenza viruses usually cause URIs in adults, they are increasingly being recognized as an important cause of LRIs in children and perhaps the second most important cause after RSVs of hospitalization of children with an ARI (Neuzil *et al*., 2002). Although influenza is considered infrequent in developing countries, its

epidemiology remains to be investigated thoroughly. The potential burden of influenza as a cause of death in children is unknown. Influenza virus type A may cause seasonal outbreaks, and type B may cause sporadic infection. Recently, avian influenza virus has caused infection, disease, and death in small numbers of individuals, including children, in a few Asian countries. Its potential for emergence in human outbreaks or a pandemic is unknown, but it could have devastating consequences in developing countries (Peiris *et al*., 2004) and could pose a threat to health worldwide.

2.4 Symptoms of ARIs

Under–five children are predisposed to ARI through some of the following symptoms such as fever, catarrh, cough, dyspnoea and difficulty in breathing. The most prevalent symptoms is fever, followed by dypsonea, cough, difficulty in breathing and catarrh (Lawoyin, 2000). ARIs include a wide range of upper and lower respiratory tract infections, which commonly present with symptoms of cough, fever and rapid breathing. ARI constitute the fourth main cause of under-five/infant morbidity and the third main cause of infant mortality. A similar study by Kazi (2008) shows that the prevalence of ARIs is relatively low for children under 6 months, peaks at 12 -23 months and falls at 24 -35 months.

2.5 Hospital visits and Admittance in Relation to ARIs

Acute respiratory infections are a major cause of hospital admission and death in Nigerian children. Between the years 2000 and 2003 it was estimated that pneumonia accounted for 20% of deaths in children under the age of 5 years in Nigeria (WHO, 2005). A study in Greenland by Koch et al., (2000) shows that 32 percent of the episodes of lower respiratory tract infections and 56 percent of the episodes of upper respiratory tract infections resulted in hospital visits, being of the same magnitude as those in the United States (Fox et al., 1998). Only 1 percent of the episodes of upper and lower respiratory tract infections resulted in hospital admittance, while in the remaining 39 percent of episodes the children were treated at the outpatient clinic. This showed that parents were sufficiently aware of the physical signs of lower respiratory tract infections in particular to seek medical attention when necessary. There is a seasonal variation in acute respiratory

infections in Nigerian children with more episodes occurring during the rainy season (Fagbule *et al*., 1994).

2.6 Prevalence of ARIs in Nigeria

A community-based prospective surveillance and case management study of acute respiratory infections (ARIs) among children aged 2–60 months of age was carried out over a 12-month period in Pakata, a semi-urban community in Ilorin, Kwara State, Nigeria. A cohort of 481 children was followed by trained community health assistants with thrice weekly home visits to record all symptoms and signs of ARIs, and institute treatment based on WHO recommendations (Fagbule *et al*., 1994). There were three episodes of mild, moderate, or severe ARI per child per year, including 1.3 pneumonia episodes per child per year. The peak of infection corresponded to the rainy season (July - November) and a smaller peak to the dry season (February-April). Most of the health worker decisions were considered appropriate, although there was a tendency toward over-treatment with antibiotic drugs. An effective referral system was established from the community to a tertiary centre. There were no ARI-related deaths during the study period. These data indicate that a system of case management using trained community health workers can improve case management of ARI and may prevent severe ARI-related disease and deaths.

In another hospital-based study in Ibadan, 28.4% of children admitted to the hospital with acute lower respiratory tract infection had acute bronchiolitis with respiratory syncithial virus being the most common viral aetiologic agent (Fagbule *et al*., 1994). There are scanty data on the bacterial aetiology of pneumonia in Nigerian children. According to WHO, 2001, about 20% of all deaths in children under 5 years are due to Acute Lower Respiratory Infections (ALRIs - pneumonia, bronchiolitis and bronchitis); 90% of these deaths are due to pneumonia. Early recognition and prompt treatment of pneumonia is life saving. Causative organisms may be bacterial (most commonly *Streptococcus pneumoniae* and *Haemophilus influenzae*) or viral. However, it is not possible to differentiate between bacterial and viral ARIs based on clinical signs or radiology.

2.7 Risk factors associated with ARIs

2.7.1 Risk Factors Associated with ARIs in Developed Countries

In the industrialized countries known risk factors for children are for instance young age (Benediktsdottis 1993), environmental tobacco smoke (Koch et al., 2003; Hajnal *et al*., 1999), home-dampness (Rylander and Megevand 2000; Karevold *et al*., 2006), and attending day-care centres (Forssell *et al*., 2006; Nafstad *et al*., 1999). Risk factors noted in relation with specific respiratory diseases, like asthma, Chronic Obstructive Pulmonary Diseases (COPD) and tuberculosis, are active smoking, low socio-economic status, occupational exposure and exposure to air pollution (Coker *et al*., 2006); Hedlund *et al*., 2006 and Schikowski *et al*., 2005).

2.7.2 Risk Factors Associated with ARIs in Developing Countries

A multitude of studies have identified various risk factors for ARI. Studies in developing countries have identified risk factors to include overcrowding, poor housing, poor sanitation, nutritional factors, indoor air pollution and parental smoking. This has been reported in studies carried out by Azizi *et al*., (1995); Cambell *et al*., (1989) and Milligan *et al*., (1999). Because of major differences in living conditions and environmental circumstances these study outcomes cannot directly be extrapolated to developed countries.

2.8 Specific Risk Factors for ARIs

2.8.1 Socio-demographic Characteristics

Among the socio-demographic factors such as age of the mother, age of the father, educational status etc, both maternal and paternal illiteracy and low socioeconomic status (SES) were significantly associated with ARI in children under-five (Savitha *et al*., 2007). A similar study carried out by Cunha *et al*., 2002 even after adjusting for other risk factors such as nutritional status and overcrowding showed a significant association.

2.8.1.1 Age

According to Koch *et al*, 2003, age was identified as a strong risk factor for both upper and lower respiratory tract infections, with the highest risk found among children aged 6–11 months. The age between 6 and 18 months has indeed been termed the period of

vulnerability (Turner *et al*, 1991). Possible mechanisms for this increased risk include degradation of maternal antibodies, immaturity of the adaptive immune system, cessation of breastfeeding, and attending child-care centers. The finding of the inverse relative risk of upper and lower respiratory tract infections for children aged 0–5 months in the multivariate analyses has been observed previously (Turner *et al*., 1991). Thus, the risk of transmission of infectious agents may be smaller in the youngest age group, as seen by the lower risk of upper respiratory tract infections, but when infected, this youngest age group experiences severity that is worse in terms of a higher rate of lower respiratory tract infections. Benediktsdottis (1993) identified young children particularly those in the preschool category as a major vulnerable group to ARI.

2.8.1.2 Sex

The risk of lower respiratory tract infections was increased for boys compared with girls, but not for upper respiratory tract infections in studies carried out by Koch *et al*., 2003. A similar pattern has been observed in some other studies (Graham, 1990), although a reverse pattern may be seen in older children (Monto, 1994). Furthermore, a longitudinal study conducted over a 3-year period in a poor, urban community in Nigeria, found that acute respiratory tract infection (ARI) was common, in particular among infants and boys (Osinusi and Oyejide, 1994).

2.8.1.3 Parental Education

Low educational levels in mothers are associated with an increased risk of ALRI hospitalizations and mortality (Victoria *et al*., 1994); this association was reduced but still remained significant after adjustment for confounding variables. In a pneumonia case control study in Brazil, however, the father's education was more strongly correlated than the mother's when both variables were included in an explanatory model (Victoria *et al*., 1994). These findings suggest that although confounding factors may account for some of the crude data related to the mother's education, this variable has an independent role in the etiology of ALRI.

2.8.1.4 Place of Residence

ARI incidence rates vary markedly between urban children (five to nine episodes per child per year) and rural children (three to five episodes) [International Consultation on the Control of Acute Respiratory Infections (ICCARI), 1991], which may be due to increased transmission as a result of crowding.

2.8.2 Nutritional Risk Factors

2.8.2.1 Low Birth Weight (LBW)

While LBW is itself an important cause of childhood mortality, it is also associated with ALRI morbidity and mortality (Victoria *et al*., 1994; Graham, 1990). Victoria *et al*., (1994) reviewed 4 studies of ALRI mortality and LBW and found a pooled estimate of 2.9 times increased risk of death for children with birth weight <2500g. There is also consistently increased incidence of ALRI in LBW infants in almost all studies with relative risks between 1.4 and 3 times, depending on the severity of LBW (Fonseca *et al*., 1996; Victoria *et al*., 1994; Graham, 1990). LBW may be associated with increased risk of ARI due to its association with other measures of socio-economic deprivation as well as because it may lead to shorter duration of breastfeeding and poorer nutritional status, both of which are independent risk factors for ARI. Nevertheless, the associations between LBW and ARI morbidity and mortality are robust to adjustment for confounding, and there are other mechanisms by which LBW itself may predispose to ARI, namely reduced immune competence and impaired lung function (Victoria *et al*., 1994).

2.8.2.2 Breastfeeding

Breastfeeding benefits have been demonstrated in multiple studies to be dose-responsive or, in other words, related to the amount of breast milk received (Kramer and Kakuma 2002; Zaman *et al*., 1997 and Bertran *et al*., 2001). For example, fully breastfed infants have been shown to have lower overall illness rates, whereas minimal breastfeeding has not been found to be protective. Breastfeeding duration also affects child morbidity.

A recent comprehensive review of the world literature to determine health benefits of exclusive breastfeeding for 6 months compared with exclusive breastfeeding for 3 to 4

months noted a decrease in the risk of gastrointestinal infection even in developed settings (Kramer and Kakuma, 2002).

No study, however, has documented a decrease in the risk of respiratory infection with 6 compared with 4 months of exclusive breastfeeding**.** Currently, most national and international authorities, including the American Academy of Pediatrics (Gartner *et al*., 2005), World Health Organization (WHO, 2002), and United Nations Children's Fund (UNICEF, 2006), recommend 6 months of exclusive breastfeeding**.**

2.8.3 Environmental Risk Factors

2.8.3.1 Attending Child Care Center

Attending a child-care center was a strong risk factor for both upper and lower respiratory tract infections and the strongest one for lower respiratory tract infections, confirming findings from other parts of the world (Louhiala *et al*., 1995 and Nafstad *et al*., 1999). Studies from Finland and Norway have reported relative risks and odds ratios of 0.95–1.99 for upper respiratory tract infections and of 0.9–6.69 for lower respiratory tract infections among children aged 1–2 and 4–5 years in child-care centers (Louhiala *et al*., 1995 and Nafstad *et al*., 1999) and, among children aged 1.5–17 months from the United States, odds ratios of respiratory illness in general of 1.6 have been reported (Louhiala *et al*., 1995). Forssell *et al*., (2001), Rylander and Megevand (2000) and Nafstad *et al*., (1999) all implicated day care attendance as one potential source of vulnerability to ARIs by children attending day-care centers.

There is little doubt that child care attendance is associated with an increased incidence of URTI and LRTI (Louhiala *et al*., 1995) and probably reflects an increased exposure to microorganisms. For instance, Celedon *et al*., 2003 reported in a high-risk population (at least 1 parent was allergic) an OR of 1.6 (95% CI: 1.0–2.4) for LRTI at age 1 in children who attended some form of child care. In the same study, child care in large groups was associated with a much higher risk of developing a LRTI as compared with child care in small groups. In a study by Marbury *et al*., 1997 child care attendance was associated with the development of lower respiratory tract illness in the first year of life (OR: 2.0; 95% CI: 1.7–2.3).

2.8.3.2 Overcrowding

Many children are exposed to very crowded conditions at home, and this increases risk of transmission of illness. Most studies in developing countries have found that the average area of habitable space per person is well below the WHO recommendation of $12m^2$ (Cardoso *et al.,* 2004), and the situation in many areas of the Western Cape is no different. While nearly 20% of Blacks in the Western Cape live in households of 6 people or more, 70% of Black dwellings comprise 3 rooms or less (Statistics South Africa 2001; Watson 1994). In a case-control study in Sao Paulo, Cardoso *et al.,* (2004), found crowding (≥ 4 people sharing the child's bedroom) to be associated with 2.5 fold increased risk of ARIs, with cases tending to live in smaller houses than controls. Other studies from developing and developed countries have found similar effects both for crowding and number of siblings (Brims *et al.,* 2005; Ozcirpici *et al.,* 2004 and Graham 1990).

Previous studies have suggested that the risk of lower respiratory tract infection in Inuit and Alaska Native infants is associated with overcrowded housing conditions. Bernerji *et al.,* 2001 noted that infants admitted to Baffin Regional Hospital because of lower respiratory tract infection generally lived in very crowded housing, with a mean of 6.4 occupants, including 3.0 children per house. This was very similar to a study carried out by Smith *et al.,* 2000 on indoor air quality and risk of lower respiratory infections among young Canadian Inuit Children. He found out a mean occupancy of 6.1 occupants per dwelling among houses visited. Similarly, among Native children in Alaska, the risk of hospital admission because of respiratory syncytial virus infection was significantly associated with living with 7 or more additional people or with 4 or more children, even after controlling for socioeconomic status (Bulkow *et al.,* 2002).

2.8.3.3 Parental Smoking

More than 150 studies have been published linking Environmental Tobacco Smoking (ETS) to respiratory illness in children, with meta-analyses finding strong evidence for associations between both prenatal maternal smoking and postnatal ETS exposure and risk of ARI in children (DiFranza *et al.,* 2004). In a review of 38 studies, Strachan *et al.,* (1997) found all but one to be consistent with an increased risk of ARI for children exposed to parental smoking, with pooled Odds' ratio (ORs) of 1.57 (95% CI 1.42 to 1.74)

for smoking by either parent and 1.72 (95% CI 1.55 to 1.91) for maternal smoking. Risk of chest illness was also increase if household members other than the child's parents smoked (OR: 1.29, 95% CI 1.16 to 1.44). When limited to children under 5, the effect is even more marked with an OR of 2.5 (95% CI: 1.86-3.36) (Brims and Chauhan, 2005). These associations with parental smoking are maintained after adjustment for confounding factors, and there is evidence of a dose-response relationship (Brims and Chauhan, 2005).

Environmental tobacco smoke was another risk factor for lower respiratory tract infection in Inuit children. In a meta-analysis (Li *et al.*, 1999), environmental tobacco smoke significantly increased the risk of hospital admission because of lower respiratory tract infection during infancy and early childhood. Presence of smokers in the home was associated with a significantly increased risk of lower respiratory tract infection in Sisimiut, Greenland (Koch *et al.*, 2003) and in Alaska (Bulknow *et al.*, 2002). Jenkins and colleagues (Jenkins *et al.*, 2004) reported that 94% of Inuit infants in Iqaluit were exposed to environmental tobacco smoke in the home and much higher than the frequency of about 25% found in southern Canada (Canadian Institute for Health Information, 2001)

2.8.3.4 Household Biomass Fuel

The use of biomass fuels for cooking and heating with resultant indoor air pollution is common in many areas in South Africa, with the rapid growth of informal housing without proper infrastructure being an important cause (Sanyal and Maduna, 2000). Although only a small proportion of all Western Cape households use solid fuels for cooking and heating (3.5% and 7.5%) respectively, extent of solid fuel use (SFU) would be notably higher among those in certain areas likely to have other risk factors for ARI, such as poverty (Statistics South Africa, 2001). Studies in two townships in Gauteng indicated that the levels of particulate matter far exceeded standards laid down by the WHO (Terblanche *et al.*, 1992). A study in Indian on risk factors for acute lower respiratory infections in under-five children reported that 93.2% of children with Acute Lower Respiratory infections (ALRI) use biomass fuel such as firewood for cooking and 14.4% does the cooking in the living room (Broor *et al.*, 2001).

Biomass fuels produce small amounts of energy but large amounts of indoor pollutants, often emitting 50 times more pollutant concentrations than energy equivalent natural gas

(Graham, 1990). Housing characteristics in developing countries with poor ventilation and dispersion may exacerbate pollutant concentrations (Brims and Chauhan, 2005). A study in very low and low income communities in an Eastern Cape township, for example, found levels of NO_2 and SO_2 to be 7 times and 13 times higher respectively than the risk-free levels considered acceptable (Sanyal and Maduna, 2000).

Air pollutants associated with solid fuel use (SFU) may adversely affect specific and non-specific host defenses of the respiratory tract against pathogens and, while, smoke from SFU is a complex and variable mixture containing a number of potentially toxic substances about which only broad generalizations can be made, there is sufficient understanding of the toxicological properties of these mixtures for them to plausibly increase risk of ARI (Smith, 2004). Children are particularly vulnerable to the hazardous respiratory effects of SFU because of the large amount of time spent with their mothers doing household cooking (Smith, 2004).

2.8.3.5 Dampness and Mould

Numerous studies have examined the potential association between damp housing conditions and respiratory ailments in occupants. The concept here is that increased humidity leads to increased mould growth and exposure, which could then lead to asthma and other respiratory conditions. The presence of home dampness and/or moulds has been reported to affect as many as 38% of Canadian homes (Dales *et al.*, 1991). Substantial problems have been identified in some First Nations communities due to a combination of inappropriate housing design, poor construction, inadequate maintenance and poor ventitilation (Lawrence and Martins, 2001). Children in particular appear more susceptible to exposure. A Canadian study found that children living in damp or mouldy homes were 32% more likely to have bronchitis (Dales *et al.*, 1991). The potential benefits of reducing mould in homes have not been evaluated.

2.8.3.6 House Dust Mites and Cockroaches

House dust mites (HDM) and cockroaches are examples of organisms that housing occupants can become sensitive to, resulting in worsening of asthma and other respiratory symptoms. HDMs thrive in the dust of homes, particularly in higher levels of indoor

humidity. Cockroaches are implicated as a major cause of asthma among inner city children in the U.S., resulting in increased hospital admissions, school absenteeism, and unscheduled medical visits for asthma (Rosenstreich *et al.,* 1997). The reduction of HDMs in houses requires substantive and comprehensive efforts. It is unclear whether these efforts provide sufficient benefit to be considered worthwhile by those who suffer from mite-sensitive asthma (Gotzsche *et al.,* 2003). Part of the problem is that there are frequently multiple simultaneous exposure sources in homes (e.g. smoking, gas stoves, cockroaches, mice, mould, and heating systems), such that reducing just one exposure may not be of sufficient benefit (Brugge *et al.,* 2003, Crain *et al.,* 2002).

2.8.3.7 Sanitation and Housing Quality

Cardoso *et al*., (2004) found children with respiratory illness to come from houses with poorer sanitation than controls, while in developed countries promotion of hand washing has been associated with reduced incidence of respiratory illness (Luby *et al.,* 2005). Even in urban areas in South Africa, 20% of people use inadequate sanitation facilities, while in rural areas this is as high as 35% (UNICEF, 2007). Poor quality housing is defined in various ways by different studies and thus it is difficult to determine effects of specific housing characteristics across a number of studies. Nevertheless, there is consistent evidence that damp and humid conditions are associated with ARI in children (Howden-Chapman 2004; Rylander and Megevand, 2000) while Ozcirpici *et al.,* (2004) found a composite poor housing status score, was associated with increased incidence of ARI.

2.9 Healthy Housing

Housing, as a neglected site for public health action, has been identified in a number of recent publications (Breysse *et al.,* 2005; Bornehag *et al.,* 2004). Housing, however, encompasses a very large range of factors, including biological (mould, cockroaches, dust mites, etc.), chemical (tobacco smoke, paints, etc.), and structural (water moisture, heat ventilation, AC, etc.). These make the quantitative evaluation of the impact of these factors on health difficult. In their "review of evidence on housing and health" presented at the Fourth Ministerial Conference on Environment and Health in Budapest, Hungary (June 2004), Bonnefoy *et al.,* (2003) point out that the existing body of evidence on the relationship between housing and respiratory health remains insufficient.

Although it is unclear whether indoor dampness causes or only aggravates preexisting respiratory conditions, such as asthma, (Breysse *et al.*, 2005) a recent extensive European Community Respiratory Health Survey (ECRHS), involving 38 study centers, not only found a significant association between self-reported mould exposure and asthma symptoms in adults, but also a higher prevalence of asthma in centers with high self-reported mould exposures (Zock *et al.*, 2002).

Housing is the place people spend the majority of their lives and one of "the main settings that affect human health" (Bonnefoy, 2004). It is well established that housing is a "key determinant of health" (Jacob, 2004), but the relationship between housing and health is complex (Smith *et al.*, 1997). Both health and housing are definitionally 'fuzzy' concepts, and their relationship is one of multi-factorial causality (Thomson *et al.*, 2001). Regardless of the complexity of the relationship, it is also clear that "tackling inequalities in housing also addresses health inequalities. Good housing and good health go together" (Smith *et al.*, 1997).

2.10 Housing influence on health

There is a well established link between health and housing, but the details of cause and effect are unclear and many of the relationships are indirect. In fact, in many cases "direct evidence is unlikely to be produced, no matter how strong the effect" (Raw *et al.*, 2001 quoted in Bonnefoy, 2004). Shaw describes the evidence as 'piecemeal', but, *"when amalgamated, the sum of the extensive range of ways in which housing is related to health is quite considerable. Thus in public health terms, it can be argued that housing now affects health in a myriad of relatively minor ways, in total forming one of the key social determinants of health" (2004).*

2.11. Indoor housing conditions

2.11.1. Dampness

The relationship between damp or mouldy indoor environments and respiratory problems has been the focus of a number of recent studies (Jaakkola *et al.,* 2005) including that conducted by the Institute of Medicine (IOM) in the United States on behalf of the Centres for Disease Control and Prevention (IOM, 2004). Charged with conducting a comprehensive review of the scientific literature (e.g., Evans *et al*., 1999; Williamson, *et al.,* 1997; Dales *et al.,* 1991; Dekker *et al.,* 1991), the study's Committee of Experts confirmed that "sufficient evidence" exists to conclude that mould and damp conditions are associated with asthma symptoms in sensitized persons, upper respiratory symptoms, cough, wheeze, and hypersensitivity pneumonitis in susceptible persons.

Sufficient evidence of an association was defined as "an association between the agent and the outcome observed in studies in which chance, bias, and confounding could be ruled out with reasonable confidence" (IOM, 2004). High levels of moisture generally correlate with higher levels of microbial growth and thus, elevated levels of air-borne mould (Pekkanen *et al.,* 2007). There appears however, contradictory studies which attempt to link specific genus types of mould and their indoor air-borne concentrations to respiratory conditions and/or cold-like symptoms (Stark *et al*., 2003).

2.11.2 Cold homes

Many homes have inefficient heating systems and the presence of a central heating system does not necessarily result in warmer homes. Issues of affordability and fuel efficiency are important when considering the health implications of cold housing. Those experiencing fuel poverty, defined as needing to spend over 10% of their income on energy to maintain an adequate standard of warmth, are likely to be particularly vulnerable. The ability to keep the home warm enough in winter, and in particular the worry that can be associated with such concern, has been shown to be associated with poor health outcomes (Evans *et al.,* 1999).

Colder temperatures in winter are also linked to excess winter deaths. The biggest causes of these winter deaths are cardiovascular and respiratory conditions, particularly for older

age groups. Wilkinson *et al*., (2001) has argued that a major reason why Britain has comparatively more winter deaths than other colder countries is the general quality of the housing stock. However, there is little association between deprivation and excess winter mortality. Lawlor *et al.*, (2000) argued that the relationship between excess winter deaths and deprivation has been inadequately investigated but found that excess winter deaths were not associated with deprivation.

Recent evidence from the Warm Front evaluation demonstrates that warmer homes are associated with lower risk of cold-related death than colder ones. Indoor temperature is a main function of a dwelling's energy efficiency (Wilkinson *et al*., 2001) and such findings indicate that improving domestic energy efficiency will deliver important health benefits.

2.11.3 Indoor risk factors for ARIs

Domestic indoor air pollution poses a risk to health with the greatest risk being associated with hygrothermal conditions (humidity and temperature), radon, house dust mites, environmental tobacco smoke and carbon monoxide (Raw *et al.*, 2001). Air pollutants tend to be most detrimental to asthmatics and the elderly. Increased levels of domestic allergens have been linked to increased risk of asthma in children, and exposure to such allergens may trigger attacks among asthmatics. However, there is limited evidence to suggest that exposure to allergens is a risk factor in the development of asthma. The health impacts of improved air quality have not been assessed (Thomson and Petticrew, 2001).

2.11.3.1 Asbestos

Inhalation of asbestos fibres causes two main kinds of cancer: mesothelioma and lung cancer. There are many sources of asbestos which may contribute to non-occupational exposures and many asbestos materials are present in homes. The risk of exposure will be related to the release of these fibres, for instance during home renovations or repairs, or when building surface materials have been damaged or have deteriorated. The link between exposure to non-occupational sources of asbestos and lung diseases (Konetzke *et al*, 1990) highlights the importance of the use of asbestos free materials in the home. Accidents in the home and home safety home and leisure accident statistics estimate that each year in the UK there are approximately 2.7 million accidents in the home which necessitate a visit to hospital and around 4,000 deaths as a result of injury in the home.

There is a strong correlation between accidental death and social class with a disproportionately high number of deaths occurring among less affluent populations (Williamson, 1997).

2.11.3.2 Overcrowding and density

The health risks of overcrowded housing were recognised as long ago as the 19th century when such conditions were associated with the spread of infectious diseases such as tuberculosis and led to an extensive slum clearance programme. Overcrowding is still recognised as a risk to health (Lowry, 1991) and has been associated with both physical and mental health risks including the spread of infectious diseases , accidental deaths and asthma , cardiovascular diseases, stress and depression.

Related to overcrowding is the issue of density and housing design. Research evidence tends to link living in flats, particularly high-rise ones, with stressful living conditions and social problems such as crime, social isolation and reduced privacy. A review of studies (Ineichen, 1993) found that residents living in high rise accommodation reported more mental health symptoms than those living in traditional style dwellings, whilst other studies reported no such association. These mixed results tend to support the view that high-rise living can have a negative effect on mental health for some groups. Such housing can provide suitable accommodation for many, and there is little conclusive evidence that the height of a home from ground level is associated with either reduced health or housing satisfaction. Research in this area also typifies the problem of confounding factors since the circumstances of high-rise living are often bound up with many other social problems (Wilkinson, 2001).

2.11.3.3 House Ownership

Type of housing tenure has consistently been associated with mortality and morbidity in Britain and elsewhere (Macintyre *et al.*, 2003), with renters experiencing worse health than owner occupiers. Many British studies have found a stronger relationship between tenure and mortality than between social class and mortality (Haynes, 2002). In terms of health inequalities it is often assumed that tenure itself may not have a direct influence on health but is rather a proxy for other factors like income and social class which do. Work

undertaken by Sally Macintyre and colleagues at Glasgow (Macintyre *et al.*, 2003) suggests that tenure may not simply be related to health because it is a marker for income. Their work has shown that social renters are more likely to experience housing stressors, such as dampness and overcrowding, as well as to be exposed to many other potentially health-damaging factors such as crime and anti-social behaviour than owner occupiers.

Social renters are also less likely than owners to have access to features which may benefit health, such as gardens and good local amenities. The authors conclude that these variables may help to explain some of the observed relationship between tenure and health and that the link, although independent of income, may be due to rented housing largely being a proxy for poor quality housing. The home has been identified as a key source of ontological security, and home owners may more readily be able to obtain the benefits from ontological security's key components of haven, autonomy and status from their homes (Hiscock *et al.*, 2000). Home ownership has been independently associated with improved health primarily because it may help to generate security and control (Hiscock *et al.,* 2000). However, research on mortgage areas has also demonstrated that stress and stress-related illnesses are associated with insecure home ownership (Nettleton and Burrows, 1998).

2.12 Outdoor Housing Conditions

Satisfaction with the neighbourhood has been linked to health. Whilst it is not an explicit health indicator it has been used as a proxy for satisfaction with life and an influence of mental health. In a recent analysis of data from the Scottish Household Survey of 2001, Parkes and Kearns (2004) have shown that neighbourhood conditions are associated with health and health behaviours, over and above the effects of poverty. After controlling for a range of socio-demographic characteristics such as age, gender, social tenure, access to a car and smoking, feeling unsafe increased the likelihood of poor health by 40%, while a high number of anti-social problems in an area increased poor health by 30%. Those who liked their neighbourhood because it was well maintained, was landscaped and had nice open spaces were more likely to engage in healthy behaviour such as walking and were less likely to smoke.

Social relationships and networks within and beyond a neighbourhood may be related to health outcomes, both positively (Coultard *et al.,* 2001) and negatively. For instance, social capital can negatively influence health behaviour by providing channels to facilitate unhealthy behaviour or educational underachievement (Gilbertson *et al.,* 2005). Components of social capital such as feelings of empowerment, levels of trust and social networks have been found to influence feelings of safety in the home and within the neighbourhood (Gilbertson *et al.,* 2005).

2.13 Atmosphere

The atmosphere is made up of mixture of gases surrounding any celestial object that has a gravitational field strong enough to prevent the gases from escaping; especially the gaseous envelop of Earth. The principal constituents of the atmosphere are nitrogen (78%) and oxygen (21%). The atmospheric gases in the remaining 1% are argon (0.9%), carbon dioxide (0.03%), varying amont of water vapour and trace amounts of hydrogen, ozone, methane, carbon monoxide, helium, neon, krypton and xenon (ESA, 2001).

Almost all the free oxygen in the air today is believed to have been formed by photosynthetic combination of carbon dioxide with water. About 570 million years ago; the oxygen content of the atmosphere and oceans became high enough to permit marine life capable of respiration. Later, some 400 million years ago, the atmosphere contained enough oxygen for the evolution of air-breathing land animals (ESA, 2001).

The water vapour content of the air varies considerably, depending on the temperature and relative humidity. With 100 percent relative humidity, the water vapour content of air varies from 190 part per million (ppm) at -40^0C to 42,000ppm at 30^0C. Minute quantities of other gases, such as ammonia, hydrogen sulphide and oxides of sulphur and nitrogen are temporary constituents of the atmosphere in the vicinity of volcanoes and are washed out of the air by rain or snow (ESA, 2001).

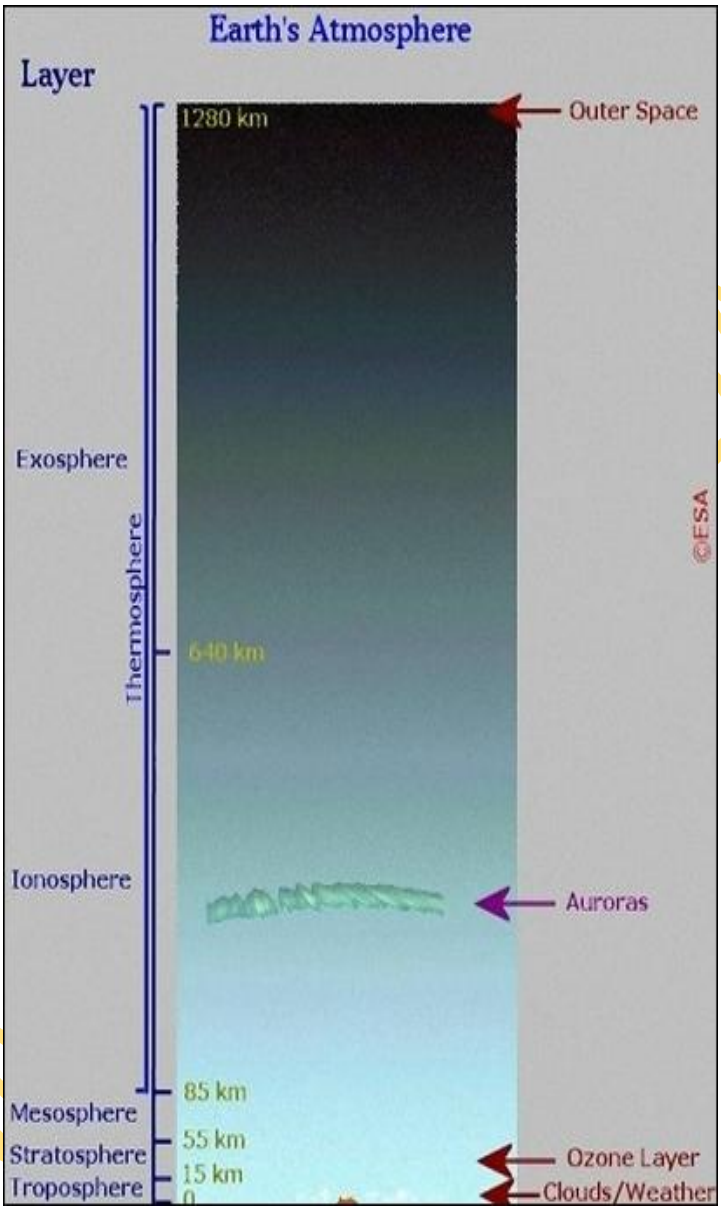


Fig 2.2: The Earth's Atmosphere

Source: European space Agency (ESA), 2001

2.13.1 Physical characteristics of the air

2.13.1.1 Air composition

The immediate environment of man comprises air on which depend all forms of life. Air is a mixture of gases that surrounds the earth and makes up our atmosphere.

Apart from supplying the life-giving oxygen, air and atmospheric conditions serve several functions. The human body is cooled by the air contact; the special senses of hearing and smell function through air by dust, smoke, toxic gases and chemical vapors has resulted in sickness and death. Human beings need a continuous supply of air to exist. The requirement for air is relatively constant (about 10-20m^3) (Parks, 2006). The air is a mixture of gases which contains molecules and particles of thousands of differential materials usually separable into chemical materials and biological forms (Jonathan, 2004).

2.13.1.2 Air Temperature

Air molecules are in constant motion. The speed of air molecules corresponds to their kinetic energy, which in turn corresponds to the amount of heat energy in the air. Air temperature is a measure of the average speed at which air molecules are moving; high speeds correspond to high temperatures. The temperature of a substance is measured by a thermometer (ESA, 2001).

2.13.1.3 Air Pressure

Air is held to the earth by gravity. This strong invisible force pulls the air downward, giving air molecules weight. The weights of the air molecules exert a force upon the earth and everything on it. The amount of force exerted on a unit surface area is called atmospheric pressure or air pressure. The air pressure at any level in the atmosphere can be expressed as the total weight of air above a unit surface area at that level in the atmosphere. Higher in the atmosphere, there are fewer air molecules pressing down from above. Consequently, air pressure always decreases with increasing height above the ground. Because air can be compressed, the density of the air (the mass of air molecule in a given volume) normally is greatest at the ground and decrease at higher altitudes. The instruments used in measuring air pressure are called Barometers (ESA, 2001).

2.13.1.4 Wind

Wind is air in motion. It is caused by horizontal variations in air pressure. The greater the difference in air pressure between any two places at the same altitude, the stronger the wind will be. The wind direction is the direction from which the wind is blowing. A north wind blows from the north and a south wind blows from the south. Wind speed is the rate at which the air moves past a stationary object. A variety of instruments are used in measuring wind. A wind vane measures wind direction while anemometers measures wind speed (ESA, 2001).

2.14 Air Quality

Air quality is an indication of healthfulness of the air based on the quantity of polluting gases and particulates (liquid droplets or tiny solid particules suspended in air) it contains. Air is considered safe if it contains no harmful chemicals or particules and only low level of other substances that become harmful in higher concentrations to humans. (Microsoft Encarta, 2008).

2.14.1 Indoor Air Quality

Indoor Air Quality is an increasing concern in the world today. In fact "the mere presence of people in a building or residence can significantly alter indoor air quality (Brooks and Davis, 1992)." In a study evaluating student performance conducted in August 2003 by the United States Environmental Protection Agency (EPA) they concluded, "recent data suggests IAQ (Indoor Air Quality) may directly reduce a person's ability to perform specific mental tasks requiring concentration, calculation, or memory (US EPA, 2001)." As the time spent indoors on average per person is on the rise (Brooksand Davis, 1992), the need for a more accurate, properly maintained HVAC (Heating, Ventilation, and Air Conditioning) system is becoming increasingly necessary. This type of system currently exists in most businesses and schools, but is absent in most residential dwellings. This type of system generally does not include humidification control. The typical system in most residential dwellings utilizes one central thermostat regulating the heating/cooling needs of the entire home. Typically schools and businesses, depending on the size, maintain a small number of strategically placed thermostats throughout the building. Unfortunately, in order to cut costs, the majority do not have a thermostat in every office

or room where students or employees spend a major portion of their day. This can lead to physical discomfort of the occupants and actual health problems. Problems with health may result in increased absenteeism and/or a decrease in productivity.

2.14.2 Importance of Indoor Air Quality

Over a decade, Canada Mortgage and Housing Corporation (CMHC) estimated 6% of the Canadian population had severe respiratory problems. This estimate has risen to 25% of the population. These statistics may serve as an indication of the growing number of indoor air quality problems in recent years. In the United States, a 1991 federal estimate indicated that approximately 15% of Americans suffer from chemical sensitivities (Mathews, 1992).

The need and importance of creating and maintaining a clean and healthy indoor environment should be evident, given the human warning signals. Presently, indoor air quality is only a problem when building occupants report symptoms. However, waiting for occupant intolerance is not satisfactory. All buildings (new and old) should maintain a practical degree of healthy indoor air for its occupants.

2.14.3 Indoor Air Meteorological Characteristics

2.14.3.1 Indoor Air Temperature

The measurable scale of the temperature refers to the Canadian index, called Humidex (Ooi, 1963). This index categorizes human comfort level which is to 'reflect perceived temperature' using combination of temperature and humidity. There is so far no study conducted to give a specific measurable scale of the temperature in the tropical region. The measurable scale also refers to the study of Abdul Rahman (1995). The reason is that perception by the people who live in tropical regions are different from those in temperate and cold regions (Wang and Wong, 2007; Singh *et al*., 2009). Abdul Rahman (1995) in his study found that the most comfortable indoor temperature in Malaysia (tropical region) ranges from 25.5-28°C compared to the general recommendation by World Health Organization (1990), from 18-28°C. The reason is hot and humid temperature throughout a year gives an impact to the people's perception (Feriadi and Nyuk, 2004) to the thermal comfort at higher temperature in contrast to those in temperate region. Scale No.2 (Table

2.1) is considered as the best level of performance of the temperature factor. The measurable scale is as shown in Table 2.1.

2.14.3.2 Indoor Air Humidity

Humidity is derived from the word 'humid' which refers to the water vapor content in the air. The scale of measurement is in percentage ranging from 0-100% relative to the amount of water vapor in the air. Relative humidity shows the level of humidity whether it is dry or humid in particular to indoor environment. Table 2.2 shows the recommended level of indoor air humidity (Wolkoff and Kjaergaard, 2007).

Relative humidity is a percentage of that maximum amount of humidity in the air at a given time and is temperature dependant. As the temperature increases or decreases so does the saturation water vapor pressure. This, in turn, causes the relative humidity to increase or decrease as a result of the direct correlation between the two (Wolkoff and Kjaergaard, 2007). Relative humidity plays an important role in how individuals perceive the comfort level and quality of the air in the indoor environment. In fact, "the human body is comfortable when relative humidity ranges between 30 and 60 percent," although, this range is not always conducive to optimal health (Choa *et al.,* 2002). The percentage of indoor relative humidity can also have a significant adverse effect on the structural soundness of buildings.

2.14.3.3 Relative Humidity

Relative humidity that is too high may breed mold, rot, or pests, such as termites or cockroaches (Maxwell, 2007). High relative humidity facilitates the growth of different varieties of mold. In fact, "all molds can potentially cause rashes, headaches, dizziness, nausea, allergic reactions including hay fever and asthma attacks (Loecher, 2004)." The effects can be much worse in people with weakened immune systems, such as the every young and the elderly. The existence of mold is often detected by a musty or mouldy (Sun *et al.*, 2007) smell. High relative humidity (greater than 50 percent) can "produce enough condensation to stain ceilings and walls and cause flaking paint and peeling wallpaper (Maxwell, 2007)."

The latter potentially increases the levels of VOC in the air. At high relative humidity levels microorganisms, such as fungi and bacteria, can survive on nonliving material including dust (Choa *et al*., 2002). High relative humidities (above 70 percent) also "tend to favor the survival of viruses composed entirely of nucleic acids and proteins." The most common groups of these viruses is the *adeno viruses* and the *coxsackie viruses*. The adeno viruses are a group of viruses that infect the membranes of the respiratory tract, the eyes, the intestines, and the urinary tract (Joel, 2006).

