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# Species Diversity and Infestation level of Cockroaches in Addis Zemen town, North West Ethiopia

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**BAHIR DAR UNIVERSITY**  
**College of Science**  
**Department of Biology**



**Species Diversity and Infestation level of  
Cockroaches in Addis Zemen town, North West  
Ethiopia**

BY:

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Bahir Dar, University

Bahir Dar, Ethiopia

August, 2014

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College of Science  
Department of Biology

**Species Diversity and Infestation level of  
Cockroaches in Addis Zemen town, North West  
Ethiopia**

A Thesis Submitted to the Department of Biology  
Presented in Partial Fulfillment of the Requirements for the  
Degree of Master of Science in Biology (Zoological Science)

BY

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August, 2014

## Thesis Approval Sheet

### Declaration

I under signed, declare that this thesis is my original work; it has not been presented in other Universities, colleges or institutions, seeking for similar degree or other purposes. All sources of the materials used in the thesis and all people and institutions who gave support for thesis work have been duly acknowledged.

Gizachew Golla

19/ 9/2014

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Name

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Signature

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Date

As thesis research advisor, I hereby certify that I have read and evaluated this thesis prepared under my guidance, by Gizachew Golla Adale entitled “**Species Diversity and Infestation level of Cockroaches in Addis Zemen, Ethiopia**”. I recommend the paper to be submitted as fulfilling the requirement for the degree of MSc in Zoology.

Melaku Wale

19/9/2014

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## ABSTRACT

The species diversity and infestation level of cockroaches was studied in four different habitats in Addis Zemen town in 2014. The objectives of the study were to determine the species diversity, to determine the factors that contribute for occurrence of cockroaches, to isolate bacteria that reside on the external body of cockroaches and to assess the knowledge of the community about cockroaches. A cross-sectional survey and an experimental study were carried out. Data were collected through field observation, experiment, questionnaires and interview from December 30 to March 30/ 2006. The housing categories were sampled using proportional allocation. Cockroaches were collected using sticky traps and identified using standard identification keys. External body surface of cockroaches was washed in sterile saline and a sample suspension was cultured on four types of media: MacConkey, Nutrient Agar, Chocolate Agar and Tryptic Agar and incubated overnight at 37°C. The presences of bacteria on cockroaches were diagnosed using Gram staining method. Data collected were analyzed using analysis of variance (SAS version 12.1) and chi-square. The results indicated that German cockroach was the only species identified in the study area during the study period. Number of cockroaches significantly varied among housing categories ( $F=13.2244$ ,  $P<0.0001$ ), housing units ( $F=9.8672$ ,  $P<.0001$ ), hygienic levels ( $F= 35.5103$ ,  $P<.0001$ ), moisture regimes ( $F=84.4703$ ,  $F<.0001$ ), crack levels ( $F=19.1$ ,  $P<.0001$ ). Areas with poor hygiene level, more moisture and full of cracks brought more cockroaches. Gram Negative and Gram Positive bacteria were isolated from external body surface of cockroaches trapped from various sites. Majority of the 235 people interviewed, i.e., house wives, civil servants and restaurant workers believed that cockroaches are not a serious problem. In conclusion, German cockroach is the dominant species and it carries pathogenic disease causing organisms. Also factors such as hygiene, moisture management and avoiding cracks help deter cockroach infestation. Therefore, appropriate measure should be taken to reduce the spread of parasitic diseases that can be transmitted by cockroaches. Hotels and residential areas must be kept free of cockroach infestation through proper sanitation, disposal of wastes, destruction of cockroach habitats and using insecticides.

**Keywords:** cockroaches, species diversity, abundance, habitat

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## ACRONYMS

CDC.....	Center for Disease Control and Prevention
ETPHTI.....	Ethiopian Tropical Public Health Training Institute
FDREMOE .....	Federal Democratic Republic of Ethiopian Ministry of Education
FDREMOH.....	Federal Republic of Ethiopian Ministry of Health
HSD.....	Honesty Significance Difference
IGR.....	Insect Growth Regulator
IPM.....	Integrated Pest Management
JMTHM.....	Journal of Macro Trends in Health and Medicine
JTRP.....	Journal of Tropical and Rural Parasitology
SAS.....	Statistical Analysis System
WHO.....	World Health Organization
WHOPES.....	World Health Organization Pesticide Evaluation Scheme

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# 1 INTRODUCTION

## 1.1. Background and Justification

Cockroaches are ancient and highly successful groups of insects. They are the world's most common insects (Heerden, 2004; Chamavit *et al.*, 2011) which exist for more than 350-400 million years on earth (Cochran, 1999). Though cockroaches are found in all habitats, their origin is referred to north tropical Africa (Ebeling and Reiersen, 1970; Koehler and Patterson, 1989; Nasirian, 2008). In terms of species, cockroaches are highly diverse across warm, humid regions of tropical and subtropical areas of the world. They are also found in a variety of situations such as on decaying leaves, under the bark of trees, under rubbish or stones, near beaches, on flowers, grasses or brush, in caves, in the nest of ants, wasps or termites and semi aquatic environment. At home, they are found in toilets, kitchens, and bed rooms (Mpuchane *et al.*, 2006), and in hospitals and restaurants (Cochran, 1999; Addisu Kinfu and Birhanu Erko, 2008). They most often breed in outdoor environments in which temperature and humidity are favorable (Schal *et al.*, 1983). Majority of them are typically nocturnal insects but there are few diurnal species (Heerden, 2004). They are mainly omnivores and eat every edible thing. However, they prefer sweets, glues, papers, soaps, paints, grease and other things.

Commonly known pest cockroach species are the German cockroach (*Blattella germanica*), the American cockroach (*Periplaneta americana*), the Brown banded cockroach (*Supella longipalpa*) and the Oriental cockroach (*Blatta orientalis*) (Goddard and Raton, 2003). Of the aforementioned species, German cockroaches are the most

known medically important urban pests found in houses and restaurants. Some of them live in close association with humans and considered the worst pests (Bayer, 2007; Snoddy, 2007).

Cockroaches are the best known common indoor pests in low-income housing of many developing countries (Rust and Reiersen, 1978; Brenner *et al.*, 1995). The presence of cockroach populations in and around urban areas is an indication that food, moisture and harborage resources are present in the vicinity. These conditions allow them to proliferate and explode into large cockroach population (Miller and Koehler, 2003).

On the other hand, cockroaches are mechanical vectors which transmit disease causing pathogens that may potentially contaminate food, kitchen utensils and food preparation surfaces (Shahraki *et al.*, 2013). They contaminate human foods and produce bad odors (Zinabu Anamo and Nega Biraki, 2008). Specially, German cockroaches have filthy ability to spoil food and produce psychological distress (Brenner *et al.*, 1995). They are considered as risk factors and health hazards to human beings (Alam *et al.*, 2013; Etim *et al.*, 2013). Studies carried out in hospitals and restaurants of Ethiopia revealed that the pathogenic bacteria were isolated from the body surface of cockroaches (Addisu Kinfu and Birhanu Erko, 2008).

The most effective method to prevent cockroach infestation is exclusion and sanitation (Ogg *et al.*, 2006). keeping them control, prevent their entry, maintain good sanitation practices, seal cracks and crevices, baits, Traps and use insect growth regulators (Miller and Koehler, 2003; Erdaw Teachable *et al.*, 2006; Kinfu Zeru and Abera Kumie, 2007).

The purpose of this research is to assess diversity of species and infestation level of cockroach in Addis Zemen town, Amhara Regional state, North West Ethiopia.

## **1.2 Statement of the Problem**

Overcrowding and poor sanitation conditions which are common in most private houses and public health facilities of developing countries provide favorable breeding ground for cockroaches (Tetteh-Quarcoo *et al.*, 2013). These pests carry different types of bacteria and involve in the transmission of some infectious diseases but the role played by these insects as vectors of pathogenic microorganisms are not well understood yet (Guyader *et al.*, 1989; Kassiri *et al.*, 2014). Many people devoted 1-2% of their annual income every year on controlling cockroach infestation (Cochran, 1999). On the other hand, such habit of repeated use of chemicals against such insects poses a problem such as pollution and resistance of cockroach (Bayer, 2007).

In the context of Ethiopia, there is no extensive study with regard to the diversity of species, infestation level and vector potentials of cockroaches (Erdaw Teachable *et al.*, 2006). The poor human waste disposal mechanism, suitable temperature (Appendix1 Table1) and moist environmental condition of Addis Zemen town may make the area an ideal natural habitat for these insects. However, there are no documented data on the role of cockroaches as carriers of parasites in this area.

Hence, this study was conducted to fill such a gap. The findings of the study provides important information that would be used for designing strategies to control these pests and decrease cockroaches infestation level and the potential mechanical role of cockroaches in transmitting parasites and other vector-borne diseases causing organisms.

### **1. 3. Objectives of the Study**

#### **1.3.1 General objective**

The main objective of this research was to assess the diversity and infestation level of cockroaches in restaurants, residential houses, public offices and clinics in Addis Zemen town, Amhara Regional state, North West Ethiopia.

#### **1.3.2. Specific objectives**

This research was carried out with the following specific objectives:

- determine the species diversity of cockroaches in the study area,
- identify factors that contribute for the occurrence or abundance of cockroaches
- determine if cockroaches carry bacteria on their body; and
- measure the scale of awareness of society about cockroaches

### **1.4. Hypotheses**

It is confirmed that the relative density of cockroaches varies in different housing units and habitats (Mahmoud *et al.*, 2013). However, it is believed that no scientific study has been done in Addis Zemen town though there are observable facts of cockroach infestation. Hence, this research was initiated to test the following null hypotheses.

1. Cockroach species vary in magnitude in the study area
2. The density of cockroaches varies with housing unit
3. Community awareness is low about the negative impact of cockroaches
4. Roaches carry bacteria on their body.



## 2 LITERATURE REVIEW

### 2.1. Diversity and Morphology of Cockroaches

Cockroaches belong to kingdom animalia, phylum arthropoda, class insecta and order Dictyoptera and suborder *Blattaria* (Feizahaddad, *et al.*, 2012). They are placed in two major super families *Blattoidea* and *Blaberoidea*, separated on the basis of reproductive strategies and morphology (Cochran, 1999); and main families of *Blattidae*, *Blattellidae*, *Blaberidae*, *Cryptocercidae* and *Polyphagidae* (Bell, 1981; Roth, 2003). They are insects with a worldwide distribution in warm, humid, and lowland areas of the tropics (Addisu Kinfu and Birhanu Erko, 2008). Approximately, there are about 4000-7500 roach species in the world of which less than one percent invades and inhabits human dwellings (Heerden, 2004).

The most common domestic cockroach species found in human dwellings are German cockroach (*Blattella germanica*), Brownbanded cockroach (*Supella longipalpa*), American cockroach (*Periplaneta americana*), Oriental cockroach (*Blatta orientalis*) Smoky brown cockroach (*Priplaneta fuliginosa*) and Turkestan cockroach (*Blatta laterlis*). Here, it is important to note that the common names of roaches do not necessarily indicate the geographical origin of the species concerned. For instance, the origin of German cockroach is referred to Ethiopia and Sudan which is now found throughout the temperate region of the world (Mistal, 1999). It is also identified that *B. germanica* is the most dominant species in the world (Kwon and Chon, 1991; Bala and Sule, 2012). A study carried out in Addis Ababa and Zeway in 2008 by Addisu Kinfu and Birhanu Erko indicated that over 50% cockroaches were *B. germanica*, while the rest were *Periplaneta brunnea*, *Pycnooscelus surinamensis* and *Supella longipalpa*.

