THE EFFICACY OF CLEANSING AGENTS IN HANDWASHING

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CERTIFICATION

I hereby certify that this Thesis is my own work towards the MSc and that, to the best of my knowledge, it contains no materials previously published by another person nor material which has been accepted for the award of any other degree of the University, except where due acknowledgement has been made in the text.

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DEDICATION

This work is dedicated to the

Most High God, for it is

"… by the grace of God I am what I am …"

1 Corinthians 15:10

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ABSTRACT

The global disease burden is enormous, with the developing countries bearing the heaviest part of this burden. Hygiene practices have been neglected for a long time, thus allowing preventable diseases to take their toll on the lives and health of millions of people. Most of these diseases, for example the faecal-oral diseases such as diarrhoea, are preventable through simple but effective and cost-effective personal hygiene practices, including handwashing. Although handwashing is an age old practice, it is done for varied reasons, and without adequate knowledge about its ability to save lives through the reduction of disease causing pathogens. The purpose of the study was to assess the efficacy of various cleansing agents employed in handwashing, to reduce microbial load on hands, since hands are known to be "mechanical vectors" in the transmission of diseases. It also offered the opportunity to identify cleansing agents available even in rural poor communities, effective in reducing pathogens and the ultimate reduction of diseases. The study was undertaken at the Ayeduase Roman Catholic Junior High School. A questionnaire survey was carried out with 100 respondents to ascertain the practice of handwashing and cleansing agents used. Samples of the thumb, index and middle fingers of the right hand of 80 students were taken to assess the level of microbial contamination on unwashed hands. Participants washed their hands with soap, dipped their right hands in seeded water (suspension of microbes) and samples of the thumb, index and middle fingers of the right hands were taken. Participants then washed their hands with the various cleansing agents provided after which final samples of the three fingers were taken. For purposes of the study, cleansing agents provided were water only, ash, citrus lime and soap. Chromocult agar was the medium used for the isolation of pathogens which were *Escherichia coli*, *Sallmonella typhi*, other Coliforms and other

Enterobacteriaceae. Data from the questionnaires administered showed that 83% of respondents washed hands after using the toilet and 77% used soap in handwashing. Laboratory analysis showed that some individuals' fingers were very dirty. Again, cleansing agents used were able to reduce microbes by more than 50%. Findings from the study indicated that hands do carry microbial contaminants. Also all the cleansing agents provided –water only, ash, citrus lime and soap – have the ability to reduce microbes on the hands. It is recommended that education be carried out to inform people, particularly the rural poor communities, to wash their hands with any of the agents that are available locally, for disease prevention and healthy lives.

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GLOSSARY

ALRIs	Acute respiratory tract infections
ASH	Agencies for School Health
CDC	U S Centers for Disease Control and Prevention
DALY's	Disability-adjusted life years
EHSD	Environmental Health Services Division
GI	Gastrointestinal infections
GMT	Greenwich Mean Time
HIP	Hygiene Improvement Project
HIV/AIDS	Human Immunodeficiency Virus/Acquired Immune Deficiency Syndrome
KMA	Kumasi Metropolitan Assembly
KNUST	Kwame Nkrumah University of Science and Technology
KVIP	Kumasi Ventilated Improved Pit latrine
PPPHW	Global Public-Private Partnership for Handwashing with soap
RCJHS	Roman Catholic Junior High School
RTIs	Respiratory Tract Infections
SARS	Severe Acute Respiratory Syndrome
SHEWA-B	The Sanitation, Hygiene Education and Water supply in Bangladesh Program

UNICEF	United Nations Children's Fund
USAID	United States Agency for International Development
USDA	United States Food and Drugs Administration
WHO	World Health Organization

CHAPTER ONE

INTRODUCTION

1.1 Background of the study

Globally, diarrhoeal disease is the second highest cause of mortality and morbidity in children under five years of age. According to the World Health Organization (WHO) Global Burden of Disease 2004 estimates, diarrhoea accounts for nearly 1.8 million deaths, or 17% of under five mortality each year in developing countries. WHO estimates that 85 to 90% of diarrhoeal illnesses in developing countries can be attributed to unsafe water and inadequate sanitation and hygiene practices (Pruess-Ustun et al.,2004)

Diseases caused by bacteria, viruses, fungi and other parasites are major causes of death, disability, and socio-economic disruption for millions (WHO, 2008; UNAIDS/WHO, 2008; Breman et al., 2004). Despite the existence of safe and effective interventions, many people lack access to needed prevention methods and treatment.

Emerging, re-emerging and novel infections increase awareness of our global vulnerability, highlight the borderless impact of disease and underscore the need for strong health care systems (Jamison et al, 2006).

Approximately 15 million people die each year due to infectious diseases. Nearly all of them are living in the developing countries (WHO, 2008). Again, WaterAid (2006) asserted that 2.2 million people in the developing countries, most of them children, die annually due to diarrhoea linked to lack of access to safe drinking water, inadequate sanitation and poor hygiene. Diarrhoea is contracted by ingesting contaminated food or drink, by direct person to person contact. It is a serious global public health problem.

According to WHO (2002), respiratory infections cause nearly 4 million deaths each year, and the victims are mostly children. It was therefore a major surprise when a study by the US Navy showed that handwashing could reduce the risk of respiratory infections by 45% among young recruits under training (Ryan et al., 2001).

Infections are prevalent in developing countries where co-infection is common. The adverse impact of infectious diseases is most severe among the poorest people, who have the fewest resources to draw from, and limited or no access to integrated health care, prevention tools and medications (UNAIDS/WHO, 2008).

Esrey et al (1996) noted that most endemic diarrhoea is not water-borne, but transmitted from person to person by poor hygiene practices. Therefore, improved hygiene (handwashing) and sanitation (latrines) have more impact than drinking water quality on health outcomes, specifically reductions in diarrhoea, parasitic infections, morbidity and mortality, and increases in child growth (Esrey et al, 1991; Hutley et al, 1997).

1.2 Statement of the Problem

Many illnesses occur unnecessarily, since the faecal-oral route of disease transmission can be easily prevented (WHO, 2003). Infectious diseases that are commonly spread through hand to hand contact include the common cold and several gastrointestinal disorders, such as diarrhoea (WaterAid, 2006).

Hygiene is, without doubt, a very important component in the reduction of the global disease burden. Handwashing, as an aspect of hygiene, has been highly recommended as a simple but effective way of preventing diseases. According to Aiello and Larson (2002), hygiene (handwashing) has a measurable impact on reducing the burden of infections in the developing world.

Correct handwashing is the single most effective way to prevent the spread of communicable diseases. Good handwashing techniques is easy to learn and can significantly reduce the spread of infectious diseases among both adults and children. Handwashing is one of a range of hygiene promotion interventions that can interrupt the transmission of diarrhoea-causing pathogens (Ejemot et al, 2008).

Esrey et al (1985) asserted that handwashing turns out to have a greater impact on diarrhoeal diseases than even water supply. This makes handwashing and its promotion an intervention with enormous potential impact on public health.

A review by Curtis and Cairncross (2003) of all available evidence suggested that handwashing with soap could reduce diarrhoea incidence by 47% and save at least 1 million lives per year. This is consistent with other studies which found that 12 handwashing interventions in 9 countries achieved a median reduction in diarrhoea incidence of 35% (Hill et al, 2001). Again, a study in Uganda by Lule et al (2005) demonstrated that the presence of soap in the house was associated with fewer diarrhoea incidents.

The core of the problem is that the practice of handwashing is however not common, and handwashing with soap is seldom, in a number of developing countries, particularly in the rural poor communities where a commodity such as soap is a luxury, and must be used only for bathing and washing clothes. There is the need, therefore, to identify alternative hand cleansing agents that would be locally available for use in rural communities. While searching for the alternatives, the efficacy of the cleansing agents must not be overlooked. The essence of the cleansing agents should be the reduction of microbes on the hands, and ultimately, the prevention of disease.

1.3 Objectives of the Study

1.3.1 Main objective

The main objective of the study was to determine the efficacy of water only, ash and citrus lime, as alternative cleansing agents to soap, in handwashing.

1.3.2 Specific objectives

The specific objectives were to:

- assess the level of practice of handwashing and types of cleansing agents used by the students;
- determine the level of microbial load on unwashed hands of the students;
- ascertain microbial load reduction on hands of the students due to alternative cleansing agents (water only, ash and citrus lime) as well as soap used during handwashing.

1.4 Research questions

The study sought to answer the following questions.

- What is the level of the practice of handwashing by the students, and what cleansing agents are used?
- What is the level of microbial load on unwashed hands of the students?
- Is there any reduction in microbial load after washing hands with water only, ash, citrus lime and soap?

1.5 Justification of the study

The importance of handwashing as a means of disease prevention cannot be overruled and all and sundry must be encouraged to practise this simple and yet effective procedure for disease reduction. There is however the need to ascertain the effectiveness of cleansing agents used in handwashing. This is particularly important in poor communities where, due to financial constraints, soap is seen as a luxury and must not be wasted in handwashing. Therefore, alternatives, at almost zero cost, must be identified, assessed to determine their efficacy to encourage handwashing.

Information from the study would:

- indicate the level of the practice of handwashing and cleansing agents used;
- identify alternative locally available cleansing agents that can be used for handwashing, especially in the rural communities;
- determine how effective the cleansing agents are in the reduction of microbes on the hands;
- provide information for public health practitioners, health educators and other interested stakeholders;
- be useful as reference in the future for similar studies.

1.6 Scope of the study

The study looked at the efficacy of various cleansing agents used in handwashing. It was to assess the level of handwashing behaviour among the students and the cleansing agents used. Again, parameters the study considered were microbial load on unwashed hands and the reduction in microbial load after washing hands with various cleansing agents.

CHAPTER TWO

LITERATURE REVIEW

2.1 Scary facts

Infectious diseases continue to exact a huge toll on the health and wellbeing of the global population. The 2008 WHO Report on the global burden of disease, based on data for 2004, assessed that, worldwide, infectious and parasitic diseases account for 9.5 million deaths a year (16.2% of all deaths).

According to the World Bank (2011), intestinal worms infect about 10% of the population of the developing world and can lead to malnutrition, anaemia and retarded growth. Furthermore, they noted that 6 million people are blind from trachoma and the population at risk in about 500 million.

Bloomfield et al. (2009), showed that a significant proportion of the global communicable disease burden is caused by diarrhoeal, respiratory and skin diseases, which could be significantly reduced by adequate water and sanitation combined with good hygiene practice.

A report prepared by Pruss-Ustun et al (2008) for WHO estimated that improving water, sanitation and hygiene has the potential to prevent at least 9.1% of the global disease burden in disability-adjusted life years (DALY's), or 6.3% of all deaths. Children, particularly those in developing countries, suffer a disproportionate share (up to 20%) of this burden. Together, pneumonia and diarrhoea account for the majority of child deaths around the world each year (PPPHW, 2008).

On the average, a person in the United States has two or three colds per year. Colds are the leading cause of absenteeism from school, and result in loss of about 150 million work days per year (Nester et al., 2001). They further noted that again in the

United States rotaviruses cause an estimated 2.7 million cases of gastroenteritis each year in individuals less than five years old, resulting in 500,000 emergency department or clinic visits, and 49,000 hospital admissions. Worldwide, 600,000 deaths are attributed to rotaviruses each year.

In Ghana, during 2000 – 2003, causes of death among children under 5 years of age was 12% for diarrhoeal diseases and pneumonia was 15%. Considering top ten causes of death for all ages in Ghana in 2002, diarrhoeal diseases were 5% (WHO, 2006).

2.2 Diarrhoeal diseases

Diarrhoeal disease still ranks very high as a major cause of illness and death among infants and young children, especially in developing nations. Approximately 750 million illnesses and 5 million deaths result annually from diarrhoea, primarily in young children (Sommers and Shulman in Shulman et al, 1992).

An estimated 88% of diarrhoeal deaths worldwide are attributable to unsafe water, inadequate sanitation and poor hygiene (handwashing) (Black et al, 2003). According to WHO (2000), diarrhoeal diseases are amongst the top three killers of children in the world today.

AWHO/UNICEF (2004) joint statement indicated that, each year, an estimated 2.5 billion cases of diarrhoea occur among children under five (5) years of age and estimates suggest that the overall incidence has remained relatively stable over the past two (2) decades**.** Published estimate of the total annual death rate from diarrhoeal diseases is 2.2 million (WHO, 2000). Victora et al. (2000) suggested 1.5 million child deaths.

More than half of these cases are in Africa and South Asia, where bouts of diarrhoea are more likely to result in death or other severe outcomes. The incidence of diarrhoeal diseases varies greatly with the seasons and a child's age. The youngest children are most vulnerable. Incidence is highest in the first two years of life and declines as a child grows older (UNICEF/WHO, 2009).

Successive estimates of global diarrhoeal deaths have fallen from 4.6 million in 1980 through 3.3 million (Bern et al, 1992), 2.9 million (Murray et al, 1997), to 2.2 million (WHO, 2000**).** Despite these declines, diarrhoea remains the second most common cause of death among children under five globally, following closely behind pneumonia, the leading killer of young children. Nearly one in five child deaths is due to diarrhoea, a loss of about 1.5 million lives each year. The toll is greater than that caused by AIDS, malaria and measles combined.

Africa and South Asia are home to more than 80% of child deaths due to diarrhoea. Just 15 countries account for almost three quarters of all deaths from diarrhoea among children under five years of age annually.

Table 2.1: Child deaths due to diarrhoea in 15 countries

RANK	COUNTRY	TOTAL NO. OF ANNUAL CHILD DEATHS DUE TO DIARRHOEA
1	India	386,600
2	Nigeria	151,700
3	Democratic Republic of the Congo	89, 900
4	Afghanistan	82,100
5	Ethiopia	73,700
6	Pakistan	53,300
7	Bangladesh	50,800
8	China	40,000
9	Uganda	29,300
10	Kenya	27, 400
11	Niger	26, 400
12	Burkina Faso	24, 300
13	United Republic of Tanzania	23, 900
14	Mali	20, 900
15	Angola	19, 700

Source: World Health Organization, Global Burden of Disease estimates, 2004 update. The totals were calculated by applying the WHO cause of death estimates to the most recent estimates for the total number of under five deaths (2007).

Diarrhoeal diseases remain a principal cause of preventable morbidity and death in developing countries. Anon (2000) suggested that residents of developing nations may experience between 5 and 20 episodes of diarrhoea per year. The WHO report (2008) on the global burden of disease noted a total of 2.16 million deaths per year calculated for data gathered in 2004. The highest levels of diarrhoeal diseases occur in Africa and the Eastern Mediterranean region.

2.2.1 Definition of diarrhoea

Diarrhoea is defined by Turner in Kumar et al (2010) as an increase in stool mass, frequency, or fluidity, typically greater than 200 grams per day. In severe cases, stool volume can exceed 14 litres per day and, without fluid resuscitation, result in death. Painful, bloody, small volume diarrhoea is known as dysentery.

2.2.2 Causes of diarrhoea

According to WHO (1999), diarrhoea is a common symptom of gastrointestinal infections (GI) caused by a wide range of pathogens, including bacteria, viruses and protozoa. However, just a handful of organisms are responsible for most acute cases of childhood diarrhoea. Rotavirus, as noted in the Weekly Epidemiological Record (2008), is the leading cause of acute diarrhoea, and is responsible for about 40% of all hospital admissions due to diarrhoea among children under five worldwide. Other major bacterial pathogens include *Escherichia coli*, *Shigella*, *Campylobacter* and *Salmonella*, along with *Vibrio cholera* during epidemics. *Cryptosporodium* has been the most frequently isolated protozoan pathogen among children seen at health facilities and is frequently found among HIV- positive patients. Though cholera is often thought of as a major cause of child deaths due to diarrhoea, most cases occur among adults and older children.

2.2.3 Transmission route of diarrhoea pathogens

Most pathogens that cause diarrhoea share a similar mode of transmission – from the stool of one person to the mouth of another. This route is also known as the faecal-oral transmission route (Nester et al, 2001). There may be differences, however, in the organisms load needed to cause clinical illness, or the route the pathogen takes while travelling between the individuals; for example, from the stool to water or food, which is then ingested.

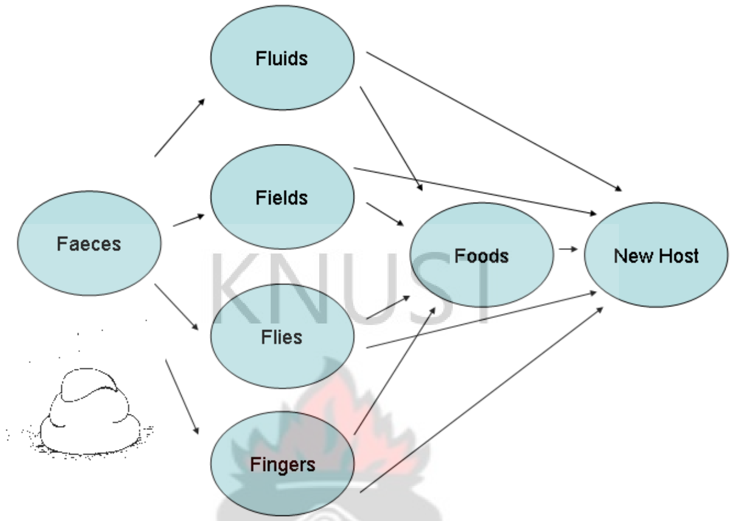


Figure 2.1: The F-Diagram (Wagner & Lanoix, 1958 in Hunt, 2001) illustrating the major transmission pathways of faecal-oral diseases.