Table 2.1: The Scale of Measurement for Temperature (ºC)

Scale	Description	Celsius
0	Cold	Less than 16
1	Cool	16 – 25.5
2	Comfort	25.5 – 28
3	Warm	28 – 32
4	Hot	32 – 40
5	Extremely Hot	Above 40

Table 2.2: The Scale of Measurement of Relative Humidity (%)

Scale	Description	%
1	Low	Below 30
2	Ideal Comfort	30 – 60
3	High	Above 60

Source: Ahmad and Mahyuddin, 2010

2.15 Air Pollution

Air pollution is one of the major environmental problems confronting the world today. Air pollution is concerned with the things humans add to or put into the air. Air pollution is thus the transfer of harmful amounts of natural and synthetic materials into the atmosphere as a direct or indirect consequence of human activity. In simple words, air pollution is the dust, gas and droplets that are stirred up into the atmosphere as a result of human activities (Jonathan, 2004).

The term "Air Pollution" signifies the presence in the surrounding atmosphere of substances (e.g. gases, mixture of gases and particulate matter) generated by the activities of man or natural disasters in concentrations that interfere with human health, safety or comfort, or injurious to vegetations and animals and other environmental media resulting in chemicals entering the food chain or being present in drinking water and thereby constituting additional source of human exposure (Park, 2006).

Air pollution could also be described as the presence of substances in air in sufficient concentration and for sufficient time, so as to be, or threaten to be injurious to human, plant or animal life, or to property, or which reasonably interferes with the comfortable enjoyment of life and property. Air pollution on the other hand refers to the discharge of harmful substances into the air to the extent that it can reduce visibility or produce undesirable odour (Mahbood and Athar, 2007).

This is an inescapable consequence of the presence of man and his activities. Today, air pollution has become more subtle and recognizes no geographical or political boundaries. However, air pollution is primarily associated with everyday human activities (Arianne *et al.*, 2007).

Air pollution most especially indoor air pollution increases the incidence of ARI by adversely affecting the nonspecific host defenses like filtration, mucociliary apparatus etc and specific host defenses like cellular and humoral host defenses. The first case-control study investigating the role of risk factors for ARI in the general population in an industrialized country showed that exposure to persons with respiratory complaints both inside and outside the household is a risk factor for ARI (Arianne *et al.*, 2007).

This increase was occasioned by the deposition of particulates or dust raised during the Harmatan season, wind movement of dry particulates and aerosols from the Sahara desert into the northern states, and burning of anthropogenic substances etc. Generally speaking, the concentration of ambient air particulate matter over Nigerian cities is about 500% higher than the 20µg/m^3 threshold of WHO (2005).

A critical examination of the spatial distribution of the ambient air particulate matter over Nigerian cities revealed that the traffic-clogged areas had the highest concentrations with mean annual values of 147.7µg/m^3. Traditional areas which also formed part of the cities, had the lowest mean ambient PM_{10} with 121.2µg/m^3 over the six years of study. This showed a difference of 26.5µg/m^3 which indicates that ambient PM_{10} concentrations in the traffic-clogged areas are about 22% higher than those in the traditional areas. This increase is occasioned by the deposition of particulate from increased vehicular movement, dust raised during the Hammatan season, wind movement of dry particulates and aerosols from the Sahara desert, and burning of anthropogenic substances (Mahbood and Athar, 2007).

2.15.1 Particulate Matter

Comparing urban values with those of the surrounding rural areas showed that ambient PM_{10} concentrations in the rural areas were generally lower than those of the urban areas. The urban environment had mean annual ambient PM_{10} that span 129µg/m^3 to 144µg/m^3, with an overall mean of 135µg/m^3, while the surrounding rural areas recorded mean annual mean ambient PM_{10} value of 57µg/m^3, indicating over 136% difference between the two landscapes. When these values were compared with the aid of paired t-test statistical analysis, results revealed that a significant difference exists in the ambient PM_{10} concentration between the urban corridors and the surrounding rural areas of Nigeria (Mahbood and Athar, 2007).

2.15.2 Organic Compounds

The classification of organic compounds represents chemical compounds that contain carbon-hydrogen bonds in their basic molecular structure. Their sources can be either natural products or synthetics, especially those derived from oil, gas, and coal. Organic

contaminants may exist in the form of gas (vapour), liquid or as solid particles in the atmosphere, food and/or water (Anderson *et al.,* 2007).

2.15.2.1 Volatile Organic Compounds (VOCs)

In the past, when human bioeffluents were considered to be the most important pollutants of indoor air, carbon dioxide ($C0_2$) was generally accepted as an indicator for indoor air quality (IAQ). $C0_2$ has lost this function partly because today many more sources than human beings emit pollutants into indoor air. In fact the widespread use of new products and materials in our days has resulted in increased concentrations of indoor pollutants, especially of volatile organic compounds (VOCs) that pollute indoor air and maybe affect human health. As a result, the air of all kinds of indoor spaces is frequently analysed for VOCs (Brown *et al.,* 1994).

As many VOCs are known to have short-term and long-term adverse effects on human health and comfort, VOCs are frequently determined if occupants report complaints about bad indoor air quality. On the comfort side VOCs are associated with the perception of odours. Adverse health reactions include irritation of mucous membranes, mostly of the eyes, nose and throat, and longterm toxic reactions of various kinds (Anderson *et al.,* 2007).

2.15.3 Inorganic Compounds

Inorganic compounds are those which do not contain carbon-hydrogen bonds in their molecular structure. They include carbon dioxide, sulphur dioxide, nitrogen oxides, carbon monoxide, ozone, lead, sand, metal, ammonia and some particulate matter.

2.15.3.1 Carbon Monoxide

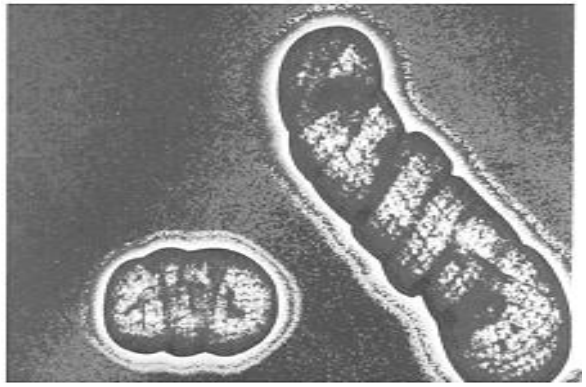
The process of combustion can produce a number of pollutants, including carbon monoxide, carbon dioxide, water vapor, and smoke (fine airborne particle material). Of these materials, carbon monoxide and particulate matter with a diameter of 2.5 micrometers (μm) or less (PM2.5) can produce immediate, acute health effects upon exposure (Bright *et al.,* 1992). Carbon monoxide is a product of incomplete combustion of organic matter (e.g., gasoline, wood, tobacco). Carbon monoxide should not be present in

a typical indoor environme. If it is present, indoor carbon monoxide levels should be less than or equal to outdoor levels (U.S. EPA 2000).

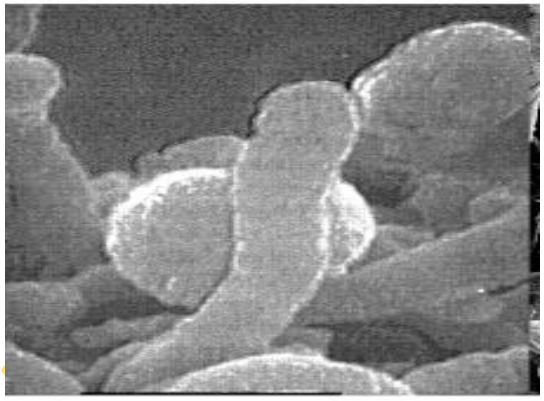
Several air quality standards have been established to prevent human exposure to carbon monoxide. EPA has National Ambient Air Quality Standards (NAAQS) to protect the public health from 6 criteria pollutants, including carbon monoxide and particulate matter (U.S. EPA, 2000).

2.15.4 Bioaerosols

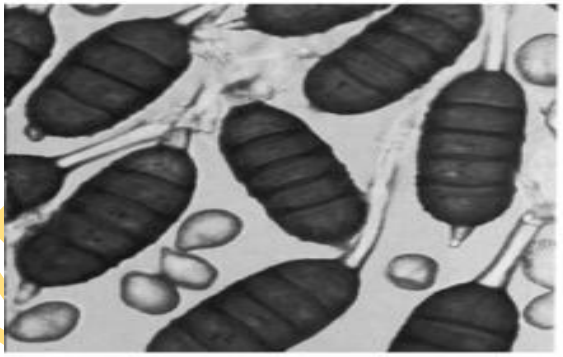
Bioaerosols are considered all airborne particles of biological origin, namely, bacteria, fungi, fungal spores, viruses, pollen and their fragments including various antigens. Particle sizes may range from aerodynamic diameters of ca. 0.5 to 100 μm (Cox and Wathes, 1995). Airborne micro-organisms become non-viable and fragmented over time due to desiccation. Indoor air contains a complex mixture of (i) bioaerosols such as fungi, bacteria and allergens [Fig 2.3 (a), (b) and (c)], and (ii) non-biological particles (e.g., dust, tobacco smoke, cooking-generated particles, motor vehicle exhaust particles, particles from thermal power plants, etc.). Exposure to several of these biological entities as well as microbial fragments (like cell wall fragments, flagella, etc.) and microbial metabolites (like endotoxin, mycotoxins and VOCs) may result in adverse health effects. In particular, increase in asthma attacks and bronchial hyper-reactivity has been correlated to increased bioaerosol levels. Elevated levels of particle air pollution have been associated with decreased lung function, increased respiratory symptoms such as cough, shortness of breath, wheezing and asthma attacks, as well as chronic obstructive pulmonary disease, cardiovascular diseases and lung cancer (WHO, 2002).



(a)



(b)



(c)

Fig 2.3: Microscopic illustration of (a) Viruses (b) Bacteria (c) Fungi

More than 80 genera of fungi have been associated with symptoms of respiratory tract allergies (Horner *et al*., 1995). *Cladosporium*, *Alternaria*, *Aspergillus* and *Fusarium* are amongst the most common allergenic genera. Metabolites of fungi including toxins and volatile organic compounds are also believed to irritate the respiratory system. Furthermore, non-biological particles may serve as carriers of fungal allergen molecules into the lung independently of the whole fungal spore. In the case of non-viable combustion particles such as tobacco, smoke or cooking-generated particles, such an interaction would have serious implications, as allergen molecules could conceivably be carried deeper into the lung, than a fungal spore would be expected to penetrate.

There is evidence that low ventilation rates and other building characteristics can lead to increased incidence of respiratory diseases caused by viruses (Fisk, 2001). No references were found for airborne viral measurements in schools, but total airborne bacteria have been reported in a number of studies. Bacterial endotoxins, present in house dust and airborne particulate matter are thought to cause a range of flu-like symptoms (Rylander, *et al.* 1992), but no references to endotoxin measurements in schools were found. Exposure to house dust mite allergens can cause asthma and trigger asthma attacks in sensitized subjects (Samet, *et al.*, 1996). House dust mites thrive under conditions of high relative humidities and allergies to them are more frequent in climates with mild humid winters (Reed and Swanson, 1986).

Numerous studies have proved that exposure to bio-aerosols, containing airborne microorganisms and their by-products; can result in respiratory disorders and other adverse health effects such as infections, hypersensitivity pneumonitis and toxic reactions (Gorny *et al*., 2002; Fracchia *et al*., 2006). Microbial damage in indoor/outdoor areas is caused most frequently by molds and bacteria. These micro-organisms have a very important role in the biogeochemical cycle, as their task consists of disintegrating organic mass to reusable metabolites. In the environment spores of molds and bacteria may become airborne and are therefore ubiquitous. They can enter indoor areas either by means of passive ventilation or by means of ventilation systems. Many genera are also emitted by indoor sources like animals, flowerpots and wastebaskets.

2.16 Indoor Environment

In indoor environments (non-industrial), the most important source of airborne bacteria is the presence of humans (Kim and Kim, 2007). Major indoor activities such as talking, sneezing, coughing, walking, washing, flushing the toilet, etc. can generate airborne biological particulate matter. Food stuffs, house plants and flower pots, house dust, pets and their bedding material, textiles, carpets, wood material and furniture stuffing, from which spores of *Alternaria*, *Aspergillus*, *Botrytis*, *Cladosporium*, *Penicillium*, *Scopulariopsis* and yeast cells are occasionally released into the air (Cox and Wathes, 1995).

Although indoor environments are considered to be protective environments, however, they can become contaminated with particles that present different and sometimes more serious risks than those related to outdoor exposures, when their concentration exceed the maximum limits. These are TS > 1000 CFUs/m3 set by the National Institute of Occupational Safety and Health (NIOSH), 1000 CFUs/m3 (ACGC) with the count for total bacteria not to exceed 500 CFUs/m3 (Cox and Wathes, 1995; Jensen and Schate, 1998).

2.16.1 Bacteria in Indoor Environments

The presence of airborne bacteria is a major issue in indoor environments such as dwellings, schools, hospitals, and day-care centers. The amount of pathogenic microorganisms is higher in indoor than outdoor air (Daisey *et al*., 2003). The potential health risks caused by exposure to airborne bacteria can occur in workplaces and residential locations at any time (Kim and Kim, 2007). Many people spend more than 90% of their time in the indoor environments. However, the source of bacteria in indoor air is mostly from outdoor air. Strong relationship between occupant density, human activity and microorganisms' concentration in the indoor air was reported. (Fleischer *et al*., 2006; Toivola *et al*., 2002).

Building-associated bacteria are mostly the common saprophytic bacteria of the normal human skin, mouth and nose that are emitted into the indoor air or those originating from outdoor air (Nevalainen *et al.,* 1991). Pets may also be an important source or carriers of

bacteria, since their presence is associated with airborne endotoxins (Park *et al.*, 2000). Common bacteria of indoor environments are also heterotrophic bacteria that grow in the water reservoirs or moist sites of the building, such as bathroom sinks (Finch *et al.*, 1978). Specifically, legionellae and non-tuberculous environmental mycobacteria occur in biofilms of water pipelines or in water reservoirs of cooling systems. Streptomycetes and other actinobacteria, *Bacillus* species and many other bacteria may grow in wetted building materials together with fungi (Andersson *et al.*, 2007). Bacterial agents include bacterial cells and spores, bacterial endotoxin which is a structural component of all gram-negative bacteria, peptidoglycans, which is another structural component of bacteria, bacterial MVOC (microbial volatile organic compounds emitted from bacterial growth) and exotoxins and other secondary metabolites produced by bacteria growing on moist building materials (Peltola *et al.*, 2001).

Like fungi, bacterial growth takes places everywhere where water is present. In indoor environments, one may find standing water in the drip pans of air-cooling devices, freezer or refrigerator, in humidifiers and on wet surfaces of bathrooms and kitchen (Ojima *et al.*, 2002). Water may also originate from leaks in plumbing or roof, or be a result of condensation or harsh rain or snowing (Speirs *et al.*, 1995). Standing water is a potential source of bacteria, and once disturbed, bacteria may become airborne. Bacterial growth in water is usually dominated by Gram-negative bacteria, and consequently, their unusual occurrence in indoor air, whether measured as viable bacteria, chemical markers, or as endotoxin, is an indication of a wet site or excess humidity in the indoor environment (Speirs *et al.*, 1995).

2.16.2 Fungi in Indoor Environments

The building-associated fungi consist of filamentous microfungi (moulds) and yeasts. The most common fungal genera occurring in indoor environments are *Penicillium*, *Aspergillus*, *Cladosporium*, *Alternaria* and yeasts (Hyvärinen *et al.*, 2002). These genera are also the most frequently occurring fungi in outdoor air, which is usually a major source of building-related fungi (Miller, 1997). The total concentrations of fungi are usually higher outdoors than indoors. Outdoor concentrations have a strong seasonal variation, resulting in lower concentrations in winter than in frost–free periods. This has

an impact on indoor air fungi as well. The phenomenon is especially notable in cold climates (Mullins, 2001).

The concentrations of fungi in indoor environments show significant spatial and temporal variation (Hyvärinen *et al.*, 2002). Spatial variation inside the buildings is caused e.g., by local sources of biological agents in certain parts of the building, but also varying activities and varying ventilation rates in different rooms may contribute to this variation. Temporal variation probably results from variation in air exchange rates, which affects the rate of removal of biological agents. The source strength in each location is also affected by the activities of the occupants, by vibrations of the building frame and other such factors.

Rao *et al.,* (1995) recently found that existing quantitative standards and guidelines for total fungi in indoor air range from <100 CFU/m^3 to >1000 CFU/m^3 as the upper limit for non-contaminated indoor environments, based primarily on baseline data rather than health effects information. Limitations in the standards and guidelines include reliance on short-term grab samples analyzed only by culture, lack of standardized protocols for data collection, analysis and interpretation, and the lack of connection to human dose-response data. In addition, since the toxin concentration in spores is most likely independent of viability, measurements of culturable fungi may not adequately reflect the potential for health problems. The most prevalent microfungal genera were *Penicillium, Fusarium, Alternaria and Cladosporium*. The occurrence of common respiratory infections is higher in exposure to building mold. This finding is consistent for both adults and children. The ultimate cause of the infection is usually common respiratory pathogens, viruses causing common cold and flu, and secondary bacterial infections, such as sinusitis or acute bronchitis.

In a study by Cox and Wathes, 1995, the number of adults who had had at least one respiratory infection during the previous 12 months was significantly higher in the mold-exposed group than in the unexposed reference group. Among children, the attack rate for respiratory infections was significantly higher for the exposed group, although almost two-thirds of the children in both study groups had at least one infection during the

previous 12 months. Similar results were found among children attending a moldy day care center.

2.17 Microbial Exposures related with Dampness and Moisture

A quite different source of fungi and bacteria is any moist or wet site where fungal or bacterial spores may germinate and start to grow, or where non-sporing bacteria and yeasts are able to proliferate. In general, building structures and indoor environments should be dry, without any mechanism that would cause constant or regular wetting of surfaces and structures. However, this is often not the case, and various problems with dampness, moisture and water damage are prevalent in all climates and building types. Such problems are strongly linked with respiratory and other adverse health effects (Bornehag *et al.*, 2001, 2004; IOM, 2004). However, the causal agents of the health effects are not yet well understood.

As soon as any material gets wet, microbial growth starts. Microbial spores and cells are present everywhere, and therefore the only factor regulating the microbial growth is availability of water. In general, the microbial types that start their growth on building or finishing materials, originate from outdoor air and other natural sources. However, the substrate on which microbial growth takes place, has a crucial role on the microbial profile that will develop on it. Both the moisture content, availability of nutrients, pH and other characteristics of the material are important in microbial growth. For example, the species profile that grows on moist wood is different from the species that derive on gypsum board (Hyvärinen *et al.*, 2002).

Among the fungal species that grow typically on moist building materials but are not part of the "normal" microbial content of indoor environments, are *Aspergillus versicolor*, *Aspergillus fumigatus*, *Stachybotrys chartarum*, *Acremonium*, *Aureobasidium*, *Chaetomium*, *Phialophora* and *Trichoderma*. Among the bacteria that contaminate moist building materials are *Streptomyces* and *Mycobacterium*. In fact, it is a whole ecosystem that develops on moist building materials, including not only many species of fungi and bacteria but also protozoa such as amoebae (Yli-Pirilä *et al.*, 2004). Amoebae may allow

the growth of *Chlamydia* and other bacteria that do not proliferate alone in environmental habitats.

The factor that makes the difference between growing microbes and those transported in and out by "normal " phenomena, is that growing microbes produce additional pollutants into the indoor air. They produce spores and small fragments of microbial material (Gorny, 2004), and secondary metabolites that may be either volatile compounds, often with characteristic smell, or non-volatile compounds many of which are characterized as microbial toxins. Fungi and bacteria isolated from houses with moisture problems have shown both cytotoxic and immunotoxic characteristics (Huttunen *et al.*, 2003; Jussila *et al.*, 2002). Thus, having a source of growing microbes in the building structures or indoor environment means quite different exposure situation.

2.18.1 Outdoor Air Pollution

Early in the 20th century dramatic episodes of outdoor air pollution in developed countries showed that air pollution could cause excess deaths and those children might be at particularly increased risk during the times of high pollution. For example, during the London fog of 1952, which was due mainly to smoke from coal burning household stoves, several thousand excess deaths occurred. Infants and young children as well as the elderly were noted to be at higher risk than others and the proportion of deaths attributed to respiratory causes was increased in comparison with the weeks before and after the fog. Outdoor air pollution has now been examined as a risk factor for respiratory morbidity and mortality in numerous epidemiological studies and the evidence continues to indicate that infants and young children are at risk for adverse effects. Even though ambient pollution levels have now declined in developed countries, the epidemiological evidence continues to indicate adverse effects on both respiratory morbidity and mortality. Indeed, new studies are indicating adverse effects of inhaled particles at levels that were previously considered to be safe and are now frequently reached in many urban areas.

Good outdoor air quality is an essential prerequisite for effective ventilation, yet increasing urbanization and contaminant emissions into the atmosphere is presenting difficulty. Significant sources of local pollution include regional industrial pollution,

pollution from vehicles and pollution emissions from adjacent buildings. In agricultural regions, pollen and chemical sprays can also be a problem. The importance of achieving good outdoor air quality cannot be overstated. Stevenson *et al*., (1999) at the London School of Hygiene and tropical medicine, for example, reports on an epidemiological study linking respiratory related deaths to traffic fumes in urban areas. Respiratory problems related to urban pollution are also reported by Anderson *et al.*, (2007). Kukadia *et al.*, (1996) have undertaken extensive measurements and studies on the impact of urban pollution inside buildings. These studies noted that the concentration of external pollutants found in monitored buildings followed the daily external variation although at a lower concentration.

2.19 Indoor Air Pollution

Indoor air pollution can be traced to prehistoric times when humans first moved to temperate climates approximately 200,000 years ago. These cold climates necessitated the construction of shelters and the use of fire indoors for cooking, warmth and light. Ironically, fire, which allowed humans to enjoy the benefits of living indoors, resulted in exposure to high levels of pollution as evidenced by the soot found in prehistoric caves (Albalak, 1999). It has been estimated that approximately half the world's population, and up to 90% of rural households in developing countries, still rely on biomass fuels (Smith, 1993). Typically burnt indoors in open fires or poorly functioning stoves, this leads to levels of air pollution that are among the highest ever measured.

In developed countries, modernization has without exception been accompanied by a shift from biofuel to petroleum products (kerosene, LPG) and electricity. In developing countries, even where cleaner more sophisticated fuels are available, households often continue to use biomass (Smith, 1993). Although the portion of global energy derived from biofuel has fallen from 50% in 1900 to around 13% currently, this trend has leveled and there is evidence that biofuel use is increasing among the poor (Smith *et al.*, 2000). Poverty is one of the main barriers to the adoption of cleaner fuels and slow pace of development in many countries implies that biofuels will continue to be used by the poor for many decades.

The table below shows the estimate of diseases related to indoor and outdoor air pollution.

Table 2.3: Estimates for Indoor and Outdoor Air Pollution

Air pollution related diseases	Outdoor (%)	Indoor (%)	DALYs Attributed (OUT)	DALYs Attributed (IN)
Acute respiratory infections (ARIs)	0.1	0.9	1,856.46	16,708.14
Ischemic heart disease (IHD)	0.6	0.4	142.02	94.68
Chronic Obstructive pulmonary Diseases (COPD)	0.7	0.3	639.1	273.9
Asthma	0.5	0.5	178.25	178.25
Trachea, Bronchus, Lung Cancer	0.7	0.3	39.375	16.875
Cerebrovascular diseases (CVD)	0.4	0.6	183.8	275.7
Tuberculosis	0.3	0.7	763.8	1,782.20
Trachoma	0.1	0.9	5.24	47.16
Cataract	0.1	0.9	16.22	145.98
			3,824.27	**19,522.89**

(Source: WHO 1999)

2.20 The Human Respiratory System

The health of the entire respiratory system is affected by the quality of the air that humans breath. In addition to oxygen, the air contains other substances including pollutants that are harmful. The respiratory system is particularly sensitive to air pollutants because much of it is made up of exposed membrane. Lungs are anatomically structured to bring large quantity of air into intimate contact with the blood system, to facilitate the delivery of oxygen (Health Canada, 2006).

2.20.1 Structure and function

The human respiratory system (Fig 2.4) is dominated by the lungs, which bring fresh oxygen into the body while expelling carbon dioxide. The oxygen travels from the lungs through the blood stream to the cells in all parts of the body. The cells use the oxygen as fuel and give off carbon dioxide as a waste gas. The waste gas is carried by the blood stream back to the lungs to be expelled. The lungs accomplish the vital process called gaseous exchange using an automatic and quickly adjusting control system. This gas exchange process occurs in conjunction with the central nervous system (CNS), the circulatory system and the musculature of the diaphragm and the chest.

The human respiratory system is classified into two: 1) the upper respiratory tract (URT) and 2) the lower respiratory tract (LRT). The upper respiratory tract is made up of the following rigid structures;

Nasal cavity: Filters the air we breathe and provide a sense of smell.

Pharynx: Act in the respiratory and the digestive system.

Larynx: Link between the pharynx and the trachea.

Trachea: The trachea is the bond with the lower respiratory tract. This is a flexible structure allowing the air to go down to the lungs.

In addition to gas exchange, the lungs and the other part of the respiratory system have important job to do related to breathing. These include:

1 Bringing all air to the proper breathing temperature
2 Moisturizing the inhaled air for necessary humidity.
3 Protecting the body from harmful substances by coughing, sneezing, filtering or swallowing.

4 Defending the lungs with the help of the cilia. Mucus and macrophages, which act to remove harmful substances deposited in the respiratory system.

Deposition of inhaled particles within the lungs varies widely depending on the particle size. Airway tissues that are rich in bioactivation enzymes can transform organic pollutants into reactive metabolites and cause secondary lung injury. Larger (coarse) particles in air pollution are more likely to deposit in the upper airways of human lungs, and affect this part of the lungs. Smaller (fine) particles penetrate deeply into the alveolar region of the lungs and appear to be able to affect more basic lung function.

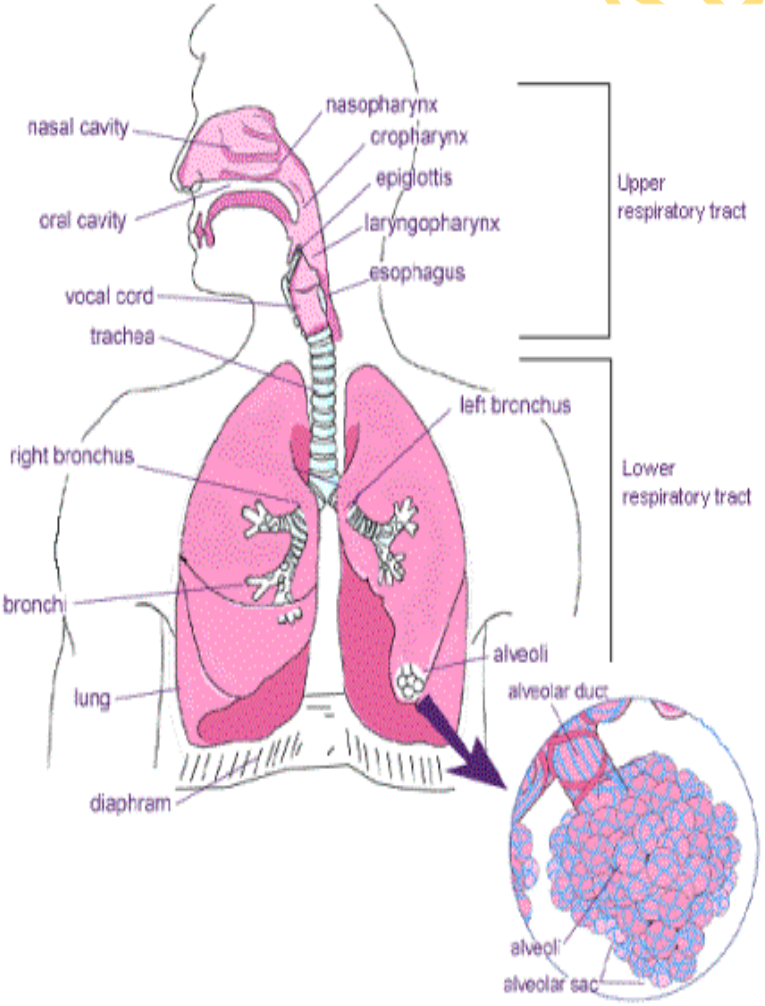


Fig 2.4: The Human Respiratory System

Source: Health Canada, 2006.

2.20.2 Transmission of Communicable Respiratory Diseases

Fig 2.5 shows the pattern of transmission of communicable respiratory diseases. Whether it is an infected human or a contaminated environmental matrix, each source (Panel A) generates particles with a characteristic range of sizes. The length of time a particle resides in the air (physical decay, Panel B) depends on its initial size, its composition, and environmental factors. Similarly, the length of time an airborne organism remains infectious (biologic decay) is affected by the infectious agent's initial metabolic state, genetic characteristics, and environment. The portion of the respiratory tract of a susceptible host in which inhaled particles are deposited (Panel C) is a function of the particles' aerodynamic size; in the middle of the range, particles may be deposited in both the upper and the lower airways.

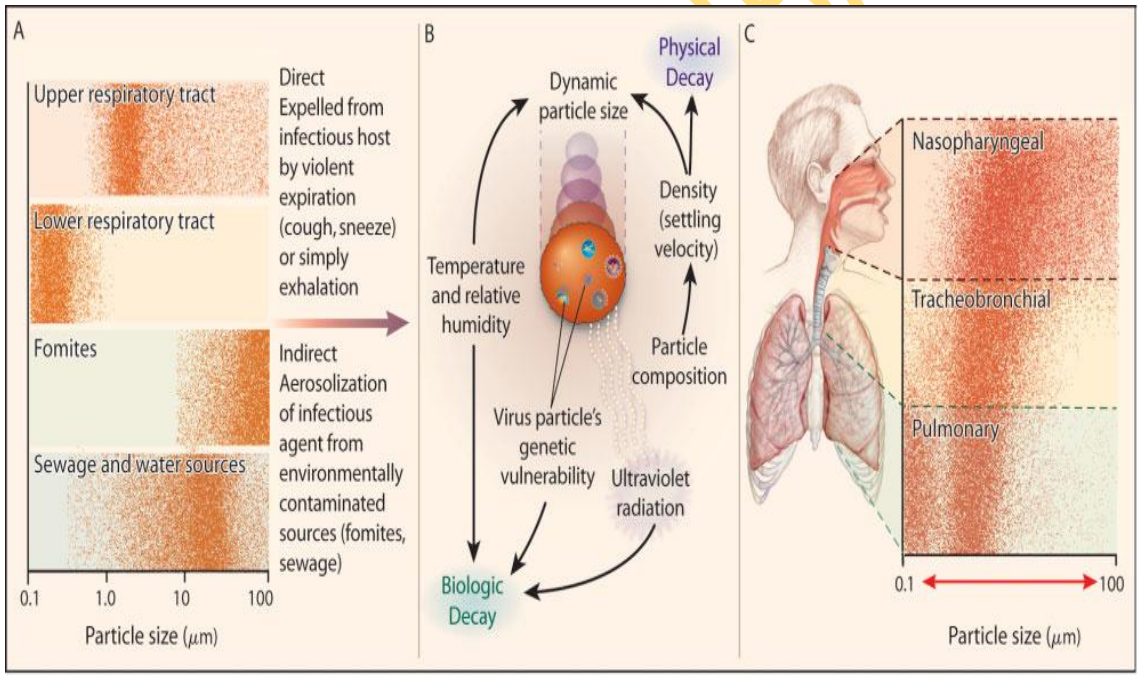


Figure 2.5: The Aerobiologic Pathway for the Transmission of Communicable Respiratory Disease.

2.21 Vulnerability of Children to Air Pollutants

2.21.1 Exposure to Xenobiotics

Children differ from adult in many ways: their absorption, metabolism, and elimination of xenobiotics, their physiology, their proportionately larger dose of an inhaled toxin, and their higher cumulative risk from toxins over time. Children, by virtue of their longer life span, have a higher risk of development of cancer from exposure to inhaled carcinogen; the fact that they spend more than 50% of their time indoor put them into contact with suspected carcinogens. Wallace (1991) has estimated that carcinogenic risk of chemicals in residential indoor air, such as VOCs and pesticides, is equal to the cancer risk radon and sidestream tobacco smoke.

The fetus is particularly vulnerable to the transmission of toxins that the mother inhales through the placent-fetal unit. Certainly, maternal smoking put the fetus at risk for growth failure and other developmental effect. Air pollutants to which the mothers are exposed to in the home or in the work place is variably conveyed to fetal tissues, depending on their absorption kinetics and whatever barrier the placenta might pose.

2.21.2 Pulmonary Physiology

Children are at risk for toxicity from inhaled toxins because of differences in their pulmonary physiology. They have a higher minute ventilatory rate (400mL/min/kg in new borne vs 150mL/min/kg in an adult) than giving them higher doses of inhaled toxins relative to adults. The volume of inhaled air also varies widely with activity level; actively playing or exercising children inhale much greater volume than those who are sedentary or asleep. Young infants are obligatory mouth breathers, and many older infants and children also breath through their mouth than adults. This difference in breathing behaviour may increase the child's risk of pulmonary exposure to respirable particules and fibres otherwise filtered in the upper airway.

A higher cardiac pulse rate and extent of tissue perfusion allows for more rapid exposure to toxins absorbed into the blood. Breathing zones are an important concept that can predispose a child to certain environmental pollutants. Because a child's breathing zone is closer to the ground (compared to 4-6ft. for adults), pollutants that are heavier than air will pose more of environmental hazard (Fenske *et al.*, 1990).

2.21.3 Pulmonary Lung Disease in Children

Pulmonary defences to infection include anatomical barriers, mucociliary, pulmonary toilet, secretory IgA and opsonizing IgB, surfactant, complement, plasma components, vasoactive substances and cells (macrophages, polymorphonuclear leukocytes). When these are individually or collectively compromised by chronic exposure to indoor air pollutants, lower respiratory tract infections are more likely to develop (Smith, 2000). The lungs have a limited ability to respond to toxic insults: irritants, inflammatory reactions, chronic inflammatory reactions, cell-mediated and immediate immune reactions and carcinogenesis (Samet and Utell, 1991). Such reactions may have exergerated effect on children by virtue of their immature pulmonary and immune development. Pediatric lung development occurs in two stages: pulmonary alveoli and capillary proliferation until the age of 5-8 years followed by growth through alveolar expansion. Thus infants and children may be more vulnerable to inflammatory reactions to particles and potential allergens, for example, because of their immature lung structure and respiratory defense mechanisms.

The combination of exposure to environmental tobacco smoke and the toxigenic molds, *Stachybotrys atra*, was possibly associated with an outbreak of acute pulmonary hemorrhage and hemosiderosis in 10 Cleveland infants in 1993-1994. Furthermore, it was felt that the rapid growing lungs of these infants were more susceptible to the inhaled trichothecene mycotoxins produced by this mold (Samet and Utell, 1991). Other studies have suggested an increase vulnerability of children to infection because of immunotoxic changes brought about by inhaled toxins. Samet and Utell (1991) studied the killing ability of macrophages harvested from volunteers exposed to elevated nitrogen dioxide concentrations against those exposed to normal air.

2.21.4 Children with Underlying Chronic Illness

Children with chronic pulmonary diseases such as cystic fibrosis or asthma are more susceptible to both indoor and outdoor pollutants exacerbating their underlying lung dysfunction. The hyper reactivity of children's airway compared to adults and their propensity of wheezing as a pulmonary response to a variety of different environmental trigger may explain in part their increased risk of asthma (Etzel, 1995). In one Canidian

study of more than 17,600 school children exposed to environmental tobacco smoke (OR 1.4), home dampness (OR 1.5), use of gas for cooking (OR 2.0) and use of a humidifier in the home (OR 1.7) were all associated with physician-diagnosed childhood asthma (Dekker *et al*., 1991) within the age group of children 6 years and younger.

2.21.5 Socioeconomic Disparities

As a result of socioeconomic disparity, more children live in poverty than do any other age group in America. Their families are more likely to live in public houses or blue collar neighbourhoods in close proximity to industry, with higher degree of environmental contamination. For example, people living near air polluting electricity generating plants have higher rate of asthma and respiratory illnesses (Weaver *et al.,* 1996).

Children living in poverty may underutilize health care services and their asthma and atopic diseases may go underdiagnosed. Joseph and her associates estimated the prevalence of physician-diagnosed asthma among urban Detroit school children in 3rd and 5th grade to be as many as 14.3% (Joseph, 2008). In a cross-sectional study, Crain and her colleague found the prevalence of asthma among children living in the Bronx, New York, to be twice the U.S. average. With higher prevalence rates among both Hispanic and lower income groups within the sample (Crain *et al.*, 2002).

2.22 Indoor Air Monitoring

Bioaerosol monitoring is a rapidly emerging area of industrial hygiene. Bioaerosol monitoring includes the measurement of viable (culturable and nonculturable) and nonviable microorganisms in both indoor (e.g., industrial, office or residential) and outdoor (e.g., agricultural and general air quality) environments. In general, indoor bioaerosol sampling need not be performed if visible growth is observed. Monitoring for bioaerosols in the occupational environment is one of the many tools the industrial hygienist uses in the assessment of indoor environmental quality, infectious disease outbreaks, agricultural health, and clean rooms. Contamination (microbial growth on floors, walls, or ceilings, or in the HVAC system) should be remedied. If personnel remain symptomatic after remediation, air sampling may be appropriate, but the industrial hygienist should keep in mind that false negative results are quite possible and should be

interpreted with caution. Other exceptions for which bioaerosol sampling may be appropriate include epidemiological investigations, research studies, or if situations indicated by an occupational physician and/or immunologist (Weaver *et al.*, 1996).

2.23 Measurement of Airborne Microbes

Eight papers were found in scientific journals and conference proceedings in which measurements of airborne bacteria were reported (Bates and Mahaffy, 1996; Gallup, *et al.*, 1993; Maroni, *et al.*, 1993 and Meklin, *et al.*, 1996). Typically, only one or a few schools were investigated often with no identification of bacterial species. The reported range varies over two orders of magnitude, from 7 colony forming units (cfu)/m^3 to 19,500cfu/m^3. Occupant density and ventilation rates, strong determinants of total levels of airborne bacteria, were not reported in these studies. When identifications were made, the most commonly observed bacteria in the literature, were *Micrococcus* and *Bacillus* species and pigmented gram negative rods such as *Flavobacterium* species, and coryneforms. Maroni, *et al*., (1993) reported finding principally species *Staphylococcus* (85% of samples), *Micrococcus* (72% of samples) and D*ifteroides* (70% of samples) in Italian classrooms. Mouilleseux, *et al.*, (1993) reported finding *Staphylococcus aureus* (33%), Enterobacteria including *Escherichia coli* (6%); *Streptococcus D (*50.6 %). Gallup, *et al.*, (1993) noted that increased counts of "normal" bacteria were observed with increased dust levels, activity, and occupancy.

Total airborne fungi in schools were reported in ten papers (Bates and Mahaffy, 1996; Maroni, *et al.*, 1993; Meklin, *et al.*, 1996 and Smedje, et al., 1996). Bates and Mahaffy (1996) investigated airborne and surface fungi in 13 classrooms in 6 Florida schools. Health complaints included stuffy sinuses, sore throats, respiratory illnesses, lethargy, itchy eyes and runny noses. Concentrations were >1,000 CFU/m^3 in one complaint and one non-complaint room, while in all other classrooms they were <700 CFU/m^3. Concentrations were generally higher in the outdoor air. Average and maximum total viable molds measured in 96 classrooms in 38 randomly selected Swedish schools were 500 CFU/m^3 and 4,500 CFU/m3, respectively (Smedje, *et al.* 1996). The most prevalent microfungal genera were *Penicillium, Fusarium, Alternaria and Cladosporium*.

Petushkova and Kandyba, 1999 studied airborne microflora of the Moscow Kremlin Cathedrals. Gravitational (sedimentation) methodology was used in this study. Concentration of bacterial flora ranged from 0.13–0.43 cfu/cm^2 for the central part of the cathedral and from 0.38–1.28 viable cfu/cm^2 for the crypt. The highest number of bacteria was found near the air-conditioning system. Among the isolated bacteria, *Micrococcus* spp. and *Rhodococcus* spp. were predominant, but species from *Pseudomonas*, *Xanthomonas*, *Alcaligenes*, *Arthrobacter*, *Flavobacterium*, *Corynebacterium*, *Cellulomonas*, *Bacillus*, *Streptomyces*, *Spirillum*, *Cytophaga*, and myxo-bacteria genera were also isolated. Fungi concentration ranged from 0.04–0.25 cfu/cm^2 in the central part of building and from 0.2–0.67 cfu/cm^2 in the crypt. The species from genera *Acremonium*, *Penicillium*, *Chrysosporium*, *Verticillium*, *Aspergillus*, *Gilmaniella*, *Geotrichum*, *Cladosporium*, and yeasts were the most frequently isolated.