## 2.2 Identifying cockroaches

Cockroach species can be distinguished from each other by their appearance and their characteristics habits and habitats. In addition different cockroach species have different colors i.e., light brown, reddish brown, dark brown and black color and some have an unpleasant odor. It is important to identify the species involved cockroaches infestation so that the most effective control can be designed (Aymere Awoke and Laikemariam Kassa, 2006).

German cockroaches (*Blattella germanica*) are one of the most common indoor domestic and the smallest pest species in the family *Blattellidae*. Their average sizes range from 10-15mm in length and have yellowish brown color. They have two parallel bands on the pronotum identifying feature of this species. The adult German cockroaches are fully winged. Sex can be separated by the darker color stout abdomen of female cockroaches and much longer supra anal plat of male cockroaches. These cockroaches virtually found in all parts of the world and more distributed in northern and southern temperate region (Cochran, 1999). They prefer food preparation areas such as kitchen, bedroom and food storage which is moist and at about temperature of 30 °c. This species reproduces more rapidly than other common pest cockroaches. A single female cockroach can produce over 35,000 individual in one year under ideal conditions but many may succumb to cannibalism and other pressure. Females carry light tan eggs case called Oothecae which is about 5-7 mm long on the tip of abdomen usually drop it two days before it hatches but sometimes Oothecae hatch within its body. The incubation period depends on the temperature. Each egg case contains about 37-44 eggs and the adult can live more than one year under ideal condition (Jones, 2008).

Brown banded cockroaches (*Supella longipalpa*) are another indoor pest species under family *Blattellidae*. They have golden brown color and V-shape lighter bands on wings and their size range from 10-14mm in length similar to German cockroaches but lack two dark strips (Ogg *et al.*, 2006). Brown banded cockroaches infestation is less common than German cockroaches. Their life span is approximately about six months under suitable temperature of 30 °c (Cochran, 1999). They prefer electrical components such as radios, television, DVD and refrigerators. They often have seen behind pictures, books, on shelves, under wall paper, in ceilings, beneath furniture close to dark areas. They are often found in offices, animal rearing facilities and restaurants. These cockroaches are abundant in Africa and in temperate zone of USA. Both sexes are fully winged and the adult male Brown banded cockroaches can fly when disturbed but female cannot (Cochran, 1999). Female glue light brown Oothecae which are 4-5mm long and crescent shaped. Single female cockroach produces over 250 offspring cockroaches per year. These cockroaches recognized by two pale bands which run horizontally across their body (Hahn and Ascerno, 2005).

American cockroaches (*Periplaneta americana*) belong to family *Blattidae* having reddish brown color. Both sexes are fully winged, cosmopolitan distribution and have elongated oval body shape (Lu *et al.*, 2014). These cockroaches are primarily live in outdoor environment. They are dispersed through commerce from Africa to South America, West Indis, southern and northern USA, distributed tropical and sub tropical region of the world including China, UK, Japan Thailand and abundant in tropical Africa. Sex is separated that females lack styli (Cochran, 1999). They occur in restaurants; food processing, grocery, latrines, out of home found in sewer, trees and under decayed

matters. The American cockroach produces unpleasant odors. The adult size ranges 35-40mm and both sexes have fully well developed wings. This species can live 3-4 years. 10-90 egg cases are produced from a single female cockroach each containing about 28 eggs and can produce over 600 cockroaches in one year. The two large dark brown spots on the shoulders of these roaches are used to identify them apart to their reddish brown color of the body (Jones, 2008).

Oriental cockroaches (*Blatta orientalis*) are also known as water bug or black beetle in and belong to the family *Blattidae*. They are tubular-shape and primarily live in outdoor dump place and can also live in indoor drains. Outdoor they are found in under barks of trees, under stones and leaves. Mostly they occur in an area that surrounded by vegetation. Oriental cockroaches prefer cooler temperature than other species. Oriental cockroach cannot fly instead move more slowly and unable to climb smooth vertical surface. Largely these species found in northern temperate zone of the world and dominant species in UK, German, South Africa, Europe, America and Australia (Cornwell and Mendes, 1981). They are medium in size measuring 20-30mm long and reddish brown or dark brown to shiny black in color and relatively long lived cockroach species. Males may have reduced wings but females are wingless. Each female oriental cockroach deposits dark red brown 8 egg cases which are 10-12mm in length, each contain 16-18 eggs and can produce up to 200 offspring in one year. Oriental cockroaches give off unpleasant odor from their bodies (Jacobs, 2013).

### 2.3 Habitat and Cockroach biology

Cockroaches live in a wide range of environments around the world and they are distributed in the warm and the humid regions of tropical and subtropical America and Africa. Cockroaches occur in all continents except Antarctica and their habit is very diverse on which adequate temperature and humidity are suitable for the survival (Schal *et al.*, 1983). Most cockroach species occur in outdoor habitats in which temperature and humidity are favorable and some cockroach species adapted indoor habitats. However, most of them live in outdoor habitats. They occupy different micro habitats such as hospitals, restaurants, offices, homes and markets (Feng *et al.*, 2009; Wannigama *et al.*, 2014) with high preference to cracks, under or inside cupboards and cabinets, where pipes or electrical wiring pass along or through a wall behind window or door frames, under tables and chairs, in upholstered furniture, in bathrooms, in radio, TV cabinets, in refrigerators, washing machines and other materials. Outdoor they are found in a great variety of habitats such as forest, deserts and cave dwelling, on dead leaves, animal dens, caves, trees, ant nests and sometimes in water (Velez, 2008). Human daily activities like cooking, eating and bathing provide water, food, shelter and warmth that trigger cockroaches to live well with human. Cracks and crevices are favorable hiding and breeding areas of cockroaches (Piper and Antonelli, 2004) but they cannot survive in very dusty and windy areas (Mpochane *et al.*, 2006), in a vacant home and temperatures above 120° F. Different cockroach species have slightly different requirements. This helps to know where to inspect and focus control efforts (Ogg *et al.*, 2006). Particularly female oviparous cockroaches select specific substrate for oviposition and embryogenesis (Schal *et al.*, 1983).

Cockroaches are insects with an incomplete life cycle which grow and mature by gradual metamorphosis. Three stages in their life cycle, these are egg, nymph, and adult (Piper and Antonelli, 2004). The nymphs generally resemble the adult except for size and the fact that their wings and genitalia are under developed. Eggs of cockroaches are covered by hard and protective layers called oothecae which are formed by the female cockroach. The oothecae are carried externally by the oviparous species or carried inside the female body by the viviparous species. In both cases, they deposit their oothecae in outdoor situation in holes, in soils, rotting wood and other substrates. Then female usually cover the opening with some appropriate materials. The free living and active nymph emerge and grow through a series of instars and molt before reaching the adult stage (Cochran, 1999). Immature cockroaches called nymphs hatch from egg cases that adult female deposits. As the nymph grows, it sheds its skin or exoskeleton then it gets larger. The development of nymph depends on the environmental temperature, although nymph stages are showing that each cockroach species has a unique number of immature stages or molts. Female cockroaches of some species are able to reproduce without mating (parthenogenesis) and produce unfertile offspring (Ogg *et al.*, 2006).

#### **2.4 Feeding and Distribution**

The majority of cockroach species are nocturnal and omnivorous that they feed on decomposing vegetable materials (Velez, 2008). The typical foods preferred by indoor cockroaches are sugar, candies, chocolate, meat, cheese, milk and bread. However, they utilize almost all materials as food. In addition they feed readily on book bindings, dead insects, blood, excrement, faeces and different kind of animals and vegetable detritus. In the tropical area, many free living cockroaches are primarily detritus feeder and other

organic matter including bird droppings. They have been shown to feed readily on faeces, sputum, skin scrapings and other human detritus as well as on a variety of foodstuffs including dead roaches (Schal and Bell, 1982). Cockroaches show cannibalistic feature, they eat their own young, injured and dead cockroaches too if food is not available (Ogg *et al.*, 2006).

Cockroaches are one of the most adaptable and successful groups of insect. Cockroaches have indiscriminate dietary habit, adult cockroaches have ability to live without food for several weeks, a week without water and they have ability to breed all over the year. These features of cockroaches' together with their nocturnal activity make them widely distributed all over the world (Baumholtz *et al.*, 2008; Abera Kumie *et al.*, 2002). Morphological, physiological and behavioral features of cockroaches allow them to colonize and survive in different environments (Fotedar *et al.*, 1989). They easily move through aided transports and are more distributed in Asia, Europe, USA, Africa, Southern Russian, United Kingdom, Spain, South America, Argentina and China. Some cockroaches are known pest insects that live with human dwellings especially in kitchens (Hoffman and Davis, 2005). The distributions of cockroach species are influenced by the environmental requirements such as altitude, soil type, food availability while altitude is the most important factors that determine spacial distribution of cockroach species. They cannot live above 2000 meter and polar region. They are strongly affected by bare or exposed localities which are unplanted and eroded by the wind (Ciliberti *et al.*, 2009).

## 2.5. Economic Importance of Cockroaches

### 2.5.1. Positive impact of roaches

Cockroaches are important to us because they can be used as tools for the research of insect physiology and toxicology and are considered a garbage collector in the terrestrial ecosystem. Roaches play role in recycling dead plants, dead animals' increments and process to balance the environment. They serve as elimination of waste products by feeding on fecal materials of animals in all tropic level (Alam *et al.*, 2013). Plant material, including floral resources, form part of the diet of many cockroach species (Schal *et al.*, 1984) and play important role act as pollinators. Nocturnal flowers are visited by cockroaches, for instance a cockroach species *Amazonian platystylata* feed liquid secretion produced by tissues at the floral apex and at the base of the ovary, so they serve as principal pollinator (Kova *et al.*, 2008). They are an important part of the food chain and play an important role in nutrient recycling (Bell *et al.*, 2008). In Asian countries cockroaches are served as a delicious food and therefore already have significance for the human food supply. It is predicted that these animals would be served as a protein source in the future in western countries (Miller and Koehler, 1993).

### 2.5.2. Medical importance of cockroach

The domestic cockroach species are synanthropic to live in close association with man in home, restaurants, hotels, kitchen, grocery, stores and dump basements where food is available. Manmade structures and activities provide sufficient moisture, food, and hiding places for cockroaches' infestation that can result in destroying property in homes; they destroy book bindings and eat every human food (Zinabu Anamo and Nega Biraki, 2008). Cockroaches ruin materials such as books, clothes and foods, imparted to dishes and secrete offensive odor (Koehler *et al.*, 2011). The cockroach species like *Periplaneta*



*americana* and *Periplaneta Rhyparobia* normally excrete compounds which are mutagenic and carcinogenic such as xanthurenic acid, kynurenic acid and 8-hydroxyquinaldic acid which are tryptophan derivatives. These compounds are present in the dropping of faeces materials by cockroach contaminate on human food make the food potential hazard to human health. The cockroaches leave fluid from their mouth with partially digested food and dropping faeces at the site where feeding take place (Cochran, 1999).