2.3 Respiratory Tract infections

A respiratory tract infection is any infection of the sinuses, throat, airways or limbs. It is usually caused by a virus (NHS Direct-Wales, 2012).

Globally, acute lower respiratory infections (ALRIs) such as pneumonia, bronchiolitis and bronchitis cause up to 4 million deaths annually, mostly in children. The major burden of ALRI diseases falls in the developing countries (WHO, 2002).

2.3.1 Transmission of Respiratory Tract infections

Luby et al (2005) indicated that it is known that some of the viruses that infect the respiratory tract are transmitted from person-to-person via the hands. Additionally, several viruses that cause respiratory tract infections predispose children to bacterial pneumonia.

Data from studies conducted by Bloomfield et al (2007) and Aiello et al (2008) showed that although the commonly held belief is that colds are spread by particles of infected mucous generated by coughs and sneezes, increasingly, there is evidence that infection can spread when fingers become contaminated by contact with the infected nose, or when surfaces such as handkerchiefs or taps and door handles become contaminated by droplets of infected mucous shed from the nose. The virus can be transmitted to some other person either by handshaking, or when contaminated surfaces are touched by that person. Individuals go on to infect themselves by touching their nose or eyes with contaminated hands.

2.4 Linkage between diarrhoeal diseases and respiratory tract infections

Many people consider measures such as handwashing for the prevention of faecally transmitted diseases such as diarrhoea as completely distinct from the control of infections transmitted in airborne droplets, when coughs and sneezes spread diseases. However, a number of studies have indicated that handwashing to prevent diarrhoeal diseases can be used to also reduce the incidence of respiratory tract infections (RTIs). Handwashing reduces the rate of respiratory infections in two ways: by removing respiratory pathogens that are found on hands and surfaces, and by removing other pathogens (in particular, enteric viruses) that have been found to cause not only diarrhoea but also respiratory symptoms (PPPHW, 2009).

According to Eccles (2003), pathogens which cause diarrhoea can also cause respiratory symptoms. This is true particularly of the enteric viruses, such as those which cause ‘gastric flu’. Unlike most enteric bacteria, enteric viruses are invasive and if they cause irritation to the epithelial cells in the gut, they are most likely to irritate the epithelial cells in the lungs. It follows that the viruses emitted when we cough may also be found in our faeces. Indeed, in some species of ducks, influenza is known to be transmitted by the faecal route rather than by aerosol (Shortridge, 1997).

Further, both respiratory and enteric pathogens are often transmitted on surfaces. The surface we most often use to inoculate ourselves with infection is the skin of our hands. In a study by Corley et al (1987), children aged 4 – 8 years were trained not to touch their nose and eyes frequently. This led to 47% reduction in laboratory-diagnosed common cold infections. It is known that viruses as those that cause colds can remain viable on surfaces for several hours (Sattar et al, 1993). Also the infective dose needed to cause infection can be very small, and people can pick up virus particles on their hands by touching objects and surfaces contaminated by aerosols from infected people (Ansari et al, 1991).

2.5 Microbial load on unwashed hands

There are grave consequences when people do not wash their hands or wash them improperly. It is known that hands are the main media for contaminants getting to people, whether the infections are airborne, oral or tactile.

Infectious diseases that are commonly spread through hand to hand contact include the common cold, and several gastrointestinal disorders such as diarrhoea (WaterAid, 2006). Human hands usually harbour microorganisms both as part of a person’s normal microbial flora as well as transient microbes acquired from the environment (Lindberg et al, 2004).

According to Kartha (200!), many people consider handwashing a waste of time. However, they are unaware that hands are hosts to many bacteria and viruses that can cause infectious diseases. Every human being comes in contact with germs and bacteria in their daily life. These harmful microorganisms are present all around – on door knobs, faucets, light switches, tables, and railings. People touch these things during the day while doing their routine work without much thought, and then touch their face, eyes, nose, and sometimes eat food too. Through these acts, the microorganisms get into the body, causing several diseases. People, who are careless at washing hands, risk catching flu, or cold, or any gastrointestinal illness (Kartha, 2001).

Mayo Clinic (2009) also asserted that as people touch one another, surfaces and objects throughout the day, they accumulate germs on their hands. In turn, they can infect themselves with these germs by touching their eyes, nose or mouth.

Hands serve as vectors transmitting pathogens to foodstuffs and drinks and to the mouths of susceptible hosts (Huttly, 1997). Many food borne diseases and pathogenic microorganisms are spread by contaminated hands. If pathogens from human faeces enter a person's mouth, they will cause diarrhoea.

School going children are exposed to greater risks of diarrhoeal disease by consuming contaminated water and food (Dasgupta, 2005). Students in schools or colleges are more likely to take meal and water without washing hands and may be exposed to risk of infection (Tambekar et al, 2007). If proper treatment is not given, this can prove fatal, particularly to children (WHO, 2006).

In Ghana, funeral celebrations are very important social functions at which hundreds of people gather. From experience, one important activity during such gatherings is handshaking. Indeed, it is considered offensive and disrespectful for cultural values when one does not proffer his hand for shaking. It is however unfortunate that when people are served snacks and food during such occasions, handwashing facilities are not made available. People therefore eat with unwashed hands. The advent of some serious gastrointestinal illnesses (for example, cholera) had been traced to such gatherings.

2.6 Handwashing defined

Handwashing is defined as the act of cleansing the hands with water or other liquid, with or without the inclusion of soap or other detergent, for the purpose of removing soil or microorganisms (Biology-online, 2011; Medconditions, 2011).

2.6.1 Attitudes of handwashing

Handwashing has been an age old practice globally. It is carried out for varied reasons, including religious, cultural, health and moral reasons. Attitudes towards handwashing are very important. They go a long way to determine the practice of handwashing and its effect on health.

In a study by Hoque et al (1995), 90 women from randomly selected households in rural Bangladesh were observed washing their hands after defaecation. Thirty-eight percent of the women used mud, 2% used ash, 19% used soap, and 41% used water only without a rubbing agent. A total of 44% of women washed both hands, while 56% washed only their left hands. About 78% of the women dried or wiped their hand on their clothes and the rest let them air dry.

According to SHEWA-B (2007), in Bangladesh (and in some regions of the sub-continent), observations on handwashing practices identified that handwashing with water alone before food preparation and eating was quite common (47 – 76%), but washing hands with soap or ash was observed ≤2% of the time. Washing of both hands with soap or ash was more common after defaecation (17 – 18 %), after cleaning a child's anus (22 – 24%) or after handling cow dung (12 – 20%). Findings also showed that availability of handwashing materials such as soap, ash or mud at the site of handwashing was low, with approximately 30%, and ≤1% of households having the specified material. Water availability was high. Hand drying was observed to take place before preparing food, after defaecation, after eating and before serving food. A high proportion of females did not dry their hands after handwashing.

A staggering one out of three Americans skips handwashing after going to the bathroom. Only 30% of people who have coughed or sneezed into their hands wash their hands afterwards. Kids are even worse. In a survey of junior high and high school boys and girls, only 58% of girls and 48% of boys washed up after using the rest room (Wisegeek. com, 2011).

Worldwide rates of handwashing with soap are very low. While many wash their hands with water, only a small percent use soap at critical times. In Ghana, for example, the rates for handwashing with soap after defaecation is 3% and after cleaning up a child is also 3% each (PPPHW, 2010).

2.6.2 Economic considerations

Efforts to modify human behaviour are complex. People can only expect to be successful if there is an understanding of what motivates, facilitates, and hinders adequate handwashing behaviour (Curtis et al, 1997; O'Boyle et al, 2001).

Curtis et al (2001) noted that modern methods of promoting handwashing can be effective and cost-effective on a large scale. Studies suggest that soap is widely available, even in poor households in developing countries, although it is mostly used for bathing and washing clothes (Borghi et al, 2002). In rural India and Bangladesh, soap is often considered a beautifying agent or for the physical feeling of cleanliness which it gives, rather than being associated with the removal of microorganisms or health benefits (Hoque and Briend, 1991; Hoque et al, 1995).

In low income communities, soil, mud or ash may be used as a zero cost alternative to soap for handwashing (Zeitlyn and Islam, 1991). Hoque et al (1995) again reported that altogether, 81% of non-soap users stated that they might use soap, but were unable to afford it.

2.6.3 Critical times for handwashing

A defensive strategy is important when trying to avoid infecting oneself with an illness lying in wait (Wisegeek.com, 2011). According to Mayo Clinic (2009), frequent handwashing is one of the best ways to avoid getting sick and spreading illness. Although it is impossible to keep hands germ-free, washing hands frequently can help limit the transfer of bacteria, viruses and other microbes.

It is possible that people do not wash their hands as often as they should. Handwashing prevents both diarrhoea and respiratory infections effectively when done properly and at critical times. The critical times must be observed and conscious efforts made to clean hands at such times.

A number of sources (Mayo Clinic, 2009; ASH, 2011, All Family Resources, 1999 and CDC, 2010) agree on a number of critical times when hands must be washed.

The critical times include:

- Before preparing food;
- Before eating;
- Before treating wounds or giving medicine;
- Before touching a sick or injured person;
- Before inserting or removing contact lenses;
- After preparing food, especially raw meat or poultry;
- After using the toilet/bathroom;
- After changing a diaper;
- After touching an animal, or animal toys, leashes or waste;
- After blowing your nose, coughing or sneezing into your hands;
- After touching a sick or injured person;
- After handling garbage or something that could be contaminated, such as a cleaning cloth or soiled shoes;
- Whenever hands look dirty.

Some include also washing hands after handling money (ASH, 2011), before going home, immediately one gets home, on arrival at the workplace (All Family Resources, 1999), after combing hair (USDA, 2011) and after smoking (Earth's kids, 2011).

2.6.4 Process of handwashing

Though people know the importance of handwashing, not many know how to do it properly. Handwashing does not mean just running water over your palms. It has to be done very carefully and in detail (Kartha, 2001).

Mayo Clinic (2009) suggests the following steps:

- Wet hands with (running) water;
- Apply cleansing agent;
- Lather well;
- Rub hands vigorously for at least 10 to 20 seconds, remembering to scrub all surfaces, including the backs of hands, wrists, between fingers and under fingernails;
- Rinse well;
- Dry hands with a clean or disposable towel or dryer.

The above steps have been advocated by several sources as well. These include ASH (2011); All Family Resources (1999); CDC (2010); Kartha (2001); Wisegeek.com (2011) and Gavin (2011).

2.6.5 Correct length of time

Equally important is the length of time that hands are to be washed. The key is to lather up hands and rub vigorously for at least 15 to 20 seconds. Some suggest singing 'Happy Birthday' or the ABCs to keep a child washing hands for the correct amount of time (Wisegeek.com, 2011). Earth's Kids (2011) suggested that children sing a fun song while washing hands to mark the time of 15 – 20 seconds, so that they know how long they wash.

Gavin ((2011) said to use soap and lather up for 20 seconds. Mayo Clinic (2009) noted that wet, soapy hands should be rubbed together outside the stream of running water for at least 20 seconds. CDC (2010) suggested scrubbing hands for 20 seconds, and while singing ‘Happy Birthday’ twice to get to 20 seconds. PPPHW (2008) also suggested singing any local fun song that would make up to 20 seconds while hands are being rubbed together after applying cleansing agent.

According to ASH (2011), hands must be rubbed together for at least 10 seconds while singing ‘Happy Birthday’ once for a perfect length of time. Rub hands vigorously until a soapy lather appears and continue for at least 15 seconds (All Family Resources, 1999). Mohave County Information Technology (2001) also recommends rubbing hands briskly for at least 20 seconds.

From the foregone discussions it can be seen that rubbing hands together vigorously for anytime between 10 to 20 seconds or more should be adequate for pathogen reduction on the hands**.**

2.6.6 Quantity of water needed for rinsing hands

Accessible and plentiful water has been shown to encourage better hygiene, particularly handwashing (Curtis and Cairncross, 2000). Also, interventions to improve water quality at the source along with treatment of household water and safe storage systems have been shown to reduce diarrhoea incidence by as much as 47% (WHO, 2008).

Hoque et al (1995), in a study, observed that as many as 74% of the 90 women rinsed their hands with 0.7 litre of water or less. They however recommend that rinsing with 2 litres of clean water was protective, although such volumes may be difficult to sustain in the absence of on-plot access to water. Since pathogens removed during handrubbing have to be rinsed away, there must be a reasonable flow of water (Standard Operating Procedures, 1997). Mayo Clinic (2009) suggested the use of running water for rinsing hands.

Water scarcity has an impact on hygiene practices such as handwashing. It could lead to person-to-person transmission due to inadequate personal and domestic hygiene. Water scarcity can therefore result in faecal-oral, skin and eye infections (Cairncross, 2011).

2.6.7 Temperature of water

Contrary to popular belief, scientific studies by Michaels et al (2002), and Laestadius and Dimberg (2005), have shown that using warm water has no effect on reducing the microbial load on hands. Hot water that is comfortable for washing hands is not hot enough to kill bacteria. Microorganisms proliferate much faster at body temperature (37 degrees C). However, warm, soapy water is more effective than cold, soapy water at removing the natural oils which hold soils and bacteria (US Food and Drugs Administration, 2006).

All Family Resources (1999) indicated that warm water should always be used for handwashing. ASH (2011), Kartha (2001), Wisegeek.com (2011) and Gavin (2011) also suggested the use of warm water for handwashing. CDC (2010) said that clean running water that was warm or cold could be used. The temperature of water has not been shown to be important in handwashing (Standard Operating Procedures, 1997).

2.6.8 Methods of drying hands

In 2005, in a study conducted by TUV Produkt und Umwelt, different hand drying methods were evaluated. The following changes in bacteria count after drying the hands were observed:

- paper towels and roll – decrease of 24%;
- cloth roller – decrease of 4%;
- hot-air drier – increase of 117%.

Again in 2008, a study was conducted by the University of Westminster Trade Group, London, and sponsored by the paper towel industry, the European Tissue Symposium to compare the levels of hygiene offered by paper towels, warm air hand dryers and the more modern jet-air hand dryers (Redway and Fawder, 2008). The key findings were as follows:

- after washing and drying hands with the warm air dryer, the total number of bacteria was found to **increase** on the average on the finger pads by 194% and on the palms by 254%;
- drying with the jet air resulted in an **increase** on the average the total number of bacteria on the finger pads by 42% and on the palms by 15%;
- after washing and drying hands with a paper towel, the total number of bacteria was **reduced** on average on the finger pads by up to 76% and on the palms up to 77%.

Both studies favoured the use of paper towels to dry hands after washing rather than the warm air dryer and the jet air. Air dryers were said to blow microbes from the toilet onto hands.

The use of clean towel or cloth has also been recommended**.** After washing, hands could be dried by waving them in the air and then allowing the air to dry them (CDC, 2010). It has been found that the practice of drying washed hands on dirty clothes contaminates them (Hoque et al, 1995).

2.7 Efficacy of cleansing agents in microbial reduction

Esrey et al (1991) have suggested that reducing the rate of pathogen ingestion causes the incidence of severe infections to begin to fall before that of mild ones. The reduction in the severity of infection is the ultimate purpose of handwashing. Therefore microbial reduction on hands would reduce the ingestion of pathogens since the hands have been proved to be the main transport route for gastrointestinal diseases, respiratory tract infections, skin infections (eg. impetigo) as well as eye infections (eg. conjunctivitis). This makes the agent employed in handwashing a necessary factor.

2.7.1 Water only

Pure water has a pH of seven, which makes it neutral. It is also known as a universal solvent. A number of studies (Cairncross, 1993; Ghosh et al, 1995; Khan, 1982; Oo et al, 2000) suggested that handwashing with water only provides little or no benefit. The application of water alone is inefficient for cleaning skin because water is often unable to remove fats, oils and proteins, which are components of organic soil (Standard Operating Procedure, 1997). Kalanke (Mali) (2011) noted that handwashing with water alone does not remove many germs.

Hoque and Briend (1991), on the contrary, showed that whilst less effective than when using a rubbing agent such as soap, mud or ash, some reductions in contamination were found when washing with water alone. Data on the effectiveness of handwashing with soap-based formulations, compared with water alone, in the removal of bacteria and viruses (Ansari et al, 1989; Mbithi et al, 1993) suggest that, in most (but not all) cases, liquid soap-based formulations were more effective than water only. However, the authors concluded that the differences were not statistically significant.