2.24 Guidelines for Microbiological Quality of Indoor Air

There have been no Polish standards or guidelines for microbiological quality of indoor air. Furthermore, there isn't any European Union directive addressing this; therefore, it is assumed to be based on particular European countries' requirements and scientific propositions (Gorny. 2004). According to current Swedish requirements the number of 500 colony-forming units (cfu) of bacteria and 300 cfu of fungal spores in 1 m^3 can be accepted in an indoor environment (Abel *et al.*, 2002). In 2001, the American Industrial Hygiene Association (AIHA) published a proposition of guidelines for the amount of airborne microorganism in different indoor environments, for example residential and commercial buildings. Guideline for residential buildings is less than 500cfu/m^3 and for commercial buildings is less than 250cfu/m^3. Other countries' requirements are similar. In Brazil total amount of airborne microorganisms (especially fungi) in enclosed space shouldn't exceed 750cfu/m^3 (Neto *et al.*, 2000). In Hong Kong good microbiological class air should include less than 1000cfu/m^3 of bacteria. In Singapore requirements for indoor air quality strictly describe concentration of bacteria on the maximum level of 500cfu/m^3 (Obbard and Fang, 2003). The recommended maximum limits are: 1000 CFUs/m^3 for the total number of bio-aerosol particles set by the National Institute of Occupational Safety and Health (NIOSH); 1000 cfu/m^3 set by the American Conference of Governmental

Industrial Hygienists (ACGIH) with the culturable count for total bacteria not to exceed 500 CFUs/m^3 (Cox and Wathes, 1995; Jensen and Schafer, 1998).

2.25 Summary of Literature review

Acute respiratory infections (ARIs) are a major cause of hospital admission and death among Nigerian children with pneumonia accounting for 20% of death among children under-five. Several factors such as overcrowding, poor housing, poor sanitation, nutrition and indoor air pollution have been reported to contribute to the acquisition of ARIs among children under-five. Although there is a dearth of information from literature on how the quality of the indoor environment particularly, the microflora predisposes under-five children to respiratory infections in Nigeria. Few available data on risk factors for ARIs were derived from studies carried out mainly in developed countries such as America and the United Kingdom and other developing countries such as Kenya, South Africa etc. Many of the studies are not generalizable due to limitation in scope and housing policy, reliance on quantitative data and inability to fully capture other environmentally specific factors that might have contributed to the infection.

Indoor air quality is of major concern particularly in Nigeria. The mere presence of people in a building or residence can significantly alter indoor air quality. Although, presently, indoor air quality is only a problem when building occupants reports symptoms. An estimated growing number of indoor air quality problems due to population growth in recent years have been reported. There is evidence that low ventilation rates and other building characteristics can result to increase incidence of respiratory diseases.

Bioaerosols represent all biologically originated aerosols which can be found both indoor and outdoor. The most important are the airborne bacteria and fungi. Humidity, human presence, type of activities and air circulation determines the level and species of airborne microflora in environment. Bacteria in indoor environment can originate from the outdoor air or from antropogenic sources such as building occupants and their activities. Specific activities such as talking, sneezing, coughing, walking, washing and toilet flushing can generate airborne biological particulate matter.

There is presently no universally acceptable airborne microbial exposure standard. Therefore, it is assumed to be based on particular European countries' requirement and specific propositions. The American Industrial Hygiene Association (AIHA) proposed an acceptable airborne microbial exposure standard for different indoor environments, such as residential and commercial buildings. Other countries' requirements such as Singapore are similar. There is no data from the Nigerian Federation on acceptable limit of exposure to indoor airborne microorganisms.

Some of the key concepts or variables derived from the literature include the following: housing standards, principles of meteorological measurement and airborne microbial evaluation.

CHAPTER THREE

METHODOLOGY

3.1 Study Design

The study design was a prospective case-control comprising on-site observations, indoor air quality monitoring for meteorological characteristics and microbial burden and questionnaire administration.

3.2 Study Site

Two specialist hospitals were purposively selected viz Oni Memorial Children's Hospital and Otunba Tunwase Emergency Clinic, University College Hospital, both located in the city of Ibadan.

3.3 Study Area

The study was carried out in Ibadan, which is located in South-west Nigeria. It is about 78 miles from Lagos and is a prominent transit point between the coastal region and the areas to the north. Its population is estimated to be, about 2,550,593 according to 2006 census and is reputed to be the largest indigenous city in Africa, south of the Sahara. The principal inhabitants of the city are the Yorubas. The city is situated at an altitude ranging from 152 to 213 metres above sea level in a tropical rain forest. The wet season of the year runs from June through October (though occasional showers occur as early as March). In the wet season, temperature ranges from 21°C to 31°C, rainfall from 8.4cm to 18.8cm and humidity from 54% to 77%. In the dry season temperature ranges from 20°C to 31°C, rainfall from 1cm to 4.4cm and humidity from 43% to 83%.

3.4 Study Population

Eligible participants were children more than one month but less than five years of age who present with signs and symptoms of ARI in the two selected health facilities; Otunba Tunwase Children Emergency Ward, University College Hospital and Oni Memorial Children Hospital. A similar number of 'controls' were also consecutively selected from

children with infection which are of similar severity to ARI but unrelated to the exposure of interest.

3.4.1 Oni-Memorial Children Hospital

Oni Memorial Children's Hospital (OMCH), Ibadan, Oyo State, Nigeria is in the south west of Nigeria and was established in 1985 as a secondary health institution, and is the only state government owned children's hospital which provides health care services exclusively for children 12 years and below in Oyo State.

3.4.2 Otunba Tunwase Children's Emergency Ward

The Otunba Tunwase Children's Emergency Ward of Department of Paediatrics, University College Hospital, Ibadan is a tertiary health institution and a major referral centre in Southwest Nigeria. The emergency ward serves all socioeconomic classes of urban population, and a sizable proportion of those who attend and are seen in the ward (although unreferred) usually come late and in a very critical state after various forms of treatment at home that had failed.

3.5 Eligibility Criteria for study participants

3.5.1 Inclusion criteria

- **Cases**

1) children above 1 month but less than 5 years of age.
2) permanent residents of Ibadan.
3) children who had cough with or without fast breathing and of less than 30 days of illness.

- **Controls**

1) children above 1 month but less than 5 years of age
2) permanent residents of Ibadan.
3) consulted the selected hospital for non-acute respiratory complaint such as diarrhoea and malaria

3.5.2 Exclusion criteria

- **Cases**

1) children below 1 month and greater than five years of age

2) children with ARI that also has other systemic illnesses such as measles, symptomatic congenital heart disease, congenital malformation or AIDS.

- **Controls**

1) children below 1 month and greater than five years of age
2) children with complaints of an ARI in less than 30 days of illness
3) belonging to the same household as the case
4) children that presents symptoms of measles or pertusis in the preceding ten days.

3.6 Sample Size Determination

The sample size for the study was calculated using the formula described by Bambgoye, 2006:

$$N = \frac{2\,(V + U)^2 \;X\; P\,(1 - P)}{(P_1 - P_0)^2}$$

where:

V = Probability of type I error, 1.68 at α =0.1

U = Probability of type II error, 0.84 at β =0.80

P_0 = 0.73, which is the proportion of the exposure factor among the controls (from proportion of controls less exposed to indoor air pollution from cooking and heating with solid fuel = 0.27). Sumi *et al*., 2002, Kirk and Smith, 2006.

OR = 1.9 which is the Odds ratio of ARI among those exposed to indoor air pollution. (Arrianne *et al*., 2007)

P_1 = the proportion of the exposure factor among the cases = $\frac{OR\,(P_0)}{1 + P_0\,(OR - 1)}$

and $P = \frac{P_0 + P_1}{2}$

Therefore, N = 200

10% of 200 was added to control for non-response.

The resulting sample size for cases and controls was 220 participants respectively.

3.7 Sampling Procedure

A two-phase sampling technique was employed for this study. In the first phase, 220 cases and controls each were recruited consecutively from the selected hospitals. Out of the 220 cases and controls recruited, only 66 cases and controls each gave consent to be followed home for indoor air assessment. Therefore, in the second phase, 66 consented cases and controls each were followed-up for household and environmental assessment. The first phase involved the administration of questionnaire (survey) based on the inclusion criteria. The second phase involved household survey as well as air quality monitoring comprising meteorological parameters and airborne microbial flora of houses among selected cases and controls (see table 3.2 for detail).

Case selection: Children in the age group of 1 month to 5 years admitted with acute respiratory infection during the study period were enrolled in the study as cases. A case of ARI is defined as "presence of cough with fast breathing rate of more than 60/min in less than 2 mth of age, more than 50/min in 2 mth to 12 mth of age and more than 40/min in 12 mth to 5 yr of age, the duration of illness being less than 30 days" (WHO, 2002). The presence of lower chest wall indrawing was taken as evidence of severe pneumonia.

Control selection: Controls that were included in the study comprise children 1 month to 5 years of age who were admitted into the same hospital as the cases for non respiratory complaints such as diarrhea and malaria during the study period. In order to avoid any gross imbalance in the case distribution, the control were group matched to cases according to age group (1-6, 7-12, 13-18, 19-24, 25-30 etc). A wide age group was selected so that matching could be easily achieved. This approach does not preclude the analysis of risk associated with smaller age interval.

3.8 Method and Instrument for Data Collection

The procedure for data collection was divided into three phases:

3.8.1 The Pre-monitoring Phase

This involved the administration of questionnaire on an interviewer-administered basis. The semi-structured questionnaire (see appendix 1) was divided into eight (8) sections namely:

SECTION A; demographic information: This section described the characteristics of the respondents in terms of some independent variables such as: age, sex, ethnicity, educational status, occupational history of mothers etc. These independent variables can not change and in most times affect the outcome variable which is Acute Respiratory Infection.

SECTION B; Child's characteristics: This section described the characteristics of the child in terms of the age, sex, birth order, length of time breastfed and health status.

SECTION C; knowledge information: This section assessed the respondent's level of knowledge as regards ARI associated with exposure to indoor environment since a lack of knowledge is identified as one of the barriers to change (Grol *et al*., 2004).

SECTION D; attitude of mother/caregivers: The attitude towards the risk associated with biocontaminants from indoor environment was documented as this might be a motivating factor to change the behaviour of every household. Likert scale was used to analyze the result obtained.

SECTION E; household characteristics: This section assessed the housing characteristics in terms of the age of the building, total number of rooms and the total number of occupants.

SECTION F; indoor exposure experience: The purpose of this section was to collect information on the different indoor exposure sources such as sanitation activities, ventilation, presence of pet, smoking, cooking method etc which could contribute to the acquisition of ARI in children under-five.

SECTION G; outdoor exposure experience: data on the school/daycare centre attended and other outdoor exposure was collected in order to control for certain confounders that may be associated with ARI.

SECTION H; health information: This section was aimed at determining the child's susceptibility, past illnesses, parental health status and previous experience of ARI in the entire family.

3.8.1.1 Validity and Reliability of Instrument

The questionnaire was pre-tested at Adeoyo Maternity Hospital, Yemetu, Ibadan. During the pretest the questionnaire were administered to 10% of the sample size i.e. 44 respondents. After the pretest, the appropriate modifications based on the pretest outcome, was effected on the instruments. The Cronbach's Alpha method was used to determine the reliability of the questionnaire. An Alpha coefficient of 0.5 and above is indicative of the reliability of the questionnaire.

Knowledge Information Section: The knowledge information section comprised of 13 questions and they were scored thus:

Total knowledge scale: 13

Maximum score: 1 and Minimum score: 0

Adequate Knowledge: $\geq 50^{th}$ percentile

Inadequate Knowledge: $< 50^{th}$ percentile

Attitude Information Section: The perception information section comprised of 9 questions and they were scored thus:

Total perception scale: 9

Maximum score: 1 and Minimum score: 0

Positive perception: $\geq 50^{th}$ percentile

Negative perception: $< 50^{th}$ percentile

3.8.2 The Monitoring Phase

This phase involved onsite observations of houses among cases and controls in addition to indoor environmental monitoring which comprised assessment of indoor meteorological conditions and airborne microbial load.

3.8.2.1 Determination of Sampling Coordinates

Plate 3.1 shows a hand-held, battery-powered factory calibrated gamin GPS which was used to determine the geographic coordinates of houses visited among cases and controls. The GPS is a satellite- based navigation system that sends and receives radio signal and provides information on location, velocity and time, 24 hours a day, in any weather condition anywhere in the world. The coordinates of the locations usually appear on the

display screen of the GPS after it acquires signals from the satellite in space. The GPS was obtained from the Department of Epidemiology, Medical Statistics and Environmental Health, College of Medicine University of Ibadan.

However, table 3.1 shows the classification of houses visited among cases and controls into high risk (HR) and low risk (LR) based on the total indoor airborne microbial load as compared with the American Industrial Hygiene Association (AIHA) guideline limit for total airborne microbial count in an indoor enivironment. Coordinates of these houses was used to determine the high risk and low risk areas in Ibadan.

Table 3.1: ARI risk category of houses

Risk Category	Criteria
High Risk Areas (HRA)	>500cfu/m³
Low Risk Areas (LRA)	<500cfu/m³

Plate 3.1 GPS Facility

3.8.2.2 Household survey/Indoor Environmental Monitoring

Table 3.2 shows the sample size distribution among cases and controls. Only 30% of cases and controls recruited were followed home for indoor environmental monitoring.

Table 3.2: Sample size distribution among cases and controls

Sample	Case	Control	Total
Sample size	220	220	440
Questionnaire Administration	220	220	440
Household Survey (30% of sample size)/Indoor Air Quality Parameters	66	66	132

3.8.2.3 Direct (onsite) Observation

An observational checklist was used to assess housing characteristics among selected cases and controls (see appendix 2). The housing characteristics included:

- General housing status
- Building age and type
- Materials used
- Presence or absence of ventilators
- The measurement of entry point (windows and doors)
- The indoor pollution sources and type of cooking facility
- Outdoor sources of indoor pollution
- Waste management practice

The housing quality scoring was based on positive option (1) for presence of essential facilities, and zero (0) for absence according to the housing quality standard by the U.S Department of Housing and Urban Development (HUD), 1999.

3.8.2.4 Indoor Air Quality Monitoring

Temperature (ºC) and relative humidity (%) of the indoor (living room, bedroom and kitchen) and outdoor environments were measured using a multi-tester N21FR and categorized according to the scale of measurement used by Wolkoff and Kjaergaard, (2007); Ahmad and Mahyuddin, (2010).

The 5-in-1 multi-function environment meter as shown in plate 3.2 has been designed to combine the functions of sound meter, light meter, humidity meter, thermometer and electrical multimeter into one easy to use instrument with scores of practical applications in schools, offices, factories, homes etc.

Plate 3.2: A 5-in-1 Multi-tester

3.9 Media Preparations

3.9.1 Nutrient Agar (NA)

A 12.6g of NA powder was weighed and suspended in 450ml sterile water contained in 800ml beaker. Mixture was stirred gently on a hotplate-stirrer and then heated with vigorous stirring and autoclaved at 121ºC for 15 minutes. The beaker was then removed from the stirrer hotplate using a magnet, and covered with aluminum foil. Mixture was allowed to cool to 50°C and poured into clean Petri dishes.

3.9.2 Potato dextrose Agar (PDA)

A 39g of PDA powder was weighed and suspended in 1litre of sterile water. The mixture was then heated with frequent agitation and boiled for 1 minute to completely dissolve the medium. Mixture was then autoclaved using a portable autoclave as shown in plate 3.5 at 121^{o} C for 15minutes. Prepared agar was then allowed to cool and poured into sterile Petri dishes.

Plate 3.3: A portable Laboratory autoclave

3.10 Microbial Assessment

Air samples for culturable microorganisms were collected using a Petri plate non-volumetric method for a sampling duration of 10mins for both indoor and outdoor air. Sampling was conducted from January to June, 2010. The microbiological agents were trapped by exposing prepared Petri dishes **(**as shown in plate 3.4) containing NA and PDA in "the livingroom, the kitchen and the bedroom" for indoor sampling and then at three points outside the building for the outdoor sampling. All samples were collected in the daytime at about 1.5 m height at the center of the room for indoor air samples and at least 2 m away from the building for outdoor samples (Mentes *et al*., 2009).

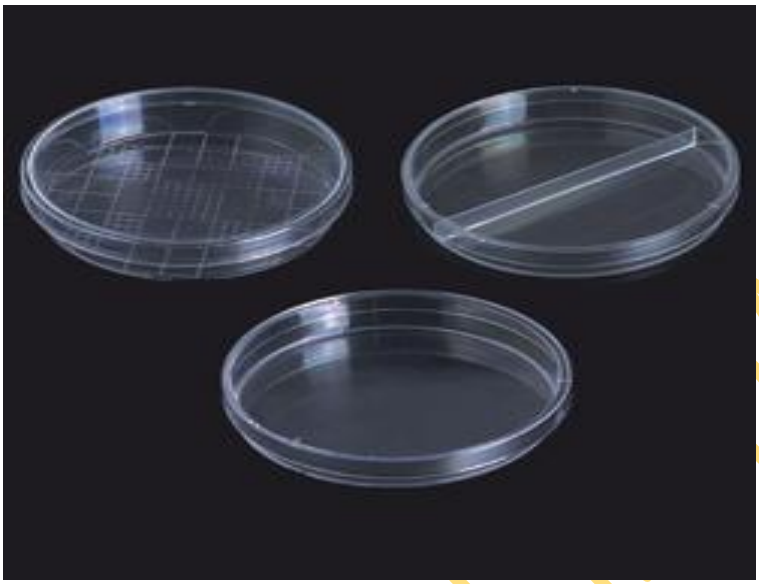


Plate 3.4: Petri plates used for culturing microorganisms

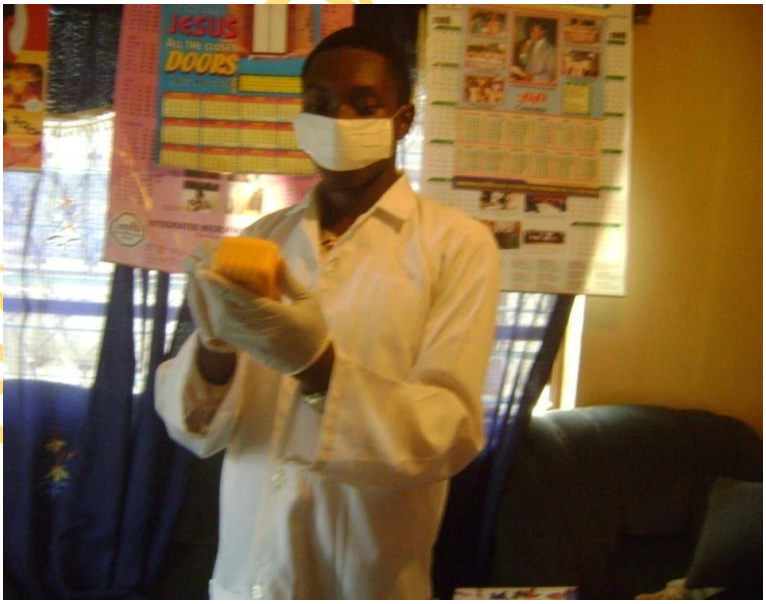


Plate 3.5: Indoor air quality monitoring using 5-in-1 Multi Tester

3.10.1 Sample Preservation and Incubation

Microbial samples collected were arranged in a ice pack and transferred to the laboratory within 24 hours before incubation. Cultures on NA were incubated using a microbiological incubator (Plate 3.6) at 35 ± 2ºC for 48 hours while PDA plates were incubated at room temperatures for 5 days prior to counting.

Plate 3.6: A microbiological Incubator

3.11 Frequency of measurement

Figure 3.6 shows the sampling points of houses visited among cases and controls. The different houses were divided into 6 sampling points which include the living room (LR), the bedroom (BR) and the kitchen (KT) for indoor samples and three (A, B and C) outdoor collection points. Table 3.3 shows the frequency of sampling. The bacteria and fungal samples were collected once from each sampling point during the day time. All meteorological measurements were carried out simultaneously with the airborne microbial collection (see fig 3.6 and table 3.3 for details).

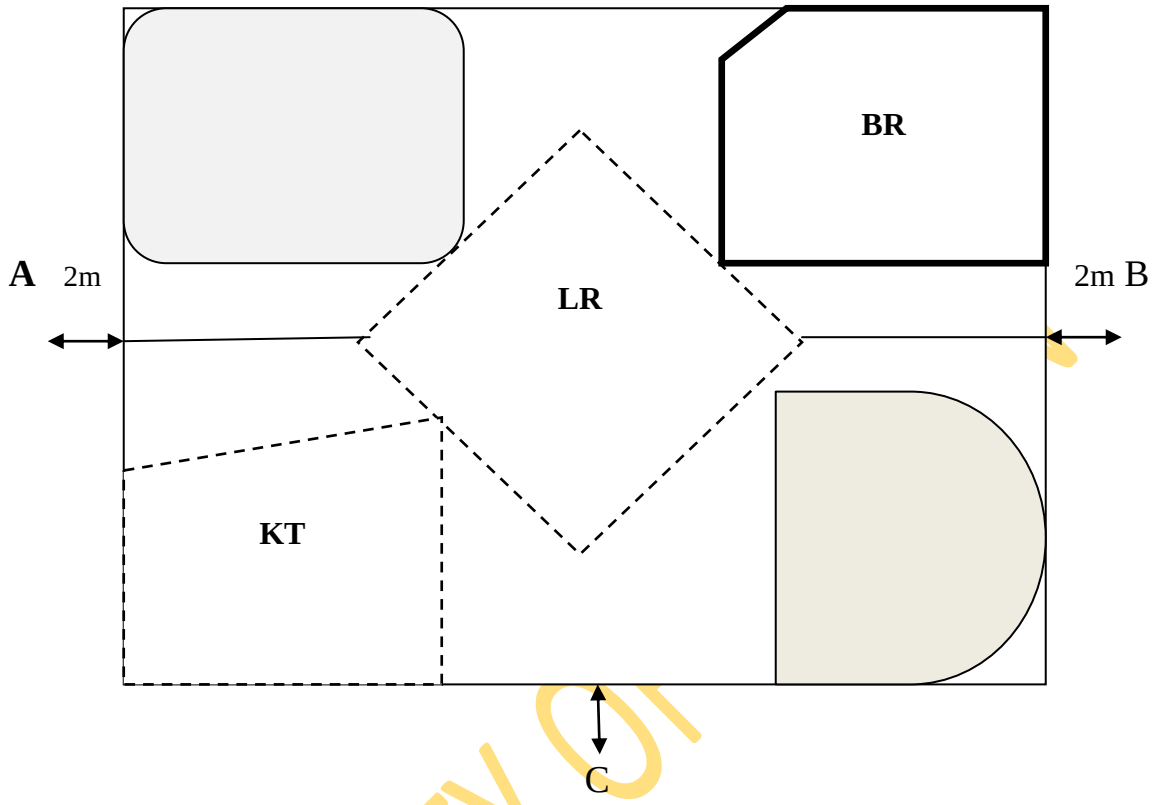


Fig 3.6: Diagram showing the indoor and outdoor sampling points. LR-living room, BR-bedroom, KT-kitchen, A-outdoor point 1, B- outdoor point 2, C-outdoor point 3

Table 3.3: Frequency of indoor and outdoor sampling

Measurement Type/ Parameter	**Number of indoor Locations**	**Number of measurements per indoor location**			**Number of outdoor measurements**			**Total number of measurements**
		Day 1	**Day 2**	**Day 3**	**Day 1**	**Day 2**	**Day 3**	
Mobile monitoring								
Temperature	3	-	1	-	-	3	-	6
Relative humidity	3	-	1	-	-	3	-	6
Bioaerosol Bacteria	3	-	1	-	-	3	-	6
Bioaerosol Fungi	3	-	1	-	-	3	-	6

3.12 The Post-monitoring Phase

3.12.1 Microbial Evaluation

The total number of colony forming units (cfu) were enumerated and converted to organisms per plate by counting the number of growth on each plate. Total number of mesophilic aerobic bacteria, yeast and moulds in the air of selected rooms was determined using Koch sedimentation method according to Polish Standard PN 89/Z-04008/08. Air microorganisms were settled gravitationally directly on the Petri plates filled with nutrient media and potato dextrose agar and exposed in sampling points for a period of time. The number of microorganisms expressed as CFU/ m^3 was estimated according to the equation:

$$CFU/m^3 = a \cdot 10000/p \cdot t \cdot 0.2$$

Where:

a – the number of colonies on the Petri dish

p – the surface of the Petri dish

t – the time of Petri dish exposure

3.12.2 Microbial Identification

Bacterial identification was based primarily on morphology, Gram staining, growth characteristic and culture characteristics. Some commonly found bacteria were identified at the genus level using standard method (Olutiyola *et al*., 1991).

Light microscope was used to determine the colonial features and the morphological structures of the fungi. The determination of the morphological structures of fungi was carried out by on material mounted on a glass slide and stained with lactophenol dye. Fungi isolated were identified to genus level based on micromorphology.

3.12.3 Staining

A gram staining technique that consists of four components**:** a primary stain (Crystal violet, methyl violet or Gentian violet)**,** mordant (Gram's Iodine)**,** decolourizer (ethyl alcohol, acetone or 1:1 ethanol-acetone mixture)**,** counter stain (Dilute carbol fuchsin,

safranin or neutral red) was employed for bacterial staining into gram positive and gram negative bacteria. On the other hand, fungi colonies were classified based on spore morphology or colony morphology.

3.12.4 Biochemical Test

Few biochemical tests were applied to each bacteria and fungi isolates according to Olutiyola *et al.*, 1991.

3.13 Statistical Analysis and Data Management

3.13.1 Data Collection Process

A risk map was developed from the survey using coordinates from the GPS with Geographical Information System software of Goggle. Selected houses were properly numbered and the air quality readings were recorded accordingly. Information collected using questionnaire were checked for completeness and accuracy. Data were imputed into the computer using the SPSS software version 15. Frequency counts was then run to detect missing cases while the data undergo cleaning.

3.13.2 Statistical Analysis

Descriptive statistics (proportion, means, standard deviation, bar graphs and frequency tables), were used to analyse and summarize the data. Knowledge and attitude questions were analysed using percentiles. Knowledge and attitude score of mothers among cases and controls below the 50^{th} percentile were grouped into inadequate knowledge while greater than 50^{th} percentile was grouped into adequate knowledge. The results are presented using tables.

T-test was used to compare differences in means values of total bacterial and fungal count between cases and controls. Total airborne bacteria and fungi count were summarized usind descriptive statistics (proportions, means, standard deviation, bar graphs, and frequency tables).

Inferential statistics Chi-square (X^2) was used to test for association between qualitative variables such as knowledge, attitude between cases and controls. While simple logistic regression was used to control for any confounding effect related to age, sex, parental

occupation and education. Odds ratios and their 95% confidence intervals were also computed. Sperman's correlation analyses were performed to determine the relationships between environmental parameters and culturable bacteria and fungal counts isolated.

CHAPTER FOUR

RESULTS

This chapter presents the results of the observational checklist, indoor and outdoor air meteorology (air temperature, relative humidity), indoor and outdoor airborne microbial (bacterial and fungal) assessment and questionnaire survey.

4.1 General Housing Conditions among cases and controls

Table 4.1 shows the housing quality among cases and controls. A large number of cases 43 (65.2%) than controls 28 (42.4%) (OR=2.5; CI= 1.3-5.1, $p<0.05$) resides in poor housing conditions. Table 4.2 and Fig 4.1 – 4.5 highlights some of the conditions of houses visited among cases and controls. A higher proportion 23 (34.8%) of houses among cases were found to lack sanitary facility compared to controls 11 (16.7%). Majority of cases 21 (31.8%) than controls 12 (17.2%) have no separate space/room for cooking. A higher proportion of houses of cases 44 (66.8%) and controls 38 (57.3%) had inadequate system of ventilation in terms of the number and size of windows per room. Damp roof was observed in 36 (54.5%) and 24 (36.3%) of houses visited among cases and controls respectively. Algal growth on walls was observed in a higher proportion of houses among cases 22 (33.3%) than controls 8 (12.1%). Majority of cases 50 (54.0%) than controls 43 (46.0%) were observed to practice open burning of refuse as a means of waste management. A large proportion of cases 36 (53.5%) than controls 17 (28.8%) were found to reside in a high density area. Sanitary condition, drainage system, ventilation, waste management, cooking practices etc were found to be more inadequate among houses of cases as compared to controls (see table 4.2 for details).

Table 4.1: Housing Quality Status among cases and controls

Category	Range of scores			df	X^2	P-value
	Poor (2-10)	Good (11-18)	Total			
Cases	43 (65.2%)	23 (34.8%)	66 (100%)	1	2.5	<0.05
Controls	28 (42.4%)	38 (57.6%)	66 (100%)			

Table 4.2: Housing Characteristics among cases and controls

Variable/Indicator	Cases (n = 66)	Controls (n = 66)	Total (n = 132)
Sanitary Condition			
Presence of feaces around facilities	18 (27.3)	6 (9.0)	24 (36.4)
Water spills around facilities	36 (54.0)	13 (19.7)	49 (37.1)
Dry and clean	15 (22.7)	38 (57.6)	53 (40.2)
No Sanitary facility	23 (34.8)	11 (16.7)	34 (25.8)
Ventilation			
1 window/room	44 (66.8)	38 (57.3)	82 (62.1)
2 windows /room	15 (22.7)	28 (42.4)	43 (32.6)
>2 windows /room	2 (3.0)	11 (16.7)	13 (9.8)
Drainage System			
Presence of organic waste	43 (65.2)	26 (39.4)	69 (52.3)
Stagnant water in drains	38 (57.6)	13 (19.7)	51 (38.6)
Well channelled drains	23 (34.8)	38 (57.6)	61 (46.2)
Cooking Space			
Absence of a kitchen	21 (31.8)	12 (17.2)	43 (32.6)
1 window in the kitchen	37 (56.1)	21 (31.8)	75 (58.2)
2 windows in the kitchen	8 (12.1)	33 (50.0)	38 (28.8)

Table 4.3: Summary of Housing Characteristics among cases and controls

Variables	Cases (n = 66)	Controls (n = 66)
Condition of Sanitary facilities	-	+
Building status	+	+
Drainage System	-	+
Waste management	-	+
Ventilation	-	+
Condition of cooking space	-	+
Condition of outdoor environment	+	+

Indicator:

Ventilation
- 1 window = -
- 2 windows = +
- >2 windows = ++

Sanitary Condition
- Presence of feaces around facilities = -
- Water spills only without faeces = +
- Dry and clean = ++

Building Status
- Presence of cracks on the walls/floor = -
- Not Cemented/Plastered = -
- Damp/moist walls with algal growth = -
- Water damage = -

Cooking space
- Absence of a kitchen = -
- 1 window in the kitchen = -
- 2 windows in the kitchen = ++

Waste Management
- Absence of waste bin = -
- Flies around waste bin = -
- Waste bin overflow = -
- Open burning of waste = -
- Waste bin covered = +

Drainage
- Presence of organic/inorganic waste = -
- Stagnant water = -
- Well channelled drains= ++