The cockroaches association with dirty environment and make them ideal vector in spreading diseases, causing allergies, ruin food and contaminating food processing environments (Mpuchane *et al.*, 2006). Cockroaches crawl through dirty areas and then walk around our homes tracking in lots of bacteria and germs and contaminate food by shedding skins. Their casts off skin and waste products can trigger allergic reactions, asthma and other illnesses (Rachael *et al.*, 2010). While asthma have several potential causes, in the indoor environment cockroach are a major asthma trigger about 23% to 60% of urban dwellers are suffered with asthma and about 50 percent of asthma is caused by due to cockroaches' existence (Ogg *et al.*, 2006). Proteins derived from cockroaches' faeces, saliva, eggs, and shed cuticles have been implicated as leading causes of allergic diseases, such as asthma (Sohn and Kim, 2012).

Several evidences show that cockroaches are carriers of medically important parasites including helminthes and protozoa. Disease causing microorganisms such as intestinal parasites, bacteria, fungi and viruses are carried by roaches (Haji Hamu *et al.*, 2012; Birkneh Tilahun *et al.*, 2012). According to the finding of Fotedar *et al.* (1991), the

nocturnal and filthy habits of cockroaches make them ideal carriers for transmitting different pathogenic microorganisms that affect man and other vertebrate animals (Kopanic *et al.*, 1994). Food Poisoning bacteria like *Salmonella*, *Staphylococcus*, *Streptococcus*, *E.coli* and other pathogenic are identified on Cockroaches bodies (Sohn and Kim, 2012). Another study carried by Wannigama *et al.* (2014) in India has shown that different Gram negative pathogenic bacteria species are isolated from *P. americana* and *B. germanica*. Literatures revealed that cockroaches carry various pathogens and play role as potential vector of food born bacteria species in gut and on external surface of cockroaches (Erdaw Teachable *et al.*, 2006; Mommad and Mohdy, 2012). Cockroaches not only transmit pathogens but are also annoying to human beings (Brenner *et al.*, 1987). When they walk across food and dishes, they may leave and regurgitate food containing bacteria that cause typhoid fever, dysentery, and other human diseases (Ebeling, 1970). Related studies revealed that the distribution and abundances of cockroaches in urban area, could impose transmission of different diseases (Lee *et al.*, 2003; Shebini and Sherbini, 2011).

## **2.6. Control and Prevention Methods**

Cockroaches are one of the most important hygienic problems, because they contaminate food with bacteria, transmit diseases and cause human allergies. For this reason, urban governments and food industries devote part of their balance to overcome the problem. One of the first steps for a correct pest management is a good knowledge of the target species (Barbagallo *et al.*, 1999).

### 2.6.1. Nonchemical Method

**Sanitation:** It is the primary controlling method by eliminating all cockroaches' food sources and cleans up spilled pet food every day. Avoid leaving unwashed dishes on counter tops, and store all food in tightly sealed containers. Remove clutter, storage boxes, bags, paper goods, old clothes, and magazines they serve as places to hide. Eliminating cockroach hiding places will make the environment much less habitable to cockroach populations (Miller and Koehler, 2003). An improvement in building construction is also reported to decrease movement of cockroaches in buildings crack and crevices (Robinson, 1999).

**Exclusion:** The entire building should be adequately sealed and secured against cockroach entry. This discourage cockroaches from entering home and by sealing any cracks in the foundation and exterior walls, eliminate all possible hiding areas and repair cracks, holes in floor, walls and ceilings, seal openings around plumbing fixtures, furnace flue, electrical outlet, window and walls, leaky water faucet and pipes should be repaired (Ogg *et al.*, 2006). Inspect bags, boxes, cartons, etc for evidence of cockroaches before they are brought into the buildings. The evidence includes a roach odor, faeces, body parts, or live cockroaches. If evidence is found, do not allow the container into the building until it is emptied and all its contents inspected. If cockroaches are already inside the building, limit their movements from place to place by sealing around pipe chases and conduit with expandable foam. In buildings that are unoccupied, flush toilets regularly to prevent roaches from entering through plumbing traps (Koehler *et al*, 2011). Eliminate hiding places such as paper, cared board, lumber fire wood and other debris next to the home provide excellent refuge for several cockroach species keep yard trash,

stacks of fire wood away from home or garage to minimize the chance of cockroaches' invasion (Piper and Antonelli, 2004).

Trap: is another non-chemical tactics available for monitoring cockroach infestation. They are primarily used as detecting and monitoring tools for German cockroach populations in the infested units (Ballard and Gold, 1983). Sticky traps can be purchased and placed indoors, near the garbage, under the sinks, in the cabinets, under and behind the refrigerators, and in the bathrooms. Sticky traps have a very sticky adhesive and slow-release food attractant inside. Cockroaches detect the food odor, enter the trap and are immobilized by the adhesive. Sticky traps are not recommended to trap outdoor cockroaches because they tend to capture many non-target beneficial insects (Piper and Antonelli, 2004) and are not resistant to weathering. A second trapping method is the use of baited jars. Any empty jar (pickle, mayonnaise, peanut butter etc.) with a rounded inside lip will suffice. Coat the inner lip of the jar with a thin film of Vaseline to keep trapped cockroaches from escaping. The jar should then be baited with a quarter slice of bread soaked in beer or water. Foods like cookies, dog food, apples, etc can also be used to attract cockroaches. The outside of the jar should be wrapped in paper towel so cockroaches can have a surface to grasp as they climb up the sides of the jar. (Miller and Koehler, 1993). Traps are important: to maintain low level of population, to locate problem areas or harborage, to monitor population increase and subsequently to reduce infestation as primary method (Barak *et al.*, 1997).

### 2.6.2 Chemical Method

Baits: Cockroach baits consist of a toxicant active ingredient formulated in a food source. Baits are usually packaged as dusts, **gels**, pastes, or granules (Koehler *et al.*,

2011; Wang and Bennett, 2006a). Baits are applied into cracks, crevices and wall voids with a bulb duster. Pastes and gels are usually purchased in which can be used alone or inserted into a bait gun for more precise application (Rust *et al.*, 1991). Substances for use as attractants can be various food items, pheromones and other attractive chemicals. A bait should consist of mixtures of attractive food materials and insecticides. Several types of baits are commercially available as pellets or pastes (Stankus *et al.*, 1990).

IGRs: (Insect Growth Regulators), this method is generally not advisable for homeowner but is use-only by professional. The compounds do not kill cockroaches instead; disrupt the normal development of immature cockroaches making them functionally sterile as adults. The most common active ingredients used in cockroach control products are hydroxyflufenoxuron and pyriproxyfen (Miller and Koehler, 2003).

Aerosol Sprays: are often used for spot treatment or areas that are difficult to reach by other means and can be used by individual home owner (Cochran, 1999). These products cannot control an infestation, but can kill individual cockroaches sprayed with the product. One or two-second spray is enough to kill a cockroach. It may not die immediately but get killed within a few minutes later. Applying much insecticide to a single cockroach is a pesticide contamination risk for people and pets living in the areas. Therefore always be sure to read the product label and only apply the recommended amount of insecticide (Ogg *et al.*, 2006).

Dusts: The dusts are normally applied for indoor cockroaches control with a squeeze-bulb duster, which puffs the dust into cracks and crevices (Ogg *et al.*, 2006). The typical

examples of dusts are silica aero gel and boric acid. Silica aero gel is used to adhere the cockroach and absorbs the protective wax covering, dehydrate the cockroach and eventually kill it. Boric acid dust is a stomach toxic that also adheres to the cockroach when it walks across the dust (Piper and Antonelli, 2004).

IPM: Integrated pest management is another important controlling technique for roach's population. The basic components of IPM are: Identify the cockroach, understand the biology and behavior of the species, determine if control is needed, identify all appropriate control measures for the specific situation, including non-chemical and chemical measures, implement safe and effective control tactics evaluate the control efforts. In managing cockroaches infestation, IPM approach includes monitoring of population before making treatments find out the pest species and where the infestation is located (Ogg *et al.*, 2006).

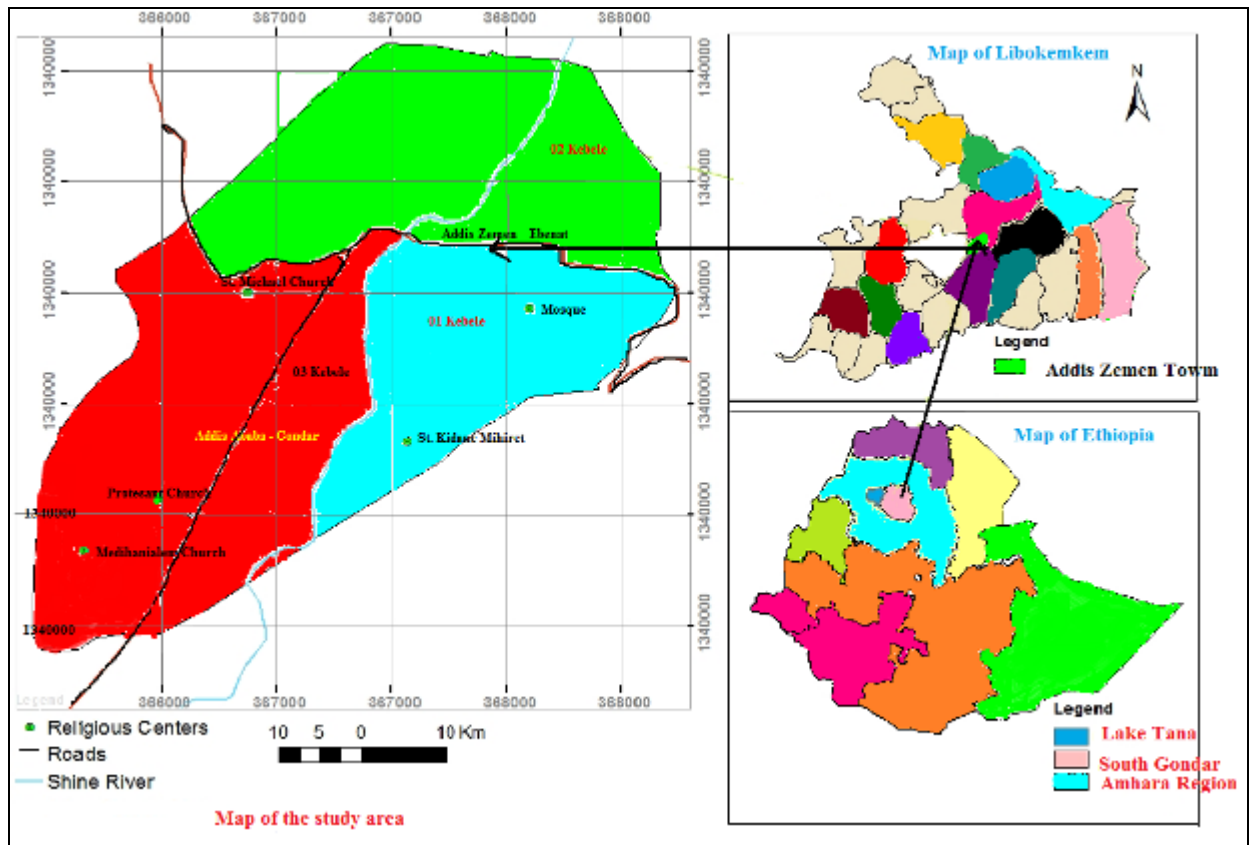
### 2.6.3. Biological Method

Almost all animals have natural enemies. Natural control methods do play an important role in managing cockroach populations. Natural cockroach enemies include wasps, nematodes, spiders, toads and frogs, centipedes, birds, lizards, geckos, beetles, mantids, ants and small mammals play very important role to help keep cockroach populations low. The wasps families of Hymenoptera are specialized on the eggs of cockroach species and ants feed on dead cockroaches (Miller and Koehler, 1993; Depickere, *et al.*, 2008).