2.7.2 Ash

Hoque and Briend (1991) indicated that the use of alternative rubbing agents (mud or ash) provided the same benefits as soap. Again, Hoque et al (1995) also found that the use of ash and soap all achieved the same level of cleanliness. Ash, however, is considered less pleasant on the hands compared with soap or soil (Hoque and Briend, 1991). Despite the positive lifesaving potential of handwashing with soap (ash), proper handwashing is not being practiced regularly by children in schools and homes (WASH United, 2010).

2.7.3 Citrus lime fruit

Scientifically known as *Citrus aurantifolia*, there are two natural groups of the citrus lime fruit – acid (sour) limes, and acidless (sweet) limes. The 'West Indian' lime, also called Mexican and Key lime is round, small-fruited, moderately seedy and highly polyembryonic; it has a thin, smooth rind, greenish flesh and a citric acid content ranging from 7% to 8%. It is usually grown as a seedling, as no satisfactory rootstock is known, but in Ghana it is grown on Rough lemon stock (Samson, 1986).

2.7.3.1 Chemical composition of citrus lime

According to Davis and Albrigo (1994) the composition of citrus fruits varies with cultivar, climate, rootstock and cultural practices. They noted that most citrus, like other fruits, are primarily water, but also contain over 400 other constituents including moderate levels of carbohydrates, organic acids, amino acids, ascorbic acid and minerals and small quantities of flavonoids, carotenoids, volatiles and lipids. Citrus fruits are low in proteins and fats.

With regards to organic acids in limes, citric acid is the primary acid (70 – 90% of total) followed by malic and oxalic acids with lesser amounts of succinic, malonic, quinic, lactic, tartaric and other related acids. Citrus fruits are a valuable source of ascorbic acid (Vitamin C). Ascorbic acid functions as a coenzyme and is an essential part of the human diet (Davis and Albrigo, 1994). Salunkhe and Kadam (1995) asserted that the acidity of citrus fruits is due primarily to citric and malic acid. Citrus juice, they indicated, has a low pH of 3.5 – 3.6, while Vitamin C content ranges from 0.3 to 0.6 mg/ml. Acid limes are very acidic, containing 5% - 8% citric acid.

2.7.3.2 Uses of the citrus lime

A study investigating the antibacterial effects of two plants extracts showed *Citrus aurantifolia* showing broad spectrum antibacterial effects on human pathogens. It is a potential antimicrobial agent and its juice is regarded as antiseptic (Philippine Medicinal Plants, 2011).

In Malaya, the Mexican lime is regarded as an antiseptic, and as a disinfectant for all kinds of ulcers as well as for superstitious uses. The peel oil is used in the perfume industry (Morton, 1987).

Citric acid is a weak organic acid found in citrus fruits. In biochemistry, citrus acid is important as an intermediate in the citric acid cycle and therefore occurs in the metabolism of almost all living things. It is most concentrated in lemons and limes. It is used as food preservative. It is also used in the biotechnology and pharmaceutical industry to passivate (make material passive or non-reactive) high purity process piping (in lieu of nitric acid) (New World Encyclopaedia, 2011).

Again, citric acid is used to adjust pH in several processes such as in food and beverages, personal care and industrial applications. It also acts as a buffer in pharmaceuticals as well as in detergents and cleaners (Jungbunzlauer, 2011).

Brock et al (1986) stated that in general, sterilization is more rapid at low pH than at neutral or higher pH, because most microorganisms are sensitive to low pH. This could make citric acid in limes an important potential agent in microbial reduction. Haemodialysis systems are subject to viruses and blood pathogens. Dialysis patients have been infected with blood-borne viruses and pathogenic bacteria. It is crucial that these machines be properly disinfected. One form of sterilization for haemodialysis units for use with people infected with hepatitis B uses citric acid with heat to sterilize the equipment (CDC, 2011).

In Ghana the citrus lime fruit is used to remove odour from hands, and body odour, particularly from the armpits and folded parts. Females also use it in genital cleansing, again, to remove odour. It has also been observed that practitioners and peddlers of traditional medicines widely promote its use as part of herbal concoctions, while plying their trade.

2.7.4 Soap

A number of studies indicate that washing hands with soap is the critical component of the handwashing behaviour (Cairncross, 1993; Ghosh et al, 1997; Khan, 1982; Oo et al, 2000). Kartha (2001) noted that the most essential thing required to wash hands is soap.

Again, studies have shown that hands can carry faeces to surfaces, to foods, and to future hosts, and handwashing with soap is effective in removing pathogens (Han et a., 1986; Kaltenthaler et al, 1991; Ansari et al, 1991). Improvements in access to safe water and adequate sanitation, along with the promotion of good hygiene practices (particularly handwashing with soap), can help prevent diarrhoea (Black et al, 2003). PPPHW (2011) affirmed that promoted on a wide enough scale, handwashing with soap can be thought of as a 'do- it-yourself' vaccine.

2.7.4.1 Choice of soap

Debate has been ongoing about the best type of soap to be used in handwashing. A study by Aiello (2007) indicated that plain soaps are as effective as consumer-grade antibacterial soaps in preventing illness and removing bacteria from the hands. Mayo Clinic (2009) admonished people to keep in mind that antibacterial soap is no more effective at killing germs than is regular soap. Using antibacterial soap may even lead to the development of bacteria that are resistant to the products' antimicrobial agents – making it harder to kill these germs in the future.

Commenting on favoured features for soap, women in Ghana cited a range of attributes – smell, cost, texture and durability, and its capacity to be used for multiple purposes. For the women, the most important attribute was the smell of the soap, and the most popular scents were mild lime and lemon. Concerning cost, cheaper soaps were preferred, although women were sometimes willing to pay more if the soap was larger or they thought it would last longer. Commenting on texture / durability, associated with cost, women preferred harder bar soaps or liquid varieties as they thought they lasted longer. So strong was the preference for hard soaps that many stored soap in cool or sunny or airy places to harden them before use. Some women thought liquid soap more economical since only a peanut size was adequate for each hand wash. Many women preferred laundry bar soap because it could be used as a multipurpose soap such as for laundering, bathing and washing dishes at the same time (PPPHW, 2010).

2.8 The act of handrubbing

It has been suggested by Hoque et al, (1995) that the key component of the handwashing process is the mechanical rubbing of the hands. They noted that the trend towards better results from handwashing with both hands, increased frequency of rubbing and an increased volume of rinsing water all support the prime importance of scrubbing / frictional motion and consequent washing out of loose bacteria with water. Although results of studies carried out suggest that the use of a rubbing agent is important, the authors suggested that the nature of the rubbing agent is a less important factor. Soap, they indicated, was more effective than soil and ash because soap users tend to rub their hands more and use more water to rinse away the soapy feeling on them.

CDC (2011) advised people to rub hands together vigorously to make a lather and to continue scrubbing for 20 seconds because it takes that long for the soap and scrubbing action to dislodge and remove stubborn germs.

2.9 Beneficial effects of handwashing

Handwashing has been regarded as a key infection-control practice since Semmelweis suggested its introduction in health care settings (Semmelweis, 1847 in Koo, 2008). The handwashing behaviour has been shown to cut the number of child deaths from diarrhoea (the second leading cause of child deaths) by almost half and from pneumonia (the leading cause of child deaths) by one-quarter (WHO, 2008).

The strong causal relationship between hand hygiene and gastro-intestinal disease risk has also been demonstrated by meta-analysis of community based interventions. Curtis and Cairncross (2003) estimated a reduction of 42 – 47% in diarrhoeal diseases associated with handwashing. Fewtrell et al (2005) showed a 44% reduction in diarrhoeal illness associated with handwashing. In a study, Aiello et al (2008) estimated that handwashing with soap combined with education could produce a 39% reduction in gastrointestinal illness. All the three meta-analyses were carried out using data from studies conducted in both developed and developing countries.

In a review of hand hygiene studies involving respiratory tract infections, Rabie and Curtis (2006) reported that hand hygiene (handwashing, education and waterless hand sanitizers) can reduce the risk of respiratory infections by 16%. Aiello et al. (2008) also estimated that the reduction in respiratory illness associated with the pooled effects of hand hygiene (handwashing with soap, use of alcohol handrubs) was 21%.

A study conducted by Luby et al (2005) reported the impact of handwashing with soap on pneumonia in children under five, in squatter settlements in Karachi, Pakistan. The results indicated a 50% reduction in pneumonia in the intervention compared with the control group. Luby et al noted that a link between handwashing and the prevention of pneumonia in developing countries is plausible on the basis that, in developing countries it is known that viruses cause pneumonia.

Another study found that children under 15 years living in households that received handwashing promotion and soap had half the diarrhoeal rates of children living in control neighbourhoods (Luby et al, 2004). Because handwashing can prevent the transmission of a variety of pathogens, it may be more effective than any single vaccine.

Handwashing can also prevent skin infections (eg. impetigo), eye infections (eg. conjunctivitis), intestinal worms, Severe Acute Respiratory Syndrome (SARS), and Avian Flu. It benefits the health of people living with HIV/AIDS. Handwashing is effective in preventing the spread of disease even in overcrowded, highly contaminated slum environments (PPPHW, 2008).

CHAPTER THREE

MATERIALS AND METHODS

3.1 Study area

3.1.1 Ashanti Region

The Ashanti Region is centrally located in the middle belt of Ghana. It lies between longitude 0.15 degrees west and 2.25 degrees west, and latitudes 5.50 degrees North and 7.46 degrees north. The Region shares boundaries with four of the ten political regions, namely BrongAhafo Region in the north, Eastern Region in the east, Central Region in the south and Western Region in the south west.

The Region occupies a total land area of 24,389 square kilometres representing 10.2% of the total land of Ghana. It is the third largest region after Northern (70,384 sq. km.) and Brong Ahafo (39,557 sq. km.) regions.

Ashanti Region has a population density of 148.1 persons per square kilometer, the third after Greater Accra and Central regions. More than half of the Ashanti Region lies within the wet semi-equatorial forest zone. Due to human activities and bushfires, the forest vegetation of parts of the region, particularly the north-eastern part, has been reduced to savanna.

Ashanti Region has an average annual rainfall of 1270mm and 2 rainy seasons. The major rainy season starts in March, with a major peak in May. There is a slight dip in July and a peak in August, tapering off in November. December to February is dry, with alternating spells of heat and cold, and dusty.

The average daily temperature is about 27 degrees Celsius. Much of the Region is situated between 150 and 300 metres above sea level. Ashanti Region is endowed with lakes, scarps, forest reserves, waterfalls, national parks, birds and wildlife sanctuaries. Notable among them are the Owabi Arboretum and Bongobiri wildlife sanctuaries.

The Region is drained by Lake Bosomtwi, the largest natural lake in the country, and Rivers Offin, Prah, Afram and Owabi. There are other smaller rivers and streams which serve as sources of drinking water for residents of some localities in the Region (ghanadistricts.com, 2006).

3.1.2 Kumasi Metropolitan Area

Kumasi has grown in a concentric form to cover an area of approximately ten (10) kilometres in radius. The Metropolitan Area shares boundaries with Kwabre East District to the north, Atwima District to the west, Ejisu-Juaben Municipality to the east and Bosomtwe District to the south. The city is rapidly growing with an annual growth rate of 5.4% (Regional Statistics Office, Kumasi (2006)). It encompasses about 90 suburbs, many of which were absorbed into the metropolis as a result of the process of growth and physical expansion. The 2000 population census kept the population at 1,170,270. It was however projected to 1,610,867 in 2006, and was further projected to be 1,889,934 in 2009.

Kumasi is located in the transitional forest zone and is about 270 kilometres north of the national capital, Accra. It is between latitudes 6.35 degrees to 6.40 degrees north and longitudes 1.30 degrees to 1.35 degrees west, with an area of about 254 square kilometres.

The metropolis falls within the wet sub-equatorial climate type. The average minimum and maximum temperatures are about 21.5 degrees Celsius and 30.7 degrees Celsius respectively. The average humidity is about 84.16% at 0900 GMT and 60% at 1500 GMT. Kumasi has a double maxima rainfall regime of approximately 214.3mm in June and 165.2mm in September.

Kumasi is privileged to be centrally placed, with major arterial roads linking it to other parts of the country. It also boasts of two State Universities, a Private University, two Health Training Institutions, a Teaching Hospital, two Teacher Training Colleges, both public and private secondary and basic schools as well as a host of public and private healthcare delivery institutions (ghanadistricts.com, 2006).

3.1.3 Oforikrom Sub-Metropolis

The Oforikrom Sub-metropolitan area is one of the 10 sub-metropolises in the Kumasi Metropolis. It is located in the southern part of Kumasi. It is one of the newly created sub-metros carved out of the Asokwa Sub-metro. It is bounded on the north by Ejisu-Juaben District, on the east by Asawasi Sub-metro, on the west by Asokwa Sub-metro and on the south by Subin Sub-metro (see Appendix D). The Sub-metropolis has a population of 210,610 with a growth rate of 5.2% (Source: 2008/2009 Survey by EHSD).The Oforikrom Sub-metro is made up of 24 towns.

Ayeduase is one of the towns located in the Oforikrom Sub-metro and adjacent to KNUST. It is bounded on the south by KNUST, on the north by Kotei, on the west by Boadi and on the east by Anwomaso (see Appendix D). It has a population of 12,574 with a growth rate of 5.2%. It has a lot of hostels and it is more like a college town.

3.1.4 Ayeduase Roman Catholic Junior High School

The school was established in 1951 as a middle school. Although it was established as a mission school, the Ayeduase Roman Catholic Junior High School (JHS) is currently a government assisted school and is therefore not fee paying. The school has a population of 170 students, 14 teachers and 1 headmaster. The students are in three classes as follows: JHS 1 – 49 students; JHS 2 – 58 students; JHS 3 – 63 students.

Ayeduase R. C. JHS has inadequate sanitary facilities – a urinal sub-divided for teachers, male and female students; KVIP toilet for teachers and a pit latrine for students. There is no water supply in the premises. The school has to buy water on a daily basis from water vendors around. However, the school has electricity, and a computer laboratory with 10 lap tops and 1 personal computer, which are used for studies.

Some challenges included inadequate teaching and learning equipment, inadequate furniture for students. Also of great importance is unavailability of staff common room and inadequate furniture for the teaching staff.

3.2 Sampling and Data collection

3.2.1 Sampling

For the questionnaire survey, one hundred (100) students, who were approximately 59% of the student population, were randomly sampled from the three (3) classes, that is, 40 from JHS 3, and 30 each from JHS 1 and 2. In each class, students were made to pick one piece of folded paper each. Anyone who picked a numbered paper was given a questionnaire to fill out.

For the hand sampling, which was carried out 9 days after the questionnaire survey, 80 (47%) students were randomly sampled, that is, 30 from JHS 1 and 25 each from JHS 2 and 3. Pieces of cards were lettered and numbered 1 to 20 according to the cleansing agent to be used. Students who picked lettered and numbered cards were given office pins to pin them on their uniforms for easy identification during the handwashing and sampling process.

3.2.2 Questionnaire survey

The questionnaire was designed to solicit information on the practice of handwashing and cleansing agents used by respondents. It had nine (9) questions, seven (7) being close ended and the others open ended. Information gathered using the questionnaire included demographic, practice of handwashing and critical times hands are washed, reason for washing hands, diseases acquired from unwashed hands, agents used during handwashing and any stomach problems suffered (see Appendix A). The 100 questionnaires were administered and all retrieved on the same day.

3.2.3 Hand sampling for laboratory analyses

3.2.3.1 Microbial Load on Unwashed Hands

The right hands of 80 students were sampled for laboratory analyses to determine microbial load on the thumb, index finger and middle finger. Samples of the three fingers were taken when hands were unwashed.

3.2.3.2 Microbial Load Reduction on Washed Hands

Participants washed their hands with Key bar soap, rubbing them together for 20 seconds, and then rinsed the hands with 0.75 litre of water. Participants waved their hands to shake water off them. Each participant followed up with dipping the right hand into seeded water. The seeded water, a suspension of microbes, was created by rinsing 100 notes of the one Ghana Cedi denomination in 1.5 litres of the water that was to be used for rinsing hands. Participants shook excess seeded water off the right hand before sampling of the three fingers – thumb, index, middle – was done. Next, students had to wash their hands with the various cleansing agents provided as follows:

- 20 participants used water only;
- 20 participants used citrus lime;
- 20 participants used ash;
- 20 participants used bar soap (ie. Key soap).

Students rubbed their hands together for 20 seconds before rinsing them with 0.75 litre of water. They waved their hands to shake off excess water. Samples of the three fingers on the right hands were then taken again to determine the reduction of microbes after the use of the various cleansing agents. The samples of the three fingers were taken directly on the medium.

A total of 240 samples were taken. The medium used was Chromocult agar for simultaneous detection of *Escherichia coli*, *Salmonella typhi*, other Coliforms and *Enterobacteriaceae*. Samples were incubated for 24 hours at 37 degrees Celsius (Byamukama et al, 2000 in Awuah, 2006).