Key: ++ = Very adequate + = Fairly Adequate
- = Inadequate

Plate 4.1: Housing condition in Oje, Ibadan

Plate 4.2: Indoor condition of a house in Bere, Ibadan

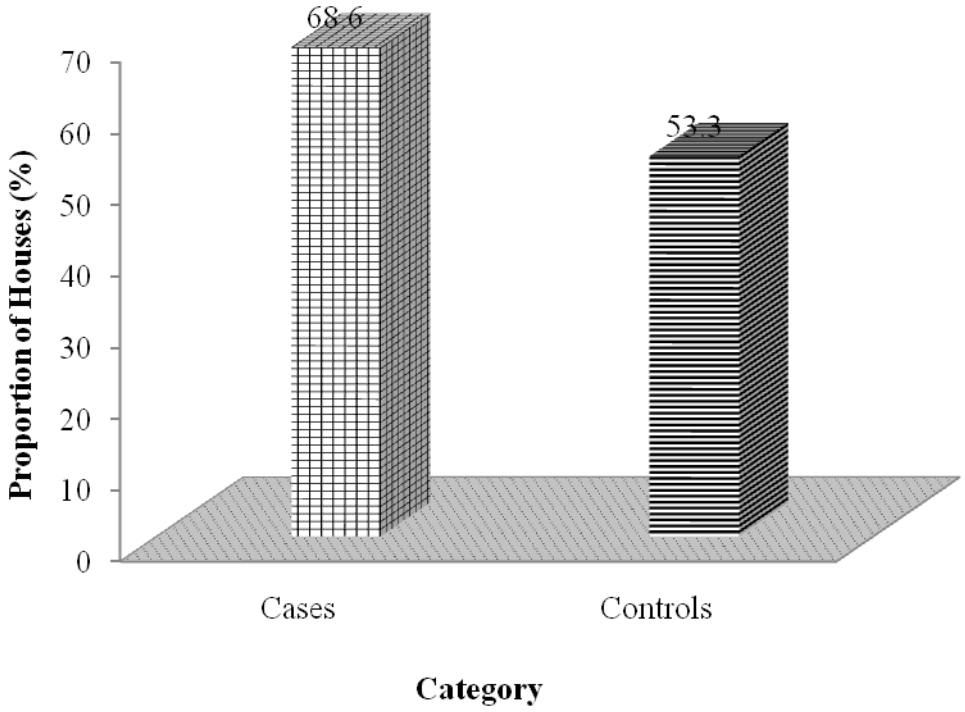


Fig 4.1: Proportion of houses with inadequate ventilation

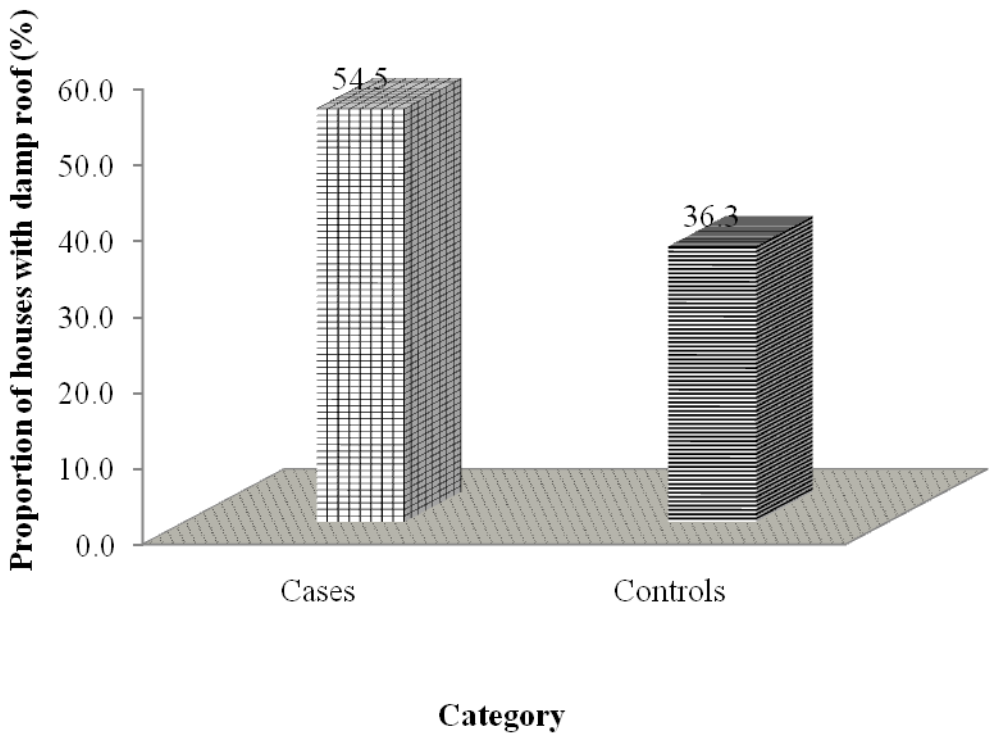


Fig 4.2: Proportion of houses with damp roof

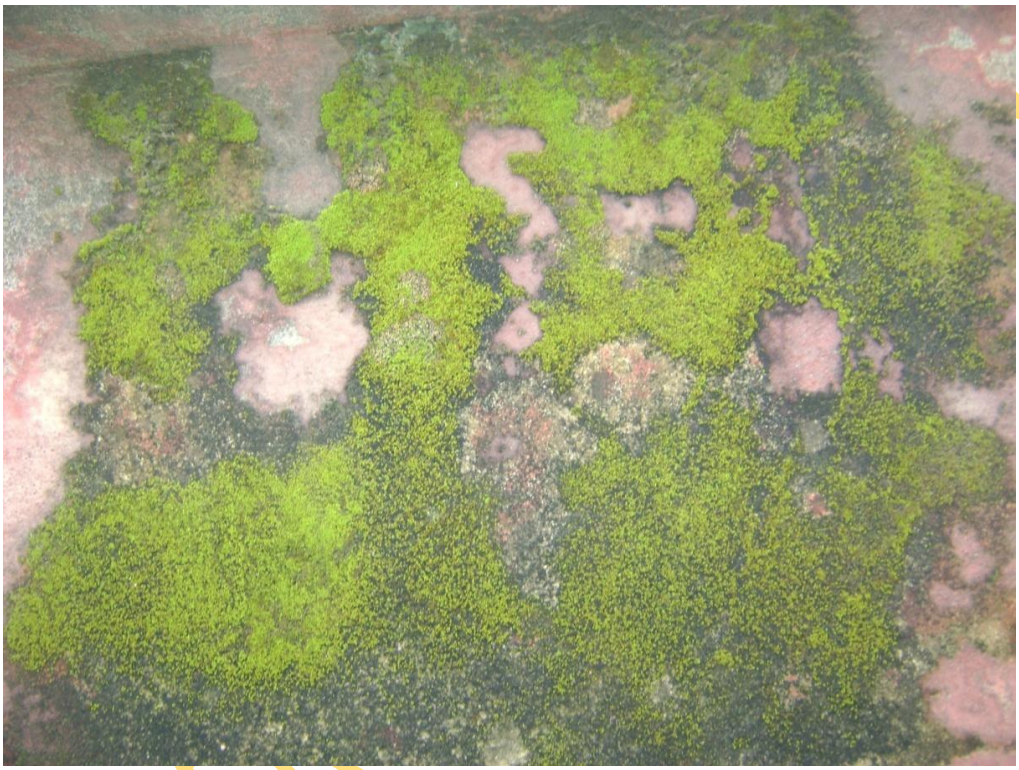


Plate 4.3: Algal growth on the wall of a house in Bere, Ibadan

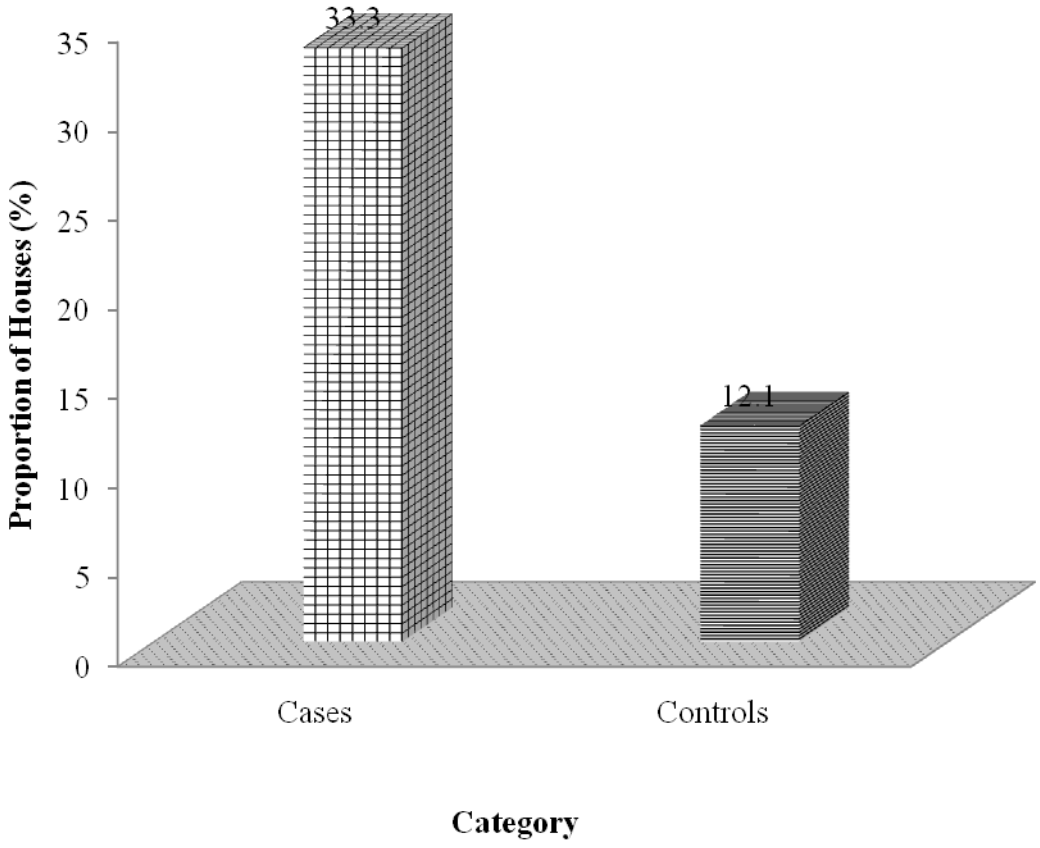


Fig 4.3: Proportion of houses with algal growth on walls

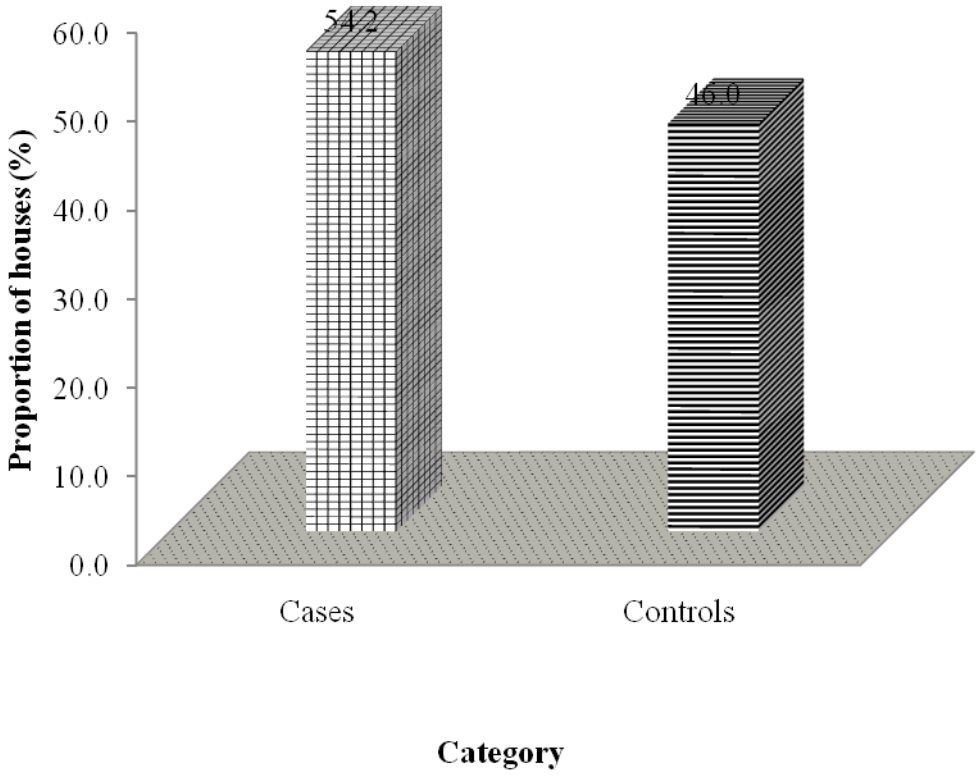


Fig 4.4: Proportion of respondents that practice open burning of refuse

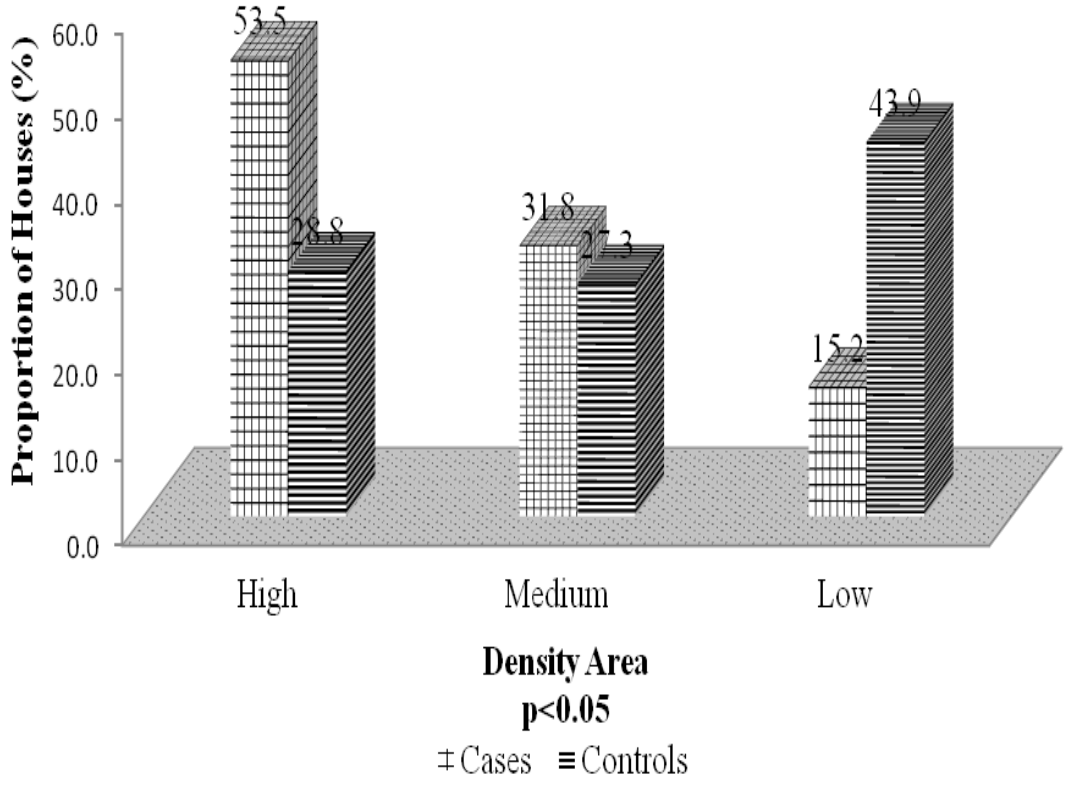


Fig 4.5: Distribution of houses among cases and controls according to housing densities

4.2 ARI Risk map for the study area

Plate 4.4 explains the ARI risk map for Ibadan. According to the map, risk of ARI was categorized into low (<500cfu/m^3) and high (>500cfu/m^3) based on the TBC in the indoor environment of houses visited among cases and controls as compared with the American Industrial Hygiene Association (AIHA) guideline limit for an indoor environment. Therfore, houses with a TBC of <500cfu/m^3 were categorized as low risk while houses with >500cfu/m^3 were categorized as high risk. Houses with low risk were indicated with green place-mark on the map while high risk houses were indicated with a red place-mark on the map (see the key for details). The longitude, latitude and elevation of houses visited among cases and controls are provided in appendix 8 amd 9.

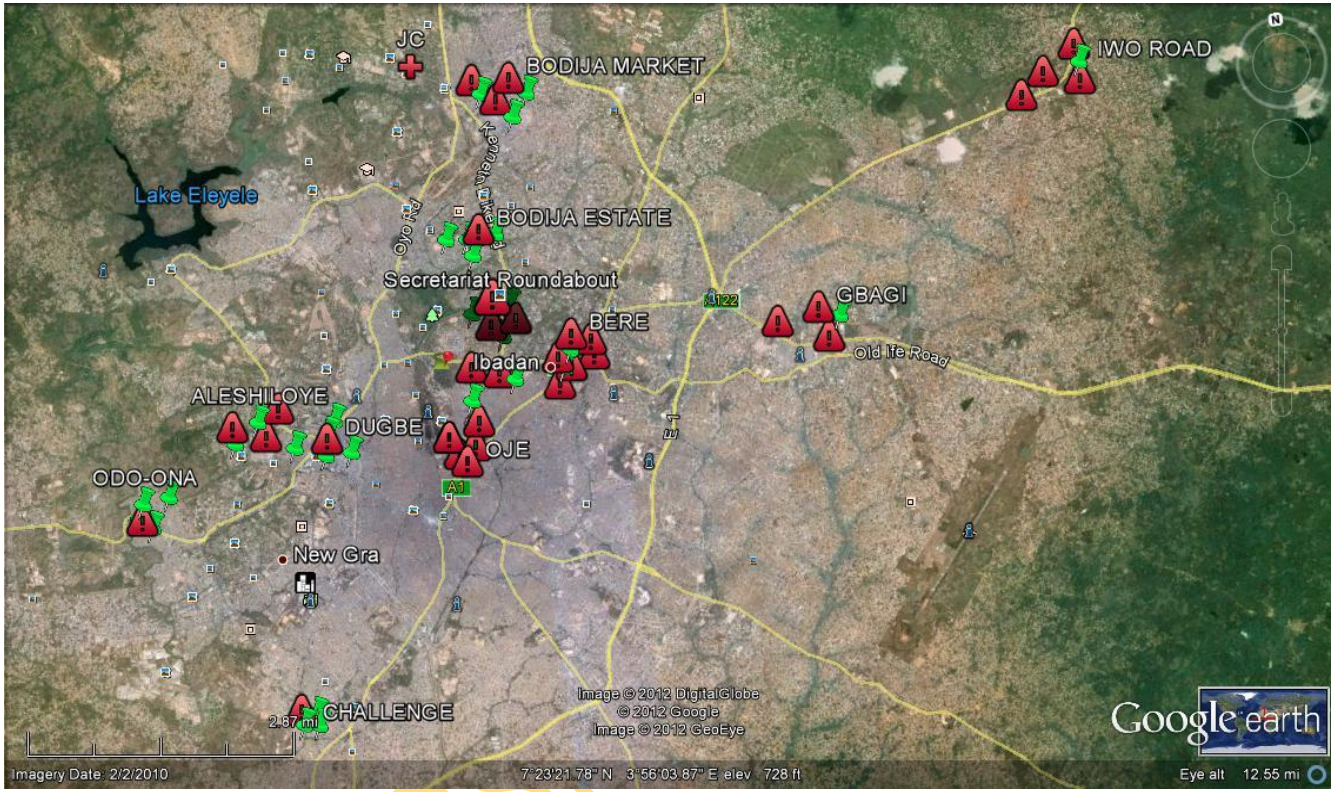


Plate 4.4: Risk Map for houses visited among cases and controls

Risk Category	Range (AIHA Guideline Limit)	Areas	Risk Symbol
High Risk Areas	>500cfu/m³	Bere, Oje, Gbagi, Agodi, Aleshinloye	
Low Risk Areas	<500cfu/m³	Bodija, Odo-Ona, Ekotedo, Challenge	

4.3 Characteristics of residential apartments occupied by cases and controls

Table 4.4 highlights the characteristics of buildings occupied by cases and controls. Fig 4.6 and 4.7 shows that a little above half of cases 120 (54.5%) and less than half of controls 97 (43.9%) reside in bungalows. In addition, one-third of cases 70 (31.8%) and about one-tenth of controls 20 (9.1%) reside in mud houses. Table 4.5 revealed that three-quarter 159 (72.3%) of cases and about two-third 120 (54.5%) of controls live in a face-to-face apartment while below half of cases 61 (27.4%) and controls 100 (44.5%) reside in self contain apartment (OR=2.2, C.I=1.5-3.2, $p<0.05$). Less cases 112 (51.4) as compared to controls 169 (78.8%) reported greater than two windows per room ($p<0.05$). About one-third of cases 57 (25.9%) and one-tenth of controls 21 (9.5%) use air conditioning system in the house. Majority of cases 92 (41.8%) than controls 64 (29.1%) reported heavy traffic close to the house (OR = 1.7; CI = 1.2 – 2.6, $p<0.05$).

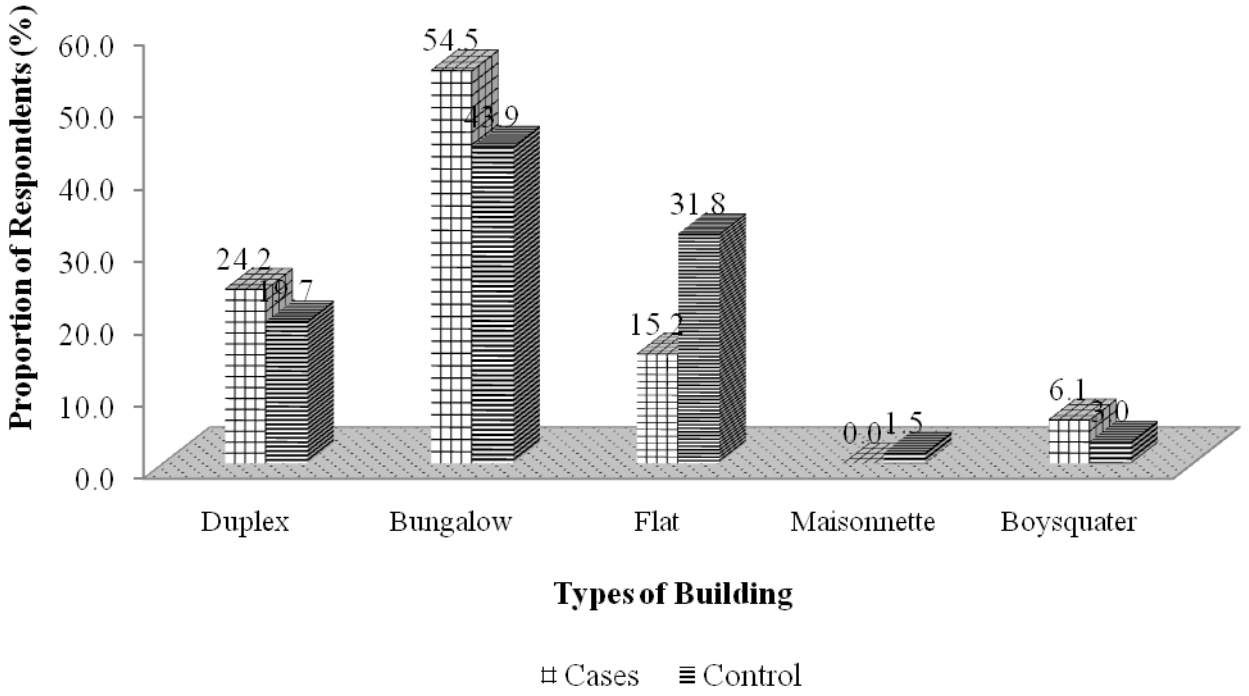


Fig 4.6: Types of building occupied by cases and controls

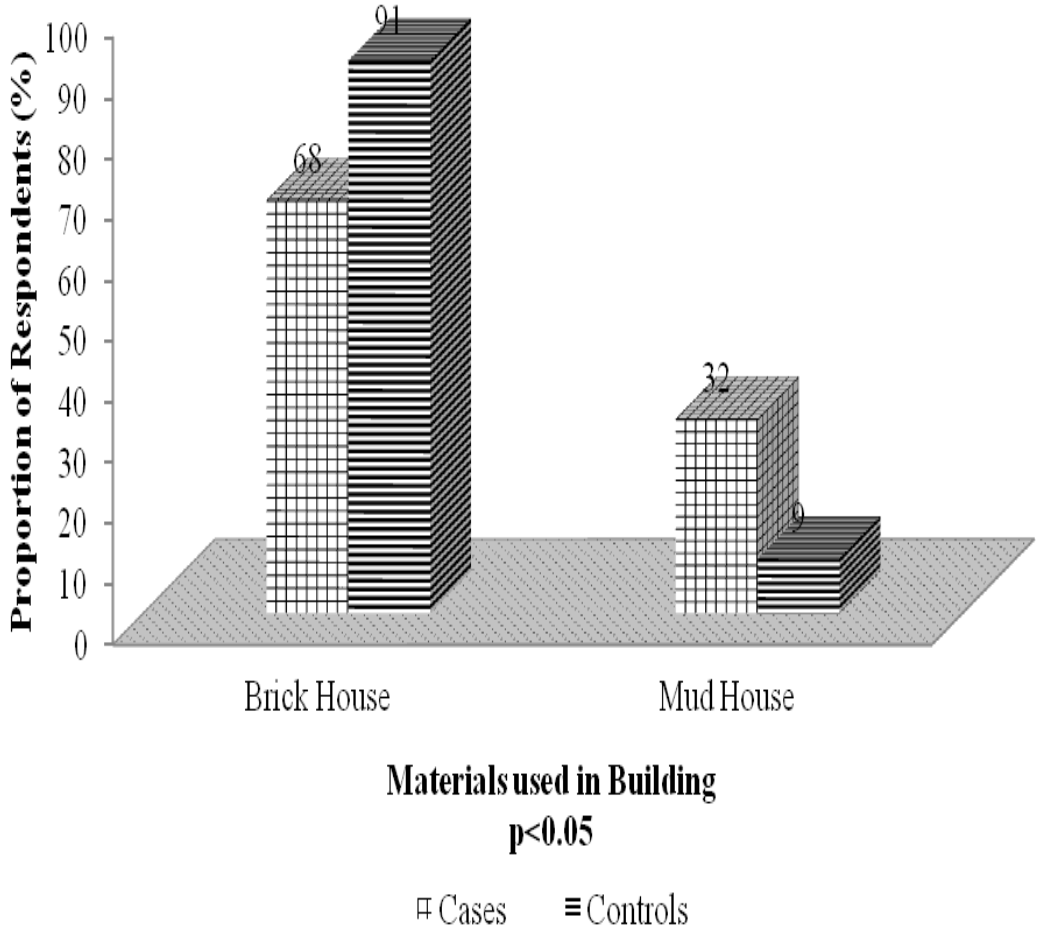


Fig 4.7: Materials used in Building

Table 4.4: Building Characteristics among cases and controls

Building Characteristics	Cases (n = 220)	Controls (n = 220)	OR (95% CI)	p-value
Dwelling Type				
Face-to-face	159 (72.3%)	120 (54.5%)	2.2 (1.5-3.2)	0.04
Self contained	61 (27.4%)	100 (44.5%)		
No of windows per room				
<2	106 (48.6%)	51 (23.2%)	3.1 (2.0 –4.7)	0.00
≥2	112 (51.4%)	169 (78.8%)		
Presence of air conditioning system				
Yes	57 (25.9%)	21 (9.5%)	3.3 (1.9-5.6)	0.00
No	163 (74.1%)	199 (90.5%)		
High Traffic Density Near Residence				
Yes	92 (41.8%)	64 (29.1%)	1.7 (1.2-2.6)	0.04
No	128 (58.2%)	156 (70.9%)		

* OR = odds ratio; CI = confidence interval

4.4 Household Characteristics as risk factors for ARIs among children under-five

According to Fig 4.8, majority of cases 146 (66.4%) and controls 116 (52.7%) were tenants while less than half of cases 74 (33.6%) and approximately half 104 (47.3%) of controls were the owner of the house. Table 4.5 shows the household characteristics of respondents among cases and controls. A higher proportion of cases 144 (65.5%) and a little more than half of controls 115 (52.3%) reported occupying not more than two rooms. More than half of respondents among cases 155 (70.5%) and almost half of controls 108 (49.1%) reported ≥5 persons in household. Majority of respondents among cases 180 (81.8%) and controls 153 (69.5%) reportedly have greater than two persons occupying a room. Less than half of respondents among cases 81 (36.8%) and almost half of respondents among controls 107 (48.6%) reported having more than two children under-five living in the house. Slightly more than half of respondents among cases 120 (54.5%) and far more than half of respondents among controls 156 (70.9%) reported two or more adult >15years sleeping in the same room as the child in question.

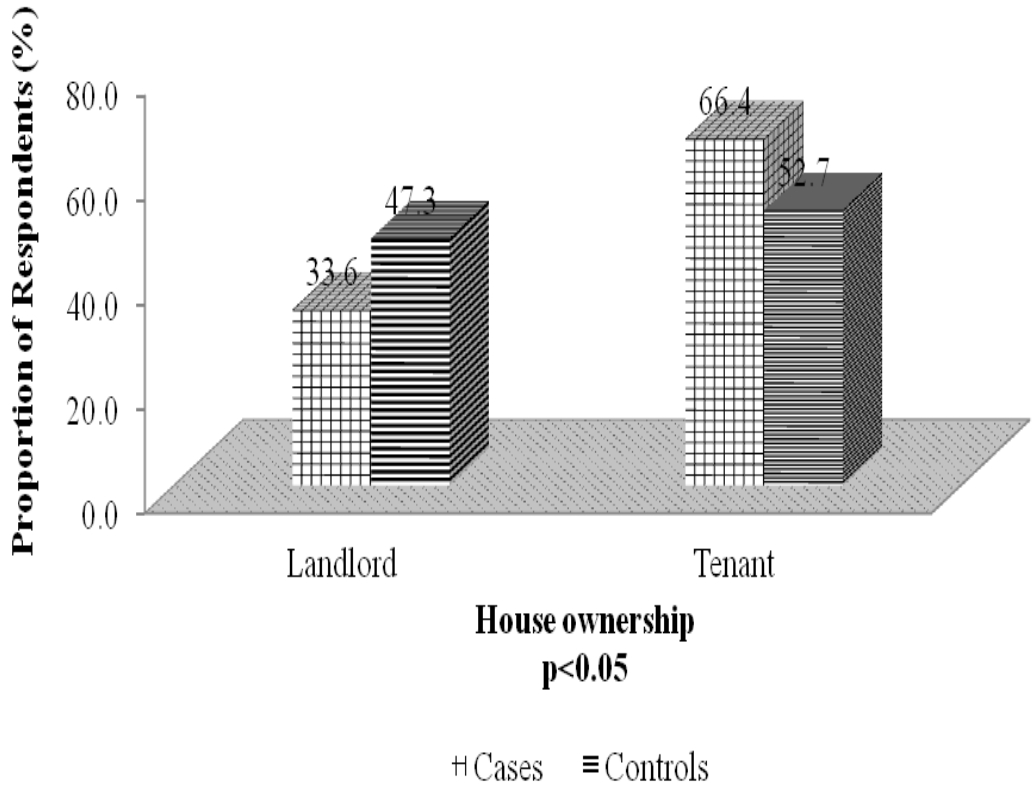


Fig 4.8: House Ownership

Table 4.5: Univariate analysis of Household risk factors for ARIs among children under-five

Variable	Case (n = 220)	Control (n = 220)	OR* (95%CI)	p-value
No of rooms occupied by household				
1 - 2	144 (65.5%)	115 (52.3%)	1.0	<0.05
>2	76 (34.5%)	105 (47.7%)	1.7 (1.1 – 2.5)	
No of persons in household				
≥5	155 (70.5%)	108 (49.1%)	2.5 (1.6 – 3.6)	<0.05
<5	65 (29.5%)	112 (50.9%)	1.0	
No of persons per room				
>2	180 (81.8%)	153 (69.5%)	1.9	<0.05
≤2	40 (18.2%)	67 (30.5%)	1.0 (1.3 – 3.0)	
No of children under-five				
1 - 2	139 (63.2%)	113 (51.4%)	1.0	<0.05
>2	81 (36.8%)	107 (48.6%)	1.6 (1.1 – 2.4)	
No of adults >15years sleeping in the same room as the child				
<2	100 (45.5%)	64 (29.1%)	1.0	<0.05
≥2	120 (54.5%)	156 (70.9%)	2.0 (1.3 – 3.0)	

* OR = odds ratio; CI = confidence interval

4.5 Environmental Risk factors for ARIs among children under-five

Table 4.6 highlights the risk factors for acute respiratory infections among children under-five as regard indoor exposures. A higher proportion of cases 86 (39.1%) than controls 46 (20.9%) reported that they keep pets at home. Far more than half of respondents for cases 195 (88.6%) and little above half of the respondents for controls 144 (65.5%) reported the use of lantern at night in the house. A little below half the respondents for cases 103 (46.8%) and controls 78 (35.5%) reportedly use mosquito coil in the house to kill mosquito. A higher proportion of respondents for cases 39 (17.8%) than controls 5 (2.3%) reported the use of firewood frequently for cooking while more respondents for cases 66 (30.0%) than controls 26 (11.8%) reported carrying the child while cooking. A higher proportion of respondents for cases 9 (4.1%) than controls 2 (0.9%) reported the presence of cigarette smokers in the house. More of respondents for cases 61 (27.7%) than controls 28 (12.7%) reported that the child attends a day care centre. Majority of respondents for cases 120 (87.3%) and less than half the respondents for controls 83 (37.7%) reported that the child is exposed to dust from within and outside the house. Majority of respondents for cases 176 (80.0%) and less than half of respondents for controls 89 (40.5%) reported that the child had previous experience of ARI. More respondents for cases 22 (10.0%) than controls 4 (1.8%) reportedly have a family history of ARI.

Table 4.6: Univariate analysis of Indoor Environmental risk factors for ARIs among Children under-five

Variable	Cases (n =N)	Controls (n =N)	OR* (95% CI)	p-Value
Keep Pet/Livestock				
Yes	86 (39.1%)	46 (20.9%)	2.4 (1.6 – 3.7)	<0.05
No	134 (60.9%)	174 (79.1%)		
Parents use Lantern at night				
Yes	195 (88.6%)	144 (65.5%)	4.1 (2.5 – 6.8)	<0.05
No	25 (11.4%)	75 (34.1%)		
Mosquito Coil				
Yes	103 (46.8%)	78 (35.5%)	1.6 (1.0 – 2.4)	<0.05
No	117 (53.2%)	142 (64.5%)		
Cooking using Firewood				
Yes	39 (17.8%)	5 (2.3%)	9.3 (3.6 – 24.0)	<0.05
No	180 (82.2%)	215 (97.7%)		
Mothers carring child while cooking				
Yes	66 (30.0%)	26 (11.8%)	3.2 (1.9 – 5.3)	<0.05
No	154 (70.0%)	194 (88.4%)		
Parents/other smokers in the house				
Yes	9 (4.1%)	2 (0.9%)	4.7 (0.9 – 21.9)	<0.05
No	211 (95.9%)	218 (99.1%)		

Table 4.6 (Contd)

Variable	Cases (n =N)	Controls (n =N)	OR* (95% CI)	p-Value
Attending Day Care Centres				
Yes	61 (27.7%)	28 (12.7%)	2.6 (1.6 – 4.3)	<0.05
No	159 (72.3%)	192 (87.3%)		
Child exposed to dust				
Yes	120 (54.5%)	83 (37.7%)	2.0 (1.4 – 2.9)	<0.05
No	100 (45.5%)	137 (62.3%)		
Child with previous ARI				
Yes	176 (80.0%)	89 (40.5%)	5.9 (3.8 – 9.0)	<0.05
No	44 (20.0%)	131(59.5%)		
Family History of ARI				
Yes	22 (10.0%)	4 (1.8%)	6.0 (2.0 –17.7)	<0.05
No	198 (90.0%)	216 (98.2%)		

* OR = odds ratio; CI = confidence interval

4.6 Perceived Indoor Sources of Pollution

Table 4.7 highlights the various indoor sources of pollution reported by respondents. Pets such as goats, dogs and cats were reported by more than half of cases 120 (54.5%) and less than half of the controls 77 (34.8%) as one of the sources of indoor pollution. A large proportion of cases 177 (80.3%) and about one-third of controls 80 (36.4%) were of the opinion that the presence of rodents in the house could contribute to pollution. More than half of cases 143 (65.2%) and less than half of controls 60 (27.3%) reported that the presence of fungal growth on walls is a major contributor to indoor pollution. Less than one-tenth of cases 9 (4.2%) and less than half of controls 73 (33.3%) perceived that the presence of houseplants could enhance indoor pollution while an equal proportion of cases 87 (39.4%) and controls 70 (31.8%) perceived that the presence of vegetation around the house could contribute to indoor pollution.

Table 4.7: Perceived Indoor Sources of pollution

Variable	Options	Cases N (%)	Controls N (%)	Total
Pets	Yes	120 (54.5)	77 (34.8)	197
	No	100 (45.5)	143 (65.2)	243
Rodents/Cockroach	Yes	177 (80.3)	80 (36.4)	257
	No	43 (19.7)	140 (63.6)	183
Algal Growth on wall	Yes	143 (65.2)	60 (27.3)	203
	No	77 (34.8)	160 (72.7)	237
Houseplants	Yes	9 (4.2)	73 (33.3)	82
	No	211 (95.5)	147 (66.7)	358
Vegetation	Yes	87 (39.4)	70 (31.8)	157
	No	133 (60.6)	150 (68.2)	283

4.7 Cooking Practices among cases and controls

Table 4.8 highlights the facilities and space used by cases and controls for cooking. A higher proportion of cases 203 (92.4%) and less than half controls 88 (39.4%) often use kerosene stove for cooking. More than half of cases 144 (65.2%) and approximately one-fifth of controls 43 (19.7%) sometimes use firewood for cooking while less than half 57 (25.8%) of cases and 33 (15.2%) of controls makes use of charcoal sometimes for cooking. A higher proportion of cases 203 (92.4%) and controls 180 (81.8%) never use gas for their cooking while almost an equal proportion of cases 100 (45.5%) and controls 127 (57.6%) sometimes make use of electric cooker for cooking.

Fig 4.9 – 4.12 highlights the places used for cooking among cases and controls. About 3 (1.5%) of cases and none of the controls reported regular cooking in the bedroom while 53 (24.2%) of cases and 20 (9.1%) controls sometimes cook in their bedrooms. Exactly one-third of cases 73 (33.3%) and approximately one-tenth of controls 20 (9.1%) often cook at the entrance door to the room. Half of the cases 110 (50.0%) and less than half 30 (13.6%) of controls make use of the outside for their cooking. Majority of cases 123 (56.1%) and controls 177 (80.3%) had a kitchen often used for cooking.

Table 4.8: Cooking Practices among cases and Controls

Variable	Option	Case N (%)	Control N (%)	Total
Kerosene stove				
	Often	203 (92.4)	88 (39.9)	291
	Sometimes	17 (7.6)	132 (60.6)	149
	Never	0 (0.0)	0 (0.0)	0
Firewood				
	Often	3 (1.5)	0 (0.0)	3
	Sometimes	144 (65.2)	43 (19.7)	187
	Never	73 (33.3)	177 (80.3)	250
Charcoal				
	Often	0 (0.0)	0 (0.0)	0
	Sometimes	57 (25.8)	33 (15.2)	90
	Never	163 (74.2)	187 (84.8)	350
Electricity				
	Often	7 (3.0)	3 (1.5)	10
	Sometimes	100 (45.5)	127 (57.6)	227
	Never	113 (51.2)	90 (40.9)	203
Gas cooker				
	Often	0 (0.0)	0 (0.0)	0
	Sometimes	17 (7.6)	40 (18.2)	57
	Never	203 (92.4)	180 (81.8)	383

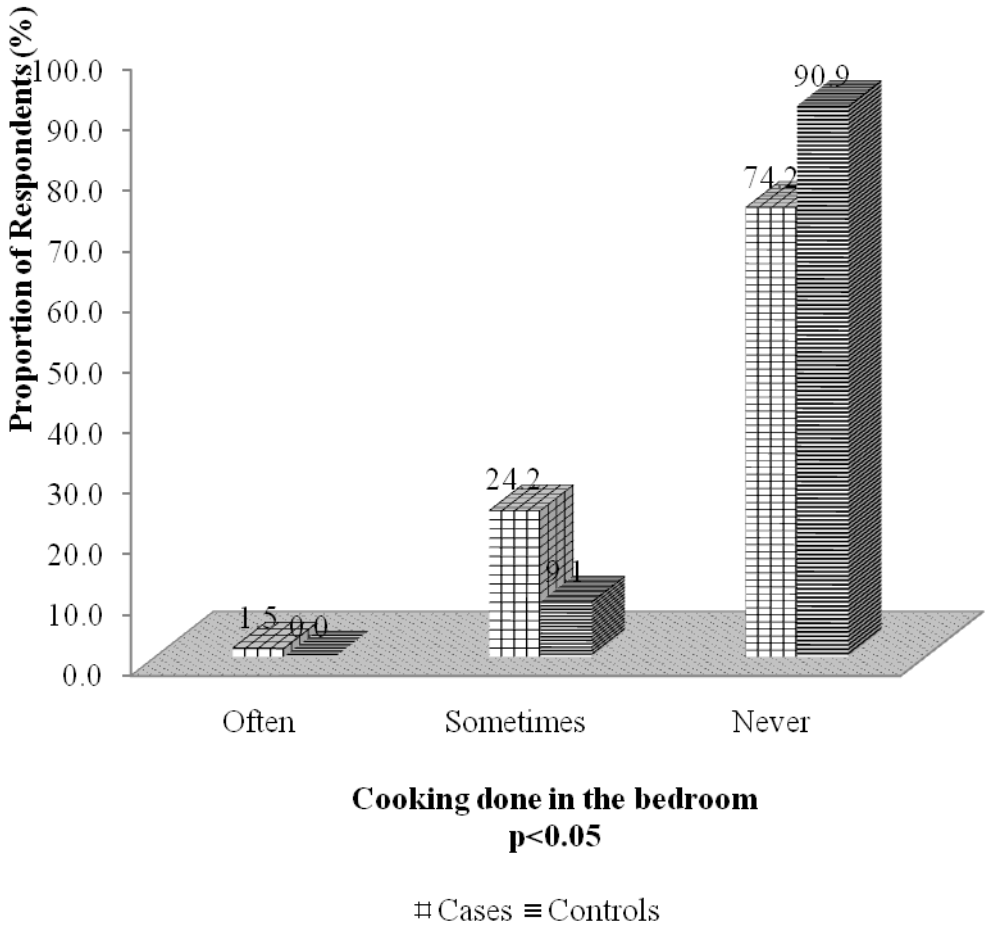


Fig 4.9: Frequency of cooking done in the Bedroom

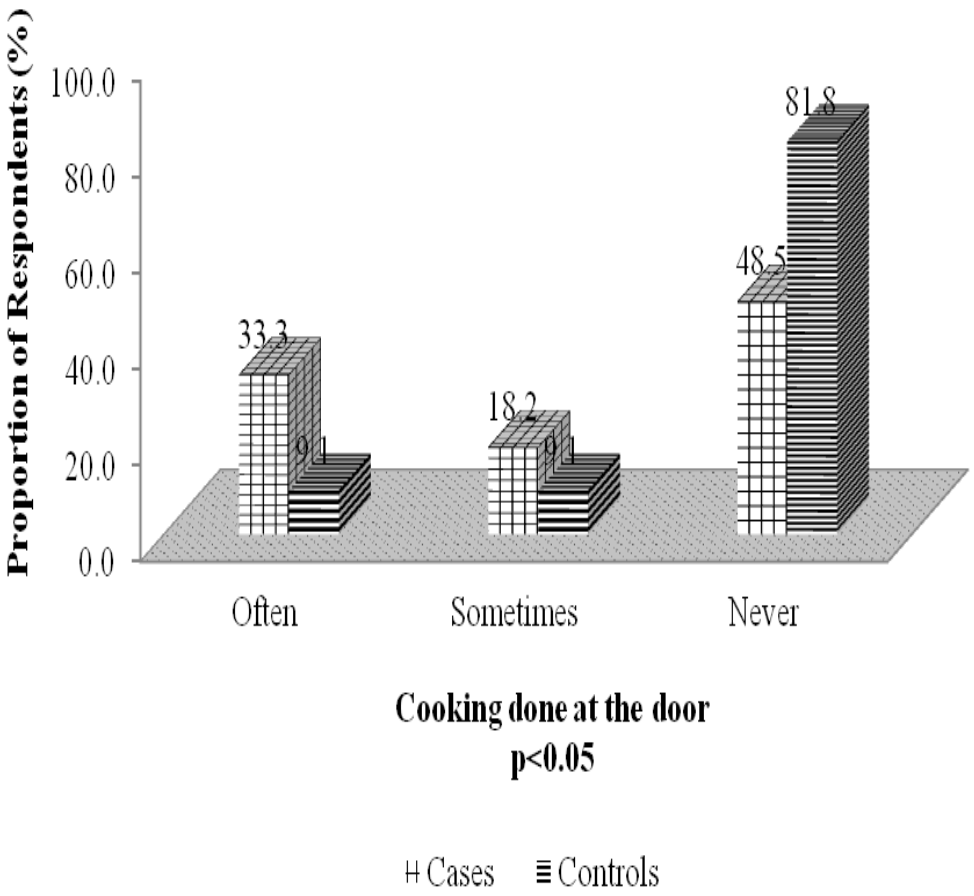


Fig 4.10: Frequency of cooking done at the entrance door

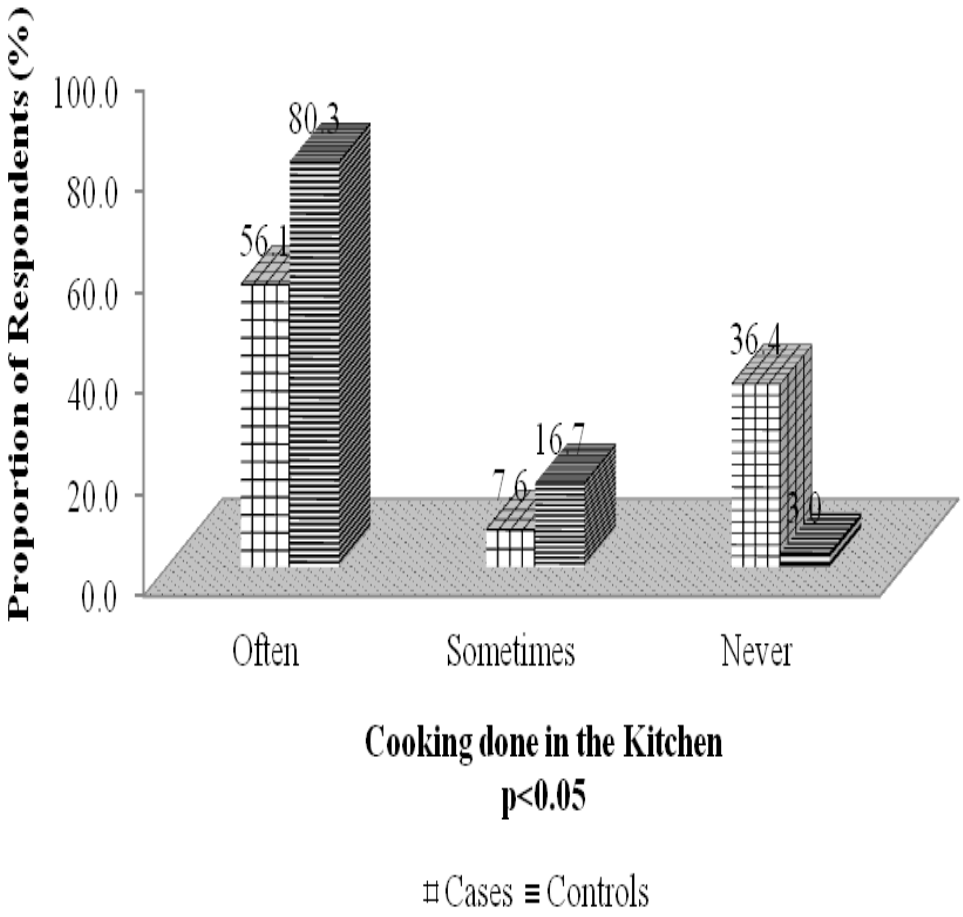


Fig 4.11: Frequency of cooking done in the kitchen

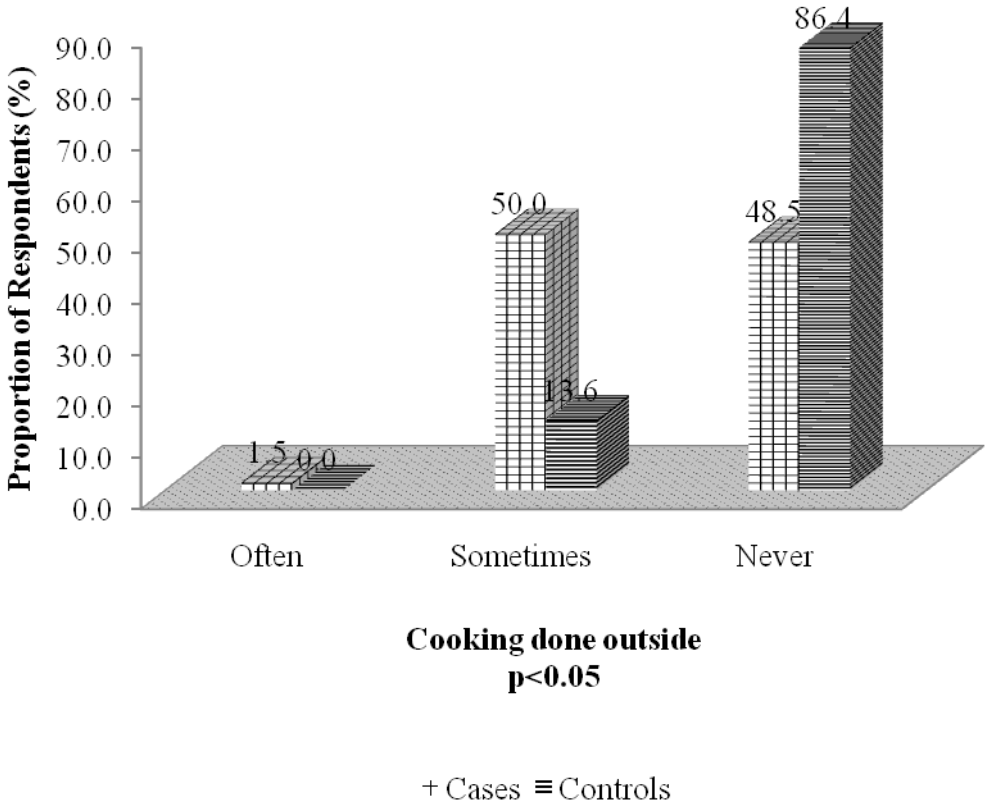


Fig 4.12: Frequency of cooking done outside the building

4.8 Relationship between Multiple factors and Acquisition of ARIs

The relationship between whether a child under-five would develop acute respiratory infections and multiple factors viz knowledge, attitude, household characteristics, indoor environmental characteristics and building characteristics was further analysed using multivariate logistic regression as shown in Table 4.9. Mothers' knowledge as regards the risk factors for acute respiratory infections was not statistically significant. Mothers' attitude towards risk factors for acute respiratory infections (OR: 1.5; CI: 1.0 – 2.2) and household characteristics such as number of persons per room (OR: 1.9; CI: 1.3 – 3.0), number of persons per household (OR: 2.5; CI: 1.6 – 3.6) and total number of children under-five (OR: 1.6; CI: 1.1 – 2.4) were statistically significant. Environmental risk factors such as keeping pets/livestock (OR: 2.4; CI: 1.6 – 3.7), use of lantern at night (OR: 4.1; CI: 2.5 – 6.8), use of firewood for cooking (OR: 9.3; CI: 3.6 – 24.0) and family history of ARIs (OR: 6.0; CI: 2.0 – 17.7) appeared to be significant and independently related to whether a child under-five would develop ARIs or not. Building characteristics such as the type of dwelling (OR = 2.2, CI = 1.5 – 3.2), number of windows per room (OR = 3.1, CI = 2.0 – 4.7) and traffic near residence (OR = 1.7, CI = 1.2 – 2.6) were also found to be statistically significant.