### 3 MATERIALS AND METHODS

#### 3.1 Description of the Study area

This study was carried out to address species diversity and infestation level of cockroaches in Addis Zemen town, the administrative center of Lebo Kemkem district. Addis Zemen town is located in South Gondar zone of the Amhara region, Northwestern Ethiopia via the road connecting Gondar and Bahir Dar town. The study area is generally characterized by moderate climate locally known as woina dega (intermediate temperature). The locality is situated at an elevation of approximately 1987 meters above sea level. It is 12°07' to 12°117' north latitude and 37°47' to 37°783' east longitude on Addis Ababa-Gondar main road about 82 km north of Bahir Dar and 93 km south of Gondar town. The area has a monomodal rainfall distribution and the rainy season runs from June to August. The dry season extends from December to March. Hot dry season and short and mild rainy season dominates the area. The mean annual temperature of study area ranges between 11.1 and 27.9°C and the total annual rainfall ranges between 900 and 1200 mm (Hialeah Zegey *et al.*, 2011). In 2010, an estimated population of Addis Zemen town was 24,894. Records show nearly five thousand residential houses, dozens of governmental offices, schools, a dozen restaurants and clinics. According to official records the town is divided in to three Kebles that have a total of 4708 residential houses, 30 governmental offices, 20 restaurants and 3 clinics (Addis Zemen Administrative office, 2014).



**Figure 1:** Map of the study area

### 3.2 Study Design study

A cross-sectional survey and experimental study in the laboratory were carried out in the study area. Indoor premises such as public offices, residential houses, restaurants and a clinic were investigated.

### 3.3 Sample Size and Sampling Techniques

Samples were collected in different habitats (bedroom, kitchen, toilet and office) from December 30 to March 30/2014. However, based on the assumption that this town has no significant ecological as well as socio-demographic variations among its three Kebele and their residents, one Kebele that is Kebele 3 with 517 residential houses was chosen. The sample size was therefore determined from total population of 1570 housing premises



comprised from 1517 residential houses, 30 governmental offices, 20 restaurants and 3 clinics existing in the town. Because each housing category (public institutions, residential houses, clinics, and restaurants) constitutes different number of rooms, proportional allocation sampling technique was adopted and sample size was determined using the formula:

$$n = \frac{z^2 * P * (1 - P)}{d^2} \dots\dots\dots(1)$$

Where  $n$  stands for the required minimum sample size;  $P$  for assumption of 50% infestation of cockroaches in the study area,  $d$  for marginal error between sample and population taken as 5%;  $z$  for a standard score corresponding to 95% confidence level which equals to 1.96. So using the above formula  $n=384$ . Using the finite population correction formula to make some logical sample size adjustment for sample size less than 10,000, the modified sample size of this study is determined as:

$$n_0 = \frac{n}{\left(1 + \frac{n}{N}\right)} \dots\dots\dots(2)$$

Where  $n_0$  is adjusted sample size;  $N$  is the size of total population (Getu Degu and Tegbar Yigezaw, 2006). Hence  $n=295$ . Since there are different strata adopting proportional allocation, i.e., If  $P_i$  represents the proportion of the population included in stratum  $i$ , and  $n$  represents the total sample size in the whole study, the number of elements selected from stratum  $i$  will be  $n.P_i$ . The same calculation was used for strata 2 to 4 using equation 3.

$$n_i P_i = n \left( \frac{N_i}{N} \right) \dots\dots\dots (3)$$

Where n=Total sample size, N=Total population, Ni= size of stratum i and Pi=Proportion of stratum i. Sample size taken from each group was therefore different (Table 1).

**Table 1: Number of category units and total number of rooms that has been studied**

Categories	Number of units per category	Approximate number of rooms per category	Types of rooms	Number of rooms studied	Number of category units	Total number of rooms
Clinics	3	30	Toilet, office	3 from each type	1	6
Hotels/Restaurants	20	200	Bed room, kitchen,	1= from each type	8	16
Public offices	30	300	Toilet, office, kitchen	1=from each type	12	24
Residential houses	1517	4551	room, bed room	1= from each type f	274	548
Total	1570	5081			295	594

### 3.4 Data Collection Procedures

#### a) Species determination

Cockroaches were collected using sticky traps according to Shahraki *et al.* (2010). These traps were convenient because they were non-toxic and were cheap (Mahmoud *et al.*, 2013). Plastic containers available in the market (10 cm × 10 × 20 cm) whose opening is curved inward were used as trap. Baits such as peeled banana skin and piece of bread soaked in water were used as bait and kept inside the containers. A band of petroleum jelly or film of Vaseline was pasted 2 cm below the opening in the inside of the container (Wang and Bennett, 2006; Haji Hamu *et al.*, 2012). The width of the band was approximately 3 cm. The outside of the jars were wrapped in paper towel so cockroaches

have a surface to grasp as they climb up the sides of the jar and plastic containers were placed nearby stoves, refrigerators, shelves, near dining tables in the kitchen, in bedrooms, on the floor, beside toilets, and offices. Cockroaches have detected the food odor (the bait) and climb up the container and drop inside but cannot check out because they get immobilized by the adhesive sleeper nature of the petroleum jelly or Vaseline. The traps were labeled with the date, housing category, like residential house and type of room, like toilet, kitchen and bed and left there for 24 hours. Containers were collected, then 5 ml formalin was added to each container to prevent cockroaches' body from decaying and cockroaches were counted and number of cockroaches per trap was recorded. Then the collected cockroaches per trap were categorized in to different infestation levels according to Mahmoud *et al.* (2013) and Shahraki (2013). Infestation level in each dwelling area were recorded and classified based on the following criteria (Table 2).

**Table 2: The category of collected cockroaches in various housing premises**

Number of cockroach captured/trap/house	Infestation level
0-1	Clean
2-3	Low
4-8	Moderate
9-26	High
27-50	Very high
>50	Abundant

Representative samples from each study unit were put in separate jars containing 96% ethanol for further identification in Bahir Dar University's Biology laboratory.

Cockroaches were identified by using dissecting microscope and identification keys (Ogg *et al.*, 2006) based on morphological characters described by Cochran (1999).

#### **b) Detection if roaches carry bacteria**

To investigate the bacteria carried by roaches, two cockroaches were samples from each category and brought to the Bahir Dar microbiology laboratory for further study. The external body surface of representative cockroaches were washed with 2 ml sterile saline, shaken for two minutes in a jar and 0.01 ml of the sample suspension was taken from each jar and then separately inoculated onto four different media namely MacConkey, Nutrient agar, Chocolate agar and Tryptic agar plates and after streaking incubated at 37°C for 24 hours (Wannegama *et al.*, 2014) (Figure 2).

Then the growth and shape of bacterial colonies were observed and number of colonies in each Petri dish were counted using digital counter and recorded. The presence of bacteria on roach's body diagnosis includes colony morphology and Gram stain method (Adeleke *et al.*, 2012; Kassiri and Kazemi, 2012). Gram Staining was done to isolate microorganism on the surface of cockroaches. A smear of the test organism was made on a clean slide, dried and covered with crystal violet for 60 seconds. Then it was washed off with clean water and covered with Lugol's iodine for 60 seconds and again washed off with clean water. The slide was decolorized with acetone-alcohol, and rinsed immediately with clean water and covered again with neutral red stain called safranin for 60 seconds, and washed off with clean water. The back of the slide was wiped clean and placed in a draining rack for the smear to air dry. Then the slide was examined under high

power 40 x microscopes. Gram positive bacteria remain dark purple, gram negatives turn to red or pink color (Christopher and Bruno, 2003).



Figure 2: Culturing of microorganisms from the surface of cockroaches on nutrient media

### c) **Field Observation**

Field observation was also carried out during the trapping process to assess the hygiene and general conditions (factors) such as moisture regime, cracks, hygiene level construction materials used to build wall of houses, use of pesticides and management of housing premises that has role to play on infestation by cockroaches using check list (Appendix3). The observed housing premises were grouped in to three groups of hygienic level according to Shah *et al.* (1996) and Lee and Lee (2000a). Hygiene level in each dwelling were also recorded and classified based on the following criteria (Table 3).

**Table 3: Hygienic classification of field observation in different housing premises**

Hygienic level	Characteristics
Good	Surfaces and floors are clear of food and uncluttered, organized /management of house, the floor always dry
Fair	There are minor food spoilage and pets' food and unwashed utensils left over night (less clutter, less food debris on floor no leaking pipe).
Low or bad	Heavy deposit of grease and grime in kitchen and ample, spilled and open food. Surface and floors are cluttered hampering access for inspection/ treatment.

**d) Community awareness**

A total of 235 people were selected randomly to determine the level of community awareness about cockroaches (Table 4). Private house owners (house wives), government office employees and restaurant workers constituted the sample. Information was gathered through interview from illiterate people and questionnaires for educated people which dealt with the sanitation status, knowledge, awareness and infestation of cockroaches. Table 4 shows the characteristics of people who were included in the study.

**Table 4: Socio-demographic characteristics of the respondents**

	Category	Frequency	Percent
Sex	Male	58	24.7
	Female	177	75.3
	Total	235	100.0
Age(year)	20-29	105	44.7
	30-39	66	28.1
	>40	64	27.2
	Total	235	100.0
Educational Status	Illiterate	81	34.5
	1-8	17	7.2
	9-12	35	14.9
	>12	102	43.4
	Total	235	100.0
Marital status	Married	145	61.7
	Not married	90	38.3
	Total	235	100.0

### **3.5 Data Analysis Technique**

The relative abundance and species diversity of cockroaches related to the different housing units and categories were analyzed using one way ANOVA (SAS Institute, 2008) and Chi-square. The analyses was used to the significance of housing category, housing units and other factors and determine relationships between the occurrence of cockroaches and factors responsible for their occurrence. Microbiological data were also analyzed using frequency and data obtained from interview and questionnaires were analyzed using descriptive statistics.

## 4. RESULTS AND DISCUSSION

### 4.1 Species Determination

#### 4.1.1 Identified species

A total of 1839 cockroaches were trapped in different habitats (residential houses, restaurants, public offices and clinic) of Addis Zemen town. 83.3% of study rooms were infested by cockroaches. All samples collected were identified to be German cockroach (*Blattella germanica*). The current study showed that German cockroach (*Blattella germanica*) is the most common indoor species especially in housing areas (Figure 3). Reports from previous studies indicate that German cockroach was the dominant species found in Ethiopia (Addisu Kinfu and Birhanu Erko, 2008) and also elsewhere in the world (Shahraraki *et al.*, 2010, 2013). In Ethiopia, *Blattella germanica* is the dominant species found in hospitals and restaurants (Erdaw Teachable *et al.*, 2006; Birkenh Tilahun *et al.* 2012; Haji Hamu *et al.*, 2012). In other countries, the same species is common in hospitals, private homes, restaurants and even in the market (Feng *et al.*, 2009), in hotels and food handling areas of home (Lee and Soo, 2002). According to Nasirian (2008), German cockroaches are the most common urban pests found in houses and restaurants. Limoe *et al.* (2012) reported that German cockroach is a major hygienic pest in residential areas in Iran.