3.3 Data Analyses

Data were analysed using the Statistical Package for Social Scientists (SPSS) 16 for Windows, Microsoft Office Excel 2010 and GraphPad Prism 5 (for ANOVA). The Confidence Interval (CI) used was 95% whilst a $P \leq 0.05$ was considered statistically significant.

CHAPTER FOUR

RESULTS AND DISCUSSIONS

4.1 The practice of handwashing and cleansing agents used

4.1.1 Demographic

Respondents were required to indicate their sex. Table 4.1 shows the sex distribution of respondents.

Table 4.1: Sex of respondents

	NO. OF PEOPLE	PERCENTAGE
Male	51	51.0
Female	47	47.0
Not indicated	2	2.0
Total	100	100.0

Data indicate that 51 respondents, representing 51.0%, were males, 47 (47.0%) were females while 2 (2.0%) did not indicate their sex. The males were therefore the majority.

4.1.2 Age distribution

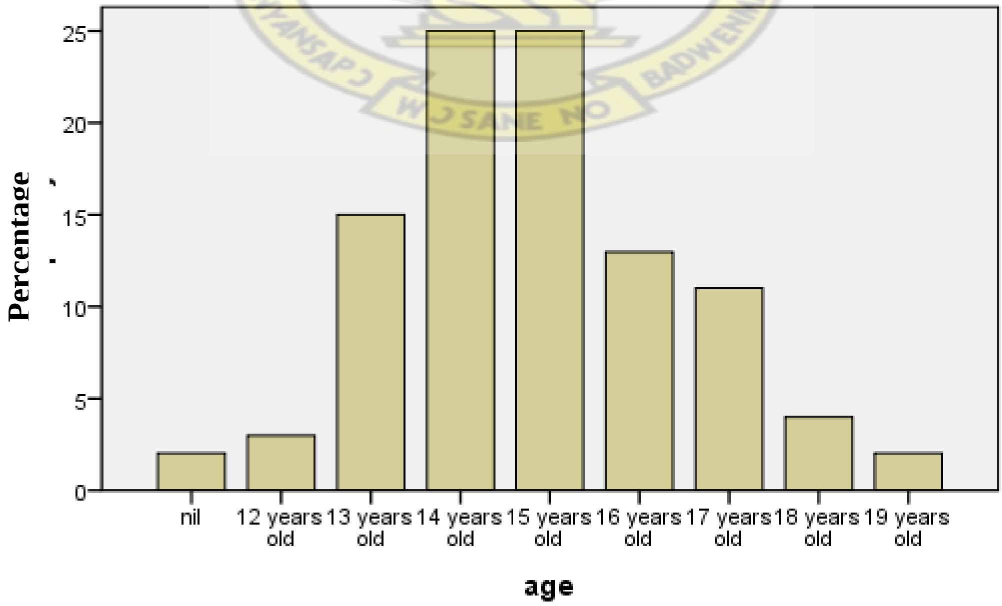


Figure 4.1: Age distribution of respondents

As depicted in Figure 4.1 the highest number of respondents was 14 and 15 years of age, with 25.0% each. They were followed by 13 years with 15 respondents which was 15.0% and 16 years with 13 respondents and 13.0%. Seventeen years were next with 11 respondents (11.0%), 18 years with 4 respondents (4.0%), 12 years with 3 respondents (3.0%) and 19 years with 2 respondents (2.0%). Two respondents (2.0%) did not provide information on their age. The respondents were matured enough to understand the questions they answered and therefore this made the data from the questionnaires credible.

4.1.3 How often hands are washed

The frequency with which hands are washed during the day, and in whatever setting, would go a long way to protect a person from ill-health. Good health has been associated with the practice of hand hygiene. Respondents were asked to indicate how often they washed their hands during the day. Responses are represented in Figure 4.2.

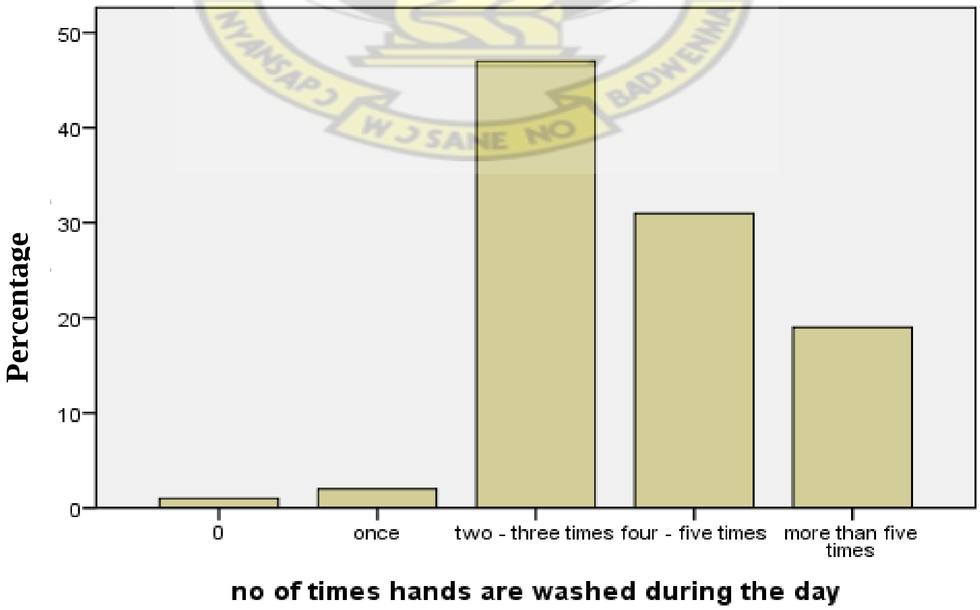


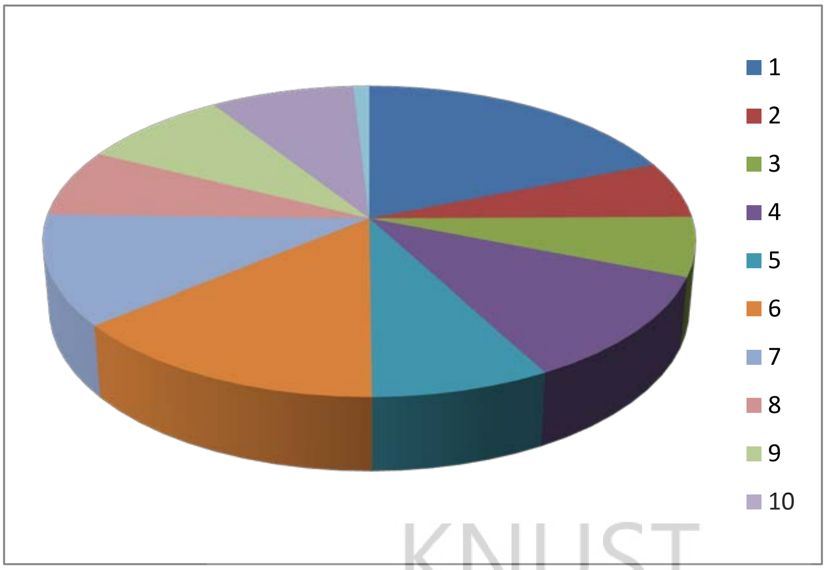
Figure 4.2: Number of times respondents washed hands during the day

From the bar chart it can be seen that the majority of 47 respondents representing 47.0% washed their hands two-three times in a day. Thirty-one respondents (31.0%) washed their hands four-five times a day, while 19 (19.0%) washed more than five times a day. The minority, 2 (2.0%) washed hands only once in a day. Respondents who indicated more than five times were asked to specify the number of times they washed hands. Thirteen respondents out of the 19 could not indicate the number of times, others 11, 10, 8 and 6 times each, one said after using hands. Mayo Clinic (2009) asserted that although it is impossible to keep hands germ-free, washing hands frequently can help limit the transfer of bacteria, viruses and other microbes. Therefore, washing hands once a day would be inadequate for protection. It must be done countless number of times during the day. Kartha (2001) affirmed that regular handwashing is the most essential factor for maintaining good health.

4.1.4 Times hands are washed

The times when hands are washed are important to the reduction of pathogen ingestion and therefore to the reduction of disease. CDC (2010), for example, called them the critical times for handwashing.

Figure 4.3: Times when respondents washed their hands



LEGEND

	TIMES	PERCENTAGE
1	after using toilet	83
2	after touching the eye	26
3	after handling uncooked food	27
4	after sneezing/coughing into hands	49
5	after changing soiled child	34
6	after eating	62
7	before cooking	50
8	after returning home from town	31
9	after counting money	37
10	after a hand shake	36
11	other	4

A high percentage of the 100 respondents (83%) indicated that they washed their hands after using the toilet. Again, 62% said they washed their hands after eating, while 50% washed before cooking. Forty-nine percent washed hands after sneezing or coughing into their hands, 37% and 36% were respondents who washed after a hand shake and after counting money respectively. Also, 31%, 27% and 26% washed hands after returning home from town, after touching uncooked food and after touching their eyes. Out of 4 respondents who indicated others, 3 specified that they washed hands before eating. These critical times, when consciously adhered to, handwashing done at such times have the potential to act as a barrier to germs transmission and disease spread.

4.1.5 Reasons for washing hands

People have various reasons why they wash their hands. Indeed such reasons may include their belief, culture, moral or health. Table 4.2 highlights the reasons given by the respondents.

Table 4.2: Why respondents washed hands

REASON	NO. OF PEOPLE	PERCENTAGE
To prevent disease / illness / sickness	45	45.0
To prevent germs / bacteria	28	28.0
After toilet	8	8.0
To remove dirt	7	7.0
For neat hands	1	1.0
For neat / healthy hands	1	1.0
For clean hands	2	2.0
After playing	1	1.0
Good for hands	1	1.0
No response	6	6.0
TOTAL	100	100.0

According to data, the majority, 45 respondents out of 100, gave reasons for washing hands as for preventing disease/illness/sickness while 28 respondents indicated to prevent germs/bacteria. This corroborates Kartha (2001), who noted that the most important advantage of handwashing is that people prevent themselves from getting infected by a number of dangerous ailments.

Furthermore, Mayo Clinic (2009) indicated that handwashing is one of the best ways to avoid getting sick and spreading illness. Handwashing interrupts the transmission of disease agents and so can significantly reduce diarrhoea and respiratory infections, as well as skin infections and trachoma.

4.1.6 Diseases from unwashed hands

Soliciting information on the diseases that can occur when respondents did not wash their hands was necessary to find out the level of their understanding on the problems that inadequate hygiene could cause. Respondents were allowed to name 2 diseases each.

Respondents were knowledgeable about diseases judging by the variety of diseases they cited. Diarrhoea was listed by 66 respondents, followed by cholera (57 respondents). This was important considering that both diseases are transmissible by the faecal-oral route, thus involving the hands (Nester et al, 2001). Other diseases mentioned included Stomach problems, Typhoid, Worms, Skin disease, Tuberculosis, Malaria/Fever, HIV, Beriberi, Headache as well as death.

4.1.7 Cleansing agents used

Agents used in handwashing are important to the reduction in pathogens that cause ill-health. Respondents were therefore requested to indicate the agents they used while they washed their hands. Table 4.3 highlights this information.

Table 4.3: Cleansing agents used in handwashing

AGENT	NO. OF PEOPLE	PERCENTAGE
Water only	28	28.0
Ash	2	2.0
Citrus Lime	10	10.0
Soap	77	77.0
Disinfectant	15	15.0
Other	3	3.0

The high percentage (77%) of respondents who washed their hands using soap was commendable. This trend could be attributable to ongoing education about the importance of handwashing to health and also the School Health Education Programme as part of the curriculum. Again, the annual Global Handwashing Day celebrated on 15th October may have made a great impact.

WASH United (2010) reiterated that, since clean hands save lives, handwashing with soap is the most effective and inexpensive way to prevent diarrhoea and acute respiratory infections, which take the lives of millions of children in developing countries every year.

While 28% of the students used water only, users of lime were 10% and ash2% Disinfectant use by 15 respondents was quite high. Disinfectants are antimicrobial and care must be taken in their use because of their ability to cause resistant pathogens when used frequently just as in the case of antimicrobial soaps (Mayo Clinic (2009).

4.1.8 Stomach problems suffered

Information was requested on whether respondents had ever suffered from any stomach problem. Results indicated that as high as 80% of respondents had suffered stomach problems.

4.1.9 Type of stomach problem suffered

The 80 respondents who had suffered stomach problems were required to indicate what they had suffered. Figure 4.4 shows the data.

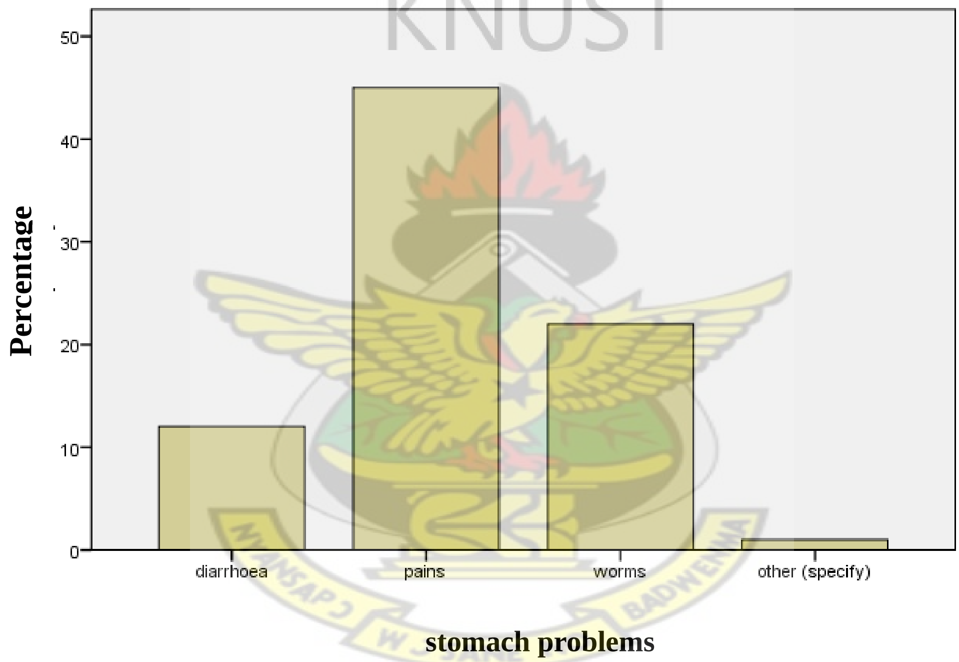


Figure 4.4: Stomach problems suffered by respondents

Majority of the respondents, 45, had suffered stomach pains, followed by 22 respondents who had been infested with worms. Also, 12 respondents had suffered from diarrhoea. One person who ticked other indicated suffering from fever. The number of respondents who had been infested with worms was significant. PPPHW (2009) asserted that indications from researches were that handwashing with soap reduces the incidence of intestinal worms, especially ascariasis and trichuriasis. Handwashing is also known to reduce diarrhoeal disease cases and mortality.

4.1.10 Deworming pills taken

Out of 100 respondents, 71 had taken deworming pills. The 71 who responded affirmatively were then asked to indicate how long ago they had taken the pills. Results are depicted in Figure 4.5.

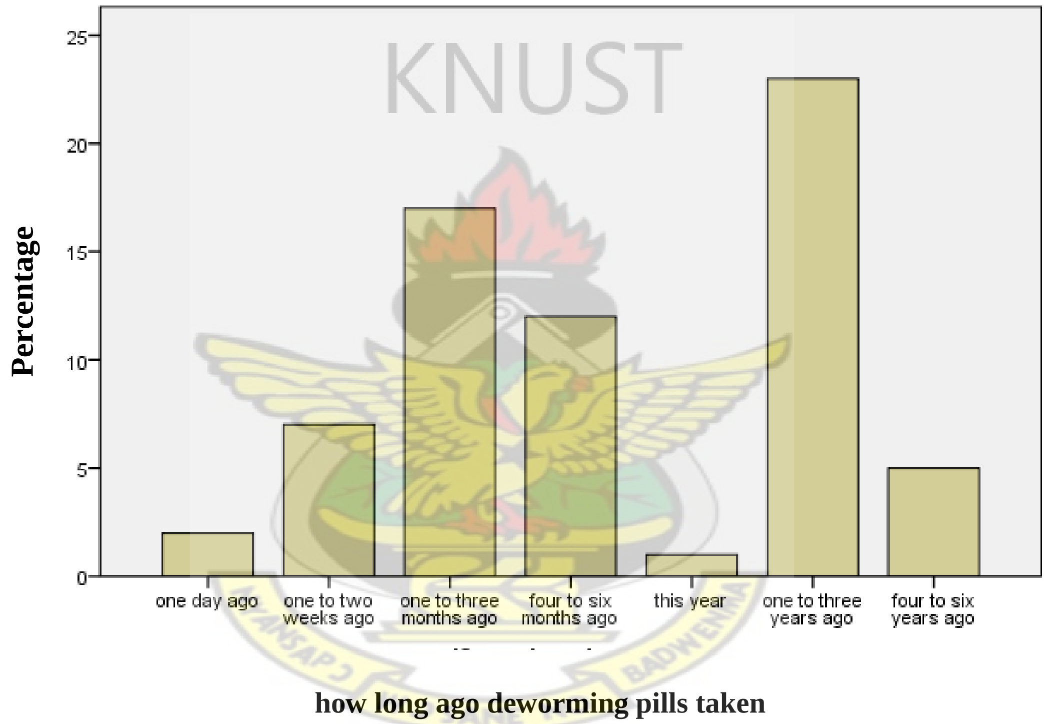


Figure 4.5: Frequency of deworming by respondents

Twenty-three respondents, being the majority had taken deworming pills 1 to 3 years ago, while 5 took pills 4 to 6 years and 1 respondent one year ago. Again, 17 respondents had taken deworming pills between 1 to three months before the survey and 12 had taken the pills 4 to 6 months earlier. One to two weeks earlier, 7 respondents swallowed deworming pills and 2 also one day before the survey. Mihrshahi et al (2009) in a study recorded the high cure rates for 3 species of soil –

transmitted helminthes with 4 monthly albendazole treatment. Deworming pills are supposed to be taken between 3 months to 4 months intervals as a precaution against worm infestation.