Table 4.9: Relationship between multiple factors and acquisition of ARI

Variables	df	Sig	Exp (B)	95% CI for Exp (B)	
				Lower	Upper
Scores					
Knowledge	1	0.7	0.9	0.6	1.4
Attitude	1	0.03	1.5	1.0	2.2
Household Characteristics					
No. of persons per room	1	0.03	1.9	1.3	3.0
No. of persons per household	1	0.00	2.5	1.6	3.6
No. of Children under-five	1	0.006	1.6	1.1	2.4
Indoor Environmental Risk Factors					
Pets/Livestock	1	0.00	2.4	1.6	3.7
Lerntern use at night	1	0.00	4.1	2.5	6.8
Firewood for cooking	1	0.04	9.3	3.6	24.0
Family history of ARIs	1	0.00	6.0	2.0	17.7
Building Characteristics					
Dwelling Type	1	0.04	2.2	1.5	3.2
< 2 windows per room	1	0.00	3.1	2.0	4.7
High traffic near residence	1	0.04	1.7	1.2	2.6

4.9 Meteorological Characteristics of indoor and outdoor environments among cases and controls

Table 4.10–4.14 highlights the mean, median (med), minimum (min) and maximum (max) meteorological characteristics of the Indoor and outdoor environment among cases and controls. Cases recorded the highest mean indoor temperature and relative humidity (RH) readings of 33.0 ± 1.3 and 69.6 ± 4.7 respectively as compared to 31.6 ± 1.9 and 63.1 ± 6.5 among controls ($p<0.05$). Almost an equal mean outdoor temperature and relative humidity (RH) readings was recorded among cases (33.1 ± 1.3 and 67.2 ± 5.0) and controls (32.6 ± 1.9 and 66.1 ± 7.1) respectively. The bedroom recorded the highest mean temperature reading among cases (33.8±1.6) and controls (31.7±1.9) respectively. Similarly, the kitchen recorded the highest mean relative humidity (RH) values of 68.4±5.4 (cases) and 64.0±5.9 (controls).

Fig 4.13 – 4.14 highlights the temperature and relative humidity (RH) category of the indoor environment in houses visited among cases and controls. A higher proportion of houses among cases 29 (87.9%) and controls 26 (78.8%) recoded a hot indoor air temperature of between 32 – 40^{o}C. Almost an equal proportion of houses among cases 4 (12.1%) and controls 7 (21.2%) recorded a warm indoor air temperature of between 28 - 32^{o}C. A higher proportion of houses among cases 27 (81.8%) than controls 17 (51.5%) recorded a high indoor air relative humidity of above 60% while almost half of the houses among controls and less than half among cases recorded an indoor air relative humidity within the comfort range of 30 – 60%.

Table 4.10 Indoor and Outdoor values of Temperature (ºC) and RH (%) among cases and controls

Sampling site	Parameter	Cases				Controls			
		Mean ±SD	Median	Min	Max	Mean ±SD	Median	Min	Max
Indoor									
Living Room	Temperature	33.0±1.3	33.0	30.3	36.0	31.6±1.9	31.6	29.5	35.2
	RH	69.6±4.7	69.6	55.4	78.1	63.1±6.5	63.0	55.0	72.0
Bedroom	Temperature	32.8±1.5	32.8	30.0	36.2	31.7±1.9	30.7	30.4	34.8
	RH	69.4±4.8	69.3	54.7	78.0	63.1±6.5	63.1	52.0	72.0
Kitchen	Temperature	33.2±1.1	33.2	29.7	35.8	31.5±2.0	31.5	29.8	35.0
	RH	69.8±5.4	69.9	55.0	77.9	63.0±5.9	63.0	55.0	72.0
Outdoor									
A	Temperature	33.4±1.1	33.4	30.4	36.5	32.6±1.9	32.5	29.5	35.8
	RH	67.3±5.0	67.5	53.4	76.2	66.1±7.1	66.1	52.0	73.0
B	Temperature	33.2±1.3	33.1	30.0	36.8	32.8±1.7	32.8	29.8	35.6
	RH	66.9±5.5	66.9	53.0	76.4	66.4±6.9	66.4	52.1	73.2
C	Temperature	32.8±1.0	32.8	30.4	36.1	32.4±2.0	32.4	29.3	35.3
	RH	67.2±5.7	67.2	53.4	76.0	65.8±7.5	65.3	51.8	72.8

Table 4.11: Mean indoor Air Temperature (ºC) of Houses among cases and controls

Category	N (%)	Indoor Air Temperature (ºC)			
		Mean	Standard Deviation	Minimum	Maximum
Cases	220 (100%)	33.0	1.3	30.0	36.0
Controls	220 (100%)	31.6	1.9	30.0	35.0

Table 4.12: Mean indoor Air Relative Humidity (%) of Houses among cases and controls

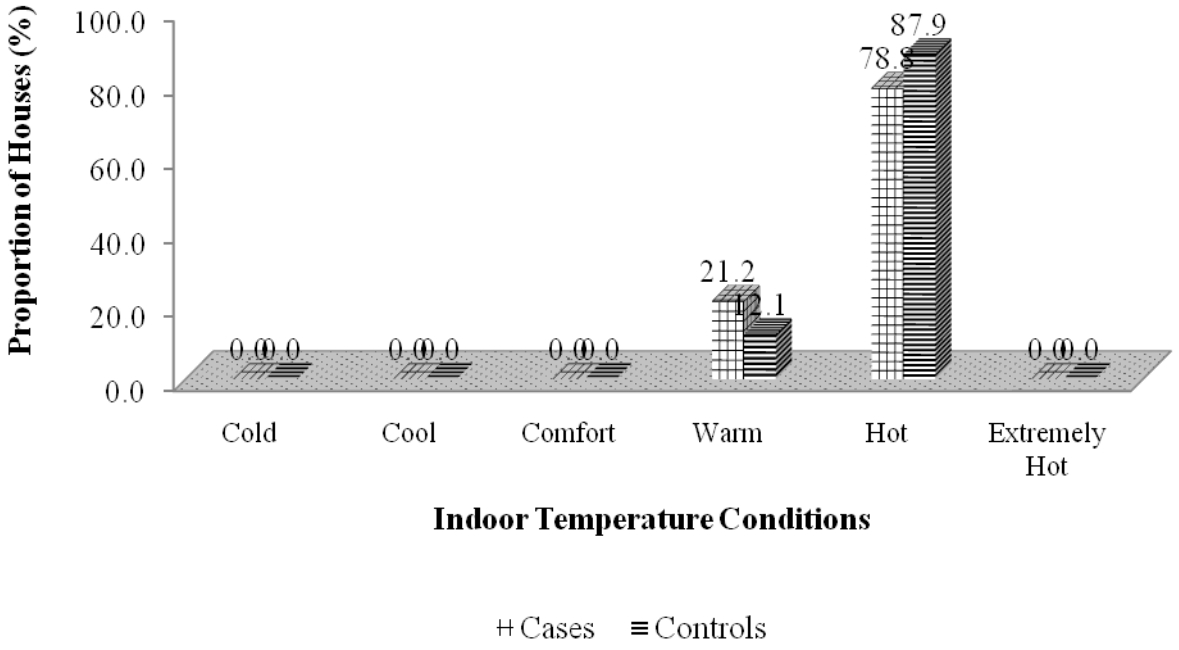
Category	N (%)	Indoor Air Relative Humidity (%)			
		Mean	Standard Deviation	Minimum	Maximum
Cases	220 (100%)	69.6	4.7	55.0	78.0
Controls	220 (100%)	63.1	6.5	55.0	72.0

Table 4.13: Mean Outdoor Air Temperature (ºC) of Houses among cases and controls

Category	N (%)	Outdoor Air Temperature (ºC)			
		Mean	Standard Deviation	Minimum	Maximum
Cases	220 (100%)	33.1	1.3	30.4	36.4
Controls	220 (100%)	32.6	1.9	29.5	35.5

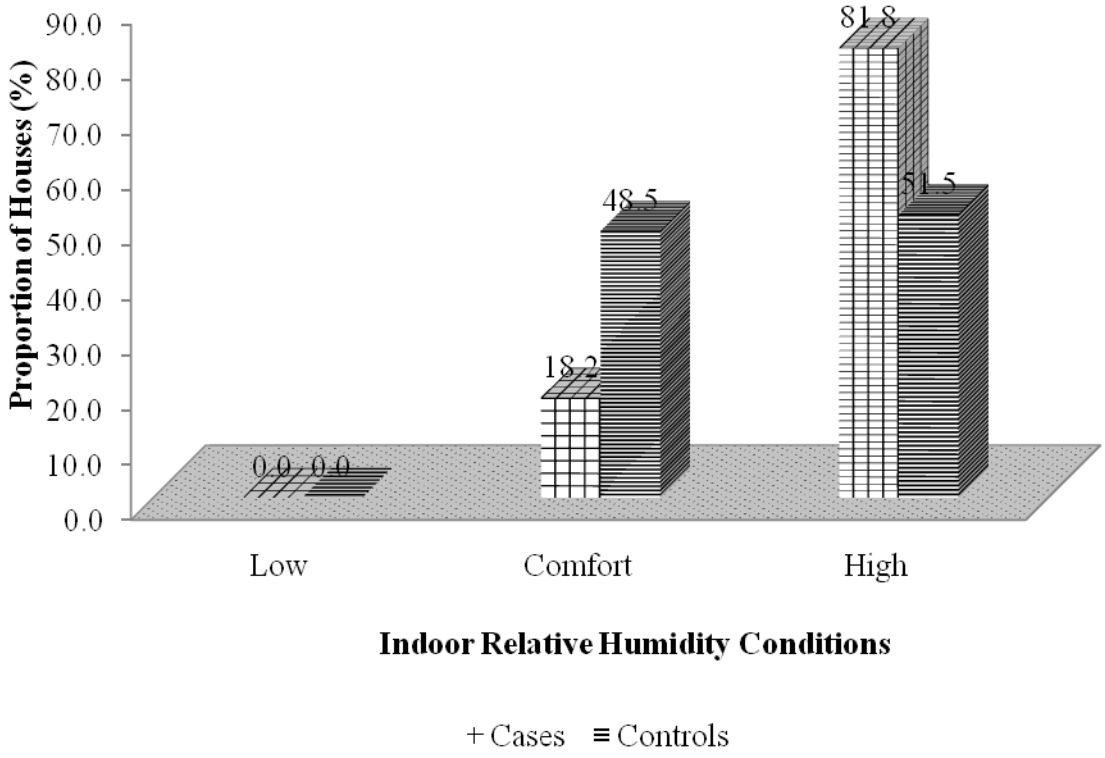
Table 4.14: Mean Outdoor Air Relative Humidity (%) among cases and controls

Category	N (%)	Outdoor Air Relative humidity (%)			
		Mean	Standard Deviation	Minimum	Maximum
Cases	220 (100%)	67.2	5.0	53.4	76.2
Controls	220 (100%)	66.1	7.1	52.0	73.0



Key: Cold = <16ºC, Cool = 16 – 25.5 ºC, Comfort = 25.5 - 28 ºC, Warm = 28 – 32 ºC, Hot = 32 - 40 ºC, Extremely Hot = >40 ºC

Fig 4.13: Indoor Temperature conditions of Houses among cases and controls



Key: Low = <30%, Comfort = 30 – 60%, High = >60%

Fig 4.14: Indoor Relative humidity conditions for houses among cases and controls

4.10 Indoor and Outdoor Airborne Microbial Burden among cases and controls

Tables 4.15 – 4.16 shows the minimum (min) and maximum (max) values of Total Bacteria Count (TBC) and Total Fungal Count (TFC) (cfu/m^3) in the indoor and outdoor environment among cases and controls. Fig 4.15 – 4.18 shows the standard error of mean TBC and TFC for indoor and outdoor measurements among cases and controls as compared to American Industrial Hygiene Association (AIHA) guideline. Mean Indoor total bacterial count for cases ($9.6x10^2$cfu/m^3) and controls ($3.5x10^2$cfu/m^3) were significantly different ($p<0.05$) while there was no significant difference in the mean indoor fungal count between cases ($0.2x10^2$cfu/m^3) and controls ($0.2x10^2$cfu/m^3). The livingroom recorded the highest mean bacterial count of $4.4x10^2$cfu/m^3 and $1.4x10^2$cfu/m^3 while the kitchen recorded the highest mean fungal count of 7.3cfu/m^3 and 8.0cfu/m^3 for cases and controls respectively (see Fig 4.21 - 4.24). The outdoor TBC among cases ($2.82x10^2$cfu/m^3) and controls ($1.8x10^2$cfu/m^3) was significantly different ($p<0.05$) while the mean outdoor fungal load was similar between houses visited for cases ($0.06x10^2$cfu/m^3) and controls ($0.07x10^2$cfu/m^3).

Concurrent outdoor air monitoring in the vicinity of the residential apartment made it possible to estimate the I/O (indoor-to-outdoor ratio) of TBC and TFC for investigated residential locations among cases and controls as compared to guideline (see Fig 4.19 and 4.20). The I/O TBC ratio among cases was found to be 4.26 as compared to 2.20 among controls. The I/O total fungal count among cases (3.6) was found to be similar to the value recorded for controls (3.4)

Table 4.15: Minimum (min) and maximum (max) TBC (CFU/m³) and the most frequently observed bacteria species among cases and controls

Sampling Location	Samp. Site	Cases			Controls		
		Min	Max	Most Frequently Observed Bacteria species	Min	Max	Most Frequently Observed Bacteria species
Indoor	LR	41.1	1320.9	*Bacillus spp., Staphylococcus spp., Micrococcus spp., Pseudomonas spp.,*	46.7	528.4	*Bacillus spp., Staphylococcus spp, Micrococcus spp., Pseudomonas spp.*
	BR	22.0	1188.8	*Bacillus spp., Staphylococcus spp., Pseudomonas spp., Micrococcus*	14.7	322.9	*Bacillus spp., Staphylococcus spp., Micrococcus spp., Flavobacterium spp.*
	KT	29.4	1056.7	*Bacillus spp., Staphylococcus spp., Pseudococcus spp., Micrococcus spp.,*	30.8	234.8	*Micrococcus spp., Bacillus spp., Staphylococcus spp.*
Outdoor	A	51.4	1056.7	*Staphylococcus spp., Bacillus spp., Micrococcus spp., Pseudomonas spp.,*	93.9	528.3	*Staphylococcus spp., Bacillus spp., Micrococcus spp., Pseudomonas spp.*
	B	56.2	1050.2	*Staphylococcus spp., Micrococcus spp., Pseudomonas spp.,*	101	538.4	*Staphylococcus spp., Micrococcus spp., Pseudomonas spp., Bacillus spp.*
	C	60.4	1102.1	*Staphylococcus spp., Bacillus spp., Micrococcus spp., Pseudomonas spp.,*	88.2	519.8	*Staphylococcus spp., Bacillus spp., Micrococcus spp., Pseudomonas spp.,*

Note: LR (Living room), BR (Bedroom), KT (Kitchen), A (Front of Building), B (Right side of building), C (Left side of building)

Table 4.16: Minimum (min) and maximum (max) TFC (CFU/m³) and the most frequently observed fungi genera of the sampling site groups for cases and controls

Sampling Location	Samp. Site	Cases			Controls		
		Min	Max	Most Frequently Observed Fungi species	Min	Max	Most Frequently Observed Fungi species
Indoor	LR	2.9	10.3	*Aspergillus spp., Penicillium spp.,Cladosporium spp., Fusarium spp., Mucor spp.*	2.9	11.7	*Penicillium spp., Aspergillus spp., Candida spp., Cladosporium spp., Fusarium spp.*
	BR	1.5	24.9	*Penicillium spp., Aspergillus spp., Cladosporium spp., Candida spp., Mucor spp.*	1.5	24.9	*Penicillium spp., Aspergillus spp., Fusarium spp., Candida spp., Cladosporium spp., Mucor spp.*
	KT	2.9	23.5	*Penicillium spp., Aspergillus spp., Candida spp., Cladosporium spp., Mucor spp. Fusarium spp., Rhizopus spp.*	1.5	23.5	*Candida spp., Aspergillus spp., Penicillium spp., Cladosporium spp., Geotrichum spp., Mucor spp., Rhizopus spp.*
Outdoor	A	2.9	14.7	*Aspergillus spp., Candida spp., Penicillium spp., Fusarium spp., Cladosporium spp.*	2.9	17.6	*Penicillium spp., Aspergillus spp., Candida spp., Cladosporium spp., Fusarium spp., Neurospora spp.*
	B	2.4	13.9	*Aspergillus spp., Penicillium spp., Fusarium spp., Cladosporium spp.*	3.4	20.1	*Aspergillus spp., Penicillium spp., Fusarium spp., Cladosporium spp.*
	C	3.1	15.1	*Aspergillus spp., Penicillium spp., Fusarium spp., Cladosporium spp., Candida spp.,*	2.3	16.9	*Aspergillus spp., Penicillium spp., Fusarium spp., Cladosporium spp., Candida spp., Neurospora spp*

Note: LR (Living room), BR (Bedroom), KT (Kitchen), A (Front of Building), B (Right side of building), C (Left side of building)

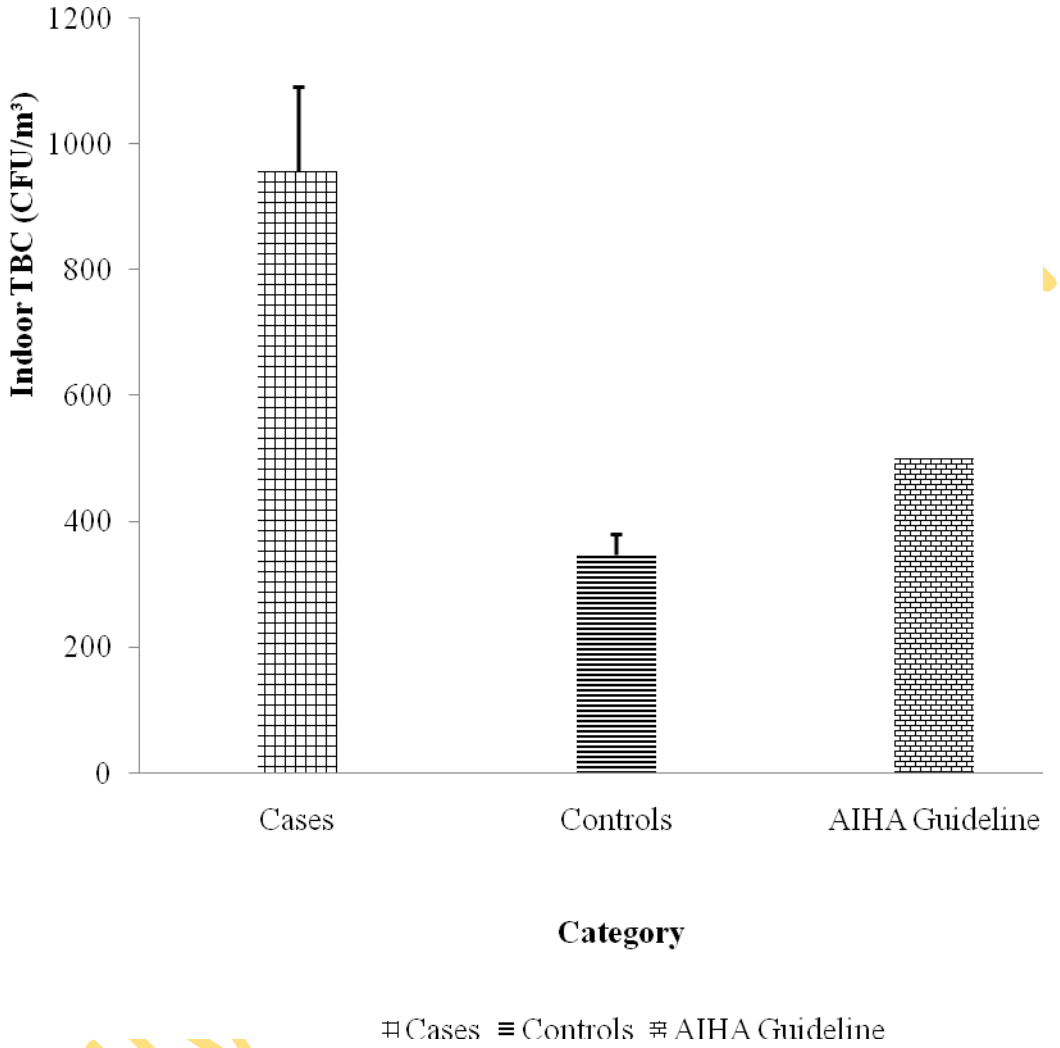


Fig 4.15: Mean Indoor TBC among cases and controls as compared with AIHA Guideline

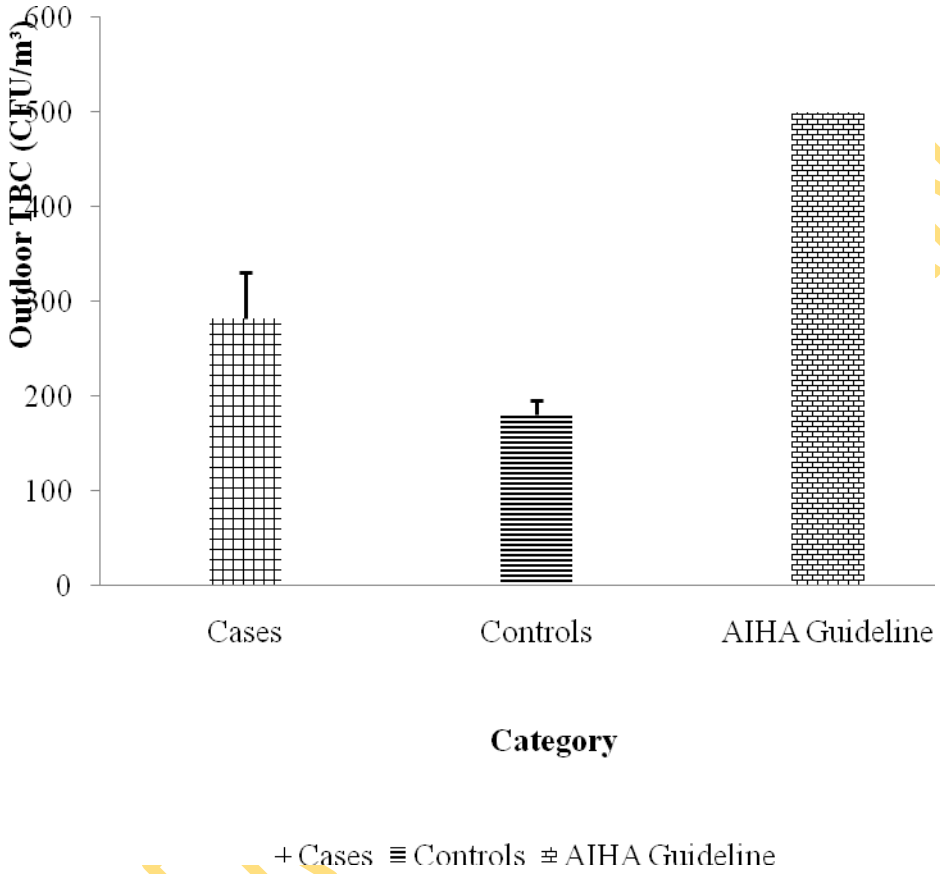


Fig 4.16: Mean Outdoor TBC among cases and controls as compared with AIHA Guideline

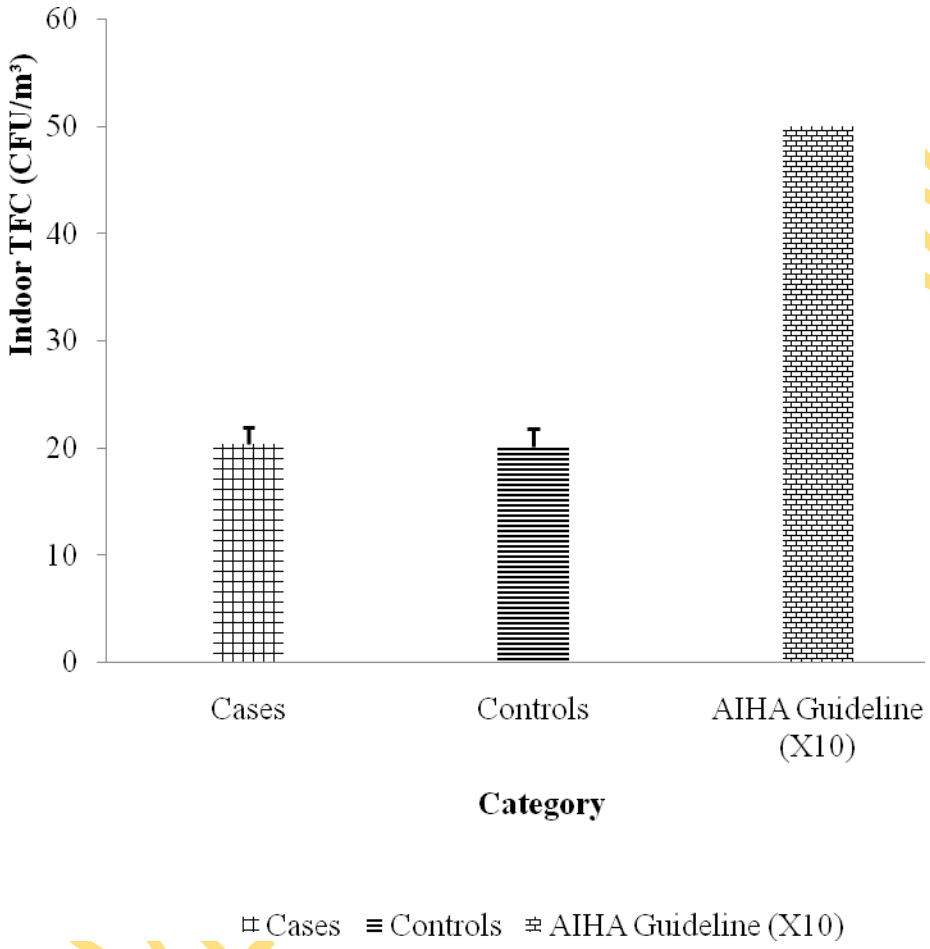


Fig 4.17: Mean Indoor TFC among cases and controls as compared with AIHA Guideline

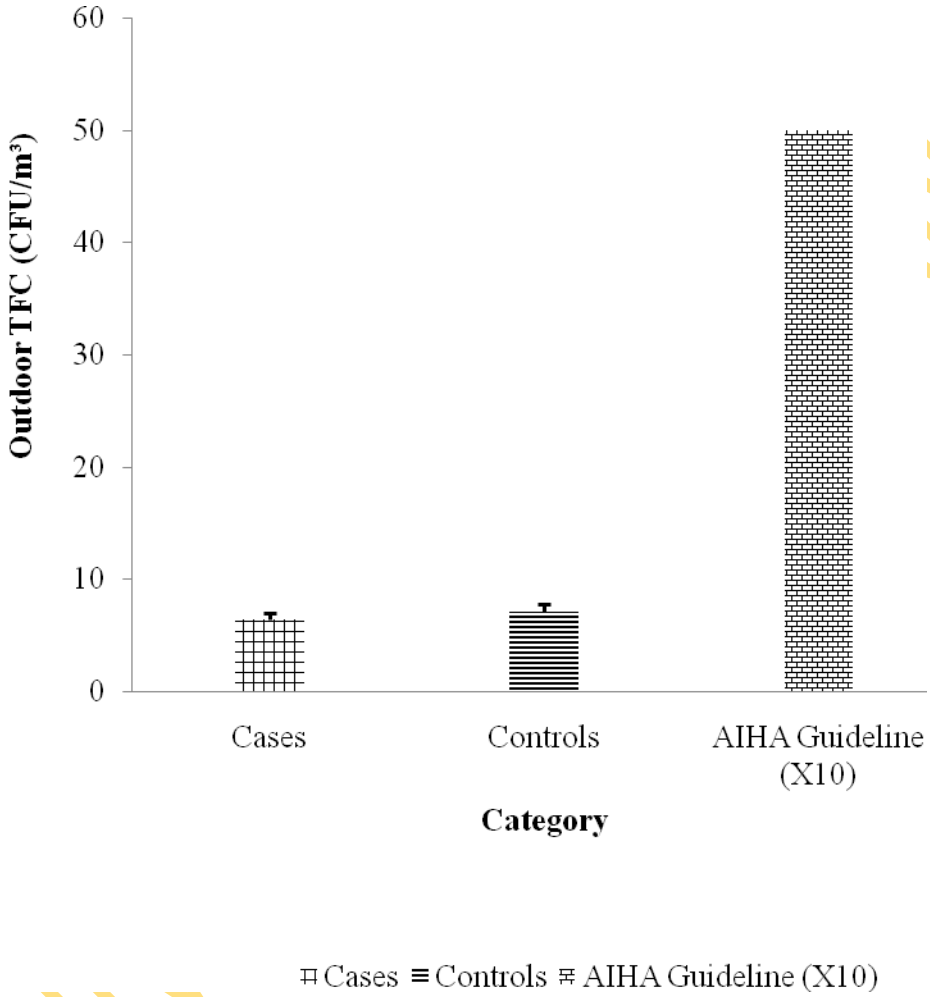


Fig 4.18: Mean Outdoor TFC among cases and controls as compared with AIHA Guideline

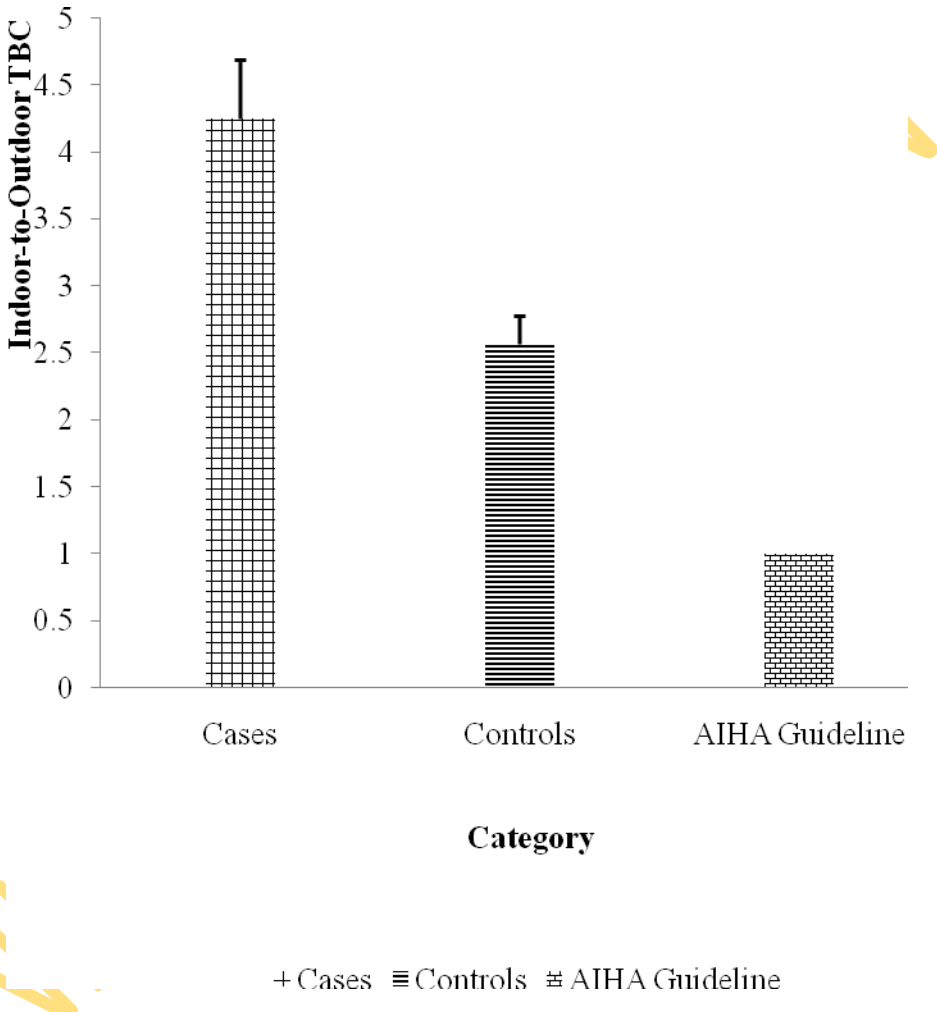


Fig 4.19: Indoor-to-Outdoor TBC among cases and controls as compared with AIHA Guideline

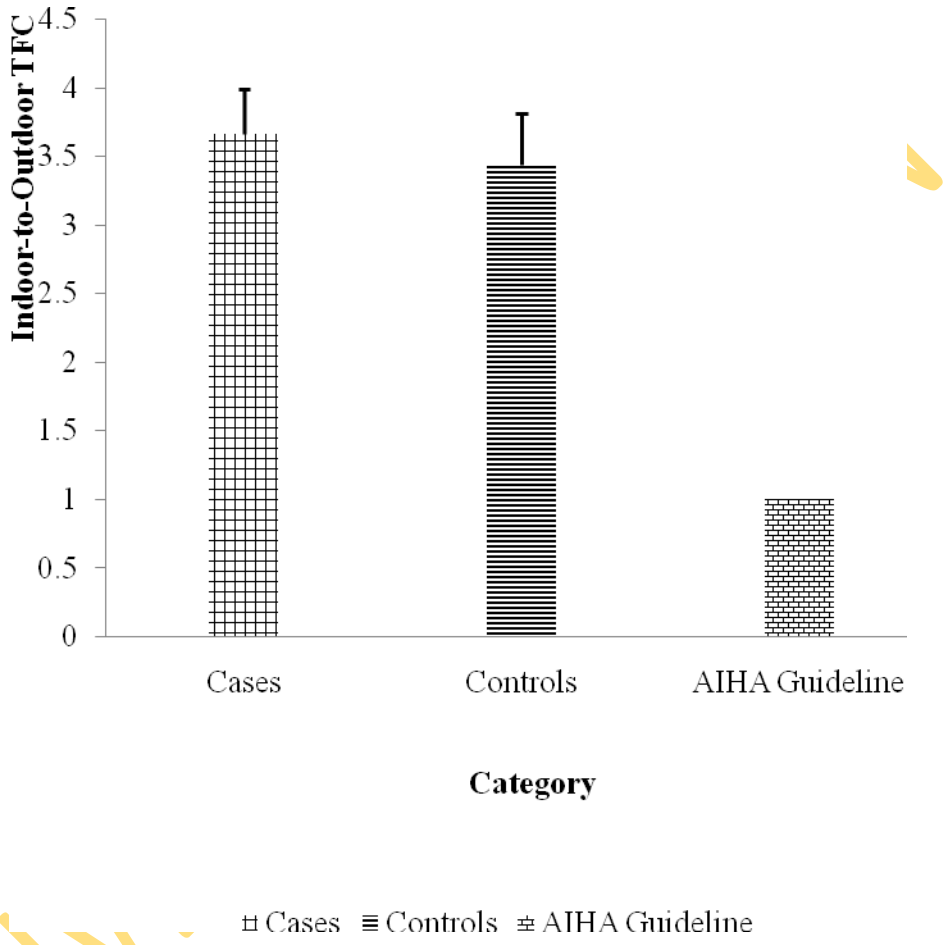


Fig 4.20: Indoor-to-Outdoor TFC among cases and controls as compared with AIHA Guideline

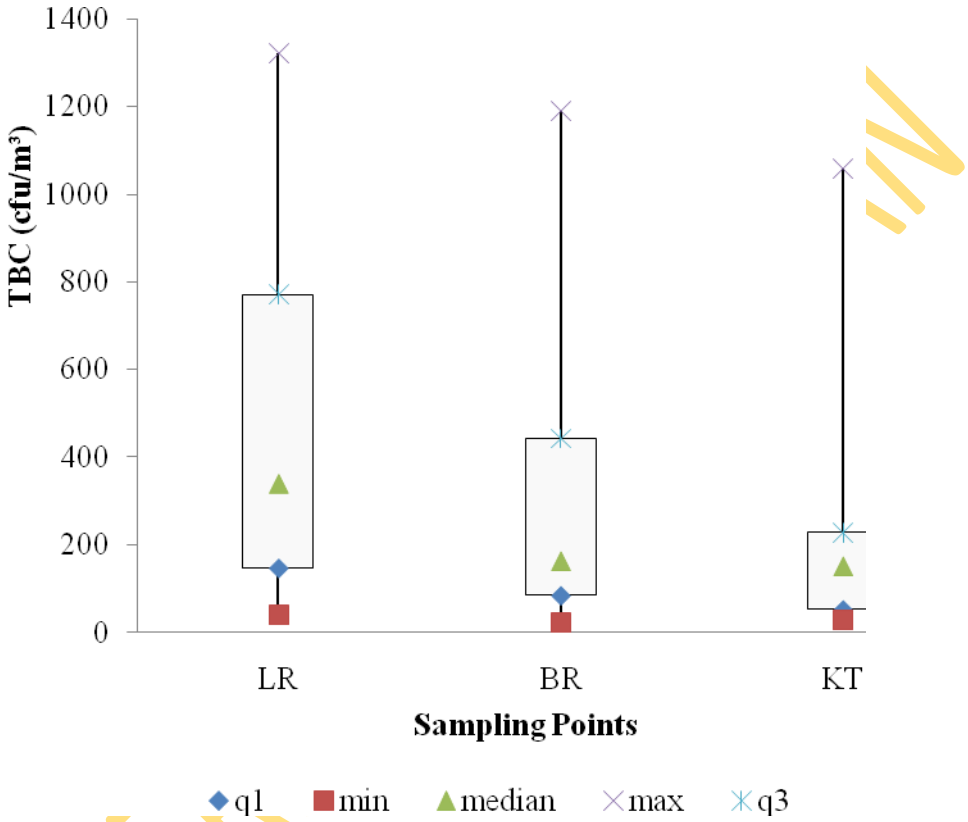


Fig 4.21: Indoor TBC at different sampling points of houses visited among cases.