**Figure 3: Representative specimens collected from different traps (German cockroaches)**

#### **4.1.2. Factors contributing for cockroach infestation**

The cockroaches trapped different infestation level showed that the infestation level of inspected total study units indicated that 17.7% clean, 10.2% low, 35.5% medium, 31.2% high and 5.4% very high infestation level.

#### **Housing categories**

As analysis of variance of housing categories (Appendix 4) indicated that abundance of cockroaches per trap was significantly different among housing categories in ( $F=13.2$ ,  $df=3$ ,  $P<0.0001$ ) (Figure 4) and cockroaches were more abundant in residential houses (mean=12.0) compared with other categories (restaurant, public office and clinic) but there was no significant difference among habitats such as restaurants, public office and clinic with respect to number of cockroaches. People cook, eat and take bath in residential houses and restaurants all of which provide cockroaches their requirements. For this reason German cockroaches prefer to live in residential houses and restaurants. Figure 4 shows that more cockroaches were trapped in residential houses followed by restaurants. Resources may guide their abundance. Public offices and clinics provide less resource thus less abundant there. It appears that public offices and health centers are regularly

cleaned, the floor washed with berekina (chlorox) and materials arranged in an orderly manner.

Similar findings have been reported elsewhere (Kells *et al.*, 1999; Turey, 2003). The current study shows the following order in number of cockroach per trap: residential house, restaurant, public office and clinic. This corroborates with previous findings (Mpuchane *et al.*, 2005; Feng *et al.*, 2009). Residential houses and restaurants are more likely to be infested by roaches because food preparation and feeding takes place more often there. Raw materials used for construction of buildings may matter. Most public institutions (offices and health centers) are made of cement, which may reduce infestation. Most residential houses are made of mud and wood and often have cracks and crevices that allow roaches easy access.

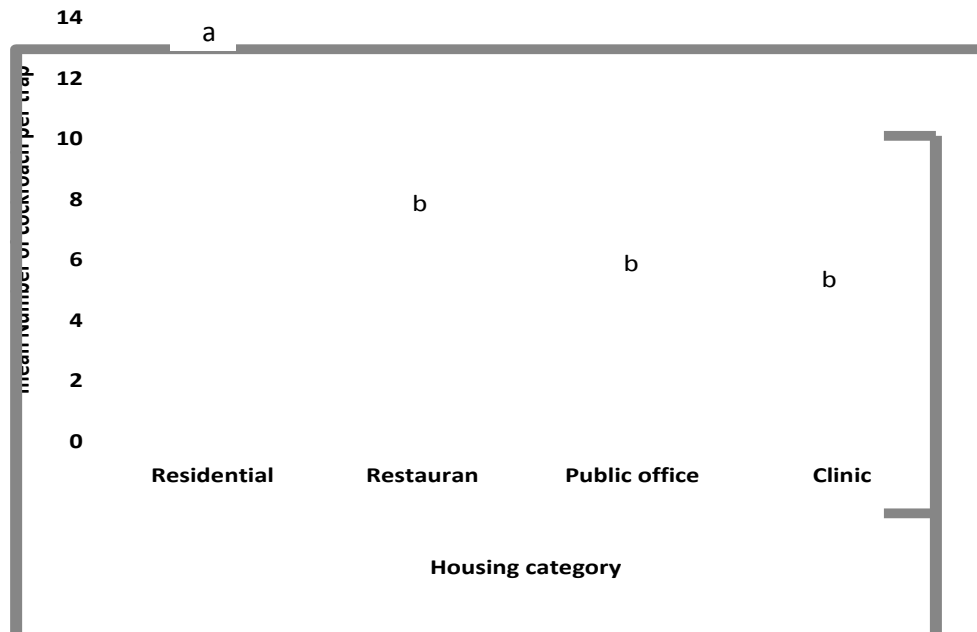
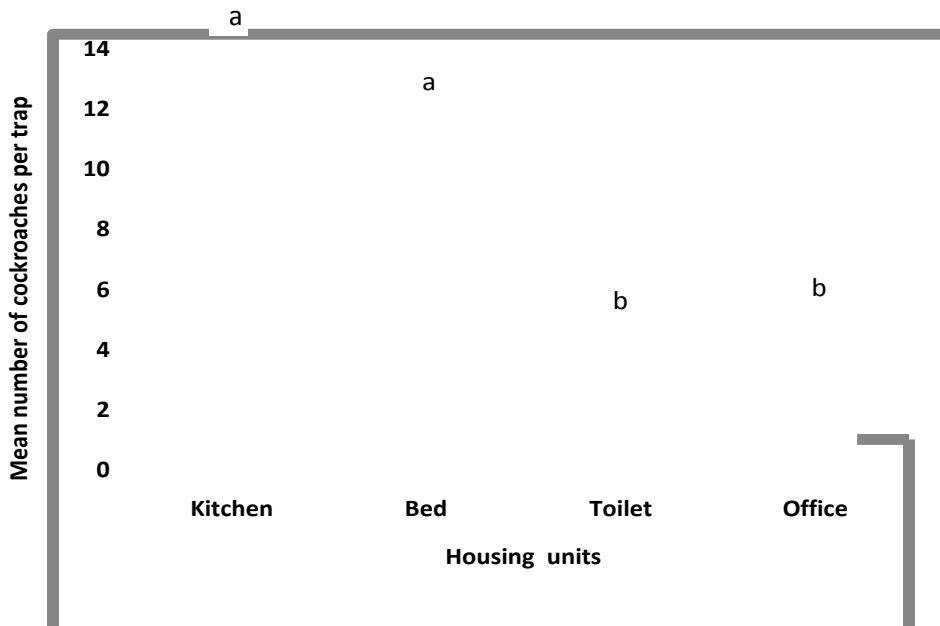


Figure 4: **The effect of different housing categories on cockroach density per trap (Means followed by the same letter are not significantly different according to Tukey HSD at  $\alpha=0.05$ ). Vertical lines on bar indicate error bar.**

## Housing Units

According to the results of the analysis of variance (Appendix4) abundance of cockroaches per trap significantly varied among housing units ( $F=9.87$ ,  $df=3$ ,  $P<0.0001$ ). More cockroaches were recorded in the kitchen (mean=12.09) and bed than in the office (mean =2.28) and the toilet (Figure 5). Cockroaches are commonly seen in the kitchen, store, bathroom, toilets, and bed. Both kitchen and bed had statistically the same number of cockroaches per trap.



**Figure 5: The effect of different Housing unit on cockroaches' density per trap** (Means followed by the same letter are not significantly different according to Tukey HSD at  $\alpha=0.05$ ). Vertical lines on bar indicate error bar.

This finding indicated that kitchens were the most suitable place for German cockroach. Humidity and food leftovers are plentiful in the kitchen inviting more roaches. Offices do not have these characteristics. Kitchen and bed were equally and heavily infested while offices and toilets were not. That means habitats matter in cockroach infestation.

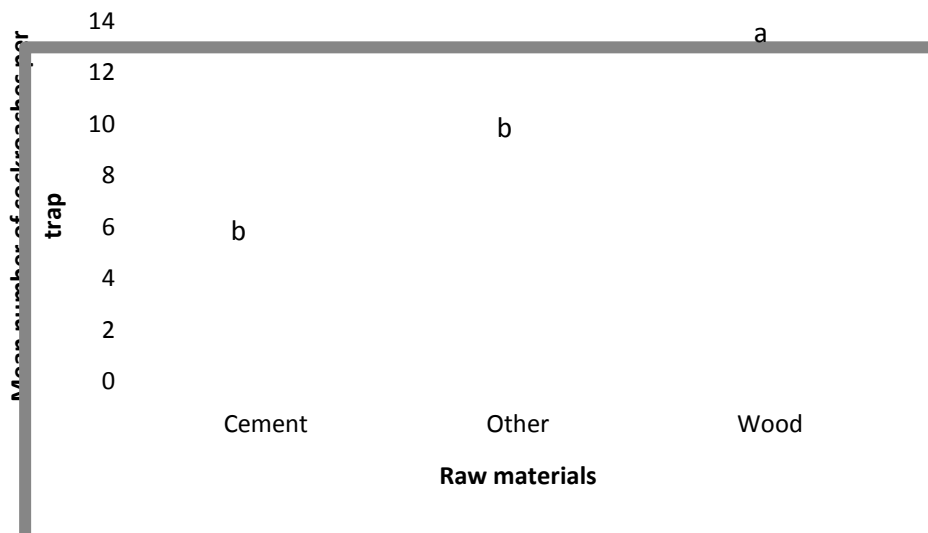
Cockroach number collected from toilet and offices were much smaller than in kitchen (Feng *et al.*, 2009). This might indicate the cleanliness of public health center and uses of disinfectant for cleaning toilets and offices making the environment less favorable for cockroaches. Accumulation of food scraps often found under refrigerators, in cupboard and other kitchen equipment invites more of them (Bennett *et al.*, 1984). This result corroborates Mpuchane *et al.* (2005) who revealed that prevalence of cockroaches' infestation in homes in the following order: kitchen, Bath room, bedroom, and toilet. Wright and Hillmann (1973) had reported a similar finding whereby number of cockroaches trapped in kitchens was greater than that of bed and bathrooms.

German cockroaches successfully breed in the kitchen of hospitals, apartments, tearooms, private house and restaurants (Tanaka and Motoki 1993; Adler *et al.*, 2002; Hoffmann and Davis, 2005). Cupboards in the bedrooms are suitable hiding and breeding places for roaches. German cockroaches often concentrate in kitchens and bathrooms where water and food is readily available (Pellegrini *et al.*, 1992; Ogg *et al.*, 2006). According to Kutrup (2003), kitchens attract more German cockroaches. Koehler *et al.* (2011) found more of them in kitchen and bathrooms. Low hygiene level of residential house makes an ideal environment for increasing the cockroach infestation. Poor fecal and garbage disposal system observed in the study area contribute for the proliferation of cockroaches.

### **Construction raw materials**

According to the results of the analysis of variance (Appendix 4) abundance of cockroaches was significantly different among house construction raw materials ( $F=19.08$ ,  $df=2$ ,  $P<.0001$ ). Houses made of wooden materials had significantly more

roaches (mean of 11.96) than cement and other materials (Figure 6). There was no significant difference between cement and other constructed houses. Houses made of cement have reduced hiding cracks and crevices compared with mud or wooden houses. Housing raw materials and construction techniques play a pivotal role in preventing cockroaches get access to the house. Improved construction techniques reduce the movement of cockroaches into the house through cracks and crevices (Robinson, 1999).