4.2 Microbial load on unwashed hands

It is a fact that hands are vectors in the transmission of many diseases. In the case of enteric diseases such as diarrhoea, for example, the hands are a vital link in the faecal-oral transmission process. It was thus important to assess the microbial load on hands, specifically on fingers. Samples were therefore taken from the thumb, index and middle fingers of the right hand of each participant. Pathogens of interest were *Escherichia coli*, *Salmonella typhi*, other Coliforms and other *Enterobacteriaceae*.

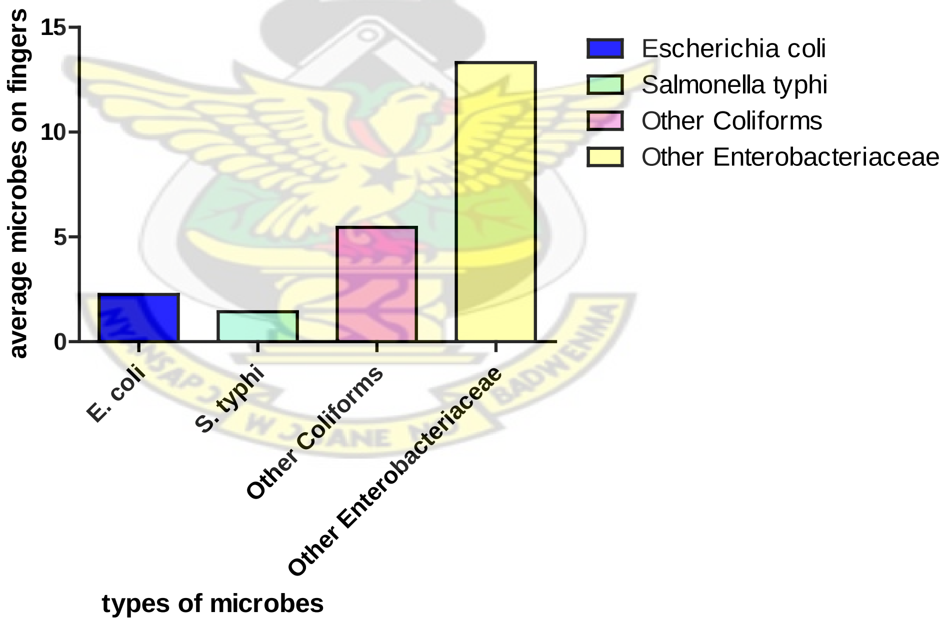


Figure 4.6: Microbial load on fingers of unwashed hands

After laboratory analysis, data in figure 4.6 indicate that counts for other *Enterobacteriaceae* which were the highest averaged 13. Other Coliforms counts were 5, *Escherichia coli* (*E. col*i) were 2 and the least, *Salmonella typhi* (*S. typhi*), 1 count. Samples from individuals showed that some fingers were very dirty. Without adequate handwashing, such people could become infected with disease. It would however also depend on the pathogen load needed to cause a particular disease.

4.3 Microbial reduction by cleansing agents

The efficacy of a cleansing agent in the reduction of microbes on hands (fingers) is important in the prevention of diseases, since that is the aim of handwashing. Many cleansing agents have been proposed, but for the purposes of this study, four agents locally available were selected – water only, ash, citrus lime and soap. After respondents had washed hands with the various agents, their thumbs, index and middle fingers of the right hand were sampled using Chromocult agar. The pathogens of interest again, were *Escherichia coli*, *Salmonella typhi*, other Coliforms and other *Enterobacteriaceae*. The results were analysed according to agents used.

4.3.1 Water only

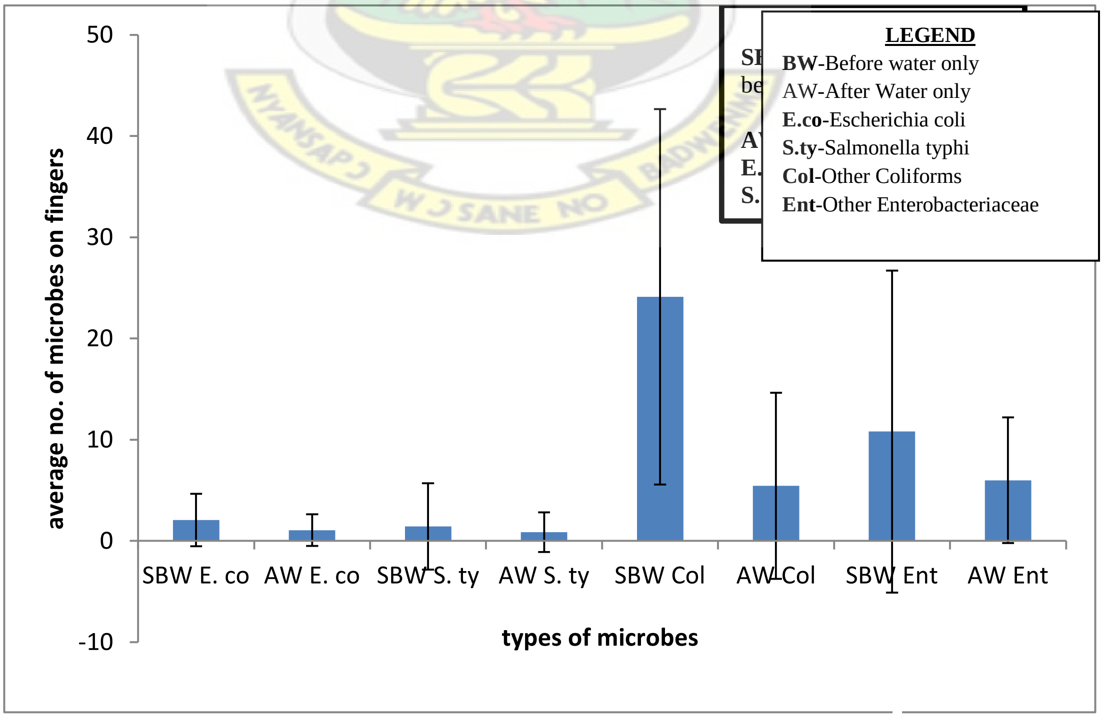


Figure 4.7: Effect of handwashing with water only on microbes

Data from laboratory analysis as depicted in figure 4.7 showed that other Coliforms counts for before water only (BW Coliforms) were 24 and were reduced to 5 counts after washing hands with water only (AW Coliforms) which was significant (P≤0.05) (as per ANOVA). The percentage removal of other Coliforms was 77.46%. Again, BW *Enterobacteriaceae* (11) was reduced to 5 (AW *Enterobacteriaceae*) and percentage removal was 44.51%. For *Escherichia coli* and *Salmonella typhi* percentage removal were 48.48% and 39.14% respectively. There was substantial removal of microbes after washing with water only, at least more than half. Hoque and Briend (1991) showed that whilst less effective than when using a rubbing agent such as soap or ash, some reductions in contamination were found when washing with water alone.

4.3.2. Ash.

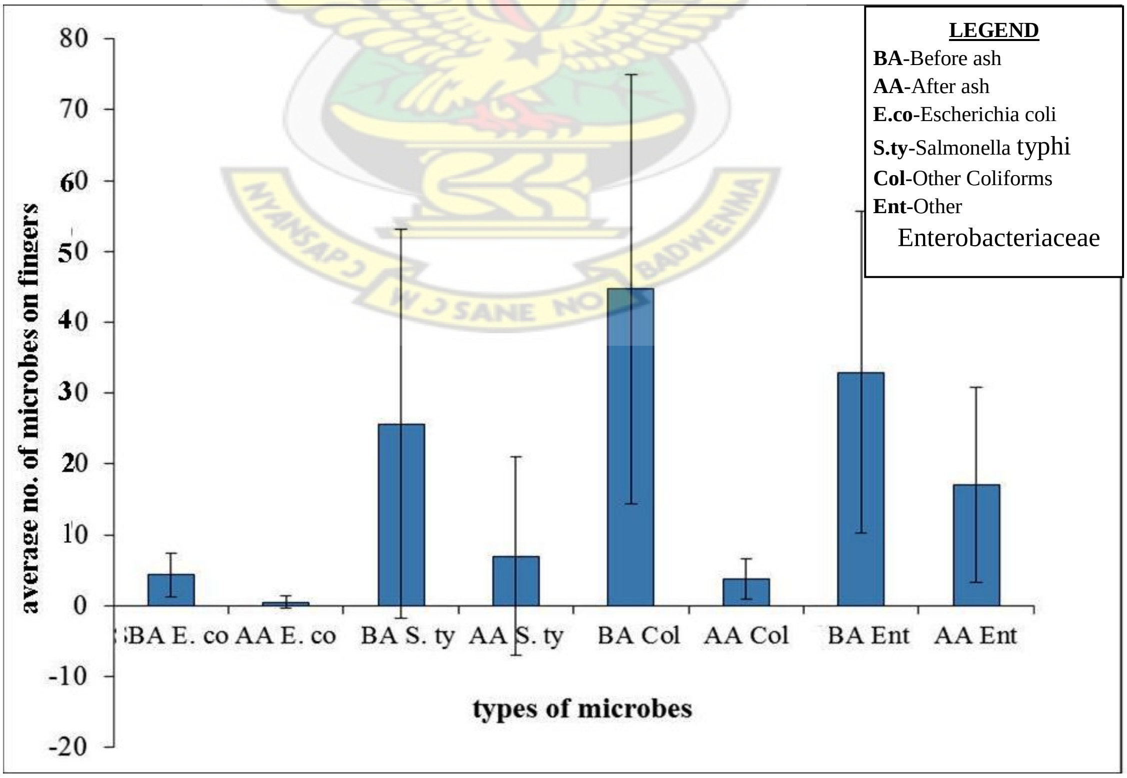


Figure 4.8: Effect of handwashing with ash on microbes

According to data in figure 4.7 other Coliforms in before ash (BA Coliforms) was 45 and reduced to 3 (AA Coliforms), and was significant (P≤0.05) with 91.64% removal after handwashing with ash. Other *Enterobacteriaceae* (BA) had counts of 33 and was reduced to 17 (AA *Enterobacteriaceae*) with 91.64% removal and this was significant (P≤0.05), and removal was 31.15%. *Salmonella typhi* (BA *S. typhi*) was 26, reduced to 7 (72.73% removal) and was significant (P≤0.05). Although *E. coli* removal was 87.69%, this was not significant (P>0.05). Removal of microbes with the use of ash was high. Since ash is not smooth it has the added property of acting as a scouring agent to dislodge microbes that would be clinging to the hands. Also ash raises the pH of water and this kills bacteria (Awuah, 2006). Hoque and Briend (1991) noted that the use of alternative rubbing agents such as ash provided the same benefits as soap.

4.3.3 Citrus lime

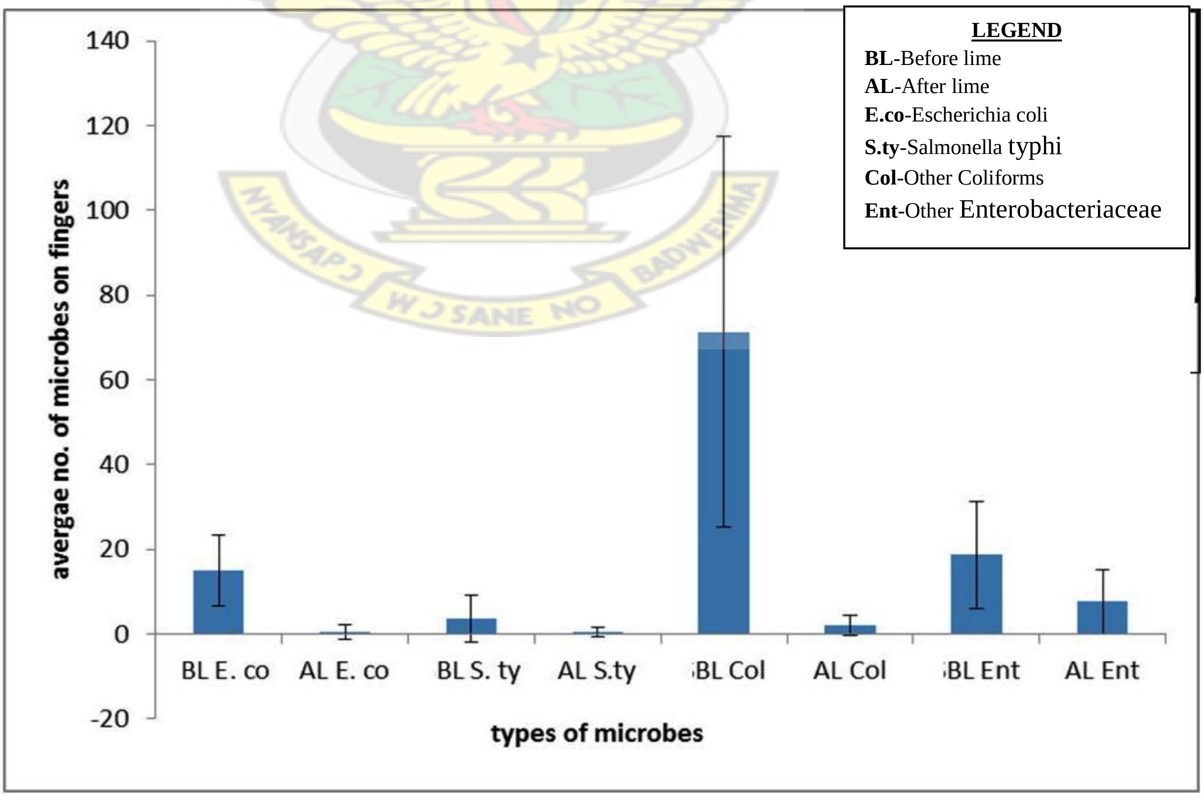


Figure 4.9: Effect of handwashing with citrus lime on microbes

From figure 4.9 the highest counts recorded were other Coliforms (BL Coliforms – 71) and reduced to 2 (AL Coliform) after handwashing with citrus lime and 97.03% removal and was significant (P≤0.05). Even though all the other types of microbes had reductions they were not significant. Removal percentage for other *Enterobacteriaceae* was 58.99%, for *E. coli*, 96.86% and for *S. typhi*, 87.10%. It is a fact that citrus lime contains citric acid which has a low pH of 3.5 – 3.6 and according to Brock (1986) generally, sterilization is more rapid at low pH because most microorganisms are sensitive to low pH. This could account for the high percentage removal of microbes on the fingers.