LR-livingroom, BR- bedroom, KT- kitchen

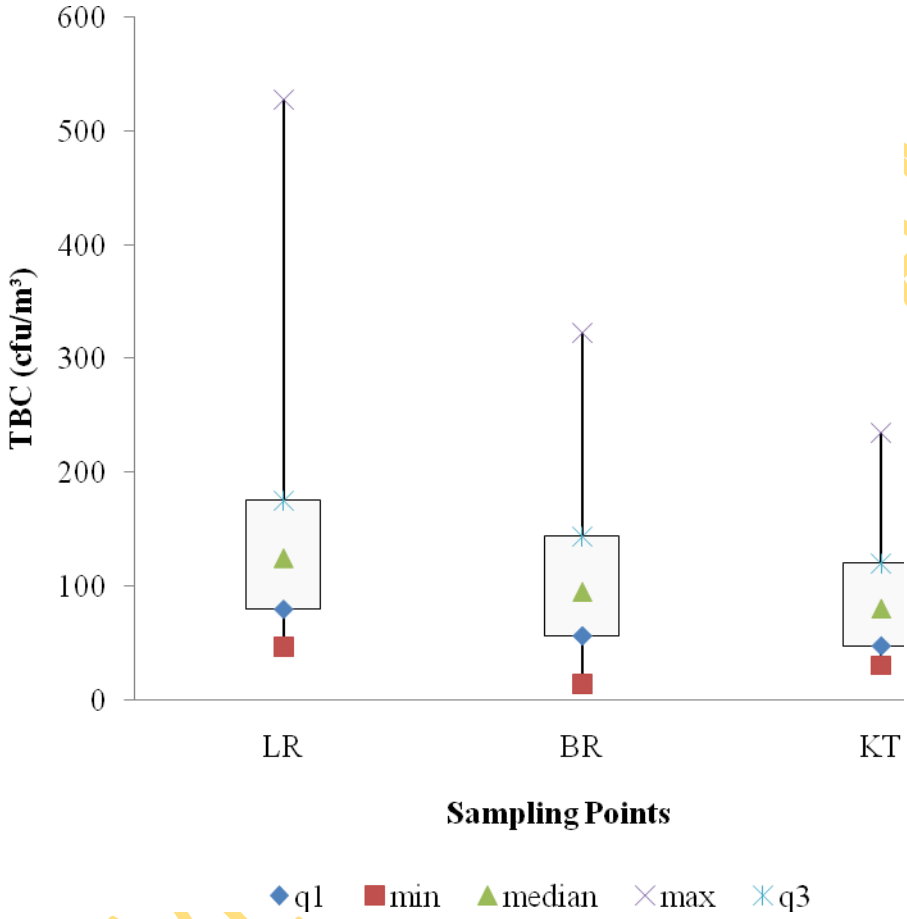


Fig 4.22: Indoor TBC at different sampling points of houses visited among controls.

LR-livingroom, BR- bedroom, KT- kitchen

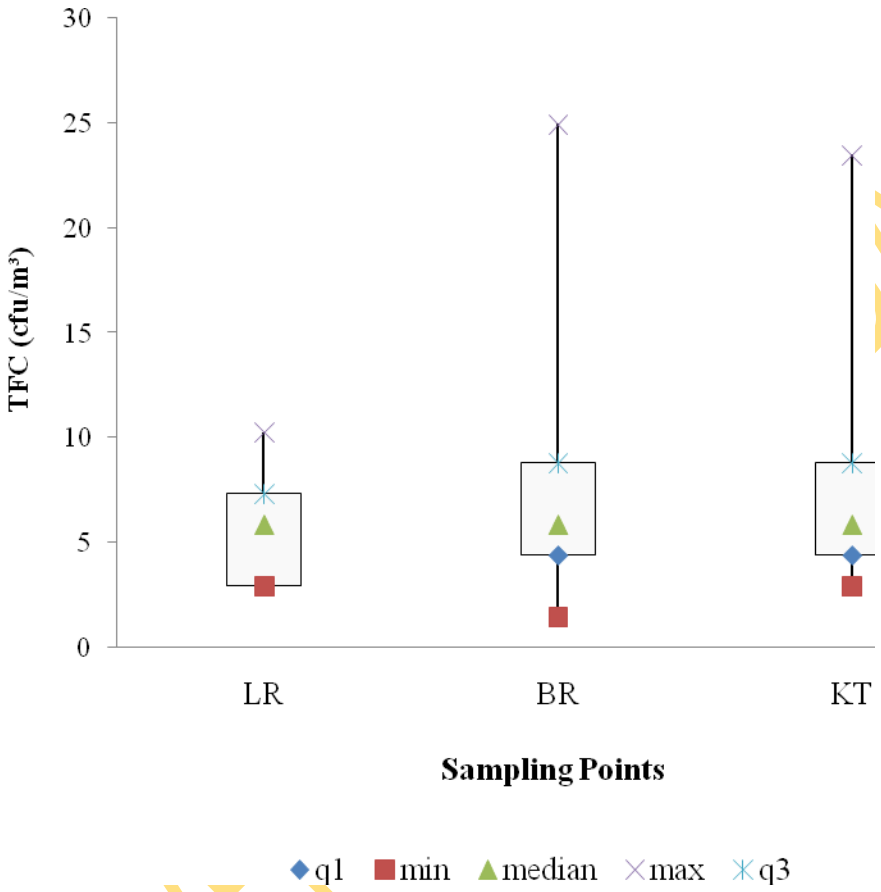


Fig 4.23: Indoor TFC at different sampling points of houses visited among cases

LR-livingroom, BR-bedroom, KT- kitchen

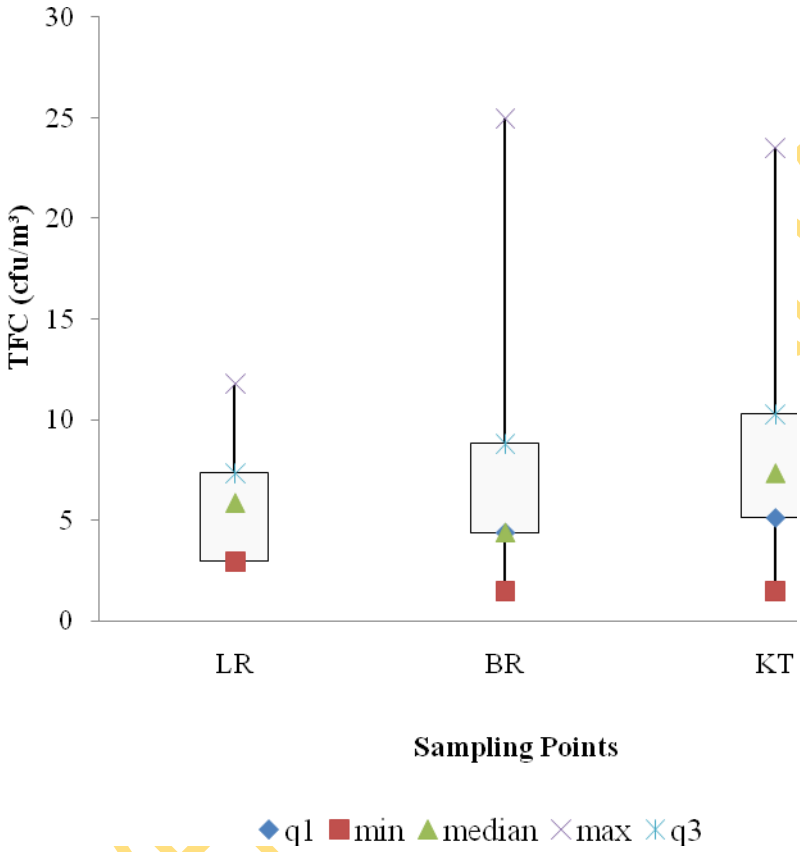


Fig 4.24: Indoor TFC at different sampling points of houses visited among controls

LR-livingroom, BR-bedroom, KT- kitchen

4.11 Relationship between Meteorological parameters and Airborne Microbial Concentration among cases and controls

Table 4.17 shows the outcome of spearman's correlation (rs) test between total bacteria and fungi levels and environmental parameters such as indoor RH, indoor temperature and level of occupancy among cases and controls. The indoor relative humidity (RH) was moderately correlated with both indoor TBC (rs = 0.276) and indoor-to-outdoor TBC ratio (rs = 0.533). The total number of persons in household (occupancy) was found to be positively correlated with indoor TBC (rs = 0.262). A strong correlation was observed between indoor TBC and indoor-to-outdoor TBC ratio (rs = 0.715) while a negatively weak correlation (rs = -0.195) exist between the indoor relative humidity and the indoor TFC. Fig 4.25 - 4.26 shows the strength of the linear relationship between indoor TBC and indoor RH (R^2 = 10.6%) and indoor TBC and number of occupancy (R^2 = 19.1%).

Table 4.17: Relationship between Indoor Environmental Parameters and Microbial Concentration using Spearmans' Rank Correlation

Variable	Indoor RH	Indoor TBC	Indoor Temp	Indoor TFC	I/O TBC	I/O TFC	Occup
Indoor RH	1.00						
Indoor TBC	0.276 0.025*	1.00					
Indoor Temp	0.164 0.189	0.142 0.254	1.00				
Indoor TFC	-0.195 0.117	0.048 0.701	0.081 0.518	1.00			
I/O TBC	0.533 0.040*	0.715 0.000**	0.035 0.781	0.059 0.636	1.00		
I/O Fungal Count	-1.061 0.624	-0.021 0.864	0.082 0.513	0.385 0.001*	0.103 0.409	1.00	
Occup	-0.057 0.652	0.262 0.033*	0.210 0.090	0.089 0.477	0.165 0.187	0.061 0.629	1.00

n = 132,

* = p< 0.05

**= p<0.001

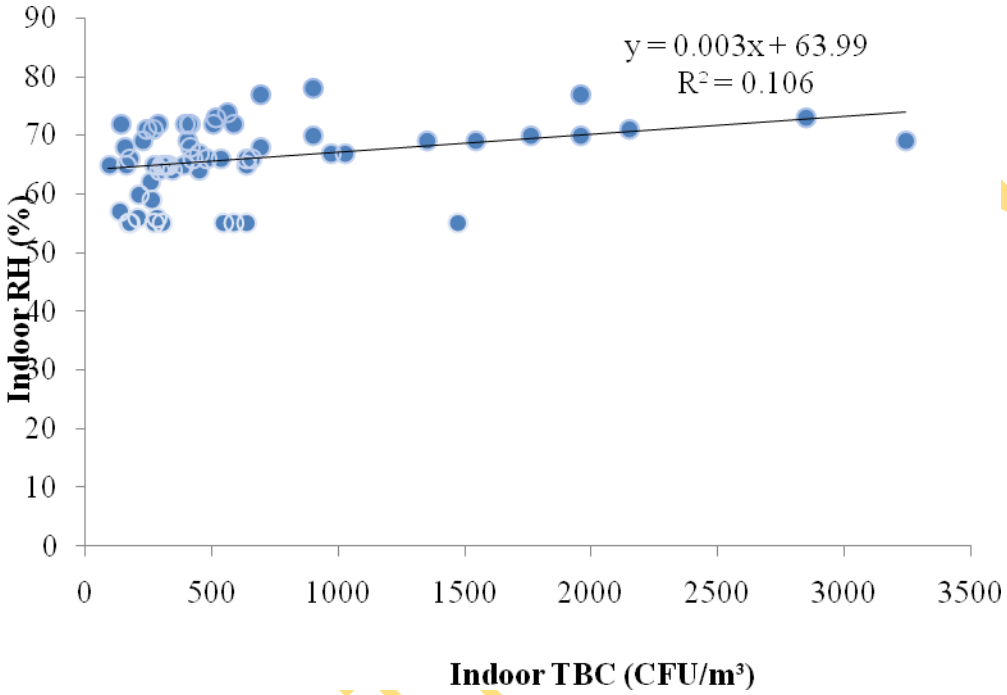


Fig 4.25: Relationship between indoor TBC and Indoor Relative Humidity

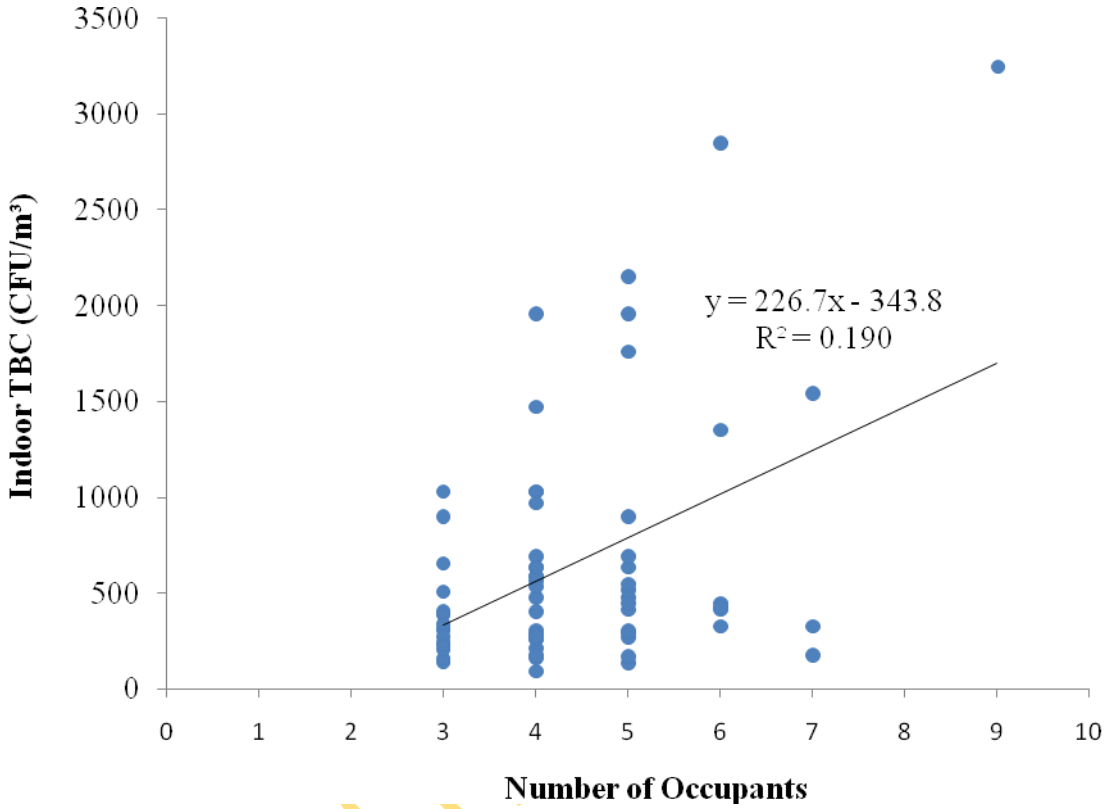


Fig 4.26: Relationship between indoor TBC and number of occupants

4.12 Profile of Airborne Microorganisms among cases and controls

Fig 4.27 and 4.28 highlights the frequently observed bacterial and fungal species among cases and controls. *Staphylococcus spp*. were recorded as the most dominant bacterial species among cases (84.8%) and controls (51.5%) respectively. *Streptococcus spp*. commonly found in ARIs was isolated in 33.3% of cases compared to 12.1% controls. *Micrococcus spp*. (60.6%, 33.3%), *Bacillus spp*. (54.5%, 24.2%) and *Pseudomonas spp*. (40.6% and 36.4%) as shown in plate 4.7 were among bacteria species isolated from cases and controls respectively. The dominant fungal species was found to be *Aspergillus spp.* 78.8% (cases) and 54.5% (controls). *Penicillium spp*. (54.5%, 36.4%), *Candida spp*. (42.4%, 30.4%), *Fusarium spp*. (24.2%, 30.3%) and *Cladosporium spp*. (36.4%, 30.3%) as shown in plate 4.5 and 4.6 were fungi species isolated among cases and controls respectively.

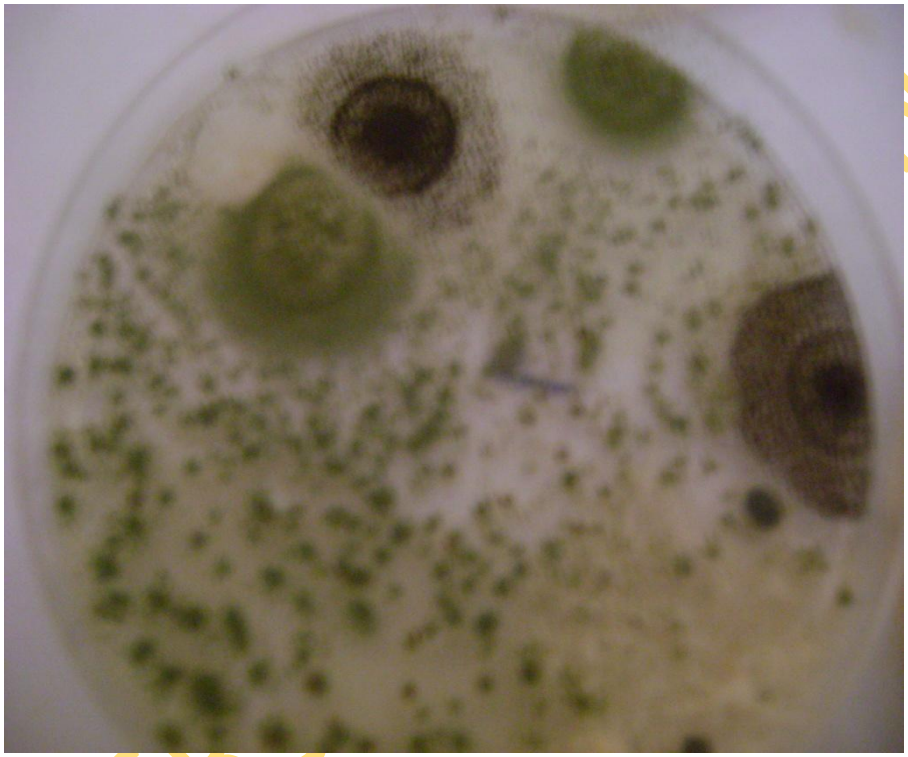


Plate 4.5: Showing growth of *Aspergillus spp.* on Potato Dextrose Agar

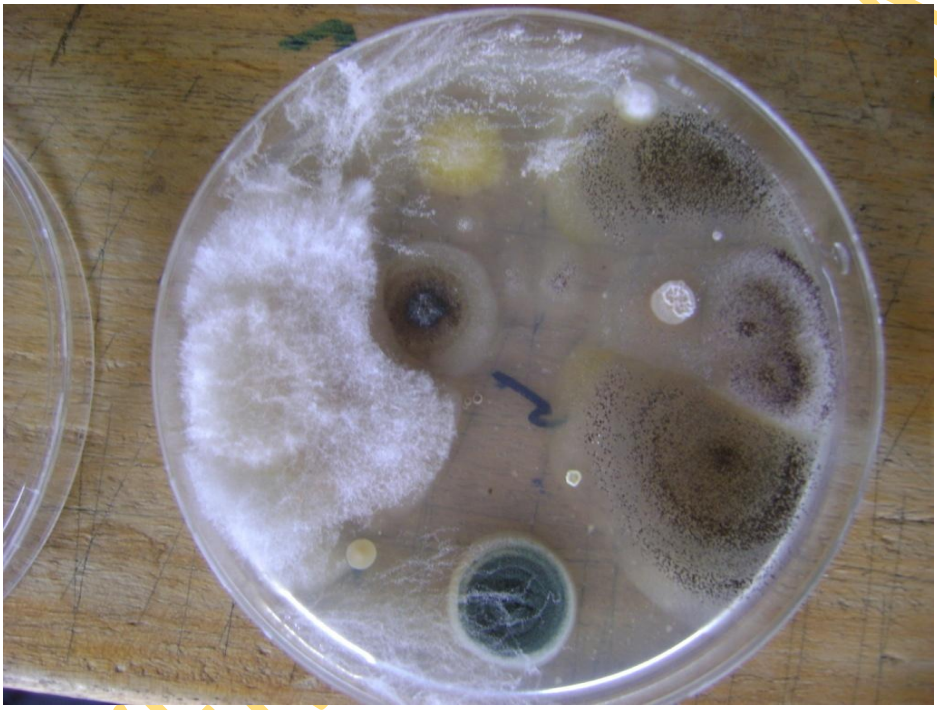


Plate 4.6: Showing growth of *Penicillium spp.* (Pink), *Aspergillus spp*. (Brown), *Cladosporium spp.* (White) *and others* on Potato Dextrose Agar

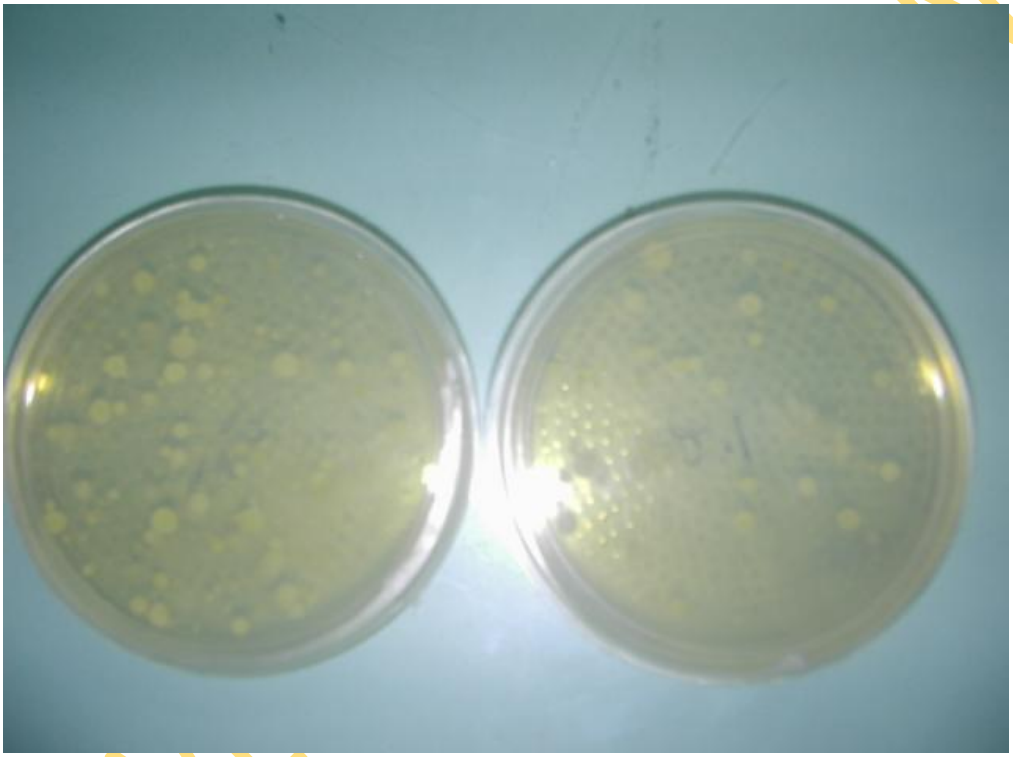


Plate 4.7: Showing bacterial colony on Nutrient Agar

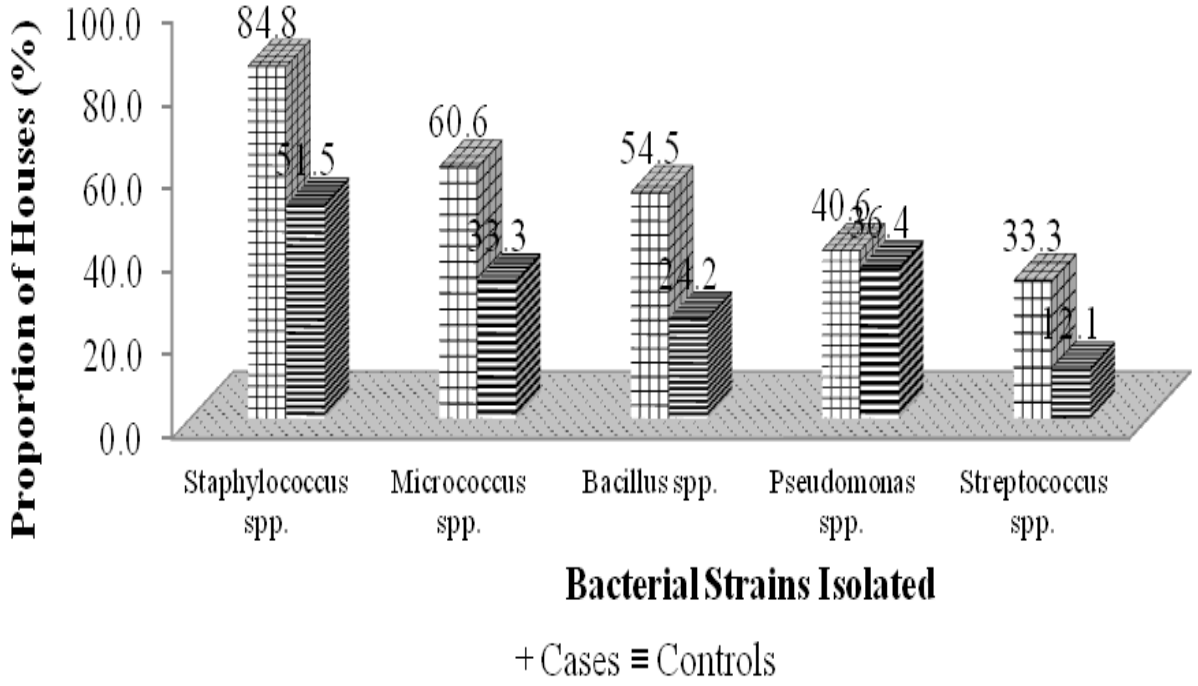


Fig 4.27 Characteristics of Bacterial strains isolated in residential apartments of cases and controls

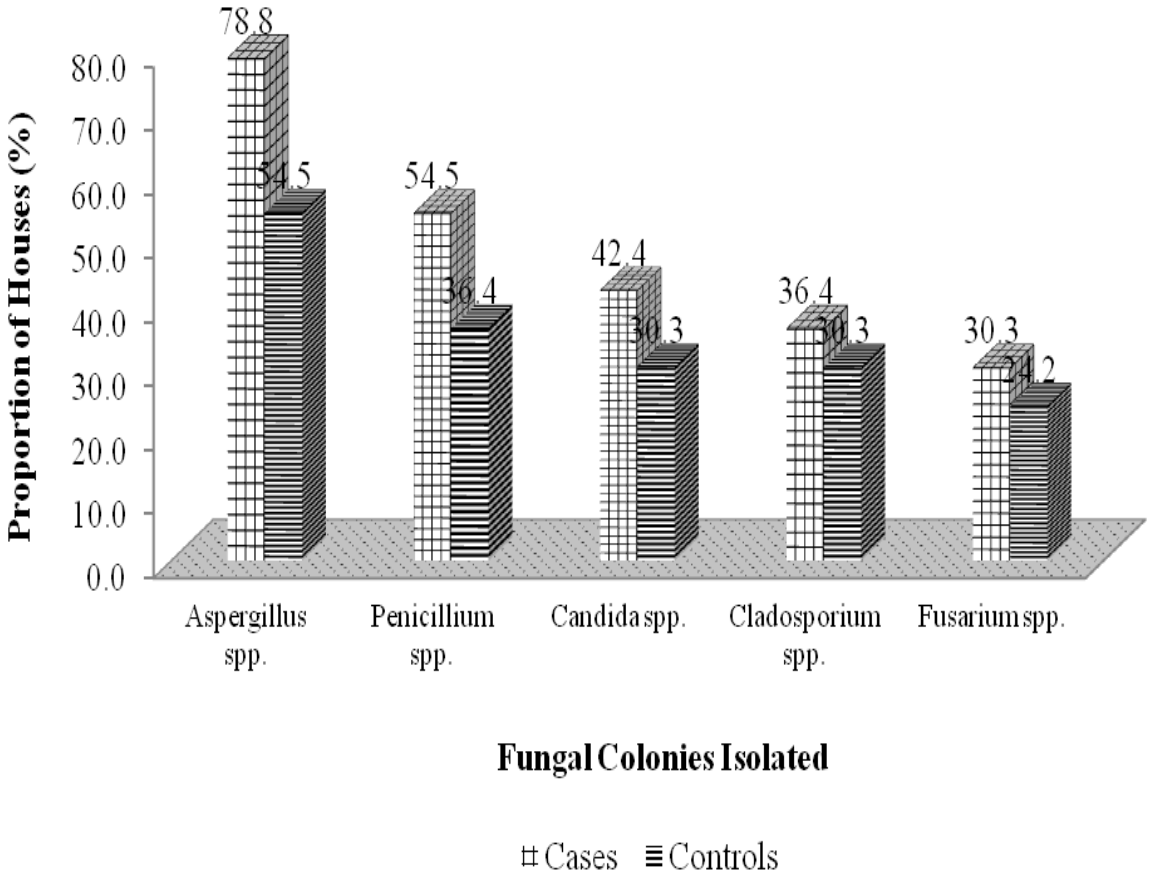


Fig 4.26 Characteristics of Fungi colonies isolated in residential apartments of cases and control

4.13 Socio-demographic characteristics of Respondents

The age of respondents among cases ranged from 15 to 47 years with a mean age of 28.77 ± 5.55 years while among the controls, the respondent ages ranged from 18 to 58 years with a mean age of 30.34 ± 6.56 years. Majority of mothers for cases 214 (97.3%) and controls 209 (95%) were below 40 years of age. Majority, 134 (60.9%) of cases and 136 (61.8%) controls respectively practice Islam while 86 (39.1%) and 84 (38.2%) respectively were Christians. Majority, 139 (63.2%) of cases were married, 72 (32.7%) were Co-habiting, 4 (1.8%) were Widowed, 3 (1.4%) were Separated and1 (0.5%) was Single and Divorced respectively while among controls, 142 (64.5%) were married, 70 (31.8%) were Co-habiting, 3 (1.4%) were Widowed, 3 (1.4%) were Separated and 1 (0.5%) was also Single and Divorced respectively. The Yoruba ethnic group was highest among respondents for cases 204 (92.7%) and controls 202 (91.8%), followed by Igbo 12 (5.5%) and 14 (6.4%) and Hausa 4 (1.8%) and 4 (1.8%) for cases and controls respectively. With respect to respondents' educational status, majority, 115 (52.3%) of cases and 115 (52.3%) controls had attained secondary education. An equal proportion of cases and controls 44 (20.0%) respectively had tertiary education, 57 (25.9%) and 58 (26.4%) had primary education while 4 (1.8%) and 3 (1.4%) respectively had no formal education. Equal proportion of cases and controls 134 (60.9%) respectively were traders, 39 (17.7%) and 40 (18.2%) were Artisans, 30 (13.6%) and 32 (14.5%) were Civil servants, 9 (4.1%) and 6 (2.7%) were Students and 8 (3.6%) respectively were housewives as shown in table 4.18.

Table 4.18: Socio-demographic characteristics of Respondents (Mothers)

Demographic Characteristics	Cases N (%)	Controls N (%)
Age: (Years)		
20 years and Below	16 (7.3%)	11 (5.0%)
21 – 25	45 (20.5%)	47 (21.4%)
36 – 30	90 (40.9%)	64 (29.1%)
31 - 35	44 (20.0%)	55 (25.0%)
36 – 40	19 (8.6%)	32 (14.5%)
41 years and above	6 (2.7%)	11 (5.0%)
Marital Status		
Single	1 (0.5%)	1 (0.5%)
Married	139 (63.2%)	142 (64.5%)
Divorced	1 (0.5%)	1 (0.5%)
Widowed	4 (1.8%)	3 (1.4%)
Separated	3 (1.4%)	3 (1.4%)
Co-habiting	72 (32.7%)	70 (31.8%)
Religion		
Christian	86 (39.1%)	84 (38.2%)
Muslim	134 (60.9%)	136 (61.8%)
Ethnicity		
Yoruba	204 (92.7%)	202 (91.8%)
Hausa	4 (1.8%)	4 (1.8%)
Igbo	12 (5.2%)	14 (6.4%)
Mother's Educational Status		
No formal education	4 (1.8%)	3 (1.4%)
Primary	57 (25.9%)	58 (26.4%)
Secondary	115 (52.3%)	115 (52.3%)
Tertiary	44 (20.0%)	44 (20.0%)
Mother's Occupation		
Trading	134 (60.9.5%)	134 (60.9%)
Artisan	39 (17.7%)	40 (18.2%)
Student	9 (4.1%)	6 (2.7%)
Civil Servant	30 (13.6%)	32 (14.5%)
Housewife	8 (3.6%)	8 (3.6%)
Family Income		
< 20000	131 (59.5%)	81 (36.8%)
20000 – 50000	86 (39.1%)	129 (58.6%)
>50000	3 (1.4%)	10 (4.5%)

Mean age of respondents (years), Cases = 28.8 ± 5.6 and Controls = 30.4 ± 6.6
Non-responses were excluded

4.14 Baseline characteristics of children

Table 4.19 highlights the basic characteristics of the age-matched children. The age of children among cases ranged from 1 – 58 months with a mean age of 20.41 ± 14.7months while among controls, the children's ages ranged from 1 – 56 months with a mean age of 20.85 ± 15.1 months. Majority 98 (44.5%) and 95 (43.2%) of cases and controls respectively were infants, 84 (38.2%) and 83 (37.7%) were toddlers while 38 (17.3%) and 42 (19.1%) respectively were preschool age. A large percentage 122 (55.5%) and 124 (56.4%) of cases and controls were males while 98 (44.5%) and 96 (43.6%) were females. More than half, 129 (58.6%) and 131 (59.5%) of cases and controls had birth weight less than 2500g while 91 (41.4%) and 89 (40.5%) had birth weight over 2500g. A higher proportion 80 (36.4%) of cases and controls respectively were second born, 55 (25.0%) respectively were first born, 51 (23.1%) and 50 (22.1%) were third born, 22 (10.0%) respectively were fourth born, 11 (5.0%) and 12 (6.0%) were fifth born while 1 (0.5%) each were the sixth born for cases and controls respectively.

Table 4.19: Baseline characteristics of the children

Child's Characteristics	Cases N (%)	Controls N (%)
Age: months		
Infant	98 (44.5%)	95 (43.2%)
Toddler	84 (44.2%)	83 (37.7%)
Preschooler	38 (17.3%)	42 (19.1%)
Sex		
Male	122 (55.5%)	124 (56.4%)
Female	98 (44.5%)	96 (43.6%)
Birth Weight		
< 2500g	129 (58.6%)	131 (59.5%)
≥ 2500g	91 (41.4%)	89 (40.5%)
Birth Order		
1^{st}	55 (25.0%)	55 (25.0%)
2^{nd}	80 (36.4%)	80 (36.4%)
3^{rd}	51 (23.1%)	50 (22.1%)
4^{th}	22 (10.0%)	22 (10.0%)
5^{th}	11 (5.0%)	12 (6.0%)
6^{th}	1 (0.5%)	1 (0.5%)

Mean age (month), Cases = 20.4 ± 14.7 and Controls = 20.8 ± 15.1

4.15 Respondents Knowledge on the risk factors for ARI

Table 4.20 highlights respondents' level of knowledge on risk factors for ARIs among children under-five. A large proportion, 215 (97.7%) and 216 (98.2%) of respondents for cases and controls had heard of ARIs while majority, 125 (56.8%) of cases and 117 (53.2%) of controls indicated that increased respiratory rate best explains ARI. Majority, 208 (94.5%) of cases and 209 (95.0%) of controls were knowledgeable on the fact that "the air we breathe contains agents that causes respiratory infections" while a little proportion of cases 42 (19.1%) and controls 53 (24.1%) had the understanding that these agents tend to be more concentrated in the indoor environment than the outdoor. Less than half, 99 (45.0%) of cases and slightly above half, 121 (55.0%) believed that large household size is a risk factor for ARIs while slightly below half of cases 105 (47.7%) and more than half of controls 136 (61.8%) understood that inadequate ventilation in the indoor environment can result in ARIs among children under five. A large proportion of cases 139 (63.2%) and controls 132 (60.0%) were of the opinion that the use of firewood for cooking predisposes children under five to ARIs while an approximately equal proportion of cases 211 (95.9%) and controls 217 (98.6%) believed that exposure to dust predisposes children under five to ARIs.

Approximately more than half of cases 192 (87.3%) and controls 150 (68.2%) understood that keeping pets in the house plays an important role in the spread of agents that causes ARIs among children under five while more than half, 164 (74.5%) of cases and 133 (60.5%) of the controls understood that children attending day care centres are more at risk of ARIs than their counterparts. Almost an equal proportion of cases 211 (95.9%) and controls 217 (98.6%) were of the opinion that malnourished children are more predisposed to ARIs than the adequately nourished children. A high percentage of cases 154 (70.0%) and controls 138 (62.7%) reported that family history of respiratory infections is a risk factor for ARIs among children under-five.

Table 4.20: Respondents knowledge on risk factors for ARIs

Variable	Options	Cases N (%)	Controls N (%)	Total
I have heard of Acute Respiratory Infections	*True	215(97.7)	216(98.2)	431
	False	5(2.3)	4(1.8)	9
ARIs are most common among infants	*True	106(42.8)	88(40.0)	194
	False	114(51.8)	132(60.0)	246
Increased respiratory rate best explain ARI	True	125(58.6)	117(53.2)	242
	False	95(41.4)	103(46.8)	198
The Air we breathe contains agents that causes ARIs	*True	208(94.5)	209(95.0)	417
	False	12(5.5)	11(5.0)	23
Indoor air contains more of these agents than the outdoor air	*True	42(19.1)	53(24.1)	95
	False	178(80.9)	167(75.9)	345
Large household size contribute to ARIs among children under five	*True	99(45.0)	121(55.0)	231
	False	132(60.0)	88(40.0)	209
Inadequate ventilation in a home is responsible for ARIs among children under five	*True	105(47.7)	136(61.8)	241
	False	115(52.3)	84(38.2)	199

Table 4.20 Respondents knowledge on risk factors for ARIs (Contd)

Variable	Options	Cases N (%)	Controls N (%)	Total
The use of fire wood for cooking predisposes children under five to ARIs	*True	139(63.2)	132(60.0)	271
	False	81(36.8)	88(40.0)	169
Exposure to dust is a risk factor for ARIs among children under five	*True	211(95.9%)	217(98.6%)	428
	False	9(4.15)	3(1.4%)	12
keeping pets in the house plays an important role in the spread of agents that causes ARIs among children under five	True	192(87.3)	150(68.2)	342
	*False	28(12.7)	70(31.8)	98
Children attending day care centres are more at risk of ARIs than those that do not attend	*True	164(74.5)	133(60.5)	297
	False	56(25.5)	87(39.5)	143
Malnourished children have a better chance of acquiring ARIs than the adequately nourished children	*True	211(95.9)	217(98.6)	428
	False	9(4.1)	3(1.4)	12
Family history of respiratory infections is a risk factor for ARIs among children under five	*True	154(70.0)	138(62.7)	292
	False	66(30.0)	82(37.3)	148

4.16 Relationship between the levels of knowledge of mothers on the risk factors for ARIs among children under-five

Mothers' knowledge on the risk factors for ARIs was analysed using percentile. The null hypothesis states that there is no significant relationship between the level of knowledge on the risk factors for ARIs among cases and controls. The proportion of cases and controls with adequate knowledge were 115 (52.3%) and 117 (53.2%) respectively. Table 4.21 shows that there is no significant relationship between the levels of knowledge of mothers of children under-five on the risk factors for ARIs among cases and controls. The null hypothesis therefore cannot be rejected.