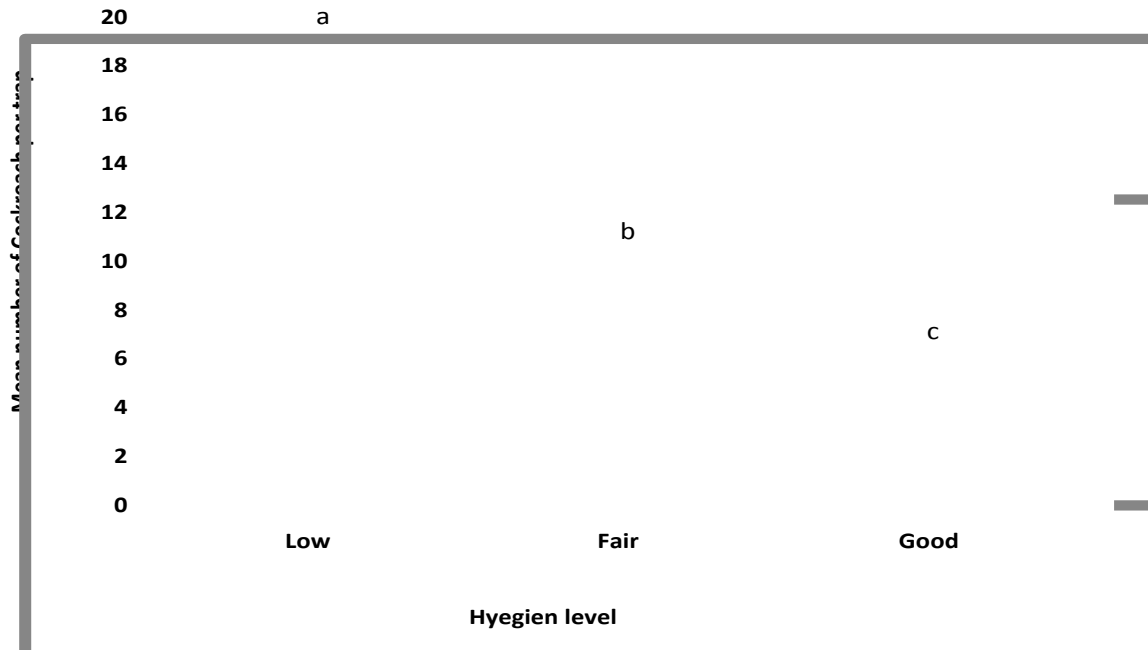


**Figure 6:** Effect of raw materials on cockroach density per trap (Means followed by the same letter are not significantly different according to Tukey HSD at  $\alpha=0.05$ ). Vertical lines on bar indicate error bar.

### Hygiene level

According to the results of the analysis of variance (Appendix 4) cockroaches infestation was significantly affected by the level of hygiene in the premises ( $F=35.51$ ,  $df=2$ ,  $p<0.0001$ ). Good hygiene significantly reduced number of cockroaches per trap than fair and low hygiene levels (Figure 7). A mean of 17.74 cockroaches were counted per trap on low hygiene regimes while only a mean of 4.68 was recorded on good hygienic

conditions. As sanitation increased, cockroach numbers declined (Figure 7). High population density was associated with poor disposal of food leftovers, with lack of proper sanitation and when ideal temperature (Shah *et al.*, 1996).



**Figure 7:** Effect of hygiene level on cockroach infestation level (Means followed by the same letter are not significantly different according to Tukey HSD at  $\alpha=0.05$ ). Vertical lines on bar indicate error bar.

Good sanitation, vacuuming and sealing of harborage reduce German cockroach species (Kardatzke *et al.*, 1981). There was significant positive relationship between infestation and poor sanitation. Factors such as dirty, cluttered, unwashed dishes left overnight and leftover food exposed or food debris enhance infestation. Similarly Shahraki *et al.* (2010) reported that sanitation has positive impact on reduction of German cockroach infestation. This study is also similar to the result investigated by Shahraki (2013), for residential house poor hygiene level was associated with the high intensity of cockroach infestation. Other studies proved that availability of food and water (Lee and Heng,

2000) and poor hygiene (Schal, 1988) would enhance cockroach infestation. Lack of proper maintenance of residential areas such as poor sanitation, presence of unwashed dishes and clutter in many housing categories and low level of sanitation contribute the severity of German cockroach infestation (Gold, 1995; Lee and Lee, 2000a; Nouredin and Farrage, 2008).

There was significance correlation between sanitation and infestation level ( $\chi^2 = 170.4$ ,  $df=8$ ,  $P<.0001$ ) (Appendix 6 Table5). There was no clearly discernible conclusion from hygienic levels but on low and fair hygienic levels resulted in high infestation. Again on fair and good hygienic conditions, medium infestation was recorded.

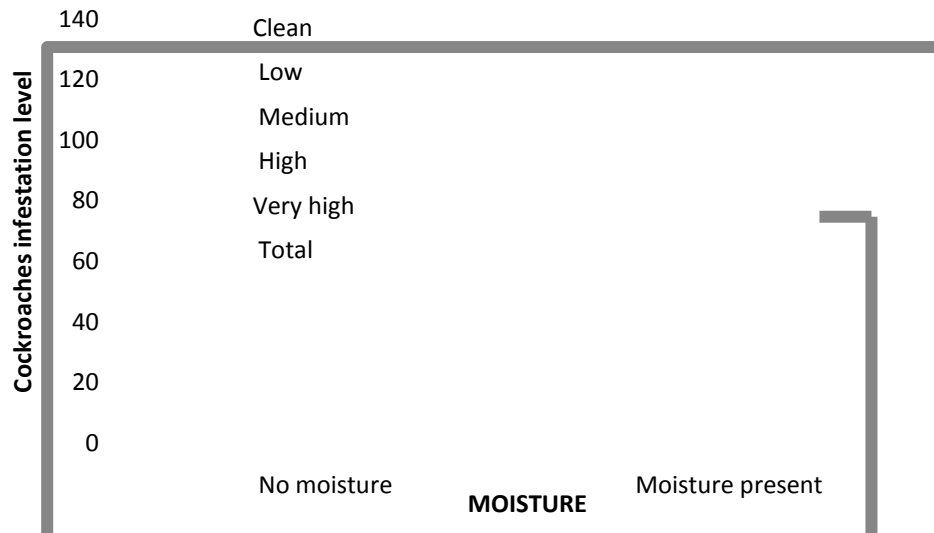
Poor management of houses in urban environments has been linked with increase in population of cockroaches (Boasec, 1999). However, other studies revealed that there is no significant relationship between numbers of cockroaches trapped with sanitation; this indicates that bad sanitation does not necessary result in higher cockroaches' infestations. According to Owens (1980) and Bertholf (1983), improved sanitation condition does not reduce German cockroaches' population. It was believed that once cockroaches establish themselves in the vicinity, adaptability of these insects makes it almost impossible for improved sanitation to reach a level that would reduce the population (Marsh and Bertholf, 1986; Lee and Lee, 2000a). However, a clean and tidy home is necessary because there is no food for cockroaches to eat and there are fewer hiding places.

### **Moisture Regimes**

Humidity (water) source is very important in cockroach infestation to occur. The results of the analysis of variance showed that cockroach numbers significantly varied between moisture levels (Appendix4) indicating significant difference in the availability of

moisture with occurrence of cockroaches ( $F=84.47$ ,  $df=1$ ,  $P<.0001$ ). More cockroaches were recorded per trap on moist areas mean of 13.85 and less number in which moisture absent mean of 3.19. Water on the floor is crucial for cockroaches along with a clutter of food debris. Ogg *et al.* (2006) reported that humidity and temperature have positive impact on cockroach infestation and proved that food and moisture are available from poor hygienic level. German Cockroaches have high water requirement and are found around kitchens and bathrooms. Water may be used to regulate roach populations (Bonney *et al.*, 2008). German and Oriental cockroaches need more moisture (Ogg *et al.*, 2006). For example, Turey (2003), reported significant correlation between humidity and population density of German cockroaches. On the other hand, Schal (1988) reported that low level of sanitation and clutters provide food, water and harborages. Figure 8 indicates that in the presence of moisture, cockroach infestation level was high or medium and even some had very high infestation levels. In contrast, no high and very high infestations were observed in the absence of moisture; instead most were under clean and medium level of infestation. The chi-square test of independence indicated that there was significance correlation between moisture and infestation level ( $\chi^2 = 75.1$ ,  $df=4$ ,  $P<.0001$ ) (Appendix 6, Table 5).





**Figure 8:** Show the association between moisture (water) and infestation level

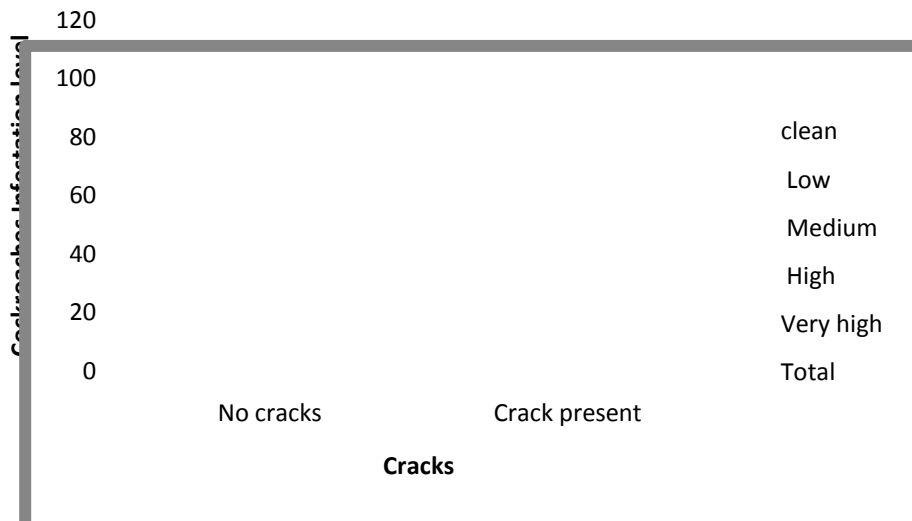
Water plays more role for German cockroaches than do food and harborages. Lack of basic services such as sanitation and supply of water could enhance more infestation (Isaac *et al.*, 2014). Deprivation of food and water had negative effect on cockroach population (Lee and Heng, 2000). Above all else, moisture favors the growth and survival of cockroaches. Positive correlation was reported between humidity and the population density of German cockroaches (Bertholf, 1983). More humidity meant more roach density (Kutrup, 2003).

### **Cracks**

The results of the analysis of variance (Appendix 4) showed that roach density varied with the level of cracks in the house ( $F=59.33$ ,  $df=1$ ,  $P< .0001$ ). More cracks gave a mean of 13.86 per trap. Cracks and crevices may serve as entry points, favorable hiding and breeding areas of cockroaches (Piper and Antonelli, 2004). Good sanitation practices, sealing cracks and crevices keep roaches away. Cockroaches have high preference to

cracks, under or inside cupboards and cabinets, where pipes or electrical wiring pass along or through a wall behind window or door frames, under tables and chairs, in upholstered furniture, in bathrooms, in radio, TV cabinets, in refrigerators, washing machines and other materials(Velez, 2008).

Figure 9 shows meant more infestation in the presence of cracks. In the absences of cracks most were under medium and clean infestation level but no very high although, some were under high infestations level. The chi-square test of independence indicated that cracks were significantly correlated with infestation level ( $\chi^2=37$ ,  $df=4$ ,  $P<.0001$ ) (Appendix 6, Table 5).