4.3.4 Soap

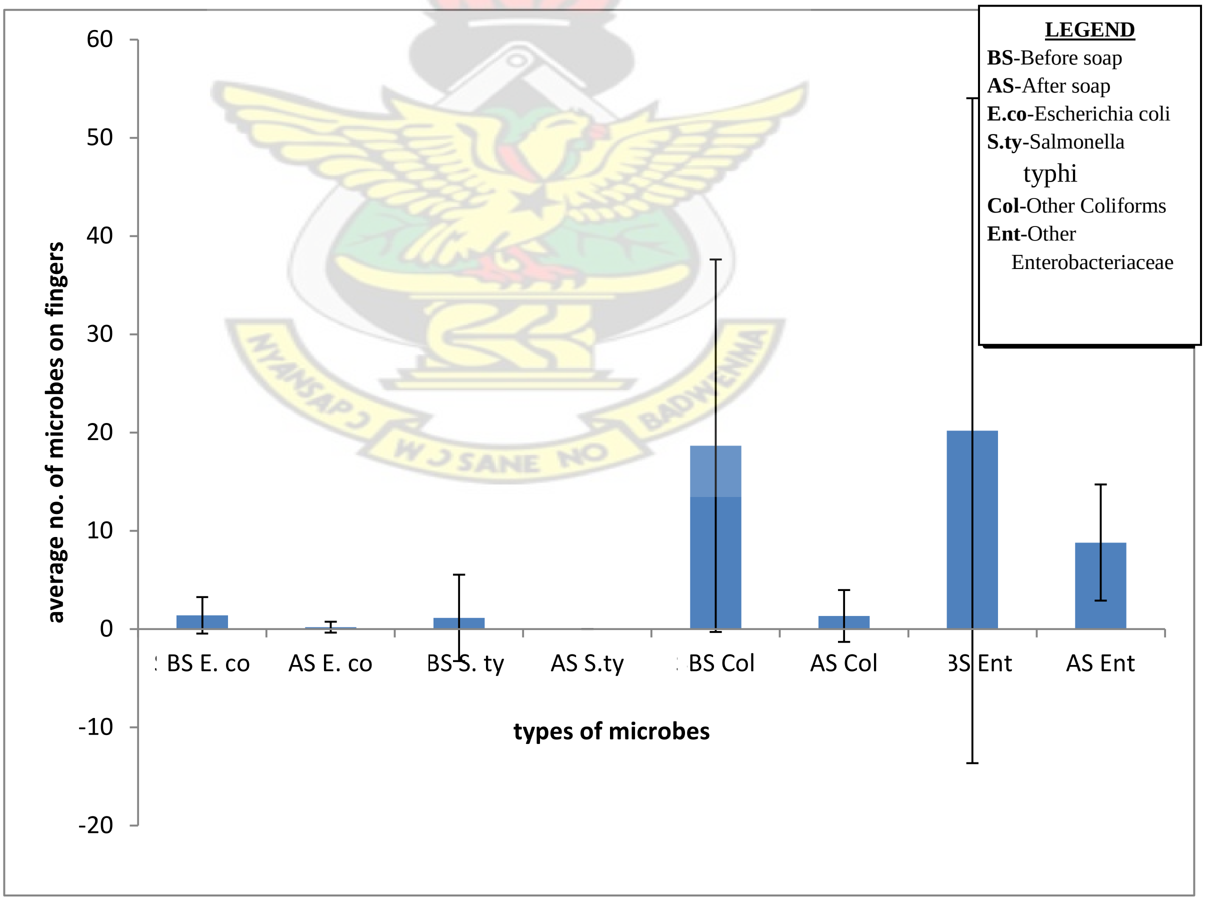


Figure 4.10: Effect of handwashing with soap on microbes

Data depicted in figure 4.10 shows that other *Enterobacteriaceae* (BS) counts were 20 and reduced to 8 (AS *Enterobacteriaceae*) after washing hands with soap, with removal of 56.44%, however this was not significant ($P>0.05$). Other Coliforms (BS Coliforms) which were 19 reduced to 1 (AS Coliforms) that is 92.86% which was significant ($P\leq0.05$). *E. coli* and *S. typhi* also recorded 85.71% and 100% removal respectively, albeit not significant. Hands washed with soap recorded a high percentage removal of pathogens from the fingers. The 100% removal of *S. typhi* from hands by soap corroborates results from a study by Tambekar and Shirsat (2009) which also recorded a 100% removal of *S. typhi* after handwashing with soap.

4.4 Comparing the efficacy of cleansing agents

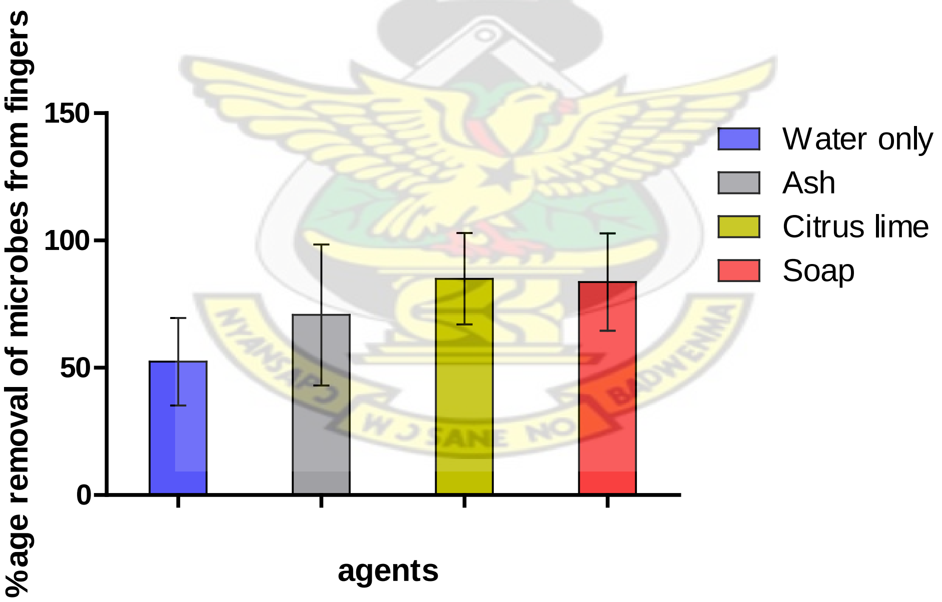


Figure 4.11: Comparison of the efficacy of hand cleansing agents

Comparing the efficacy of the cleansing agents, the graph in figure 4.11 indicates that there were reductions in microbial load after washing hands with the various cleansing agents, which were water only, ash, citrus lime and soap. Water only recorded microbial removal of 52.40%, ash recorded 70.75%, citrus lime recorded 85% removal and soap 83.75% removal. ANOVA analysis however indicated that the differences were not statistically significant ($P > 0.05$). Results from similar studies suggested that ash and soap were more or less equally effective in reducing faecal coliform contaminants on hands. Although soap appeared effective, the difference was not significant. The researchers, Hoque et al (1995) and Anuradha et al (1999) also noted that washing hands with plain water reduced contamination on the hands but was less effective than washing with agents, but again the result was not significant. The findings thus affirm the results of this study.

CHAPTER FIVE

C0NCLUSION AND RECOMMENDATION

5.1 Conclusion

Results of the questionnaire survey on the practice of handwashing and cleansing agents used showed that a high number of the students washed their hands after using the toilet. Students were knowledgeable in the fact that when they washed hands they could prevent diseases and germs from getting to them. Diarrhoea and cholera were the most prominent diseases noted by the students as could be acquired from not washing hands. The cleansing agent most used was soap. This may be the results of efforts being made to educate school children to wash their hands for good health and as agents of change, to affect their community positively. Also the annual Global Handwashing Day celebration may have contributed immensely to the current trend.

Laboratory analysis of samples on unwashed hands indicated that a number of the individual samples had much growth which was indicative of how dirty the hands were. It was probably because participants had been cleaning their compound and may not have washed their hands. Also the school did not have water supply. Water was purchased from water vendors around the school for use during the day. The water is stored in containers standing around the urinals and toilets. If those places are not kept clean students are not likely to go there to wash their hands. This therefore is a matter of concern in the pursuit of hand hygiene practices.

Microbial reduction on fingers after participants washed hands with various cleansing agents was substantial as data showed after analysis. The agents used were water only, ash, citrus lime and soap. All these agents are available locally. Although some of the reductions were not statistically significant, it is important to note that they reduced microbial load on the fingers of participants. This shows that the agents have the capacity to reduce microbes, and thus can prevent infection, which is the aim of handwashing. The lower the microbial load on hands the less likely people will become infected. Also reduction in pathogen load would reduce the severity of a disease and stall its ability to spread easily. Any of the agents can therefore be used in handwashing since they all have some effect on the reduction of microbes. It is therefore desirable to wash hands with any of the agents available than not to wash hands at all.

5.2 Recommendations

It is therefore recommended that;

1. education must be carried out to promote the use of locally available cleansing agents in handwashing, to motivate people to wash their hands by all means especially in the rural poor communities;
2. hygiene education must be intensified on information on how disease is spread and how disease can be prevented by the simple act of handwashing;
3. future studies be carried out to determine the efficacy of other hand cleansing agents on the market;
4. authorities must make efforts to improve on water supply to enhance personal hygiene practices which include handwashing.

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APPENDICES

Appendix A: QUESTIONNAIRE

QUESTIONNAIRE

THE EFFICACY OF CLEANSING AGENTS USED IN HANDWASHING

The study is on “The practice of handwashing and cleansing agents used”. You are hereby assured that all information supplied are strictly confidential.

Date: ……………………………….

PART A: BACKGROUND INFORMATION

(Tick or dill in as appropriate)

1. Sex
   a. Male [ ]
   b. Female [ ]
2. Age ………………………………………….

PART B: PRACTICE OF HANDWASHING AND CLEANSING AGENTS USED

3. How often do you wash your hands during the day?
   a. Once [ ]
   b. Two – three times [ ]
   c. Four – five times [ ]
   d. More than five times (specify) ………………………………. [ ]
4. At what times do you wash your hands?
   a. After using the toilet [ ]

b. After touching the eyes [ ]

c. After handling uncooked food [ ]

d. After sneezing, coughing [ ]

e. After changing a soiled child [ ]

f. After eating [ ]

g. Before cooking [ ]

h. After returning home from town [ ]

i. After counting money [ ]

j. After a hand shake [ ]

k. All of the above [ ]

l. Other (specify) ……………………………………………… [ ]

5. Why do you wash your hands? ……………………………………………..

……………………………………………………………………………………..

6. Name 2 diseases that you can get when you do not wash your hands?

a. ……………………………………………………………………………

b. ……………………………………………………………………………

7. What cleansing agents do you use to wash your hands?

a. Water only [ ]

b. Ash [ ]

c. Citrus lime [ ]

d. Disinfectants [ ]

e. Other (specify) ………………………………………………… [ ]

8. i. Have you ever suffered from any stomach problems?

a. Yes [ ]

b. No [ ]

8. ii. If yes, what was it?

a. Diarrhoea [ ]

b. Pains [ ]

c. Worms [ ]

d. Other (specify) ……………………………………………… [ ]

9. i. Have you ever taken deworming pills?

a. Yes [ ]

b. No [ ]

9.ii.If yes, how long ago? …………………………………………………….

Appendix B: STATISTICAL DATA

MICROBIAL LOAD ON FINGERS OF UNWASHED HANDS

Number	*E. coli*	*S. typhi*	*Coliform*	*Enterobac*
1	0	12	25	31
2	10	0	12	45
3	0	0	0	7
4	1	0	1	10
5	1	2	1	14
6	7	3	4	17
7	0	4	0	9
8	0	2	5	17
9	10	0	25	22
10	0	0	0	11
11	9	1	35	17
12	2	3	3	0
13	0	0	1	0
14	2	0	4	69
15	0	0	1	6
16	0	0	1	1
17	0	0	0	12
18	0	0	0	1
19	0	0	11	8
20	6	8	7	14
21	0	0	3	5
22	2	2	10	10
23	0	1	5	7
24	6	7	15	61
25	0	35	12	26
26	1	0	6	3
27	1	0	3	3
28	0	0	2	5
29	7	5	10	11
30	0	5	26	25
31	1	1	6	7
32	7	1	12	26
33	2	0	11	11
34	2	0	0	3
35	0	0	3	4
36	2	5	9	34
37	22	0	5	22
38	1	1	12	40
39	3	2	5	9
40	2	0	2	25

41	0	0	0	3
42	1	0	2	13
43	0	0	0	10
44	12	0	13	11
45	0	1	1	2
46	0	0	2	11
47	0	0	11	9
48	0	0	0	2
49	5	0	2	13
50	0	1	2	17
51	0	0	2	8
52	1	0	2	5
53	0	0	3	18
54	0	0	0	3
55	0	0	2	4
56	7	0	50	10
57	0	0	1	10
58	0	0	0	5
59	1	0	0	10
60	1	0	2	7
61	0	0	0	3
62	0	0	2	19
63	2	0	1	0
64	0	0	7	3
65	17	3	1	8
66	0	0	1	24
67	6	0	3	7
68	0	0	0	1
69	0	0	0	12
70	1	0	0	30
71	0	0	1	11
72	2	0	2	4
73	8	0	9	55
74	0	0	0	4
75	0	3	0	6
76	0	1	0	5
TOTAL	**171**	**109**	**415**	**1011**
Average	2.25	1.434211	5.460526	13.30263
St Dev	4.102438	4.437223	8.559503	13.68505

MICROBIAL REDUCTION ON HANDS BY CLEANSING AGENTS

WATER ONLY

Number	SBW E. co	AW E. co	SBW S. ty	AW S. ty	SBW Col	AW Col	SBW Ent	AW Ent
1	1	0	4	6	10	2	8	10
2	0	2	0	0	26	1	0	7
3	0	0	0	0	17	1	4	2
4	0	2	0	0	50	0	9	15
5	0	0	0	0	20	1	0	0
6	5	0	0	0	21	1	11	4
7	2	0	0	0	20	2	0	0
8	0	1	0	0	36	4	5	6
9	7	2	1	5	53	36	7	0
10	0	1	0	0	8	4	0	0
11	8	0	1	0	58	11	0	0
12	2	0	0	3	5	7	33	10
13	2	6	0	0	5	15	1	9
14	4	2	17	0	1	0	51	0
15	1	0	0	0	44	0	4	17
16	1	1	0	0	12	2	40	16
Total	33	17	23	14	386	87	173	96
Average	2.0625	1.0625	1.4375	0.875	24.125	5.4375	10.8125	6
St Dev	2.594064	1.569235	4.273465	1.962142	18.54319	9.18672	15.9006	6.218253

ASH

Number	SBA E. co	AA E. co	SBA S. ty	AA S. ty	SBA Col	AA Col	SBA Ent	AA Ent
1	11	0	13	1	75	2	29	33
2	5	0	71	0	42	4	60	5
3	4	0	42	7	69	7	24	27
4	6	0	45	0	59	3	16	1
5	4	0	18	7	8	1	55	50
6	3	2	26	4	35	4	13	5
7	4	0	9	12	15	0	28	10
8	10	1	75	56	99	2	56	25
9	4	0	4	2	44	2	28	19
10	6	2	5	5	27	4	24	18
11	3	1	0	0	75	9	4	2
12	1	0	0	0	27	4	19	18
13	0	0	1	7	82	9	31	18
14	4	0	8	4	11	5	17	1
15	0	2	68	0	2	0	90	25
Total	65	8	385	105	670	56	494	257
Average	4.333333	0.533333	25.66667	7	44.66667	3.733333	32.93333	17.13333
St Dev	3.109126	0.833809	27.45559	14.02549	30.34014	2.840188	22.68564	13.7678

CITRUS LIME

Number	SBL E. co	AL E. co	SBL S. ty	AL S.ty	SBL Col	AL Col	SBL Ent	AL Ent
1	8	0	22	2	48	0	26	10
2	14	0	4	2	184	2	22	14
3	6	0	4	0	52	0	12	5
4	10	7	0	0	76	2	11	9
5	12	1	3	0	150	1	24	5
6	24	0	0	0	50	0	23	1
7	11	0	7	0	50	4	13	0
8	26	0	6	0	67	5	27	0
9	2	0	2	0	17	8	19	20
10	6	0	6	0	41	0	10	0
11	5	0	0	0	84	2	6	3
12	24	0	0	0	60	1	20	12
13	22	0	0	0	115	1	11	1
14	19	0	1	0	38	0	11	3
15	16	0	0	0	16	4	10	9
16	24	0	0	0	120	0	12	12
17	26	0	7	4	45	6	60	26
Total	255	8	62	8	1213	36	317	130
Average	15	0.470588	3.647059	0.470588	71.35294	2.117647	18.64706	7.647059
St Dev	8.223442	1.699913	5.44221	1.124591	46.13424	2.446486	12.49971	7.491171

SOAP

Number	SBS E. co	AS E. co	SBS S. ty	AS S.ty	SBS Col	AS Col	SBS Ent	AS Ent
1	4	0	0	0	11	1	6	19
2	0	0	0	0	8	0	11	11
3	0	0	17	0	0	0	130	7
4	1	2	0	0	15	2	18	12
5	0	0	0	0	24	1	5	18
6	0	0	0	0	12	4	7	6
7	0	0	0	0	9	0	30	3
8	4	0	0	0	20	0	10	18
9	0	0	0	0	13	0	0	0
10	1	0	0	0	65	0	4	4
11	0	1	0	0	2	10	59	10
12	3	0	0	0	7	1	12	4
13	0	0	0	0	14	1	3	5
14	3	0	0	0	20	0	2	10
15	5	0	0	0	60	0	6	5
Total	21	3	17	0	280	20	303	132
Average	1.4	0.2	1.133333	0	18.66667	1.333333	20.2	8.8
St Dev	1.843909	0.560612	4.389381	0	18.94981	2.636737	33.83194	5.906413

PERCENTAGE REMOVAL OF MICROBES (USING AVERAGES)

WATER ONLY

	E. coli	S. typhi	Coliform	Enterobac
SBW	2.0625	1.4375	24.125	10.8125
AW	1.0625	0.875	5.4375	6
Percentage removal	**48.48485**	**39.13043**	**77.46114**	**44.50867**