Table 4.21: Relationship between the levels of knowledge of mothers on riskfactors for ARIs among cases and controls

Category	Range of scores			df	X^2	P-value
	Inadequate 0-13 (< 50th percentile)	Adequate 14-19 (≥ 50th percentile)	Total			
Cases	105(47.7%)	115(52.3%)	220(100%)	1	0.9	>0.05
Controls	103(46.8%)	117(53.2%)	220(100%)			

Mean Knowledge Score, Cases = 17.9 ± 2.9 and Controls = 17.9 ± 2.6

4.17 Attitude of Respondents towards risk factors for ARIs among under-five Children

Table 4.22 highlights the attitudes of mothers as regards the risk factors of ARIs. Slightly more than half of cases 123 (55.9%) and controls 117 (53.2%) disagreed that the air inside a room is different from the air outside the room, while almost half of the number of cases 100 (45.5%) and less than half of controls 84 (38.2%) disagreed that cross ventilation in the house should be encouraged rather than the use of air conditioning systems. A great proportion of cases 175 (79.5%) and controls 204 (92.7%) agreed that they prefer to live in a building where there are so many people around than to live in an isolated building while an equal number of cases 145 (65.9%) and controls 143 (65.0%) agreed that they cannot do without using firewood for cooking. More than half of cases 179 (81.4%) and controls 202 (91.8%) disagreed that the use of mosquito coils should be discouraged among households while almost half of the number of cases 109 (49.5%) and less than half of the controls 88 (40.0%) agreed that parental smoking influences the respiratory function of a child.

More than half of cases 159 (72.3%) and controls 174 (79.1%) agreed that they prefer that their children attend day care centres rather than staying at home. Slightly more than half of cases 115 (52.3%) and controls 128 (58.2%) agreed that exclusive breastfeeding of a child is very difficult to practice. Almost an equal proportion of cases 137 (62.3%) and controls 131 (59.5%) agreed that ARIs can be prevented by avoiding contact with people with respiratory complaints while a greater proportion of controls than cases disagreed that nothing can be done to prevent ARIs among children under-five.

Table 4.22: Attitude of Respondents towards risk factors for ARIs among Children under-five

Variable	Options	Cases N (%)	Controls N (%)	Total
There is no difference between the air inside a room and the air outside the room	Agree	91(41.4)	102(46.4)	193
	Indifferent	6(2.7)	1(0.5)	7
	Disagree	123(55.9)	117(53.2)	240
Cross ventilation in the house should be encouraged rather than the use of air conditioning systems	Agree	57(25.9)	74(33.6)	141
	Indifferent	63(28.6)	62(28.2)	125
	Disagree	100(45.5)	84(38.2)	174
I prefer to live in a building where there are so many people around rather than living in an isolated building	Agree	175(79.5)	204(92.7)	379
	Indifferent	37(16.8)	16(7.3)	53
	Disagree	8(3.6)	0(0.0)	8
I cannot do without using firewood for cooking	Agree	145(65.9)	143(65.0)	288
	Indifferent	9(4.1)	8(3.6)	17
	Disagree	66(30.0)	69(31.4)	135
Usage of mosquito coil should be discouraged among households	Agree	36(16.4)	13(5.9)	49
	Indifferent	5(2.3)	5(2.3)	10
	Disagree	179(81.4)	202(91.8)	381
Parental smoking influences the respiratory ability of a child	Agree	109(49.5)	88(40.0)	197
	Indifferent	28(12.7)	32(14.5)	60
	Disagree	83(37.7)	100(45.5)	183
Under-five children should be taken to a day care centre rather than staying at home	Agree	159(72.3)	174(79.1)	333
	Indifferent	22(10.0)	8(3.6)	30
	Disagree	39(17.7)	38(17.3)	77
Exclusive breastfeeding is very difficult to practice	Agree	115(52.3)	128(58.2)	243
	Indifferent	16(7.3)	14(6.4)	30
	Disagree	89(40.5)	78(35.5)	167
I believe ARIs can be prevented by avoiding contact with people with respiratory complaints	Agree	137(62.3)	131(59.5)	268
	Indifferent	32(14.5)	19(8.6)	51
	Disagree	51(23.2)	70(31.8)	121

4.18 Relationship between mother's attitudes towards risk factors for ARIs among cases and controls

The attitude of mothers as regard risk factors for ARIs among children under-five was also analysed using percentile. The null hypothesis states that there is no significant relationship between mothers' attitude towards risk factors for ARIs among cases and controls. Table 4.23 shows a significant relationship between the attitudes of mother as regard the risk factors for ARIs among children under-five. The null hypothesis therefore can be rejected.

Table 4.23: Relationship between mother's attitudes as regard risk factors for ARIs among cases and controls.

Category	Range of scores			df	X^2	P-value
	Negative 9-20 (< 50th percentile)	Positive 21-31 (≥ 50th percentile)	Total			
Cases	103(46.8%)	117(53.2%)	220(100%)	1	1.5	<0.05
Controls	125(56.8%)	95(43.2%)	220(100%)			

Mean Attitude Score, Cases = 27.8 ± 4.1 and Controls = 28.5 ± 4.4

CHAPTER FIVE

DISCUSSION

5.1 Characteristics of residential apartments occupied by cases and controls

The findings from this study revealed that a high proportion of cases 43 (65.3%) resides in houses with poor housing conditions (OR=2.5 C.I=1.3-5.1, $p<0.05$). This poor housing status was due to lack of essential housing facilities such as space, adequate ventilation, good sanitary conditions etc. This is in line with a study carried out by Ozcirpici *et al*., (2004) who found a composite poor housing status scores to be associated with increased incidence of ARIs. A poor level of sanitation was found among a higher proportion of cases than controls. This agreed to the report by Cardoso *et al*., (2004) who found children with respiratory illness to come from houses with poor sanitation than controls. Building factors or pollution in buildings most frequently and consistently associated with respiratory health effects are the presence of moisture, water damage, overcrowding and microbiological pollutants (Bornehag and Blomquist, 2001).

The present study found a higher proportion of cases (32%) than controls (9%) living in mud houses. This obviously reflects the age of the building, that is, the period it was built. In agreement to this fact a study carried out by Savitha *et al*., 2006, found that there was a significant association between mud housing and acute lower respiratory infection (ALRI). A similar result was found by Sikolia *et al*., 2002 in their study on the prevalence of acute respiratory infections and its associated risk factors, where they found 73% of children living in mud walled houses with ARI (RR=1.13). This could be due to the fact that mud floors tend to break up easily and release dust and particles.

This study found children that inhabit a face-to-face apartment to be 2.2 times more likely to develop ARIs than children that live in self-contained apartment. It is understandable that such apartments encourage overcrowding, although, it could be due to poverty. The high level of inadequacy in ventilation observed among a large proportion of cases

(66.8%) was based on the absence of a required minimum number of windows- 2 per room. In support of this fact, the finding from this study shows that a large proportion of cases (48.6%) reported < 2 windows per room (OR=3.1; CI=2.0-4.7, p<0.05).

It was observed from this study that a large proportion of children with ARIs inhabit homes with damp roof. This could be as a result of leaking roof or a high environmental moisture content. Although this study failed to demonstrate damp roof as a statistically significant risk factor for ARIs in children, a similar Canadian study found that children living in damp or moldy homes were 32% more likely to have Bronchitis (Dales *et al*., 1991). Similarly, algal growth was observed on the walls of a higher proportion of houses visited among cases. This probably was the result of the high level of moisture which has been known to support algal growth. In accordance with Pekkanen *et al*., (2007), high levels of moisture generally correlate with higher levels of microbial growth and thus, elevated levels of air-borne mould.

A large proportion of cases (53.5%) were found to reside in high density areas of Ibadan according to the Density distribution by the Urban and Regional Planning Department of the University of Ibadan, (2006). To corroborate this fact, a high number of respondents among cases (41.8%) reported a high traffic density near residence.

1.2 Household characteristics as risk factors for ARIs

The findings from this study showed that a higher proportion of cases 146 (66.4%) were tenants. This is in agreement with a report by Macintyre *et al*., (2003) who suggested in his study that house renters are more likely to experience housing stressors, such as dampness and overcrowding, as well as to be exposed to many other potentially health-damaging factors.

According to this study, the mean number of occupancy among cases was found to be 6.0 ± 1.5 as compared 4.0 ± 1.0 among controls (p<0.05). A similar study by Bernerji *et al*., (2001) noted that infants admitted to Baffin Regional Hospital because of lower respiratory tract infection generally lived in very crowded housing, with a mean of 6.4 occupants, including 3.0 children per house. Thomas *et al*., (2007) in a study on indoor air quality and risk of lower respiratory tract infections in young Canadian Inuit Children also

reported a very similar finding of 6.1 occupants per dwelling which implicated overcrowding as a risk factor for ARIs. This high level of overcrowding recorded among a higher proportion of cases (more than seven persons in household including children under-five) could be attributed to the fact that a large number reside in a face-to-face apartment of numerous households.

This study revealed that the mean number of persons per room among cases (3.0 ± 1.2) was higher when compared to controls (2.0 ± 0.8) $p<0.05$. The increase number of persons per room (> 2 persons per room) reported among cases could be due to space in terms of room number and size available for household use (OR=1.9; CI= 1.3 - 3.0, $p<0.05$). In a similar case-control study in Sao Paulo, Cardoso *et al*., (2004), found crowding (≥ 3 people sharing the child's bedroom) to be associated with 2.5 fold increased risk of ARIs, with cases tending to live in smaller houses than controls.

The mean number of children under-five among cases (3.0 ± 0.9) was found to be higher than among controls (2.0 ± 0.7) $p<0.05$. However, children belonging to a household of > 2 children under-five according to our study were found to be 1.6 times more likely to develop ARIs as compared to households with ≤ 2 children under-five years of age. This is in agreement with Celedon *et al*., (1999) in a study to document the risk factors for acute lower and upper respiratory tract infections among children under-five. This study also found ≥ 2 children under-five sleeping in the same room with the child in question to being associated with a 1.3 fold increase risk of ARIs. Similarly, Brims *et al*., (2005) and Ozcirpici *et al*., (2004) found increased number of siblings under-five sharing the same bed with the child to be significantly associated with increase risk of ARIs. In contrast, it is interesting to note that the risk of morbidity and mortality from an ALRI in a study carried out by Francisco *et al*., 1993 in two similar communities was smaller with increase number of children aged <5 years sharing the same bed. The good knowledge of the mothers on child care with respect to respiratory infections and increased ventilation in the child's room could have been responsible for this outcome.

5.3 Indoor Environmental factors among children under-five

Participants that took part in this study were asked to select a list of activities that occurs in their homes. The results of the indoor residential exposure showed that a large percentage of cases 195 (88.6%) were exposed to kerosene lantern at night. It was found that children exposed to kerosene lamps over a period of time are 4.1 times more likely to have ARIs. Sharma *et al*., (1998) in his study on indoor air quality and acute lower respiratory tract infections reported a similar finding. Such lamps are potential sources of emission of harmful particulate matter (<2.5µ) like polycyclic aromatic hydrocarbons, aliphatic hydrocarbons, nitrated hydrocarbons etc which are inhaled deep into the lungs (Smith, *et al*., 2000)

This study revealed that 65.2% of cases sometimes use firewood for cooking. This was reported to depend of the steadiness of electricity supply. About 33.3% often does the cooking at the entrance door to the living room while 24.2% sometimes does the cooking in the living room. This was obviously as a result of lack of a separate kitchen for cooking. A similar study by Broor *et al*., (2001) and Smith *et al*., (2000) on risk factors for severe acute lower respiratory tract infections in under-five children found 93.2% of children with ALRI to use biomass fuel such as firewood for cooking and 14.4% does the cooking in the living room (no separate kitchen). In line with these findings, Sikolia *et al*., (2002) found a large proportion of children (71%) living in houses using firewood to had developed ARI (RR=1.42). The present study also shows that children carried by their mothers while cooking were 3.2 times more likely to have ARIs than their counterpart. This supports the fact that the woods are burnt in simple stoves with very incomplete combustion generating a lot of toxic products that adversely affect specific and non-specific local defenses of the respiratory tract which result into respiratory illnesses (Smith, 2004).

The findings from this study indicated parental smoking or any other smoker in the house as a risk factor for ARIs in children under-five (OR= 4.7; CI= 0.9-21.7, $p<0.05$). This could be due to the accumulation of emissions from cigarette smoking in the indoor environment as a result of inadequate ventilation. This support of a report by Sikolia *et al*., (2002) who found 71.4% of children living in houses where the parent are smokers to

have developed ARI (RR=1.03) as compared to 69.0% of children living in houses where the parents were not smokers. Therefore, indoor air pollution especially smoke emissions contribute to ARIs among children under-five (Brims and Chauhan, 2005).

According to this study, a large proportion of children with ARIs were reported to attend day care centres. Children attending day care centres were found to be 2.6 times more likely to have ARIs when compared to children who do not attend. A possible reason for this could be the inadequate ventilation and overcrowding experienced in most of the day care centres. A similar study by Forssell *et al*., (2001) and Rylander and Megevand (2000) implicated day care centres as one potential source of vulnerability by children under-five to ARIs. Nafstad *et al*., (1999) in a study on day care centres and respiratory health also found attending a child care centre to be a strong risk factor for both upper and lower respiratory tract infections.

The present study found children with previous experience of ARIs to be 5.9 times more at risk of ARIs when compared to children without any previous experience of ARIs. This support a report by Silvio *et al*., (2008) that children with a personal history of respiratory diseases constitute a high-risk group. An increased level of family history of ARIs was reported among a large proportion of cases 22 (10.0%) than controls 4 (1.8%) (OR= 6.0; CI=2.0-17.7, $p<0.05$). This is understandable considering the fact that it could be transferred in genes from one generation to another. The result of this study showed a significant difference in most of the indoor exposures. This difference in exposures may be due to multiple factors which include: the level of knowledge, environmental influences, economic status, attitude etc.

5.4 Meteorological Characteristics of indoor and outdoor environments among cases and controls

According to the temperature and relative humidity scale by Ahmad *et al*., (2010), the indoor and outdoor air temperature of houses visited among cases and controls were beyond the comfort level (25.5 – 28^{o} C). It should be useful to clarify that, in general, the average temperature of Ibadan during the dry season (November - March) use to be lower than that observed in 2010. This study showed that none of the houses visited among cases and controls recorded an indoor air temperature within the comfort level. This could

probably be due to the current changes in atmospheric climatic conditions. The mean indoor and outdoor air temperature of houses among cases (33.1±1.3, 33.0 ± 1.2) was slightly higher than the values for controls (31.6 ± 1.9; 31.6 ± 1.8) ($p<0.05$). A similarl study by Sibel *et al*., (2009) in Turkey found the mean indoor (21.0 ± 3.7ºC) and outdoor (11.1 ± 8.4ºC) air temperature to be much lower. This difference is obviously due to the nature of the environment where the study was carried out.

In similar terms, a higher proportion of houses visited among cases and controls recorded indoor RH values above the comfort level (30 – 60%). The high RH's observed for large proportion of houses among cases could be as a result of high moisture content. The mean indoor and outdoor air RH among cases (69.6 ± 4.7; 67.2 ± 5.0) was found to be higher than among controls (63.1 ± 6.5; 66.1 ± 7.1) ($p< 0.05$). The high indoor relative humidity could breed mold, rot or pests, such as termite or cockroach. With such high relative humidity levels, microorganisms such as fungi and bacteria, can survive on non-living materials including dusts (Choa *et al*., 2002). A positive relationship was found between Indoor RH and indoor TBC, although, the linear relationship was weak (R^2 = 10.6%) which could be due to the weak coefficient of correlation (rs = 0.26). High relative humidity above 70% also tends to favour the survival of viruses that infect the membrane of the respiratory tract.

5.5 Airborne Microbial Burden among cases and controls

The findings from this study revealed that, during the study period (January – April, 2010) the indoor bacterial load of houses visited among cases was almost four times higher than the outdoor concentration. Some possible conditions that could have contributed to this situation include the fact that occupants spend more time in the indoor environments, the windows were poorly designed, with inadequate ventilation such that the indoor air relative humidity was high enough to support bacterial growth. Tong and Lighthart (2000) also found that the bacterial counts were higher in indoor air than outdoor air during winter. The results were indicative of the fact that the outdoor environment contributes to microbial build-up in indoor environment. This was also similar to a study carried out by Halide *et al*., (2010), Fang *et al*. (2007) and Nevalainen and Seuri (2005) on indoor and outdoor airborne bacteria in child daycare.

The indoor airborne bacterial load among cases ($9.6x10^2cfu/m^3$) was higher than the acceptable limit proposed by the American Industrial Hygiene Association (AIHA, 2001) for residential locations ($\leq 5.0x10^2cfu/m^3$) compared to controls ($3.5x10^2cfu/m^3$) while the indoor fungal load was almost similar among cases and controls. The high bacteria load recorded among cases could be due to overcrowding, poor housing status and inadequate ventilation. In addition, a higher microbial load (>500cfu/m³) was recorded in high risk areas of Ibadan such as Bere, Oje, Gbagi etc. A positive relationship was noticed between the level of occupancy and indoor TBC, although, the linear relationship was not very strong (R^2 = 19.1%). Similarly, Toivola *et al*., (2002) recorded the highest bacterial burden in an overcrowded environment. This suggests that the number of persons in household is directly proportional to the level of bacteria build-up in the indoor environment.

According to this study, the highest bacteria burden was recorded in the living room. There are several possible reasons for this. The living room is the most commonly used rooms by household. Individuals are constantly active in this setting and airborne bacteria were dispersed into the air from crowded group of people according to Toivola *et al*., (2002). Therefore, the airborne microorganisms could be said to be of human origin. In similar terms, Bartlett *et al*. (2004) found that occupants contribute to the concentration of indoor airborne bacteria and the individual concentration of bacteria such as *Micrococci* and *Staphylococci* are related to occupancy or occupant activity.

This study found out that the indoor-to-outdoor (I/O) ratio of airborne bacteria among cases (I/O = 4.26) and controls (I/O = 2.20) satisfies the fact that contamination is of indoor origin. This is no doubt the result of inadequate ventilation and increased number of occupancy. In contrast, Brickus *et al*., (1998) found that the microbiological concentration in the indoor air was similar to the outdoor values, which means that the indoor-to-outdoor concentration ratio (I/O) was close to 1.

However, by comparing obtained average values of I/O ratios with that proposed by Siqueira *et al*., (2004) (I/O ≤ 1.5 = good; I/O = 1.5-2.0 = regular; I/O > 2 = poor indoor ambient conditions), the indoor ambient conditions among cases can be estimated as

relatively poor as compared to a regular indoor ambient conditions among controls. A similar study by Roos *et al*., (2004) agreed to the fact that the most probable source of air contamination by microorganisms were indoor sources.

5.6 Morphological Profile of Airborne Microorganisms among cases and controls

This study also found that the predominant bacteria species observed indoor and outdoor among cases and controls were Gram-positive bacteria: *Staphylococcus spp*., *Micrococcus spp*., *Bacillus spp*., *Pseudomonas spp*., and *Streptococcus spp*. A similar study carried out by Halide *et al*., (2010) found that most of the bacteria isolated from the indoor and outdoor environments of day care centre were Gram-positive bacteria: *Staphylococcus spp.*, *Bacillus spp.*, *Streptococcus spp*. and *Micrococcus spp*. Majority of these bacteria occur in most environments; particularly in dusty, unsanitary places inhabited by human or other animals. Many of the species of bacteria isolated from the buildings were normal flora of such environments and are non-pathogenic. Predominant fungal species isolated from both the indoor and outdoor samples among cases and controls were: *Aspergillus spp*., *Penicillium spp*., *Candida spp*. *Cladosporium spp*. and *Fusarium spp*. in descending order.

5.7 Socio-demographic characteristics of mothers/caregivers

The findings from this study revealed that, the mean age of mothers of cases and controls were 28.7 ± 5.5 and 30.3 ± 6.5 years and the age range was between 15.0 – 47.0 and 18.0 – 58.0 years respectively. The relatively young age of mothers of cases and controls was expected because of the age of children considered for the study. The respondents for cases and controls were majorly Muslims and belonged to the Yoruba ethnic group. This is obviously expected in a study of this nature. The secondary level of education recorded among majority of respondents for cases and controls could be as a result of poverty and the nature of the communities that visit the hospitals. Similar low level of education was also reported by Osinusi and Oyejide (1994) among respondents in a poor urban community in Nigeria.

5.8 Socio-demographic characteristics of children under-five

The mean age of cases and controls were 20.4 ± 14.1 and 20.5 ± 15.1 months and the age range was between 1.0 – 58.0 and 1.0 – 56.0 months respectively. This survey affirmed that most cases were infants (<12 months) which is in support of the findings by Koch *et al*., 2003. A study by Kazi, (2008), also reported that infants (age <12 months) suffered more from ARIs than toddlers (age 12-23 months) and children (24-59 months). This study found that a large proportion of cases and controls were boys. A similar pattern was observed in a study carried out by Osinusi and Oyejide (1994) in a poor urban community in Nigeria. This was consistent with previously published findings from the National Family Health Survey (NFHS) that boys with ARIs are more likely than girls to be taken to a health facility for medical treatment (IIPS, 1995). The high level of low birth weight observed from this study may be attributed to poverty and poor nutritional status. A study by Prasad *et al*., (2010) on risk factors for ARIs among under-fives in Solapur found that a high proportion of cases were underweight at birth.

5.9 Respondents Knowledge on the risk factors for ARIs

Understanding people's knowledge, beliefs and attitude as regard ARIs is crucial as it can help to direct educational initiatives and public health communication (Ward *et al*., 1997). An adequate level of knowledge on risk factors for ARIs was recorded among a large proportion of cases 115 (52.3%) and controls 117 (53.2%) p>0.05. The knowledge recorded obviously has no relationship with the level of education. This finding contradicts the report by Sarab, 2007 in a study of upper respiratory infections and its association with knowledge, attitude and practice among Malaysians. A similar study carried out by Akpala and Okeke, 1996 in Enugu, Nigeria also found out that as many as 60% of respondents were knowledgeable about the causes of ARIs among children.

The high level of knowledge observed among respondents when asked if they had heard of acute respiratory infections before the commencement of this study could be due to previous experience of mothers of a pneumonic child, health promotion in hospitals and clinics, and communication among neighbors and relatives. Result from this study showed that a large proportion of respondents for cases and controls believed that increase respiratory rate best explains ARIs. This could also be connected with past experience and

witness of ARI cases as previously stated. In contrast, studies of perceptions of pneumonia signs by Muhe, (1996), found that Ethiopian and Pakistani mothers did not recognize rapid breathing as serious signs of ARIs.

The poor knowledge recorded among respondents for cases when asked if large household size contribute to ARIs among children under-five could be attributed to low level of education, religion and the nature of the communities that visit the hospitals. In contrast, a study by Thomas *et al*., 2007 on indoor air quality and risk of acute respiratory infections in young Canadian Inuit Children found a good knowledge of respondents about issues relating to overcrowding. A large proportion of respondents for cases and controls shear the opinion that inadequate ventilation in a home contribute to ARI acquisition among children under-five. This knowledge could be linked to mothers' experience about child care. Similar findings have been documented by Akpala and Okeke (1996) in a study of the perception of infant acute respiratory infections among mothers in Enugu, Nigeria. The high knowledge recorded among respondents for cases and controls when asked if the use of fire wood for cooking could predispose children under-five to ARIs could be the result of past exposure experience either by friends, relatives, neighbours or self.

A large proportion of respondents for cases and controls had an adequate knowledge when asked if children attending day care centres are more at risk of ARIs than children that do not attend. This is consistent with the research carried out by Simiyu *et al*. (2003) to determine the knowledge, attitude and practices of caregivers regarding acute respiratory infections among children in Kenya.

Approximately all the respondents for cases and controls were of the opinion that malnourished children have a higher chance of acquiring ARIs than the adequately nourished children. A similar finding was reported by Oyejide and Osinusi (1990) that caregivers were of a strong opinion that adequate breastfeeding of a child is a protective factor for ARIs.

5.10 Respondents Attitude towards the risk factors for ARIs

The attitude and behaviour of mothers concerning factors that affect the health of their children are formed at an early stage in life. Knowledge and understanding of health may reinforce formed attitudes. A high positive attitude towards risk factors of acute respiratory infections was recorded among a large proportion of cases 117 (53.2%) than controls 95 (43.2%) $p<0.05$. This is in line with a study carried out by Simiyu *et al*., (2003) on mother's knowledge, attitude and practices regarding ARIs in children.

The disagreement among a large proportion of respondents for cases and controls with respect to the attitude of promoting cross ventilation rather than the use of air conditioning systems could be attributable to societal influence about the use of air conditioning systems. Similarly, the positive attitude of respondents towards living in an overcrowded apartment could be associated with low level of education, culture and the nature of respondents' community. A similar response was reported by Kazi *et al*., 2008 in a study on risk factors for ARIs among children under-five in Bangladesh. He found a large number of mothers of children with ARIs to be inclined to living in an overcrowded environment.

Respondents' attitude towards the use of firewood for cooking was highly positive among cases and controls. Although, majority of respondents are aware of the diverse health effect of cooking using firewood particularly among children under-five (Graham, 1990) but due to poverty, it remained the cheapest and most affordable means of cooking. Similarly, a high proportion of respondents were of the opinion that parental smoking influences the respiratory function of a child. A study by Savitha *et al*., (2007) affirms that parental smoking reduces local defense mechanisms and predisposes children to respiratory illness.

With respect to prevention strategies, the believe among a large proportion of respondents that ARIs among children under-five could be prevented by avoiding contact with people with respiratory complaints could be as a result of respondents' understanding of the nature of the signs and symptoms of ARIs. A study by Akpala and Okeke (1996) reported a similar finding that majority of respondents were of the opinion that contact with person with respiratory infections could be a risk factor for ARIs.

5.10 Risk of ARIs and Environmental Health Management

This research sugguest that multiple interventions are required in reducing the acquisition of ARIs among children under-five. Indoor exposure to risk factors for ARIs is inevitable most especially among children under-five. Nevertheless, mothers or caregivers must engage in preventive strategies to reduce the risk associated with ARIs among children under-five. According to Ozcirpici *et al*., (2004), poor housing status are associated with increase incidence of ARIs. Inadequate ventilation, increased number of occupancy and high airborne microbial burden contributes to ARI acquisition among children under-five. Mothers or caregivers must be made aware of this information so as to ensure that these housing indicators are made adequate in order to reduce the acquisition of ARI among children under-five.

According to this study, the use of kerosene lamps, mosquito coils, firewood for cooking and parental smoking are potential sources of emission of harmful particulate matter which are inhaled deep into the lungs (Sharma *et al*., 1998). A long time exposure to these sources could compromise the health and wellbeing of a child. It is therefore of importance that mothers or caregivers prevent child's exposure to these factors. This preventive measure may be provided through avoidance. Avoidance which involves educating mothers or caregivers on the importance of making use of less hazardous household utilities such as electric lamps, mosquito net and electric cooker should be adopted.

Adequate air exchange is necessary in buildings for diluting many air pollutants of indoor origin. It is known that ventilation is necessary to remove the indoor-generated pollutants to acceptable values. But as the limit values of all indoor pollutants are not known, the exact determination of required ventilation rates based on pollutants concentrations and associated risk is seldom possible (Seppänen & Fisk, 2004). The effects of ventilation on indoors air quality and health is a complex issue. Most of the existing literature indicates that increasing ventilation rate will be an effective way to improve indoor air quality.

The Americal Indusrial Hygiene Association (AIHA) proposed a guideline of <500cfu/m^3 total microbial load in an indoor environment to protect the respiratory health of

occupants. It is therefore of importance that mothers or caregivers endeavour to maintain a total airborne microbial load of below guideline by promoting adequate ventilation (Seppänen & Fisk, 2004).

Health education is suggested to be an important tool in the prevention of respiratory infections among children under-five (Sarab, 2007). Thus, an educational campaign should be undertaken to educate mothers or caregivers on the risk of acute respiratory infections among children under-five. They should be made aware of the place of good housing conditions and practices and effective ventilation in the hierarchy of control measures.

CHAPTER SIX

CONCLUSIONS AND RECOMMENDATIONS

6.1 Conclusions

This study assessed the residential indoor meteorological parameters, housing characteristics and airborne microbial load in relation to the risk of acute respiratory infections among children under-five in Ibadan. The knowledge and attitude of mothers towards risk factors for acute respiratory infections among children under-five was documented. Risk factors in the indoor environment were also determined using a specially prepared interviewer administered questionnaire and an observational checklist. Indoor and Outdoor meteorological conditions and airborne microbial concentration were determined using specialized equipments for determining air temperature, relative humidity, total bacterial and total fungal count.

Housing as a neglected site for public health action has been identified in this study. There is strong empirical evidence that suggests that damp, cold, and mouldy housing is associated with respiratory infections among children under-five. Based on logistic regression analysis, overcrowding and poor housing conditions constituted significant independent risk factors for ARIs among under-five children.

Environmental risk factors such as poor housing status (OR=2.5, CI=0.9-3.1), poor ventilation (OR=3.1, CI=2.0-4.7), increased number of occupancy (OR=2.5, CI=1.6-3.6), use of lantern (OR=4.1, CI=2.5-6.8), the use of mosquito coil at night (OR=1.6, CI=1.0-2.4) and the use of firewood for cooking (OR=9.3, CI=3.6-24.0) were significantly higher among cases than the controls. This may have contributed to an increase vulnerability to respiratory infections among cases. A higher exposure to the risk factors for acute respiratory infections was observed among cases than controls with respect to housing status, building characteristics, materials used in building, indoor practices and indoor environmental conditions. For domestic exposure there was however a significant

difference in the exposure to pets in the house. Cases had significant exposure to dust from the indoor and outdoor environmental sources and to smoke from the use of firewood for cooking.

The mean indoor air temperature values of houses visited exceeded the comfort level for indoor air temperature (25.5 - 28º C) and even the WHO standard of 18.0 – 28.0º C but owing to the characteristic high temperature condition in this part of the world, it is unlikely to have any significant effect on the respiratory ability of children under-five years of age. The outdoor values of air temperature were slightly higher than the indoor readings among cases and controls which suggest that the outdoor air is hotter than the indoor air. The mean indoor air relative humidity values of houses visited also exceed the comfort level for indoor air relative humidity.

The mean indoor total bacteria count among cases ($9.6x10^2 cfu/m^3$) was far above all existing guidelines including the American Industrial Hygiene Association (AIHA) guideline for residential buildings and the American Conference of Governmental Industrial Hygienists (ACGIH) guideline of less than $500cfu/m^3$ when compared with controls ($3.5\ x10^2 cfu/m^3$) while the outdoor values were far below the AIHA guideline for residential buildings and within the limit for commercial locations. The mean total bacteria load among cases was found to be three times higher than among controls. A similar count of indoor total fungi ($0.2x10^2 cfu/m^3$) was isolated from the houses of cases and controls respectively. These values were within the recommended limit for indoor fungal load in residential buildings. A significantly weak linear relationship was observed between indoor TBC and Indoor RH (R^2 = 10.6%). The indoor ambient environmental condition among cases (I/O = 4.26) was found to be poor as compared to a more or less regular indoor ambient environmental conditions among controls (I/O = 2.20).

A high knowledge of mothers as regard risk factors for acute respiratory infections among children under-five was recorded for cases and controls. In addition, a high level of positive attitude among mothers of cases towards the risk factors for acute respiratory infections was also noted in the face of certain reservations.

Therefore, this study has been able to implicate poor housing status in terms of inadequate ventilation, overcrowding and unhygienic housing conditions as an independent risk factor for acute respiratory infections among children under-five. The indoor environment has also been implicated as major source of microbial contamination. The level of occupancy was found to be directly proportional to the concentration of bacteria in the indoor environment. Although, the level of linear relationship between Indoor TBC and level of occupancy was low probably due to the low coefficient of correlation. In addition, a total indoor airborne bacteria count of over 500cfu/m^3 has been found to trigger acute respiratory infections among children under-five.

6.2 Recommendations

6.2.1 Exposure Reduction at Individual Level

Children's vulnerability to acute respiratory infections especially from the indoor environment should be reduced through the following ways:

1. Encourage good housing status by maintaining good sanitary conditions
2. Prevent damp roof and algal growth on walls
3. Promote adequate ventilation in the house by increasing the number of windows in order to provide sufficient dilution to maintain the concentration of microbial contamination within acceptable level at all times.
4. Reduce overcrowding by increasing the number of room per person.
5. Avoid cooking in the room or very close to the room by providing a separate room or better done outside.
6. Avoid carrying children while cooking. They could be looked after by neighbours or relatives while cooking is going on in order to reduce the rate of exposure to smoke.
7. Avoide the use of smoke generating sources such as candle and kerosene lamps in the house. Instead use rechargeable lamps
8. Proper assessment of the day care centre the child attends to ensure that it is ventilated and not overcrowded.
9. Reduce child's continuous exposure to contaminants indoor by allowing them spend reasonable time outdoor.

6.2.2 Provision of Care at Health Facility Level

The provision of extended care to children with acute respiratory infections by health care centres should be ensured through the following ways:

10. Reduce child's vulnerability to acute respiratory infections by providing mothers with necessary information on the importance of good attitude towards the risk factors for acute respiratory infections among children under-five.
11. Educate mothers on the effect of parental smoking on the respiratory capacity of children under-five.
12. Educate mothers on the importance of exclusive breastfeeding on ARI prevention among children under-five.

6.2.3 Support at Governmental Level

13. Empower health workers to carry out proper routine monthly monitoring of houses in Ibadan. This obviously could improve and promote good housing conditions among the people.
14. Provide cheap and affordable residential apartments at strategic locations in Ibadan in order to reduce overcrowding in some major areas.
15. Empower the ministries of environment both at the federal and state levels in all states of the federation to monitor the air quality of residential areas by the provision of funds, purchase of equipments and other utilities such as vehicles and provision of adequate man power.

6.2.4 Future Outlook

1. Carry out a longitudinal seasonal monitoring of residential indoor air quality to determine the trend and pattern of airborne microbial load across the seasons.
2. Conduct community surveys to determine the viral etiology of ARIs among children under- five in Ibadan.
3. Conduct surveys in day care centers on indoor air quality and its respiratory effect among children under-five.

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APENDICEIES

Appendix 1

A QUESTIONNAIRE ON INDOOR AIR QUALITY AND RISK OF RESPIRATORY INFECTIONS AMONG UNDER-FIVE CHILDREN PRESENTING IN TWO HOSPITALS IN IBADAN, NIGERIA

Dear Respondent,

I am Fakunle Gregory Adekunle, a post graduate student majoring in environmental health in the Faculty of Public Health, College of Medicine, University of Ibadan and presently on a research titled: "**INDOOR AIR QUALITY AND RISK OF RESPIRATORY INFECTIONS AMONG UNDER-FIVE CHILDREN PRESENTING IN TWO HOSPITALS IN IBADAN, NIGERIA**". This research is purely for academic purpose. The findings will be of immense benefit in the area of identifying indoor risk factors for acute respiratory infection. Please note that you are not required to write your name on the questionnaire. Kindly feel free to express your opinion and be rest assured that your response will be kept strictly confidential. Your honest and sincere response to the following questions will be highly appreciated.

Thanks for your co-operation

Fakunle G. A.

SERIAL NUMBER____

INSTRUCTIONS: PLEASE TICK (√) OR FILL IN ANSWERS WHERE APPROPRIATE

SECTION A: DEMOGRAPHIC CHARACTERISTICS OF CAREGIVERS

1.	Age of Respondent (last birthday)	…….years
2.	Gender of Respondent	1. Male [ ] 2. Female [ ]
3.	Respondent Relationship with the child	1. Mother [ ] 2. Father [ ] 3.Grandparent [ ] 4. Uncle [ ] 5. Aunty [ ] 5. Others……
4.	Marital status	1.Single[ ] 2.Married[ ] 3.Divorced[ ] 4.Widowed [ ] 5. Separated [ ] 6. Co-habiting[ ]
5.	Religion	1. Christianity [ ] 2. Islam [ ] 3. Traditional[ ] 4.Others (specify) [ ]……
6.	Ethnicity	1. Yoruba [ ] 2. Hausa [ ] 3. Igbo [ ] 4. Others [ ]……
7.	Educational status of mother	1. No formal education [ ] 2. Primary [ ] 3. Secondary [ ] 4. Tertiary [ ] 5. Others, specify……
8.	Educational status of father	1. No formal education [ ] 2. Primary [ ] 3. Secondary [ ] 4. Tertiary [ ] 5. Others, specify…….
9.	Mother's occupation	1. Trading [ ] 2. Artisan [ ] 3. Farming [ ] 4. Student [ ] 5. Teacher [ ] 6. Civil servant[ ]
10.	Father's occupation	1. Trading [ ] 2. Artisan [ ] 3. Farming [ ] 4. Student [ ] 5. Teacher [ ] 6. Civil servant[ ]

11. Family income…….

SECTION B: CHILD CHARACTERISTICS

11. Age of the child (last birthday)…….. months.
12. Sex of the child. 1. Male [ ] 2. Female [ ].
13. Birth order. 1. 1st [ ] 2. 2nd [ ] 3. 3rd [ ] 4. 4th [ ] 5. 5th [ ] 6. 6th [ ]
14. Birth weight (grams) …….

SECTION C: KNOWLEDGE INFORMATION

15. Have you ever heard of Acute Respiratory Infections (ARIs)? 1. Yes [ ] 2. No[ ]
16. Which of the following best explains what ARI is? 1. Fever with no respiratory associate [ ] 2. Increased respiratory rate [ ] 3. Difficulty in breathing [ ] 4. disease of the respiratory system [ ]
17. The air we breathe contain agents that cause ARIs. 1. Yes [ ] 2. No [ ] 3. Don't Know [ ]
18. Indoor air contains more of these agents than the outdoor air. 1. Yes [ ] 2. No [ ] 3. Don't know [ ]
19. The following are factors that contribute to ARIs acquisition among under-five children

Factors	**Yes**	**No**	**Don't Know**
a) Large household size			
b) Inadequate ventilation system in homes			
c) Fire wood for cooking			
d) Exposure to dust			
e) Keeping pets in the house			

20. Attending day care centres predisposes children under-five to ARIs. 1. Yes [ ] 2. No[ ] 3. Don't Know [ ]
21. Malnourished children have a better chance of acquiring ARIs. 1. Yes [ ] 2. No [ ]
22. Family history of respiratory infections contribute to ARI acquisition among children under-five. 1. Yes [ ] 2. No [ ]

SECTION D: ATTITUDE OF MOTHERS/CAREGIVERS

Instruction: For each statement, please indicate by ticking (√) whether you strongly Agree (**SA**), Agree (**A**), Not Sure (**NS**), Disagree (**D**), or Strongly Disagree (**SD**)

S/N	Statement	(SA)	(A)	(NS)	(D)	(SD)
23.	ARIs acquisition among children under-five has nothing to do with ventilation in the house					
24.	Usage of air conditioning systems in the house should be encouraged rather than cross ventilation					
25.	A large household size can contribute to ARIs acquisition among under-five children					
26.	I cannot do without using firewood for cooking					
27.	Usage of mosquito coil should be discouraged among households					
28.	Parental smoking influences the respiratory ability of a child					
29.	Under-five children should be taken to day care centre rather than staying at home					
30.	Exclusive breastfeeding is very difficult to practice					
31.	I believe ARIs can be prevented by avoiding contact with people with respiratory complaints					

SECTION E: HOUSEHOLD CHARCTERISTICS

32. House ownership. 1. Landlord [ ] 2. Tenant [ ]
33. Age of building (in years)……..
34. Number of rooms used by household. ……..
35. Household size…….
36. Total number of children under-five. …….
37. Number of persons per room…….
38. Number of children 0 – 5 years sleeping in the same room as the child……
39. Number of adult sleeping in the same room as the child……..
40. Which of the following activities takes place in/around your house? 1. Food preparation [ ] 2. Refuse dumping [ ] 3. Transportation [ ] 4. Food processing 5. Farming [ ] 6. Beauty saloon [ ] 7.Others (specify)……..