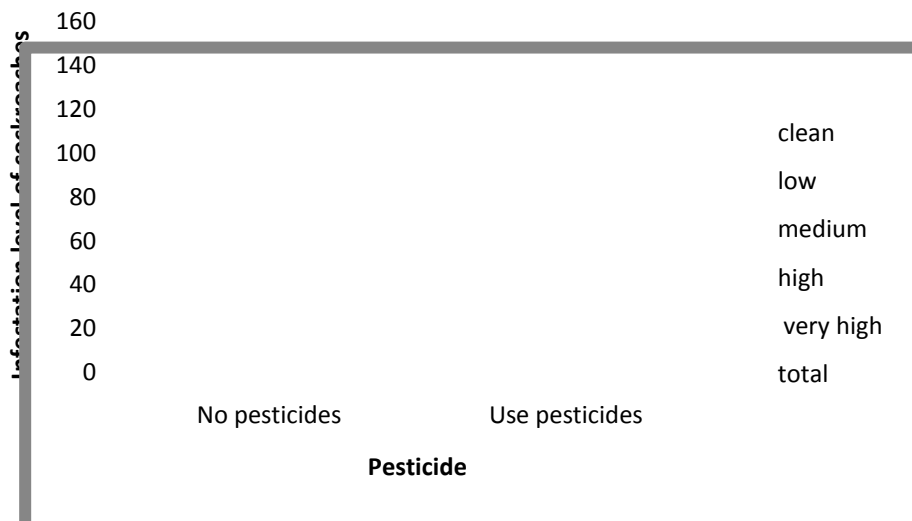
**Figure 9:** Show the association between crack and infestation level

Cracks, crevices, moisture and food sources are important breeding areas of roaches (Hoffmann and Davis, 2005). Harborages like cracks, crevices, and clutter are the primary roach controlling strategies that reduce roaches population (Ogg *et al.*, 2006).

Therefore cockroach numbers were more on buildings with cracks than those that are sealed better.

## Pesticides

The analysis of variance of the abundance of cockroaches ( $F=1.3, df=1, P=0.25$ ) (Appendix 4) gave no significant difference whether pesticides were used or not in relation to cockroach numbers trapped. This study revealed cockroach infestation level was similar in houses that use pesticides and those who did not use. Inadequate and irregular use of pesticides against cockroaches in the study premises lead to no difference in abundance of *Blattella germanica*. The chi-square test of independence indicated that no significance association was observed between pesticide usage levels and infestation by cockroaches ( $\chi^2=8.9, df=4, P>.01$ ) (Appendix6, Table 5). However, although not significant, pesticide use seems to have reduced general infestation level (Figure 10).



**Figure 10:** Show the association between using pesticide and infestation level

The cockroaches control was irregularly implemented and insufficient application of pesticides in most premises. Use of convectional insecticides are often insufficiently effective to provide lasting control of major wide spread infestation of *Blattella germanica*. This study agreed with Lee (1995) who reported inconclusive results. In addition the life cycle of German cockroaches is short and populations can recover. This may render roaches more difficult to control than other species reported by (Lee *et al.*, 2003). In contrast, Schal (1988) reported strong correlation between cockroaches' infestation and insecticides treatment. Large cockroach population was associated with untreated sites (Taylor, 1987).

#### **4.2 Do Cockroaches Carry Bacteria?**

After washing the external surface of cockroaches, preparing a suspension culture and culturing o different media (Figure 11), the growth and shape of bacterial colonies were identified and number of colonies in each Petri dish were counted using digital counter and recorded.

The presence of bacteria on the body of the cockroaches was diagnosed based on the colony morphology and Gram stain method. The bacteria have grown in all media i.e., MacConkey, Nutrient agar, Chocolate agar and Tryptic agar. This result has shown circular gram negative bacteria more dominant in public institutions and clinics where as in the restaurant and residential houses, gram positive and circular bacteria were common (Figure 12). This result has shown Gram negative and Gram positive bacteria exist on the external body surface of cockroaches trapped from different premises. Fakoorziba *et al.* (2010) reported that the feeding mechanism, filthy breeding habitat and nocturnal habit of cockroaches make it an ideal carrier of various pathogenic microorganisms which they

can carry on their body parts, skin, gut, vomit and faeces. Cockroaches live on anything, rotten food, faeces, fresh food, fermenting products, and then move from one location to another easily and become efficient vectors of human diseases.

Many studies have revealed both gram negative and gram positive bacteria were isolated from external body parts of cockroaches but Gram negative bacteria were the most predominant bacteria isolated (88%) (Rivault *et al.*, 1993 b; Branscone, 2002; Wannama *et al.*, 2014). Cockroaches carry microorganisms that cause diseases (Chan *et al.*, 2004; Graczyk *et al.*, 2005). Cockroaches carry not only bacteria but also protozoa, helminthes, fungi and viruses (Tatfeng *et al.*, 2005). Pathogenic parasites have been found on external parts of cockroaches (Chaichanawongsoraj *et al.*, 2004; Salehzadeh *et al.*, 2007).

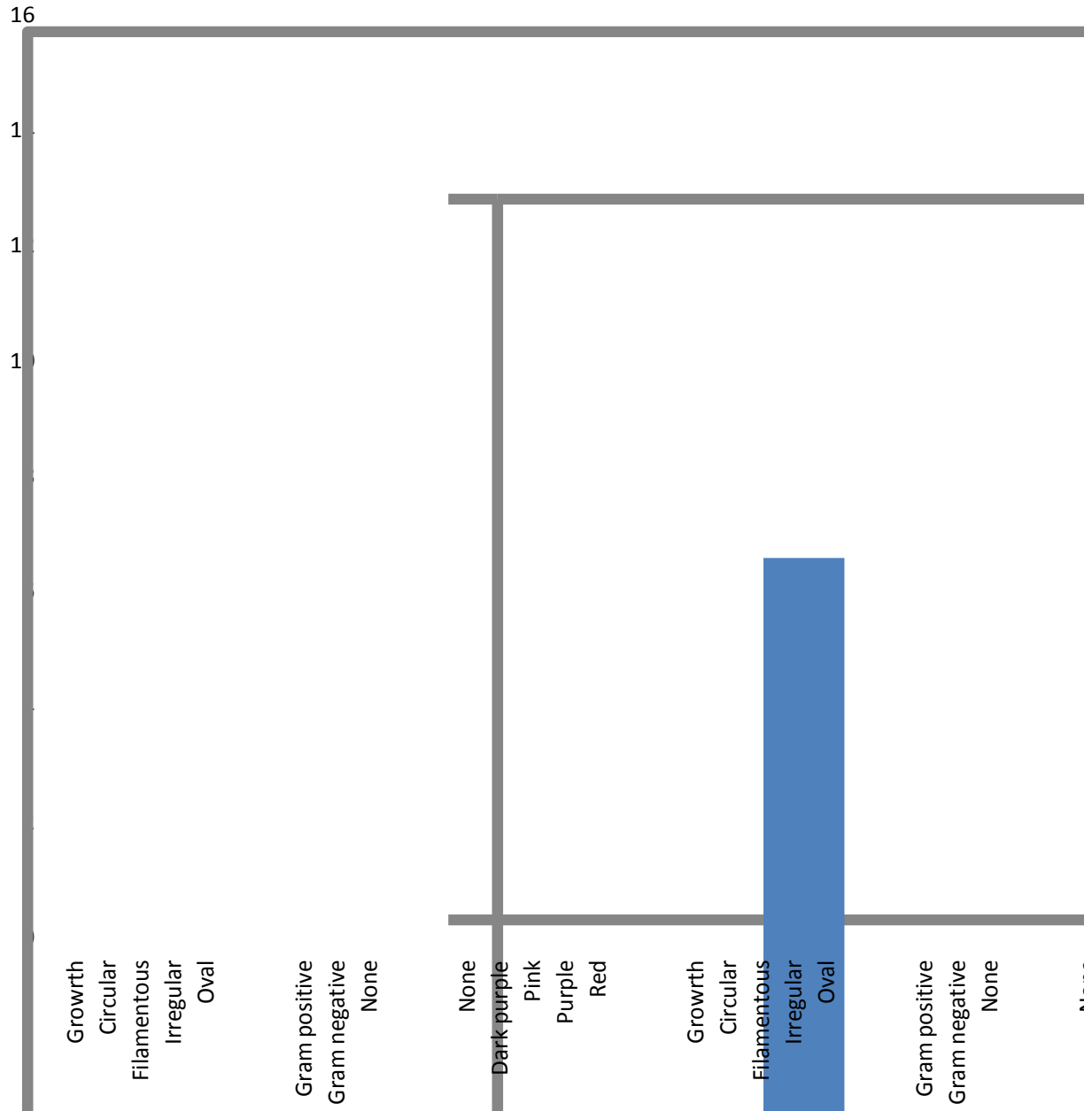


Figure 11: Bacterial growth pattern, type and color at different premises

Cockroach carried Gram positive while Gram negative bacteria are better adapted to infect in the gut. The bacterial diversity was significantly more in sensitive facilities such as hospital and restaurants. However, pesticide and bactericides were frequently applied

in clinics and public offices (Feng *et al.*, 2009). Cockroaches as carrier of microorganisms is an established fact in different part of the world (Fotedar *et al.*, 1991; Cloarec *et al.*, 1993a; Rivault *et al.*, 1994; Praero *et al.*, 2002; Tاتفeng *et al.*, 2005; Erdaw Teachable *et al.*, 2006). Fakoorziba *et al.* (2010) investigated that German and American cockroaches serve as vector of pathogenic bacteria. Gram negative bacteria have been isolated from the body surface of German cockroaches (Wannngama *et al.*, 2014). Antibiotic resistant Gram negative bacteria were also isolated from German cockroaches (Shah *et al.*, 1996). A study carried out in Beijing by Feng *et al.* (2009), revealed that 32 species of Gram negative bacteria were isolated from the external and 23 species of Gram negative bacteria from the gut of German cockroaches. However, Gram negative bacteria species had less richness externally than internally.

#### **4.3 Awareness of Community**

The information gathered from the people through interview indicated that many people are not aware about the economic importance of cockroaches. All the respondents' response indicated that all people know cockroaches. Most (93.6%) of the respondents houses were found infested with cockroaches and only 6.4% respondents houses were free from cockroach infestation. Over 70% of the respondents indicated that roaches are more concentrated and commonly seen in the kitchen. This is similar to the result that tried to determine the role of housing units on cockroaches. Kitchens and bedrooms are suitable avenues for roaches. About (64.7%) people believed that cockroaches are neither useful nor harmful and about 17% of people considered cockroaches as causative agent of diseases. This indicates that many people do not consider the presence of cockroaches and parasitic infection as a serious problem even though they are disgusted by their

unsightly appearance. This may pose human health problems. 7.7% of respondents believed cockroaches are not something to worry about. Most respondents (92.3%) feel discomfort at the sight of roaches and 22% respondents believe cockroaches may transfer diseases.

About 18.3% of the respondents were unable to figure out whether cockroaches were useful or harmful. The presence of cockroaches at home and apartment disturbs dwellers. Part of distress is because many people dislike any bugs in the home (Ogg *et al.*, 2006). German cockroaches not only spoil food but also transfer pathogens, cause allergic reactions and psychological distress on many people (Brenner *et al.*, 1995). As respondents answer indicated that most of them use traditional prevention methods to control cockroaches by sweeping the floor (38.1%), by closing properly (48.1%) and 13.6% did not use any method apart from removing them by hand.