ASH

	E. coli	S. typhi	Coliform	Enterobac
SBA	4.333333	25.66667	44.66667	32.93333
AA	0.533333	7	3.733333	22.68564
Percentage removal	**87.69231**	**72.72728**	**91.64179**	**31.11647**

CITRUS LIME

	E. coli	S. typhi	Coliform	Enterobac
SBL	15	3.647059	71.35294	18.64706
AL	0.470588	0.470588	2.117647	7.647059
Percentage removal	**96.86275**	**87.09678**	**97.03215**	**58.99054**

SOAP

	E. coli	S. typhi	Coliform	Enterobac
SBS	1.4	1.133333	18.66667	20.2
AS	0.2	0	1.333333	8.8
Percentage removal	**85.71429**	**100**	**92.85715**	**56.43564**

Legend

E. coli – *Escherichia coli*

E. co – *Escherichia coli*

S. typhi – *Salmonella typhi*

S. ty – *Salmonella typhi*

Col – Coliform

Enterobac – *Enterobacteriaceae*

Ent – *Enterobacteriaceae*

SBW – Seeded water before water only

AW – After water only

SBA – Seeded water before ash

AA – After ash

SBL – Seeded water before lime

AL – After lime

SBS – Seeded water before soap

AS – After soap

SEEDED WATER

Sample no.	E. coli	S. typhi	Coliform	Enterobac
SW1	1	0	10	0
SW2	2	8	0	32
SW3	11	2	11	28
TOTAL	14	10	21	60

WELL WATER

Sample no.	E. coli	S. typhi	Coliform	Enterobac
WW1	0	5	55	120
WW2	0	0	33	0
WW3	43	63	0	37
TOTAL	43	68	88	157

Legend

SW – Seeded water

WW – Well water

COLUMN STATISTICS:

MICROBIAL LOAD ON FINGERS

	E. coli	S. typhi	Coliform	Enterobacteriaceae
Number of values	76	76	76	76
Minimum	0.0	0.0	0.0	0.0
25% Percentile	0.0	0.0	0.2500	4.250
Median	0.0	0.0	2.000	10.00
75% Percentile	2.000	1.000	7.000	17.00
Maximum	22.00	35.00	50.00	69.00
Mean	2.250	1.434	5.461	13.32
Std. Deviation	4.102	4.437	8.560	13.69
Std. Error	0.4706	0.5090	0.9818	1.571
Lower 95% CI of mean	1.313	0.4203	3.505	10.19
Upper 95% CI of mean	3.187	2.448	7.416	16.44
Sum	171.0	109.0	415.0	1012

COLUMN STATISTICS: WATER ONLY REDUCTION OF MICROBES

	SBW E. coli	AW E. coli	SBW S. typhi	AW S. typhi	SBW Coliform	AW Coliform	SBW Enterobacteriaceae	AW Enterobacteriaceae
Number of values	16	16	16	16	16	16	16	16
Minimum	0.0	0.0	0.0	0.0	1.000	0.0	0.0	0.0
25% Percentile	0.0	0.0	0.0	0.0	8.500	1.000	0.0	0.0
Median	1.000	0.5000	0.0	0.0	20.00	2.000	4.500	3.500
75% Percentile	3.500	2.000	0.7500	0.0	42.00	6.250	10.50	9.750
Maximum	8.000	6.000	17.00	6.000	58.00	36.00	51.00	17.00
Mean	2.063	1.063	1.438	0.8750	24.13	5.438	10.81	5.250
Std. Deviation	2.594	1.569	4.273	1.962	18.54	9.187	15.90	5.768
Std. Error	0.6485	0.3923	1.068	0.4905	4.636	2.297	3.975	1.442
Lower 95% CI of mean	0.6802	0.2263	-0.8397	-0.1705	14.24	0.5423	2.340	2.177
Upper 95% CI of mean	3.445	1.899	3.715	1.921	34.01	10.33	19.29	8.323
Sum	33.00	17.00	23.00	14.00	386.0	87.00	173.0	84.00

COLUMN STATISTICS: ASH REDUCTION OF MICROBES

	SBA E.coli	AA E. coli	SBA S.typhi	AA S. typhi	SBA Coliform	AA Coliform	SBA Enterobacteriaceae	AA Enterbacteriaceae
Number of values	15	15	15	15	15	15	15	15
Minimum	0.0	0.0	0.0	0.0	2.000	0.0	4.000	1.000
25% Percentile	3.000	0.0	4.000	0.0	15.00	2.000	17.00	5.000
Median	4.000	0.0	13.00	4.000	42.00	4.000	28.00	18.00
75% Percentile	6.000	1.000	45.00	7.000	75.00	5.000	55.00	25.00
Maximum	11.00	2.000	75.00	56.00	99.00	9.000	90.00	50.00
Mean	4.333	0.5333	25.67	7.000	44.67	3.733	32.93	17.13
Std. Deviation	3.109	0.8338	27.46	14.03	30.34	2.840	22.69	13.77
Std. Error	0.8028	0.2153	7.089	3.621	7.834	0.7333	5.857	3.555
Lower 95% CI of mean	2.612	0.07158	10.46	-0.7671	27.86	2.160	20.37	9.509
Upper 95% CI of mean	6.055	0.9951	40.87	14.77	61.47	5.306	45.50	24.76
Sum	65.00	8.000	385.0	105.0	670.0	56.00	494.0	257.0

COLUMN STATISTICS: CITRUS LIME REDUCTION OF MICROBES

	SBL E.coli	AL E. coli	SBL S. typhi	AL S. typhi	SBL Coliform	AL Coliform	SBL Enterobacteriaceae	AL Enterobacteriaceae
Number of values	17	17	17	17	17	17	17	17
Minimum	2.000	0.0	0.0	0.0	16.00	0.0	6.000	0.0
25% Percentile	7.000	0.0	0.0	0.0	43.00	0.0	11.00	1.000
Median	14.00	0.0	2.000	0.0	52.00	1.000	13.00	5.000
75% Percentile	24.00	0.0	6.000	0.0	99.50	4.000	23.50	12.00
Maximum	26.00	7.000	22.00	4.000	184.0	8.000	60.00	26.00
Mean	15.00	0.4706	3.647	0.4706	71.35	2.118	18.65	7.647
Std. Deviation	8.223	1.700	5.442	1.125	46.13	2.446	12.50	7.491
Std. Error	1.994	0.4123	1.320	0.2728	11.19	0.5934	3.032	1.817
Lower 95% CI of mean	10.77	-0.4034	0.8489	-0.1076	47.63	0.8598	12.22	3.795
Upper 95% CI of mean	19.23	1.345	6.445	1.049	95.07	3.376	25.07	11.50
Sum	255.0	8.000	62.00	8.000	1213	36.00	317.0	130.0

COLUMN STATISTICS: SOAP REDUCTION OF MICROBES

	SBS E.coli	AS E. coli	SBS S. typhi	AS S. typhi	SBS Coliform	AS Coliform	SBS Enterobact	AS Enterobact
Number of values	15	15	15	15	15	15	15	15
Minimum	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
25% Percentile	0.0	0.0	0.0	0.0	8.000	0.0	4.000	4.000
Median	0.0	0.0	0.0	0.0	13.00	0.0	7.000	7.000
75% Percentile	3.000	0.0	0.0	0.0	20.00	1.000	18.00	12.00
Maximum	5.000	2.000	17.00	0.0	65.00	10.00	130.0	19.00
Mean	1.400	0.2000	1.133	0.0	18.67	1.333	20.20	8.800
Std. Deviation	1.844	0.5606	4.389	0.0	18.95	2.637	33.83	5.906
Std. Error	0.4761	0.1447	1.133	0.0	4.893	0.6808	8.735	1.525
Lower 95% CI of mean	0.3789	-0.1105	-1.297	0.0000e+000	8.173	-0.1269	1.464	5.529
Upper 95% CI of mean	2.421	0.5105	3.564	0.0000e+000	29.16	2.794	38.94	12.07
Sum	21.00	3.000	17.00	0.0	280.0	20.00	303.0	132.0

ANOVA

Table Analyzed	Water only reduction of microbes
One-way analysis of variance	
P value	≤ 0.0001
P value summary	***
Are means signif. different? ($P \leq 0.05$)	Yes
Number of groups	8
F	10.75
R squared	0.3854
Bartlett's test for equal variances	
Bartlett's statistic (corrected)	145.0
P value	≤ 0.0001
P value summary	***
Do the variances differ signif. ($P \leq 0.05$)	Yes

ANOVA Table	SS	df	MS
Treatment (between columns)	7014	7	1002
Residual (within columns)	11180	120	93.21
Total	18200	127	

Newman-Keuls Multiple Comparison Test	Mean Diff.	q	Significant? P ≤ 0.05?	Summary
AW S. typhivs SBW Coliform	-23.25	9.633	Yes	***
AW S. typhivs SBW Enterobacteriaceae	-9.938	4.117	No	ns
AW S. typhivs AW Coliform	-4.563	---	No	ns
AW S. typhivs AW Enterobacteriaceae	-4.375	---	No	ns
AW S. typhivs SBW E. coli	-1.188	---	No	ns
AW S. typhivs SBW S. typhi	-0.5625	---	No	ns

AW S. typhivs AW E. coli	-0.1875	---	No	ns
AW E. coli vs SBW Coliform	-23.06	9.555	Yes	***
AW E. coli vs SBW Enterobacteriaceae	-9.750	---	No	ns
AW E. coli vs AW Coliform	-4.375	---	No	ns
AW E. coli vs AW Enterobacteriaceae	-4.188	---	No	ns
AW E. coli vs SBW E. coli	-1.000	---	No	ns
AW E. coli vs SBW S. typhi	-0.3750	---	No	ns
SBW S. typhivs SBW Coliform	-22.69	9.400	Yes	***
SBW S. typhivs SBW Enterobacteriaceae	-9.375	---	No	ns
SBW S. typhivs AW Coliform	-4.000	---	No	ns
SBW S. typhivs AW Enterobacteriaceae	-3.813	---	No	ns
SBW S. typhivs SBW E. coli	-0.6250	---	No	ns
SBW E. coli vs SBW Coliform	-22.06	9.141	Yes	***
SBW E. coli vs SBW Enterobacteriaceae	-8.750	---	No	ns
SBW E. coli vs AW Coliform	-3.375	---	No	ns
SBW E. coli vs AW Enterobacteriaceae	-3.188	---	No	ns
AW Enterobacteriaceaevs SBW Coliform	-18.88	7.820	Yes	***
AW Enterobacteriaceaevs SBW Enterobacteriaceae	-5.563	---	No	ns
AW Enterobacteriaceaevs AW Coliform	-0.1875	---	No	ns
AW Coliform vs SBW Coliform	-18.69	7.743	Yes	***
AW Coliform vs SBW Enterobacteriaceae	-5.375	---	No	ns
SBW Enterobacteriaceaevs SBW Coliform	-13.31	5.516	Yes	***

ANOVA

Table Analyzed	Ash reduction of microbes
One-way analysis of variance	
P value	≤ 0.0001
P value summary	***
Are means signif. different? (P ≤ 0.05)	Yes
Number of groups	8
F	11.91
R squared	0.4267
Bartlett's test for equal variances	
Bartlett's statistic (corrected)	164.1
P value	≤ 0.0001
P value summary	***
Do the variances differ signif. (P ≤ 0.05)	Yes

ANOVA Table	SS	df	MS
Treatment (between columns)	27030	7	3862
Residual (within columns)	36310	112	324.2
Total	63340	119	

Newman-Keuls Multiple Comparison Test	Mean Diff.	q	Significant? P ≤ 0.05?	Summary
AA E. coli vs SBA Coliform	-44.13	9.493	Yes	***
AA E. coli vs SBA Enterobacteriaceae	-32.40	6.969	Yes	***
AA E. coli vs SBA S.typhi	-25.13	5.406	Yes	**
AA E. coli vs AA Enterobacteriaceae	-16.60	3.571	No	ns
AA E. coli vs AA S. typhi	-6.467	---	No	ns

AA E. coli vs SBA E.coli	-3.800	---	No	ns
AA E. coli vs AA Coliform	-3.200	---	No	ns
AA Coliform vs SBA Coliform	-40.93	8.805	Yes	***
AA Coliform vs SBA Enterobacteriaceae	-29.20	6.281	Yes	***
AA Coliform vs SBA S.typhi	-21.93	4.718	Yes	*
AA Coliform vs AA Enterobacteriaceae	-13.40	---	No	ns
AA Coliform vs AA S. typhi	-3.267	---	No	ns
AA Coliform vs SBA E.coli	-0.6000	---	No	ns
SBA E.colivs SBA Coliform	-40.33	8.676	Yes	***
SBA E.colivs SBA Enterobacteriaceae	-28.60	6.152	Yes	***
SBA E.colivs SBA S.typhi	-21.33	4.589	Yes	**
SBA E.colivs AA Enterobacteriaceae	-12.80	---	No	ns
SBA E.colivs AA S. typhi	-2.667	---	No	ns
AA S. typhivs SBA Coliform	-37.67	8.102	Yes	***
AA S. typhivs SBA Enterobacteriaceae	-25.93	5.578	Yes	***
AA S. typhivs SBA S.typhi	-18.67	4.015	Yes	*
AA S. typhivs AA Enterobacteriaceae	-10.13	---	No	ns
AA Enterobacteriaceaevs SBA Coliform	-27.53	5.922	Yes	***
AA Enterobacteriaceaevs SBA Enterobacteriaceae	-15.80	3.399	Yes	*
AA Enterobacteriaceaevs SBA S.typhi	-8.533	1.835	No	ns
SBA S.typhivs SBA Coliform	-19.00	4.087	Yes	*
SBA S.typhivs SBA Enterobacteriaceae	-7.267	1.563	No	ns
SBA Enterobacteriaceaevs SBA Coliform	-11.73	2.524	No	ns

ANOVA

Table Analyzed	Citrus lime reduction of microbes

One-way analysis of variance	
P value	≤ 0.0001
P value summary	***
Are means signif. different? (P ≤ 0.05)	Yes
Number of groups	8
F	31.43
R squared	0.6322

Bartlett's test for equal variances	
Bartlett's statistic (corrected)	287.0
P value	≤ 0.0001
P value summary	***
Do the variances differ signif. (P ≤ 0.05)	Yes

ANOVA Table	SS	df	MS
Treatment (between columns)	67320	7	9617
Residual (within columns)	39170	128	306.0
Total	106500	135	

Newman-Keuls Multiple Comparison Test	Mean Diff.	q	Significant? P ≤ 0.05?	Summary
AL E. coli vs SBL Coliform	-70.88	16.71	Yes	***
AL E. coli vs SBL Enterobacteriaceae	-18.18	4.284	Yes	*
AL E. coli vs SBL E.coli	-14.53	3.425	No	ns
AL E. coli vs AL Enterobacteriaceae	-7.176	---	No	ns
AL E. coli vs SBL S. typhi	-3.176	---	No	ns
AL E. coli vs AL Coliform	-1.647	---	No	ns

AL E. coli vs AL S. typhi	0.0000	---	No	ns
AL S. typhivs SBL Coliform	-70.88	16.71	Yes	***
AL S. typhivs SBL Enterobacteriaceae	-18.18	4.284	Yes	*
AL S. typhivs SBL E.coli	-14.53	---	No	ns
AL S. typhivs AL Enterobacteriaceae	-7.176	---	No	ns
AL S. typhivs SBL S. typhi	-3.176	---	No	ns
AL S. typhivs AL Coliform	-1.647	---	No	ns
AL Coliform vs SBL Coliform	-69.24	16.32	Yes	***
AL Coliform vs SBL Enterobacteriaceae	-16.53	3.896	No	ns
AL Coliform vs SBL E.coli	-12.88	---	No	ns
AL Coliform vs AL Enterobacteriaceae	-5.529	---	No	ns
AL Coliform vs SBL S. typhi	-1.529	---	No	ns
SBL S. typhivs SBL Coliform	-67.71	15.96	Yes	***
SBL S. typhivs SBL Enterobacteriaceae	-15.00	---	No	ns
SBL S. typhivs SBL E.coli	-11.35	---	No	ns
SBL S. typhivs AL Enterobacteriaceae	-4.000	---	No	ns
AL Enterobacteriaceaevs SBL Coliform	-63.71	15.02	Yes	***
AL Enterobacteriaceaevs SBL Enterobacteriaceae	-11.00	---	No	ns
AL Enterobacteriaceaevs SBL E.coli	-7.353	---	No	ns
SBL E.colivs SBL Coliform	-56.35	13.28	Yes	***
SBL E.colivs SBL Enterobacteriaceae	-3.647	---	No	ns
SBL Enterobacteriaceaevs SBL Coliform	-52.71	12.42	Yes	***

ANOVA

Table Analyzed	Soap reduction of microbes
One-way analysis of variance	
P value	≤ 0.0001
P value summary	***
Are means signif. different? (P ≤ 0.05)	Yes
Number of groups	8
F	5.513
R squared	0.2563
Bartlett's test for equal variances	
Bartlett's statistic (corrected)	
P value	
P value summary	ns
Do the variances differ signif. (P ≤ 0.05)	No