SECTION F: INDOOR EXPOSURE EXPERIENCE

41. How often do you clean your surrounding? 1. daily [ ] 2. weekly [ ]3. monthly[ ]

42. Which of the following conditions do you experience in the house?

Factors	Yes	No
a. Room temperature too cold		
b. Room temperature too hot		
c. Stuffy air		
d. Dry air		
e. Unpleasant odor (smoke, fumes,chemicals, waste bin)		
f. Dust		
g. Dirt		
h. Leaky roof during rainfall		
i. Outdoor sources of pollution(traffic, smoke, fumes, soot)		

43. Do you keep pets? 1. Yes [ ] 2. No [ ]

44. What type of pet……

45. How do you ensure adequate ventilation in your house? 1. By Opening the windows [ ] 2. By opening the door [ ] 3.the use of ceiling Fan[ ] 4.The use of standing Fan [ ] 5. the use of Air-conditioner [ ]

46. Do the following conditions occur in your house?

Condition	Yes	No
a. Inadequate Ventilation		
b. Dampness on Wall		
c. Algal growth on wall		
e. Cracks on wall		
f. Cracks on floor		

47. Which of the following do you use indoor on a regular basis which you can notice?

	Yes	No	Never
Air spray			
Perfume			
Insecticide			
Lantern			
Candle			
Mosquito coil			
Generator			

48. Which of the following do you use for cooking?

Cooking Practices	Often	Sometimes	Never
Kerosine Stove			
Firewood			
Gas Cooker			
Electric Cooker			
Place of Cooking			
In the Bedroom			
At the Entrance door			
In the Kitchen			
Outside the Building			

49. How many times do you cook in a day? 1. Once [ ] 2. Twice [ ] 3. Three times [ ] 4. More than three times [ ]
50. Do you smoke? 1. Yes [ ] 2. No [ ]
51. Are there people that smoke cigarette or other forms of tobacco in your house? 1. Yes [ ] 2. No [ ] 3. Not really [ ]
52. Where do you treat any of your children that present with symptoms of ARI? 1. Home [ ] 2. Hospital/Clinic [ ] 3. Do nothing [ ].
53. Do you use nose protection such as nose mask for the child whenever you are cooking or sweeping? 1. Yes [ ] 2. No [ ]

SECTION G: OUTDOOR EXPOSURE EXPERIENCE

54. Has the child started schooling? 1. Yes [ ] 2. No [ ]. **If No, go to question 61-63**
55. Type of school? 1. Private [ ] 2. Public [ ] 3. Daycare [ ] 4. Lesson Class [ ]
56. Do you think your child's classroom is overpopulated? 1. Yes [ ] 2. No [ ]
57. Is the school very close to the following? 1. Market [ ] 2. Industry [ ] 3. Major road [ ] 4. Hospital [ ] 5.Dumpsite [ ] 6. Residential areas [ ]
58. Is the child always with you? 1. Yes [ ] 2. No [ ]
59. What is the nature of your work? 1. Hawking [ ] 2. Teaching [ ] 3.Counter seller [ ] 4. Cooking [ ] 6. Computer operator [ ] 7 Others (specify)……...
60. Where do you spend most of your day time? 1. At home [ ] 2. In the Market [ ] 3. At the shop [ ] 4. in the office [ ] 5. On the street [ ] 6.Others (specify)…….

SECTION H: HEALTH HISTORY

61. Has the child ever had any form of respiratory infections? 1. Yes [ ] 2. No [ ] 3. Not really [ ]

62. Was there any history of respiratory illness in the family? 1. Yes [ ] 2. No[ ] 3. Not really [ ]

63. If Yes specify……

64. Which of the following symptoms/diseases has the child suffered from in the last one month?

65. Is the child presently on drugs? 1. Yes [ ] 2. No [ ]

66. If Yes, please name the drug……

67. Has the child ever visited any hospital because of respiratory problem? 1 Yes [ ] 2. No [ ]

68. If Yes, when……

69. Did any family members cough during the past two weeks? 1. Yes [ ] 2.No[ ]

70. If yes, was the cough accompanied with shortness of breath?1. Yes [ ]2.No[ ]

71. How frequent does the cough occur? 1. Once [ ] 2. Sometimes [ ] 3. Regularly [ ]

THANK YOU FOR YOUR TIME

Appendix 2

OBSERVATIONAL CHECKLIST FOR HOUSE ASSESSMENT

Houes No…….

Date……..

Address……

……

Residential Contact…….

Phone: Home ( )……. Work ( )…….

SECTION A: HOUSING QUALITY ASSESSMENT

Facilities	Criteria	Yes	No
Sanitary Facilities			
	Presence of Sanitary Facility?		
	Facility in proper operating condition?		
	Facility usable in privacy?		
Food Preparation and Refuse Disposal			
	Suitable space for food preparation?		
	Suitable space to store food?		
	Suitable space to serve food in a sanitary manner?		
Space and Security			
	Presence of a livingroom, a kitchen and a bathroom?		
	A bedroom to every two persons?		
	Accessible windows from the outside?		
Thermal Environment			
	Presence of heating systems?		
	Presence of air conditioning systems?		
	Systems in good condition?		
Illumination and Electricity			
	Adequate natural or artificial illumination?		
	Minimum of two windows in the living room/bedroom?		
Structure and Materials			
	Defect in ceiling, walls and floors?		
	Weather-proof roof?		
	Defect in the foundation and exterior wall structures?		
Interior Air Quality			
	Adequate air circulation?		
	Bedroom with a minimum of two windows?		
Water Supply			
	Adequate water supply?		
	Water source in good condition?		

Sanitary Condition			
	Dwelling in good sanitary condition?		
	Presence of rodent infestation?		

SECTION B: BUILDING CONSTRUCTION CHARACTERISTICS

Type of building …… Finished ( ) Unfinished ( )

Total number of rooms……..

Building material (√)

Material	INDOOR			OUTDOOR		
	Present in good condition	Present in poor condition	Absent	Present in good condition	Present in poor condition	Absent
WALL MATERIAL						
Cement						
Concrete						
Mud						
Glass						
Wood						
ROOF MATERIAL						
Asbestos						
Cement						
Drop ceiling						
FLOOR MATERIAL						
Cement						
Concrete						
Block						
Sand						

SECTION C: VENTILATION (√)

Location of windows/doors allows cross-ventilation? 1. Yes [ ]. No [ ]

Visible condensation of dust on window……..

Presence of window blind……., Type……

Number/Surface Area of Air Spaces

Dimension	Living room	Bed room	Kitchen	Bath room
WINDOW				

Number				
Material				
L X B X H				
DOOR				
Number				
Material				
L X B X H				

SECTION D: INDOOR POLLUTION SOURCES (√)

Source of pollution	**Absent**	**Present but minimal**	**Present and numerous**
Pets			
Rodent			
Fungal growth on walls			
Leaking roof			
Houseplants			
Vegetation			

SECTION G: BUILDING COMPONENTS AND FURNISHING

Component	**Present**	**Absent**
old or deteriorated furnishings		
materials containing damaged asbestos		
Dust on Furniture		
Damp Roof		
microbiological growth in areas of surface condensation		
Wet clothes in the room		

SECTION H: WASTE MANAGEMENT PRACTICE

Solid waste management facility	**Absent**	**Present and functional**	**Present and non-functional**

Refuse bin			
Open burning			
Pit dumping			
Composting			
Sanitary landfill			

Sanitary inspection of refuse bin if present: Yes/No

Waste bin kept inside the house.....

Waste bin uncovered.....

Waste bin over filled.....

SECTION I: SANITARY CONVINIENCE

Sanitary	**Absent**	**Present**
Facility		
Water closet		
Aqua privy		
Potty		
Pit latrine		
Bush		
Location	**Yes**	**No**
Indoor		
Outdoor		

Inspection of Sanitary facilities: Yes/No

Presence of faeces around facility.....

Presence of faeces and water spills.....

Presence of water spills only.....

Appendix 3

APPROVAL OBTAINED FROM UI/UCH ETHICAL REVIEW COMMITTEE

INSTITUTE FOR ADVANCED MEDICAL RESEARCH AND TRAINING (IAMRAT)
COLLEGE OF MEDICINE, UNIVERSITY OF IBADAN. IBADAN, NIGERIA.
Director: **Prof. A. Ogunniyi,** B.Sc(Hons), MBChB, FMCP, FWACP, FRCP (Edin), FRCP (Lond)
Tel: **08023038583, 08038094173**
E-mail: **aogunniyi@comui.edu.ng**

UI/UCH EC Registration Number: **NHREC/05/01/2008a**

NOTICE OF FULL APPROVAL AFTER FULL COMMITTEE REVIEW

Re: Indoor Air Quality and Risk of Respiratory Infections among Under-Five Children Presenting in Two Hospitals in Ibadan, Nigeria

UI/UCH Ethics Committee assigned number: UI/EC/12/0011

Name of Principal Investigator: **Gregory A. Fakunle**

Address of Principal Investigator: Department of EMSEH,
College of Medicine,
University of Ibadan, Ibadan

Date of receipt of valid application: 25/01/2012

Date of meeting when final determination on ethical approval was made: **19/04/2012**

This is to inform you that the research described in the submitted protocol, the consent forms, and other participant information materials have been reviewed and given *full approval by the UI/UCH Ethics Committee.*

This approval dates from 19/04/2012 to 18/04/2013. If there is delay in starting the research, please inform the UI/UCH Ethics Committee so that the dates of approval can be adjusted accordingly. Note that no participant accrual or activity related to this research may be conducted outside of these dates. *All informed consent forms used in this study must carry the* UI/UCH EC *assigned number and duration of* UI/UCH EC *approval of the study.* It is expected that you submit your annual report as well as an annual request for the project renewal to the UI/UCH EC early in order to obtain renewal of your approval to avoid disruption of your research.

The National Code for Health Research Ethics requires you to comply with all institutional guidelines, rules and regulations and with the tenets of the Code including ensuring that all adverse events are reported promptly to the UI/UCH EC. *No changes are permitted in the research without prior approval by the* UI/UCH EC *except in circumstances outlined in the Code. The* UI/UCH EC *reserves the right to conduct compliance visit to your research site without previous notification.*

Professor A. Ogunniyi
Director, IAMRAT
Chairman, UI/UCH Ethics Committee
E-mail: uiuchirc@yahoo.com

Appendix 4

INFORMED CONSENT FORM

IRB Research approval number:

This approval will elapse on:

Title of Research:

Indoor Air Quality and risk of Respiratory Infections among under-five children presenting in two hospitals in Ibadan, Nigeria.

Name and Affiliation of Researcher:

This study is being conducted by Mr. Fakunle Gregory Adekunle, Department of EMSEH, Faculty of Public Health, College of Medicine, University of Ibadan.

Purpose(s) of Research:

To document how the quality of the indoor air environment of residential locations predisposes children under-five to respiratory infections.

Procedure of the research, what shall be required of each participant and approximate total number of participants that would be involved in the research:

This research would be divided into two phases. In the first phase, cases and controls would be recruited consecutively from each selected hospital. Systematic random sampling technique would then be employed to recruit participants to be followed home for indoor air assessment. The 1st phase would involve the administration of the questionnaire (survey) based on the inclusion criteria. The 2nd phase would involve household survey as well as meteorological and airborne microbial assessment of houses among selected cases and controls. Only 30% of the total population in the Phase 1 was recruited into phase II.

Expected duration of research and participant(s) involvement:

This research will be expected to last for an approximately five months.

Risk(s):

It is expected that this research would pose no physical, biological or social harm to all the research participants as all the procedures involved are non-invasive and no samples (blood, urine, saliva) would be collected. It is understood that in the process of recall in

phase I certain emotional harm might be experienced. This type of harm is not anticipated in this study.

Cost of participating, If any, of joining the research:

Your participating in this research will cost you nothing but your small amount and effort.

Benefit(s):

This research would help you in determining the following:

a) The household characteristics that predisposes children under-five to respiratory infections
b) The housing characteristics that contribute to respiratory infections among children under-five
c) The indoor meteorological conditions of your house
d) The indoor airborne microbial load to which you are exposed to.

Confidentiality:

All information collected in the study would be given code number and no name will be collected. Phone numbers would only be used to contact the participants for Phase II and in the presentation of findings. This is to ensure that no link is established with you. As part of my responsibility to conduct this research properly, officials from the UI/UCH Ethical Review Committee may have access to these records.

Voluntariness:

Your participation in this research is entirely voluntary.

Consequence of participant's decision to withdraw from research:

You can also choose to withdraw from the research at anytime. Please note that some information that has to be obtained about you before you choose to withdraw may have been modified or used in reports and publication. These cannot be removed anymore. However, the research promise to make good efforts to comply with your wishes as much as is practicable.

Any apparent or potential conflict of Interest:

This research work is strictly for academic purpose and is self funded. No attempt is being made to favour any of the participants.

Statement of person Obtaining Informed Consent:

I have fully explained this research work to ……
and have given sufficient information, including the risks and benefits, to make an informed decision.

Date……..

Signature……

Name……

Statement of person giving Consent:

I have read the description of the research. I understand that my participation in this research is voluntary. I know enough about the purpose, methods, risks and benefits of the research study to judge that I want to participate in it. I understand that I may freely stop being a part of the study at anytime. I have received a copy of the consent form.

Date……

Signature……

Name……

Detailed contact information including contacts address, telephone, fax. E-mail and any other contact information of researcher(s), institutional HREC and Head of Institution:

If you have any question about your participation in this research, you can contact the Principal Investigator, Fakunle G. A. at the Department of EMSEH, Faculy of Public Health, College of Medicine, University of Ibadan. His phone number and e-mail address are 08154205861 and fakunz@yahoo.com respectively. You can also contact the Head of Department of EMSEH, Faculty of Public Health, College of Medicine, University of Ibadan.

Thanks.

Appendix 5

LABORATORY RESULT FOR INDOOR AND OUTDOOR AIRBORNE MICROBIAL LOAD

Airborne Bacterial Count (TBC) (CFU/m³)

House No	Cases					Controls				
	LR	BR	KT	OUT	Organism	LR	BR	KT	OUT	Organism
1	900	120	500	720	*Bacillus spp., Staphylococcus spp., Micrococcus spp.*	38	30	23	360	*Micrococcus spp, Staphylococcus spp, Bacillus spp*
2	620	340	720	510	*Staphylococcus spp, Bacillus spp, Pseudomonas spp, Micrococcus spp*	32	10	21	100	*Bacillus spp, Pseudomonas spp, Staphylococcus spp*
3	605	380	400	200	*Streptococcus spp, Staphylococcus spp, Pseudomonas spp, Bacillus spp*	88	63	25	80	*Bacillus spp, Micrococcus spp, Flavobacteria spp*
4	520	440	220	400	*Bacillus spp, Staphylococcus spp, Micrococcus spp*	78	87	160	140	*Bacillus spp, Pseudomonas spp, Staphylococcus spp, Micrococcus spp.*
5	82	35	150	195	*Bacillus spp, Micrococcus spp, Staphylococcus spp*	76	62	55	84	*Bacillus spp, Staphylococcus spp, Flavobacteria spp*
6	400	185	310	380	*Bacillus spp, Micrococcus spp, Staphylococcus spp*	110	74	23	86	*Micrococcus spp, Staphylococcus spp, Bacillus spp*
7	320	125	220	120	*Flavobacteria spp, Staphylococcus spp, Micrococcus spp, Bacillus spp*	120	99	55	100	*Staphylococcus spp, Pseudomonas spp, Bacillus spp*
8	660	46	98	340	*Micrococcus spp, Staphylococcus spp, Bacillus spp*	55	102	58	88	*Micrococcus spp, Bacillus spp, Pseudomonas spp*

9	28	61	32	125	*Bacillus spp, Micrococcus spp, Pseudomonas spp*	180	69	95	75	*Bacillus spp, Pseudomonas spp, Micrococcus spp*
10	95	85	120	35	*Bacillus spp, Pseudomonas spp, Staphylococcus spp*	180	61	23	150	*Staphylococcus spp, Bacillus spp, Micrococcus spp*
11	100	110	55	68	*Staphylococcus spp, Bacillus spp, Pseudomonas spp*	55	25	35	120	*Bacillus spp, Flavobacteria spp, Micrococcus spp*
12	130	220	32	65	*Bacillus spp, Flavobacteria spp, Micrococcus spp, Pseudomonas spp*	85	24	30	130	*Staphylococcus spp, Bacillus spp, Pseudomonas spp*
13	69	42	35	55	*Bacillus spp, Flavobacteria spp, Staphylococcus spp*	98	68	28	220	*Bacillus spp, Pseudomonas spp, Micrococcus spp*
14	120	29	100	95	*Staphylococcus spp, Micrococcus spp, Bacillus spp*	65	28	50	110	*Flavobacteria spp, Staphylococcus spp, Bacillus spp*
15	220	600	102	105	*Bacillus spp, Staphylococcus spp*	180	98	85	210	*Pseudomonas spp, Micrococcus spp, Staphylococcus spp*
16	360	110	120	75	*Staphylococcus spp, Micrococcus spp, Bacillus spp*	38	30	42	165	*Bacillus spp, Micrococcus spp, Staphylococcus spp*
17	160	59	20	53	*Pseudomonas spp, Bacillus spp, Micrococcus spp*	42	40	38	64	*Staphylococcus spp, Bacillus spp, Streptococcus spp*
18	530	200	52	81	*Micrococcus spp, Staphylococcus spp, Bacillus spp*	47	76	62	132	*Bacillus spp, Staphylococcus spp, Micrococcus spp*
19	700	110	32	650	*Pseudomonas spp, Flavobacteria spp, Bacillus spp, Staphylococcus spp*	54	40	25	80	*Staphylococcus spp, Micrococcus spp, Pseudomonas spp*
20	230	220	130	140	*Staphylococcus spp, Micrococcus spp, Bacillus spp*	150	180	42	115	*Pseudomonas spp, Flavobacteria spp, Staphylococcus spp*
21	100	42	130	105	*Bacillus spp, Flavobacteria spp, Staphylococcus spp*	98	37	63	120	*Bacillus spp, Micrococcus spp, Staphylococcus spp*

22	300	29	160	130	*Micrococcus spp, Bacillus spp, Staphylococcus spp, Pseudomonas spp*	87	120	70	78	*Pseudomonas spp, Bacillus spp, Staphylococcus spp*
23	220	600	102	105	*Bacillus spp, Staphylococcus spp*	53	65	60	103	*Bacillus spp, Flavobacteria spp, Micrococcus spp*
24	360	110	120	75	*Staphylococcus spp. Micrococcus spp. Bacillus spp*	49	70	35	150	*Bacillus spp, Staphylococcus spp, Micrococcus spp*
25	160	240	20	53	*Pseudomonas spp, Bacillus spp, Micrococcus spp*	62	45	79	96	*Bacillus spp, Micrococcus spp, Staphylococcus spp*
26	530	56	52	81	*Micrococcus spp, Staphylococcus spp, Bacillus spp*	82	35	150	195	*Bacillus spp, Pseudomonas spp, Staphylococcus spp*
27	700	108	32	650	*Pseudomonas spp, Flavobacteria spp, Bacillus spp, Staphylococcus spp*	95	185	120	101	*Staphylococcus spp, Bacillus spp, Pseudomonas spp*
28	230	87	130	140	*Staphylococcus spp, Micrococcus spp, Bacillus spp*	100	125	55	85	*Bacillus spp, Flavobacteria spp, Micrococcus spp*
29	110	15	33	120	*Pseudomonas spp, Bacillus spp, Staphylococcus spp*	130	46	56	65	*Bacillus spp, Flavobacteria spp, Staphylococcus spp*
30	90	120	36	190	*Bacillus spp, Staphylococcus spp, Pseudomonas spp, Micrococcus spp*	69	61	76	120	*Staphylococcus spp, Micrococcus spp, Bacillus spp*
31	240	340	98	113	*Staphylococcus spp, Bacillus spp, Micrococcus spp*	120	85	100	95	*Bacillus spp, Staphylococcus spp, Micrococcus spp*
32	78	380	160	84	*Staphylococcus spp, Bacillus spp, Pseudomonas spp, Micrococcus spp*	220	110	102	105	*Staphylococcus spp, Micrococcus spp, Bacillus spp*
33	37	440	55	84	*Streptococcus spp, Staphylococcus spp, Pseudomonas spp, Bacillus spp*	360	220	120	132	*Micrococcus spp, Staphylococcus spp, Pseudomonas spp*

Airborne Fungal Count (colony) (TFC) (CFU/m³)

House No	Cases					Controls				
	LR	BR	KT	OUT	Organism	LR	BR	KT	OUT	Organism
1	3	9	5	5	*Candida spp, Fusarium spp, Penicillium spp*	4	2	6	7	*Aspergillus spp, Penicillium spp*
2	2	5	8	8	*Candida spp, Penicillium spp., Aspergillus spp.*	6	6	8	4	*Penicillium spp, Cladosporium spp*
3	4	4	5	10	*Fusarium spp, Candida spp, Aspergillus spp, Neurospora spp*	5	3	4	5	*Aspergillus spp, Cladosporium spp., Penicillium spp*
4	6	4	8	9	*Aspergillus spp, Penicillium spp, Candida spp, Fusarium spp*	2	6	5	6	*Candida spp, Aspergillus spp*
5	2	2	4	5	*Penicillium spp, Aspergillus spp, Cladosporium spp*	4	3	5	2	*Penicillium spp, Cladosporium spp*
6	5	4	6	3	*Penicillium spp, Candida spp, Aspergillus spp, Cladosporium spp*	4	2	6	7	*Cladosporium spp, Aspergillus spp, Penicillium spp*
7	7	5	5	2	*Aspergillus spp, Penicillium spp, Fusarium spp*	4	3	7	10	*Candida spp, Aspergillus spp*
8	5	2	3	4	*Aspergillus spp, Penicillium spp, Cladosporium spp, Fusarium spp*	3	4	5	6	*Cladosporium spp, Aspergillus spp, Penicillium spp*
9	2	4	2	5	*Aspergillus spp, Cladosporium spp., Penicillium spp*	2	3	2	5	*Candida spp, Penicillium spp., Aspergillus spp.*
10	2	5	3	2	*Geotrichum spp, Aspergillus spp, Penicillium spp*	8	5	7	3	*Aspergillus spp, Penicillium spp, Candida spp, Fusarium spp*
11	4	3	5	4	*Penicillium spp, Cladosporium spp*	5	3	3	3	*Fusarium spp, Candida spp, Aspergillus spp, Neurospora spp*

12	5	17	16	4	*Penicillium spp, Candida spp, Aspergillus spp*	2	2	4	6	*Aspergillus spp, Cladosporium spp., Penicillium spp*
13	3	10	8	3	*Aspergillus spp, Neurospora spp, Penicillium spp*	3	4	6	9	*Candida spp, Fusarium spp, Penicillium spp*
14	4	8	8	6	*Candida spp, Aspergillus spp*	2	9	12	12	*Cladosporium spp, Aspergillus spp, Penicillium spp*
15	5	5	4	7	*Aspergillus spp, Penicillium spp*	2	3	8	3	*Candida spp, Penicillium spp., Aspergillus spp.*
16	6	6	7	5	*Aspergillus spp, Penicillium spp, Cladosporium spp*	4	7	6	2	*Aspergillus spp, Penicillium spp, Fusarium spp*
17	5	3	4	5	*Cladosporium spp, Aspergillus spp, Penicillium spp*	8	9	4	6	*Penicillium spp, Candida spp, Aspergillus spp*
18	2	1	3	2	*Penicillium spp, Fusarium spp.*	2	5	2	3	*Aspergillus spp, Penicillium spp, Cladosporium spp, Fusarium spp*
19	2	2	3	2	*Candida spp, Penicillium spp*	2	3	4	3	*Aspergillus spp, Penicillium spp, Cladosporium spp*
20	5	4	4	4	*Aspergillus spp, Penicillium spp*	2	3	4	3	*Cladosporium spp, Aspergillus spp, Penicillium spp*
21	4	4	4	5	*Penicillium spp, Candida spp*	3	3	4	2	*Penicillium spp, Candida spp, Aspergillus spp*
22	3	9	3	4	*Fusarium spp, Aspergillus spp*	4	1	3	3	*Candida spp, Penicillium spp*
23	5	6	7	5	*Aspergillus spp, Penicillium spp*	5	1	2	2	*Penicillium spp, Fusarium spp,*

24	6	3	4	5	*Aspergillus spp, Penicillium spp, Cladosporium spp*	2	3	11	9	*Candida spp, Penicillium spp*
25	5	1	3	2	*Cladosporium spp, Aspergillus spp, Penicillium spp*	2	1	1	3	*Aspergillus spp, Fusarium spp, Geotrichum spp, Penicillium spp*
26	2	2	3	2	*Penicillium spp, Fusarium spp.*	2	2	1	5	*Aspergillus spp, Penicillium spp*
27	2	4	4	4	*Candida spp, Penicillium spp, Aspergillus spp*	2	5	3	2	*Cladosporium spp, Aspergillus spp, Penicillium spp*
28	5	4	4	5	*Aspergillus spp, Penicillium spp*	4	3	5	4	*Aspergillus spp, Penicillium spp*
29	2	9	3	4	*Candida spp, Aspergillus spp, Fusarium spp*	5	17	16	4	*Candida spp, Aspergillus spp, Fusarium spp*
30	6	4	3	3	*Aspergillus spp, Fusarium spp, Geotrichum spp, Penicillium spp*	3	10	8	3	*Fusarium spp, Aspergillus spp*
31	7	4	6	3	*Penicillium spp, Candida spp, Aspergillus spp*	4	8	8	6	*Aspergillus spp, Penicillium spp, Cladosporium spp*
32	2	6	5	6	*Candida spp, Penicillium spp*	5	5	4	7	*Aspergillus spp, Penicillium spp*
33	4	3	5	2	*Candida spp, Aspergillus spp, Fusarium spp*	6	6	7	5	*Candida spp, Aspergillus spp, Fusarium spp*

LR: Living Room, **BR**: Bedroom, **KT**: Kitchen, **OUT**: Outdoor [Point **A (right), B (left), C (front) of Building**]

Appendix 6

TEMPERATURE LEVEL (ºC)

House No	Cases				Controls			
	LR	BR	KT	OUT	LR	BR	KT	OUT
1	35.50	35.30	33.60	35.40	35.20	35.20	30.60	34.60
2	35.40	35.50	32.30	35.50	30.10	31.20	31.20	30.70
3	33.80	33.60	30.10	33.80	29.60	29.80	29.80	29.50
4	33.60	33.80	32.40	32.80	30.10	30.00	30.10	30.00
5	32.80	32.80	32.20	32.90	30.70	30.60	30.30	30.30
6	33.50	33.20	32.80	33.00	32.00	32.00	32.00	32.00
7	32.70	32.70	32.10	32.20	30.10	30.00	30.10	30.00
8	32.70	32.40	31.80	32.10	30.70	30.60	30.30	30.30
9	34.90	34.90	34.50	34.40	32.00	32.00	32.00	32.00
10	33.10	33.10	32.60	33.20	34.20	34.60	34.50	34.50
11	32.80	33.30	33.20	32.60	30.20	30.50	30.50	30.30
12	34.00	34.00	31.20	34.00	35.20	35.50	35.40	35.50
13	33.60	33.60	33.80	34.00	32.40	32.40	32.10	32.20
14	33.50	33.60	32.90	33.50	29.50	29.80	29.80	29.80
15	33.00	33.00	32.80	32.70	30.10	30.00	30.10	30.00
16	32.70	32.70	32.60	33.00	30.70	30.60	30.30	30.30
17	32.80	32.90	31.50	32.80	32.00	32.00	32.00	32.00
18	30.30	30.50	30.50	30.40	30.10	30.00	30.10	30.00
19	35.10	35.50	35.50	34.10	34.20	34.60	34.50	34.50
20	31.40	31.40	33.50	31.50	30.20	30.50	30.50	30.30
21	31.50	31.40	31.40	31.30	35.20	35.50	35.40	35.50
22	31.30	31.30	31.50	31.20	32.40	32.40	32.10	32.20
23	31.40	31.50	31.50	31.10	29.50	29.80	29.80	29.80
24	32.50	32.40	33.40	32.60	30.10	30.00	30.10	30.00
25	32.30	32.20	32.30	32.40	30.70	30.60	30.30	30.30
26	32.10	32.20	32.20	32.20	32.00	32.00	32.00	32.00
27	32.70	32.70	32.40	32.80	30.70	30.60	30.30	30.30
28	33.50	33.70	33.40	33.60	32.00	32.00	32.00	32.00

29	35.60	35.60	35.70	35.30	34.20	34.60	34.50	34.50
30	36.30	36.20	36.30	36.40	30.20	30.50	30.50	30.30
31	32.10	32.20	32.20	32.20	35.20	35.50	35.40	35.50
32	32.70	32.70	32.40	32.80	32.40	32.40	32.10	32.20
33	33.50	33.70	33.40	33.60	29.50	29.80	29.80	29.80
34	35.50	35.30	33.60	35.40	35.20	35.20	30.60	34.60
35	35.40	35.50	32.30	35.50	30.10	31.20	31.20	30.70
36	33.80	33.60	30.10	33.80	29.60	29.80	29.80	29.50
37	33.60	33.80	32.40	32.80	30.10	30.00	30.10	30.00
38	32.80	32.80	32.20	32.90	30.70	30.60	30.30	30.30
39	33.50	33.20	32.80	33.00	32.00	32.00	32.00	32.00
40	32.70	32.70	32.10	32.20	30.10	30.00	30.10	30.00
41	32.70	32.40	31.80	32.10	30.70	30.60	30.30	30.30
42	34.90	34.90	34.50	34.40	32.00	32.00	32.00	32.00
43	33.10	33.10	32.60	33.20	34.20	34.60	34.50	34.50
44	32.80	33.30	33.20	32.60	30.20	30.50	30.50	30.30
45	34.00	34.00	31.20	34.00	35.20	35.50	35.40	35.50
46	33.60	33.60	33.80	34.00	32.40	32.40	32.10	32.20
47	33.50	33.60	32.90	33.50	29.50	29.80	29.80	29.80
48	33.00	33.00	32.80	32.70	30.10	30.00	30.10	30.00
49	32.70	32.70	32.60	33.00	30.70	30.60	30.30	30.30
50	32.80	32.90	31.50	32.80	32.00	32.00	32.00	32.00
51	30.30	30.50	30.50	30.40	30.10	30.00	30.10	30.00
52	35.10	35.50	35.50	34.10	34.20	34.60	34.50	34.50
53	31.40	31.40	33.50	31.50	30.20	30.50	30.50	30.30
54	31.50	31.40	31.40	31.30	35.20	35.50	35.40	35.50
55	31.30	31.30	31.50	31.20	32.40	32.40	32.10	32.20
56	31.40	31.50	31.50	31.10	29.50	29.80	29.80	29.80
57	32.50	32.40	33.40	32.60	30.10	30.00	30.10	30.00
58	32.30	32.20	32.30	32.40	30.70	30.60	30.30	30.30
59	32.10	32.20	32.20	32.20	32.00	32.00	32.00	32.00
60	32.70	32.70	32.40	32.80	30.70	30.60	30.30	30.30
61	33.50	33.70	33.40	33.60	32.00	32.00	32.00	32.00
62	35.60	35.60	35.70	35.30	34.20	34.60	34.50	34.50
63	36.30	36.20	36.30	36.40	30.20	30.50	30.50	30.30

64	32.10	32.20	32.20	32.20	35.20	35.50	35.40	35.50
65	32.70	32.70	32.40	32.80	32.40	32.40	32.10	32.20
66	33.50	33.70	33.40	33.60	29.50	29.80	29.80	29.80

LR: Living Room, **BR**: Bedroom, **KT**: Kitchen, **OUT**: Outdoor [Point **A (right), B (left), C (front) of Building**]

Appendix 7

RELATIVE HUMIDITY LEVEL (%)

House No	Cases	Controls

	LR	BR	KT	OUT	LR	BR	KT	OUT
1	65.80	69.50	71.00	60.80	53.40	56.20	60.40	67.80
2	63.50	63.80	75.40	61.00	61.20	61.40	65.20	63.20
3	67.00	66.80	68.60	67.60	60.50	60.70	64.20	63.60
4	53.40	53.60	58.10	53.40	68.00	68.10	70.00	69.50
5	72.00	72.00	75.30	70.10	54.20	54.50	58.60	52.00
6	69.10	69.70	73.50	69.80	71.00	71.00	73.70	70.00
7	68.00	68.00	71.30	68.80	68.00	68.10	70.00	69.50
8	69.80	70.20	76.30	70.30	56.30	67.10	69.30	68.10
9	71.60	71.60	73.40	69.70	71.00	71.00	73.70	70.00
10	71.60	71.60	74.10	69.60	52.80	53.20	58.40	55.80
11	66.30	70.50	67.60	67.20	53.40	53.60	58.10	53.40
12	70.40	70.40	80.40	63.00	55.40	55.60	58.30	56.20
13	70.40	70.40	72.40	63.00	71.20	71.20	73.20	73.00
14	66.00	66.00	68.70	66.30	59.60	59.50	62.20	59.20
15	65.30	65.30	65.30	63.00	68.00	68.10	70.00	69.50
16	65.50	68.10	72.80	63.50	67.10	67.30	69.30	68.10
17	69.70	76.60	78.80	70.40	53.40	53.60	58.10	53.40
18	78.10	78.80	76.20	76.20	68.00	68.10	70.00	69.50
19	75.50	75.90	80.10	75.40	62.10	63.00	65.40	65.00
20	78.10	78.10	75.60	74.20	53.40	53.60	58.10	53.40
21	72.30	72.50	72.80	72.20	63.60	63.90	65.20	64.30
22	59.20	64.50	66.40	60.50	71.20	71.20	73.20	73.00
23	70.50	71.10	72.60	71.50	58.30	58.50	59.80	58.30
24	67.20	67.60	72.50	67.00	68.00	68.10	70.00	69.50
25	64.60	64.70	64.90	64.90	53.40	53.60	58.10	53.40
26	68.70	69.60	70.60	69.40	71.00	71.00	73.70	70.00
27	66.90	66.90	67.50	67.00	53.40	53.60	58.10	53.40
28	67.60	67.80	67.90	67.80	71.00	71.00	73.70	70.00
29	72.10	72.10	77.50	73.20	62.10	63.00	65.40	65.00
30	71.20	64.70	76.30	64.90	53.40	53.60	58.10	53.40
31	68.70	69.60	72.10	69.40	63.60	63.90	65.20	64.30
32	58.40	58.90	61.20	58.50	53.40	53.60	58.10	53.40
33	67.60	67.80	67.90	67.80	66.20	66.50	68.30	66.50
34	65.80	69.50	71.00	60.80	53.40	56.20	60.40	67.80

35	63.50	63.80	75.40	61.00	61.20	61.40	65.20	63.20
36	67.00	66.80	68.60	67.60	60.50	60.70	64.20	63.60
37	53.40	53.60	58.10	53.40	68.00	68.10	70.00	69.50
38	72.00	72.00	75.30	70.10	54.20	54.50	58.60	52.00
39	69.10	69.70	73.50	69.80	71.00	71.00	73.70	70.00
40	68.00	68.00	71.30	68.80	68.00	68.10	70.00	69.50
41	69.80	70.20	76.30	70.30	56.30	67.10	69.30	68.10
42	71.60	71.60	73.40	69.70	71.00	71.00	73.70	70.00
43	71.60	71.60	74.10	69.60	52.80	53.20	58.40	55.80
44	66.30	70.50	67.60	67.20	53.40	53.60	58.10	53.40
45	70.40	70.40	80.40	63.00	55.40	55.60	58.30	56.20
46	70.40	70.40	72.40	63.00	71.20	71.20	73.20	73.00
47	66.00	66.00	68.70	66.30	59.60	59.50	62.20	59.20
48	65.30	65.30	65.30	63.00	68.00	68.10	70.00	69.50
49	65.50	68.10	72.80	63.50	67.10	67.30	69.30	68.10
50	69.70	76.60	78.80	70.40	53.40	53.60	58.10	53.40
51	78.10	78.80	76.20	76.20	68.00	68.10	70.00	69.50
52	75.50	75.90	80.10	75.40	62.10	63.00	65.40	65.00
53	78.10	78.10	75.60	74.20	53.40	53.60	58.10	53.40
54	72.30	72.50	72.80	72.20	63.60	63.90	65.20	64.30
55	59.20	64.50	66.40	60.50	71.20	71.20	73.20	73.00
56	70.50	71.10	72.60	71.50	58.30	58.50	59.80	58.30
57	67.20	67.60	72.50	67.00	68.00	68.10	70.00	69.50
58	64.60	64.70	64.90	64.90	53.40	53.60	58.10	53.40
59	68.70	69.60	70.60	69.40	71.00	71.00	73.70	70.00
60	66.90	66.90	67.50	67.00	53.40	53.60	58.10	53.40
61	67.60	67.80	67.90	67.80	71.00	71.00	73.70	70.00
62	72.10	72.10	77.50	73.20	62.10	63.00	65.40	65.00
63	71.20	64.70	76.30	64.90	53.40	53.60	58.10	53.40
64	68.70	69.60	72.10	69.40	63.60	63.90	65.20	64.30
65	58.40	58.90	61.20	58.50	53.40	53.60	58.10	53.40
66	67.60	67.80	67.90	67.80	66.20	66.50	68.30	66.50

LR: Living Room, **BR**: Bedroom, **KT**: Kitchen, **OUT**: Outdoor [Point **A (right), B (left), C (front) of Building**]

APPENDIX 8

SAMPLING COORDINATES FOR HOUSES VISITED AMONG CASES

Houses	Longitude	Latitude	Elevation (ft)
H1	07º 31· 279N	E003º 53· 107E	754
H2	07º 33· 125N	E003º 53· 369E	861
H3	07º 35· 605N	E003º 53· 225E	650
H4	07º 33· 315N	E003º 53· 513E	780
H5	07º 34· 418N	E003º 53· 123E	671
H6	07º 33· 392N	E003º 53· 036E	767
H7	07º 35· 785N	E003º 53· 341E	678
H8	07º 33· 202N	E003º 53· 526E	674
H9	07º 34· 088N	E003º 53· 083E	621
H10	07º 33· 752N	E003º 53· 999E	768
H11	07º 32· 417N	E003º 53· 782E	860
H12	07º 33· 791N	E003º 53· 087E	823
H13	07º 34· 378N	E003º 53· 164E	635
H14	07º 33· 119N	E003º 53· 385E	741
H15	07º 31· 595N	E003º 53· 555E	629
H16	07º 34· 708N	E003º 53· 215E	559
H17	07º 33· 618N	E003º 53· 119E	846
H18	07º 35· 234N	E003º 53· 720E	641
H19	07º 32· 307N	E003º 53· 183E	730
H20	07º 33· 545N	E003º 53· 231E	628
H21	07º 31· 870N	E003º 53· 530E	711
H22	07º 34· 344N	E003º 53· 190E	646
H23	07º 33· 120N	E003º 53· 204E	654
H24	07º 33· 264N	E003º 53· 644E	865
H25	07º 35· 458N	E003º 53· 036E	882
H26	07º 34· 698N	E003º 53· 276E	635
H27	07º 33· 336N	E003º 53· 103E	831
H28	07º 35· 190N	E003º 53· 061E	765
H29	07º 33· 712N	E003º 53· 264E	692
H30	07º 34· 219N	E003º 53· 023E	797
H31	07º 33· 112N	E003º 53· 154E	671
H32	07º 35· 276N	E003º 53· 210E	868
H33	07º 33· 012N	E003º 53· 101E	895

APPENDIX 9

SAMPLING COORDINATES FOR HOUSES VISITED AMONG CONTROLS

Houses	Longitude	Latitude	Elevation (ft)
H1	07º 31· 173N	E003º 53· 120E	697
H2	07º 33· 621N	E003º 53· 119E	672
H3	07º 35· 429N	E003º 53· 005E	564
H4	07º 33· 235N	E003º 53· 103E	670
H5	07º 34· 634N	E003º 53· 163E	766
H6	07º 33· 593N	E003º 53· 126E	863
H7	07º 29· 388N	E003º 53· 161E	652
H8	07º 30· 627N	E003º 53· 136E	869
H9	07º 33· 992N	E003º 53· 013E	781
H10	07º 31· 344N	E003º 53· 019E	673
H11	07º 33· 495N	E003º 53· 332E	875
H12	07º 32· 622N	E003º 53· 387E	661
H13	07º 34· 429N	E003º 53· 464E	450
H14	07º 33· 119N	E003º 53· 685E	859
H15	07º 31· 625N	E003º 53· 255E	662
H16	07º 33· 388N	E003º 53· 385E	719
H17	07º 34· 838N	E003º 53· 409E	643
H18	07º 35· 274N	E003º 53· 280E	626
H19	07º 32· 197N	E003º 53· 113E	857
H20	07º 33· 665N	E003º 53· 161E	755
H21	07º 31· 571N	E003º 53· 330E	658
H22	07º 34· 294N	E003º 53· 290E	863
H23	07º 36· 423N	E003º 53· 274E	776
H24	07º 33· 153N	E003º 53· 344E	677
H25	07º 33· 338N	E003º 53· 066E	676
H26	07º 34· 309N	E003º 53· 216E	768
H27	07º 32· 136N	E003º 53· 143E	671
H28	07º 35· 498N	E003º 53· 361E	865
H29	07º 33· 412N	E003º 53· 434E	766
H30	07º 34· 114N	E003º 53· 093E	895
H31	07º 31· 207N	E003º 53· 174E	673
H32	07º 35· 142N	E003º 53· 320E	669
H33	07º 33· 251N	E003º 53· 481E	890