The information obtained from the interview indicated that a considerable proportion of the respondents (49.4%) directly use food contaminated by cockroaches while 54.9% of respondents use food utensils contaminated by cockroaches by removing them by hand. The floors of the private houses are suitable for cockroaches because of the clutter of food left on the food table, dishes, poorly organized house and more water droplets. Around 87.2% of respondents replied that their family members had felt sick, 28.5% asthma, 29.8% allergic and 28.9% typhoid and *Guardia*. Cockroaches are represented one of the most common sources of indoor allergens worldwide (Sohn and Kim, 2012). These things may happen because of the role cockroaches play in disease transfer. Cockroaches are believed to cause asthma, allergic reactions and other diseases. Cockroaches are cause



of allergic reaction and asthma and carry microorganisms that cause food-borne diseases (Mpuchane *et al.*, 2006).

## **5. CONCLUSION AND RECOMMENDATION**

### **5.1 CONCLUSION**

The German cockroach is found in residential houses, restaurants, health and public institutions of Addis Zemen town. Residential houses and kitchens are more suitable areas for cockroaches. Moisture, hygiene level, materials used to build wall of housing premises and cracks are main factors that affect the infestation of German cockroach, as a result cockroach infestation levels vary in different housing categories. Bacteria are carried by external body surface of German cockroach. The knowledge of people about the role of cockroaches in human health is low.

### **5.2 RECOMMENDATIONS**

The isolation of the bacteria from cockroaches' body surface indicated that those pests could pose health problems to humans. Management of cockroach infestation should target to reduce their spread. Lower the carrying capacity of the environment by eliminating the resources needed by cockroaches such as water food and harborages.

This should involve

- 1) Maintain good sanitation and proper management of houses. Proper disposal of wastes along with eliminate of cockroach habitats or breeding sites, sealing cracks and crevices.

- 2) Effective and comprehensive educational program should be in place and needs to enhance the knowledge (awareness) of society about the negative impact of cockroaches and the control techniques to be adopted.
- 3) Further research needs to be conducted to determine bacterial species carried on external and internal body of cockroach

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## 7 APPENDICES

### Appendix 1 Meteorological Data in weather situation in and around Addis Zemen

Table 1: Show the maximum and minimum monthly temperature and rain fall

No	Month	Temperature Degree			Mean Rain fall (mm)
		Salsas			
		Maximum	Minimum	Mean temperature	
1	January	32.1	9.3	20.7	0.0
2	February	34.6	10.4	22.5	0.0
3	March	34.5	10.6	22.6	0.0
4	April	33.5	10.6	22.1	0.0
5	May	32.1	32.1	32.1	4.6
6	June	28.7	14.6	21.7	4.9
7	July	25.2	13.9	19.6	18.3
8	August	25.1	14.3	19.7	7.9
9	September	27.0	14.3	20.7	2.7
10	October	27.0	13.6	20.3	2.2
11	November	28.0	12.7	20.4	0.3
12	December	27.8	9.4	18.6	0.0

Sours: National Meteorological Agency Service Bahir Dar Brach office, Ethiopia in 2013/2014

**Appendix 2: Show questionnaire and descriptive statistics for the awareness of the local community towards cockroaches (n=235)**

Table 2: Show the questionnaire and statistical analysis

No	Questions	Alternative	Respondents' Response		
			Frequency	Percent	Chi-square
1.	Do you know cockroaches?	Yes	235	100	
		No	0	0	
2.	If your answer for question number 1 is yes, where do you know them?	Home	220	93.6	$\chi^2 = 384.8, \Rightarrow P < 0.0001$
		Offices	11	4.7	
		Restaurants	4	1.7	
3.	Do cockroaches are found in your house?	Yes	220	93.6	$\chi^2 = 178.8, \Rightarrow P < 0.0001$
		No	15	6.4	
4.	If cockroaches are found in your house, where are they more concentrated?	Kitchen	173	73.6	$\chi^2 = 172.6, \Rightarrow P < 0.0001$
		.Bed room	37	15.7	
		Living room	25	10.6	
5.	What do you feel about due to the presence of cockroaches in your house?	I feel discomfort	217	92.3	$\chi^2 = 168.5, \Rightarrow P < 0.0001$
		I don't worry	18	7.7	
6.	What is reason if you feel discomfort due to the existence of cockroaches in home?	They make my house dirty	109	46.4	$\chi^2 = 82.5, \Rightarrow P < 0.0001$
		They cause noise	53	4.7	
		They cause disease	11	22.6	
		Do not know	62	26.4	
7	If cockroaches contaminate your foods what would you do?	Remove cockroach & Use the food	116	49.4	$\chi^2 = 85.2, \Rightarrow P < 0.0001$
		Discard the food	100	42.6	
		use food by removing contaminated	19	8.1	

8	8. If cockroaches contaminate your foods utensils what would you do?	Removing Cockroaches & use materials	129	54.9	$\chi^2_1 = 2.3, \Rightarrow P < 0.0001$
		.I use utensils after washing	106	45.1	
9	What mechanisms do you use to prevent cockroaches from contaminating foods and Food utensils in the house	keeps the house clean	90	38.1	$\chi^2_2 = 44.5, \Rightarrow P < 0.0001$
		Properly close container	113	48.1	
		do not use any method	32	13.6	
10	10. In your opinion are cockroaches useful or harmful?	Harmful	40	17	$\chi^2_2 = 104.0, \Rightarrow P < 0.0001$
		I don't know	152	64.7	
		Neither useful nor harmful	43	18.3	
11	What looks like the hygienic level of your house?	Good	45	19.1	$\chi^2_2 = 129.2, \Rightarrow P < 0.0001$
		very good	30	12.8	
		Fair	160	68.1	
12	In what way you try to prevent cockroach infestation in your home	. Roach killer	50	21.3	$\chi^2_2 = 55.2, \Rightarrow P < 0.0001$
		directly killing as observed	53	22.6	
		Keeping the house clean	132	56.2	
13	If you have used, pesticides for what purpose was it?	To kill fleas and bed bugs	42	17.9	$\chi^2_2 = 163.3, \Rightarrow P < 0.0001$
		To kill cockroaches	170	72.3	
		Did not use	23	9.8	
14	Is there someone in your family who has been feeling sick?	Yes	205	87.2	$\chi^2_2 = 130.3, \Rightarrow P < 0.0001$
		No	30	12.8	
15	If your answer for question number 14 is yes what was the health problem?	Allergic	70	29.8	$\chi^2_3 = 18.8, \Rightarrow P < 0.0003$
		Typhoid and Guardia	68	28.9	
		Asthma	67	28.5	
		No	30	12.8	

**Appendix 3: Check list used during field observation in trapping housing unit.**

Table 3: Check list used during field observation

	Owners name	Housing category	Housing unit	Construction of house (Made from)			Moisture		Hygienic level of houses			Use of Pesticide		Cracks		Number of cockroaches trapped	Infestation level				
				Cement	Wood	Other	yes	no	Good	Fair	Low	Yes	No	yes	no		clean	Low	Medium	High	Very high
1																					
2																					
3																					
4																					
5																					
6																					
7																					
8																					
9																					
10																					

Date of visiting/--/---/2014

## Appendix 4: Statistical analysis of various factors on abundance of cockroaches.

Table 4: Analysis of Variance of Various Factors

### Analysis of variance Housing category (Effect Test)

Source	DF	sum of squares	F ratio	P value
Housing category	3	2885.5583	13.2244	<0.0001

### Least squares Means housing category

Level	Least squares Means	Standard error	Mean
Clinic	2.000000	2.8427960	2.0000
Residential house	12.014286	0.7207804	12.043
Restaurant	4.875000	2.1320970	4.8750
Public institution	2.541667	1.7408499	2.5417

### Analysis of variance housing units (Effect Test)

Source	DF	sum of squares	F ratio	P value
Housing unit	3	2254.0731	9.8672	<.0001

### Least squares Means housing units

Level	Least squares Means	Standard error	Mean
Bed	10.474359	.9880493	10.4744
Kitchen	12.089744	.9880493	12.0897
Office	2.277778	2.0567887	2.2778
Toilet	2.5333333	2.2530992	2.5333

### Analysis of variance raw material (Effect Test)

Source	DF	sum of squares	F ratio	P value
Raw material	2	2781.5027	19.0771	<.0001

### Least squares Means raw material

Level	Least squares Means	Standard error	Mean
Cement	2.930233	1.3020717	2.9302
Other	5.400000	3.8184238	5.4000
Wood	11.957447	.7190508	11.9574

Analysis of variance **Hygiene** (Effect Test)

Source	DF	sum of squares	F ratio	P value
Hygiene level	2	4515.4515	35.5103	<.0001

**Least squares Means Hygiene level**

Level	Least squares Means	Standard error	Mean
Fair	8.892857	.08699993	8.892
Good	4.677966	1.0380841	4.6780
Low	17.739130	1.1756543	17.7391

Analysis of variance **moisture** (Effect Test)

Source	DF	sum of squares	F ratio	P value
Moisture	1	5084.7161	84.4707	<.0001

**Least squares Means Moisture**

Level	Least squares Means	Standard error	Mean
No Moisture	3.191781	.90807115	3.1918
With Moisture	13.844828	.72036452	13.8448

Analysis of variance **cracks** (Effect Test crack)

Source	DF	sum of squares	F ratio	P value
Cracks	1	3935.9780	59.3319	<.0001

**Least squares Means cracks**

Level	Least squares Means	Standard error	Mean
No cracks	4.682353	.88343107	4.6824
With cracks	13.855769	.79866649	13.8558

Analysis of variance (Effect Tests) pesticides

Source	DF	Sum of Squares	F Ratio	P value
Pesticide use	1	113.53312	1.3083	0.2542

**Least Squares Means Table pesticides**

Level	Least Sq Mean	Std Error	Mean
No pesticides	10.176056	0.7817422	10.1761
Yes use pesticides	8.382979	1.3588103	8.3830



**Appendix 5: Pictures of common pest cockroach species used for comparison in this study**



A



B



C



D

A German cockroach B. Brown banded cockroach C. Oriental cockroach D. American cockroach (Source: Ogg *et al.*, 2006 pp 7)

### Appendix 6: Statistical analysis of Infestation level of study units

Table 5: Show test of independence of infestation level in relation various factors using chi-square

factors	Condition	Infestation level						Total	$\chi^2$
		Clan	Low	Medium	High	Very high	Total		
Moisture	No moisture	34.3%	21.4%	44.3%	0%	0%	100%	$\chi_4^2 = 75.1,$ $\Rightarrow P < .0001$	
	Moisture present	7.8%	3.5%	30.2%	50%	8.6%	100%		
Hygiene level	Good	28.8%	16.9%	42.4%	11.9%	0%	100%	$\chi_8^2 = 170.4,$ $\Rightarrow P < .0001$	
	Fair	12.4%	9.9%	42%	33.3%	2.5%	100%		
	Low/dirty	13%	2.2%	15.2	52.2%	17.4%	100%		
Cracks	No cracks	26.8%	15.9%	43.9%	13.4%	0%	100%	$\chi_4^2 = 37,$ $\Rightarrow P < .0001$	
	Crack present	10.6%	5.8%	28.9%	45.2%	9.6%	100%		
Pesticides	No pesticides	14.5%	12.3%	31.9%	35.5%	5.8%	100%	$\chi_4^2 = 8.9,$ $\Rightarrow P = .06$	
	Use pesticides	25%	6.25%	45.8%	18.8%	4.2%	100%		