ANOVA Table	SS	df	MS
Treatment (between columns)	7567	7	1081
Residual (within columns)	21960	112	196.1
Total	29530	119	

Newman-Keuls Multiple Comparison Test	Mean Diff.	q	Significant? P ≤ 0.05?	Summary
AS S. typhivs SBS Enterobacteriaceae	-20.20	5.587	Yes	**
AS S. typhivs SBS Coliform	-18.67	5.163	Yes	**
AS S. typhivs AS Enterobacteriaceae	-8.800	2.434	No	ns
AS S. typhivs SBS E.coli	-1.400	---	No	ns
AS S. typhivs AS Coliform	-1.333	---	No	ns
AS S. typhivs SBS S. typhi	-1.133	---	No	ns

AS S. typhivs AS E. coli	-0.2000	---	No	ns
AS E. coli vs SBS Enterobacteriaceae	-20.00	5.532	Yes	**
AS E. coli vs SBS Coliform	-18.47	5.108	Yes	**
AS E. coli vs AS Enterobacteriaceae	-8.600	---	No	ns
AS E. coli vs SBS E.coli	-1.200	---	No	ns
AS E. coli vs AS Coliform	-1.133	---	No	ns
AS E. coli vs SBS S. typhi	-0.9333	---	No	ns
SBS S. typhivs SBS Enterobacteriaceae	-19.07	5.274	Yes	**
SBS S. typhivs SBS Coliform	-17.53	4.850	Yes	**
SBS S. typhivs AS Enterobacteriaceae	-7.667	---	No	ns
SBS S. typhivs SBS E.coli	-0.2667	---	No	ns
SBS S. typhivs AS Coliform	-0.2000	---	No	ns
AS Coliform vs SBS Enterobacteriaceae	-18.87	5.218	Yes	**
AS Coliform vs SBS Coliform	-17.33	4.794	Yes	**
AS Coliform vs AS Enterobacteriaceae	-7.467	---	No	ns
AS Coliform vs SBS E.coli	-0.06667	---	No	ns
SBS E.colivs SBS Enterobacteriaceae	-18.80	5.200	Yes	**
SBS E.colivs SBS Coliform	-17.27	4.776	Yes	**
SBS E.colivs AS Enterobacteriaceae	-7.400	---	No	ns
AS Enterobacteriaceaevs SBS Enterobacteriaceae	-11.40	3.153	No	ns
AS Enterobacteriaceaevs SBS Coliform	-9.867	---	No	ns
SBS Coliform vs SBS Enterobacteriaceae	-1.533	---	No	ns

ANOVA	
Table Analyzed	Comparison of Cleansing Agents
One-way analysis of variance	
P value	0.0752
P value summary	ns
Are means signif. different? (P ≤ 0.05)	No
Number of groups	8
F	2.162
R squared	0.3868

ANOVA Table	SS	df	MS
Treatment (between columns)	760100	7	108600
Residual (within columns)	1205000	24	50210
Total	1965000	31	

Newman-Keuls Multiple Comparison Test	Mean Diff.	q	Significant? P ≤ 0.05?	Summary
AS vs BL	-423.0	3.775	No	ns
AS vs BA	-364.8	---	No	ns
AS vs BS	-116.5	---	No	ns
AS vs BW	-115.0	---	No	ns
AS vs AA	-67.75	---	No	ns
AS vs AW	-14.75	---	No	ns
AS vs AL	-6.750	---	No	ns
AL vs BL	-416.3	---	No	ns
AL vs BA	-358.0	---	No	ns
AL vs BS	-109.8	---	No	ns
AL vs BW	-108.3	---	No	ns
AL vs AA	-61.00	---	No	ns
AL vs AW	-8.000	---	No	ns
AW vs BL	-408.3	---	No	ns
AW vs BA	-350.0	---	No	ns
AW vs BS	-101.8	---	No	ns
AW vs BW	-100.3	---	No	ns
AW vs AA	-53.00	---	No	ns
AA vs BL	-355.3	---	No	ns

AA vs BA	-297.0	---	No	ns
AA vs BS	-48.75	---	No	ns
AA vs BW	-47.25	---	No	ns
BW vs BL	-308.0	---	No	ns
BW vs BA	-249.8	---	No	ns
BW vs BS	-1.500	---	No	ns
BS vs BL	-306.5	---	No	ns
BS vs BA	-248.3	---	No	ns
BA vs BL	-58.25	---	No	ns

COLUMN STATISTICS

Comparing the efficacy of cleansing agents

	WATER	ASH	CITRUS	SOAP
Number of values	4	4	4	4
Minimum	39.13	31.12	58.99	56.44
25% Percentile	40.47	41.52	66.02	63.76
Median	46.50	80.21	91.98	89.29
75% Percentile	70.22	90.65	96.99	98.21
Maximum	77.46	91.64	97.03	100.0
Mean	52.40	70.79	85.00	83.75
Std. Deviation	17.14	27.68	17.95	19.12
Std. Error	8.572	13.84	8.974	9.561
Lower 95% CI	25.12	26.75	56.44	53.32
Upper 95% CI	79.68	114.8	113.6	114.2

ANOVA

Comparing the efficacy of cleansing agents

Parameter	
Table Analyzed	Data 1
One-way analysis of variance	
P value	0.1534
P value summary	ns
Are means signif. different? (P < 0.05)	No
Number of groups	4
F	2.102
R square	0.3445

ANOVA Table	SS	df	MS
Treatment (between columns)	2755	3	918.5
Residual (within columns)	5243	12	436.9
Total	7999	15	

Newman-Keuls Multiple Comparison Test	Mean Diff.	q	Significant? P < 0.05?	Summary
WATER vs CITRUS LIME	-32.60	3.119	No	ns
WATER vs SOAP	-31.36	---	No	ns
WATER vs ASH	-18.40	---	No	ns
ASH vs CITRUS LIME	-14.20	---	No	ns
ASH vs SOAP	-12.96	---	No	ns
SOAP vs CITRUS LIME	-1.244	---	No	ns

Appendix C: EXPERIMENTAL SETUP

Plate C1: Inputs ready for the handwashing exercise

Plate C2: Getting ready to wash with lime

Plate C3: Hand sampling

Plate C4: Washing hands with soap

Plate C5: Rinsing hands

Plate C6: Dipping right hand in seeded water (that is, suspension of microbes)

Plate C7: Washing hands with ash

Plate C8: Shaking excess water from hands

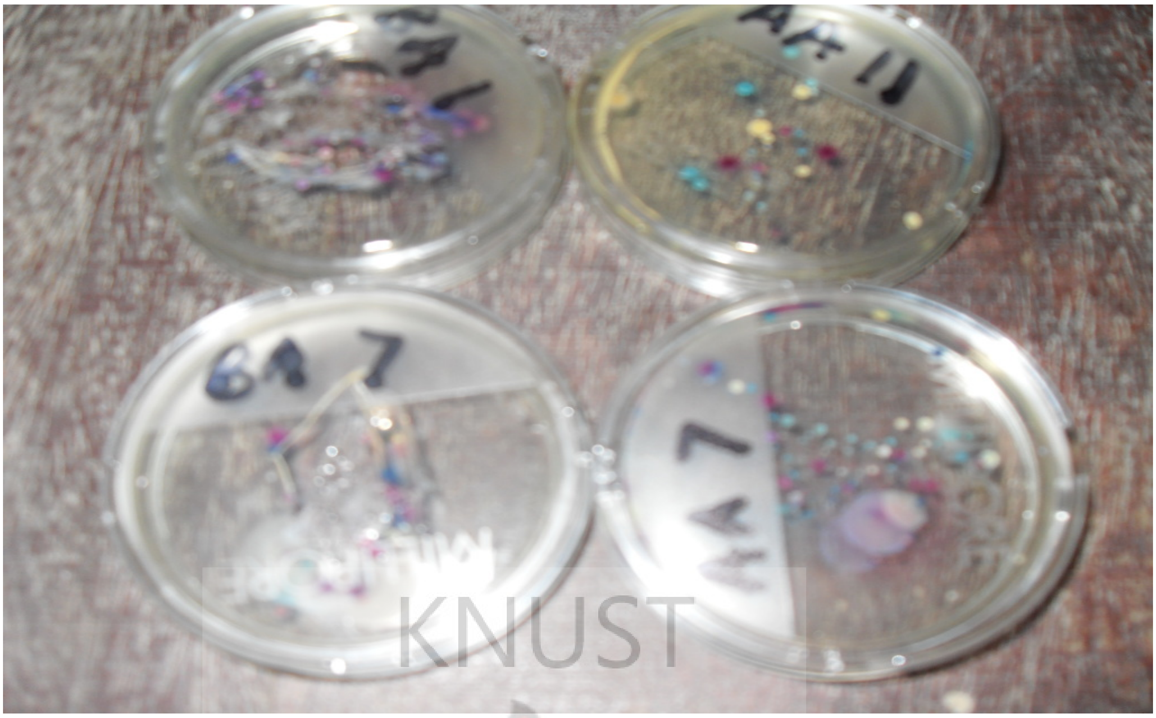
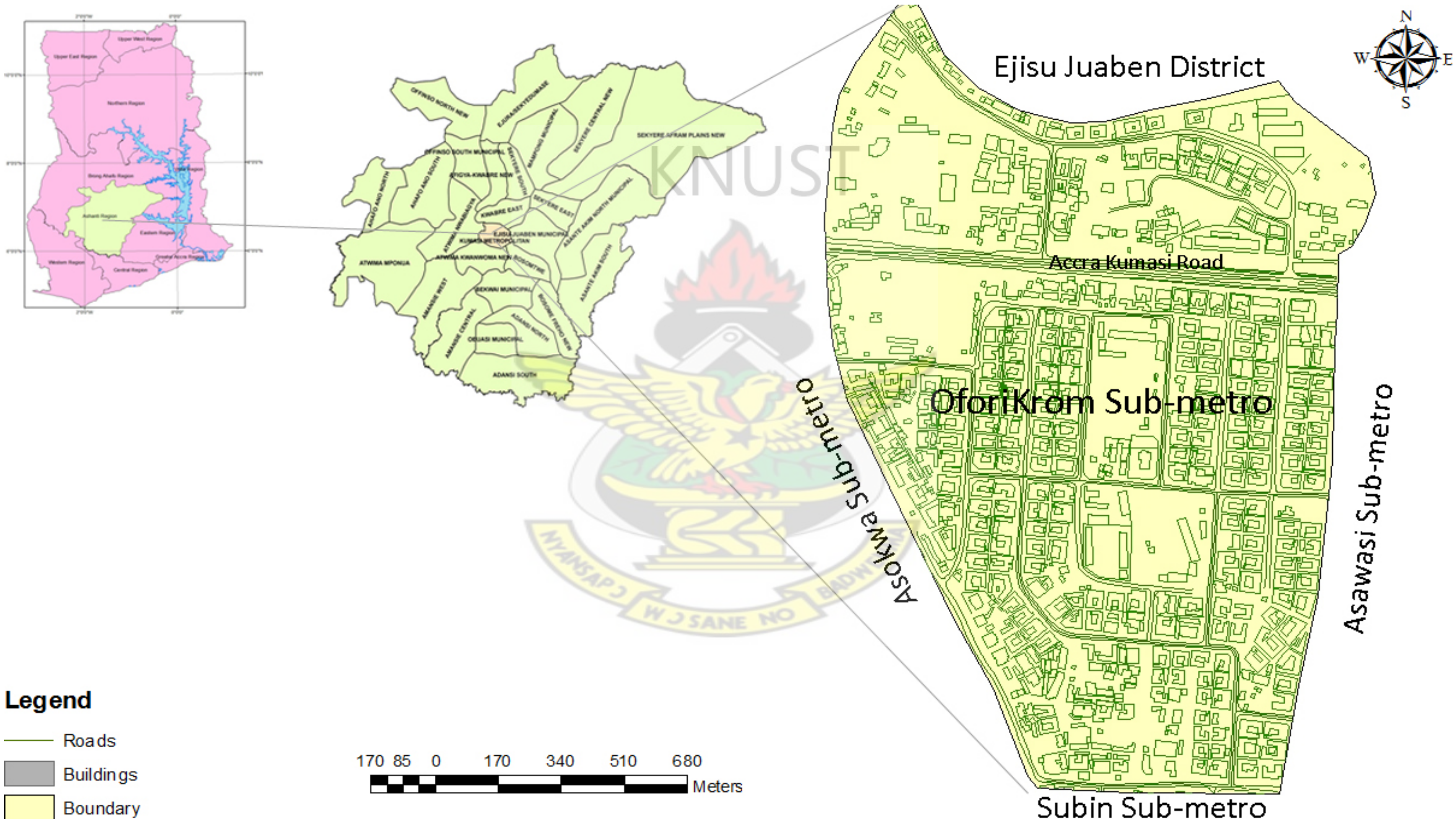


Plate C9: Plates with microbial colonies on Chromo cult agar

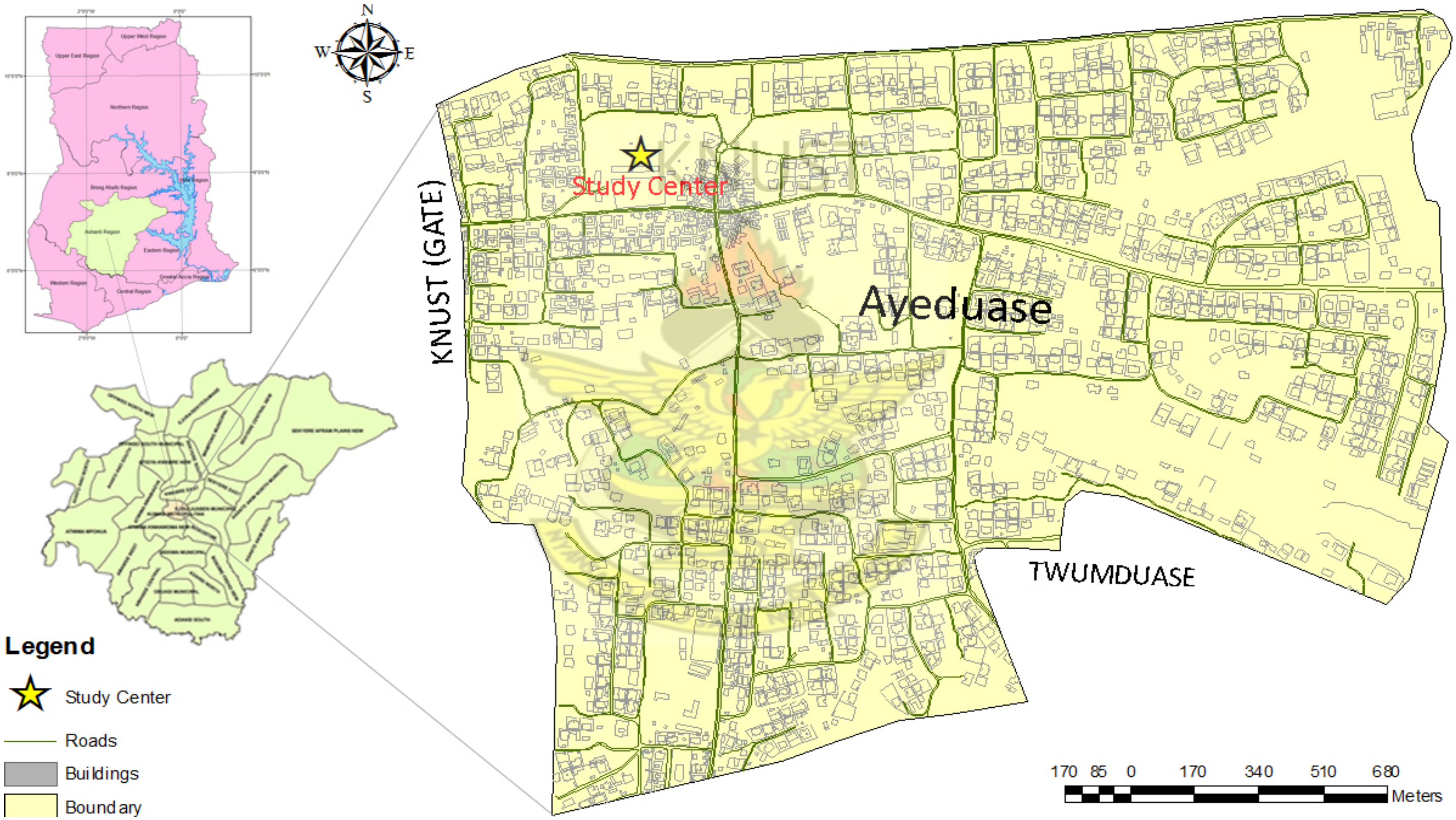
Plate C10: Researcher examining plates in the laboratory

Appendix D: MAP OF OFORIKROM SUB-METROPOLIS



Source : Geomatic Department (2012)

Appendix E: MAP OF AYEDUASE



Source : Geomatic Department (2012)