KWAME NKRUMAH UNIVERSITY OF SCIENCE AND TECHNOLOGY,

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IDENTIFICATION AND QUANTIFICATION OF OBSOLETE CHEMICALS IN SECOND CYCLE INSTITUTIONS IN THE ASHANTI REGION OF GHANA

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A THESIS SUBMITTED TO THE DEPARTMENT OF THEORETICAL AND APPLIED BIOLOGY, COLLEGE OF SCIENCE, KWAME NKRUMAH UNIVERSITY OF SCIENCE AND TECHNOLOGY IN PARTIAL FULFILMENT OF THE REQUIREMENT FOR THE DEGREE OF

MASTER OF SCIENCE IN ENVIRONMENTAL SCIENCE

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DECLARATION

I, Sekyere Paul Appiah, declare that I have fully undertaken the study reported herein under the supervision of Dr. Osei Akoto and that except for portions where references have been duly cited, it has neither been submitted in whole nor part for the award of any degree in this institution or elsewhere.

Sekyere Paul Appiah …………………………… ………………………
Signature Date

Certified by
Dr. Osei Akoto …………………………… ………………………
(Supervisor) Signature Date

Certified by
Dr. Mathew Addo Glover …………………………… ………………………
(Head of Department) Signature Date

DEDICATION

I humbly dedicate this work to my mother Madam comfort Asamoah for her support in my education.

ACKNOWLEDGEMENT

To the Most High God I say; *glory, and wisdom, thanksgiving and honour.*

Also to my mother, I gratefully acknowledge your kind support given me from the beginning in pursuit of my master degree. To my brothers and sisters, I say thank you all.

I owe a huge debt of gratitude to my supervisor, Dr. Osei Akoto of Chemistry Department for his tremendous contribution and patience throughout this work. I am very much enthused by the spontaneous response received from the following people; Mr. Patrick Avosse and Mr. Patrick Adu Poku all in Chemistry Department of Afua Kobi Ampem Girls Senior High School, as well as Mr. Mohammed Musa of Toase Senior High School.

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ABSTRACT

Chemicals may be defined as a pure substance with definite compositions, characteristics and properties which occurs in nature or through chemical reactions. Chemicals used in Ghana can be categorized into bulk, fine chemicals and research chemicals. The imported ones are usually meant for practical work, demonstrations and for research in educational institutions. It is appropriate to state that not all chemicals used in our educational institutions for practical work and demonstrations are imported. Greater numbers of the chemicals purchased or donated to the educational institutions have short shelf life and may be characterized largely as poisons, hazardous or toxic. A major problem of concern that arises is that if the quantities of the chemicals found in the schools exceeds that required, little or no considerations are made on how to store the excess chemicals. This may lead to piling up of the excess chemicals over a period of time. These excess chemicals for which no immediate use is required are noted as Obsolete Chemicals. This research work focused on how to classify and quantify the obsolete chemicals in the selected second cycle schools in the Ashanti region of Ghana. The research enumerated the possible dangers that obsolete chemicals may pose to the laboratory personnel, the general public and to the environment.

A total of 439 obsolete chemicals were recorded in this study of which 398 were classified and 41 were unidentified. Out of the 398 whose identity were detected and classified, 179, representing 44.97 percent of the identified were unlabeled while 219 representing 55.03 percent were labeled.

The total weight of obsolete chemicals from all the schools was 168.2kg. Nkawie Senior High Technical School recorded the least value of 32.32kg whiles Afua Kobi Ampem Girls' Senior High School recorded the highest value of 102.5kg which is twice as much as the sum of the weights recorded from the other two schools.

CHAPTER ONE

1.0 INTRODUCTION

1.1 Background

Chemicals are indispensable commodities in most of our economic activities and plays essential roles in our daily life activities. They provide a wide range of benefits, which cannot be enumerated and overlooked, which includes increasing medical, agricultural and industrial productivity and improvements in the control of disease (EPA, 1997). Despite these essential benefits from chemicals, they have the potential to cause considerably irreparable health and environmental problems from their production through to disposal. The improper use of chemicals can adversely cause pollution to the environment, which can affect the quality of the air, water, soil and human health (EPA, 1997). The production of chemicals in Ghana forms only about 3% of their total demands in the country and as such the rest of the products are imported (EPA, 1997).

These chemicals are classified as bulk, fine and research, which are usually used for educational, agricultural, industrial, health and domestic purposes. The excess chemicals for which no immediate use is required are noted as Obsolete Chemicals (Ephraim, 2013). Obsolete chemicals could be described as chemical waste and covers unneeded, outdated or expired, chemicals that have lost their identity, which are normally contained in aged and decrepit containers, and these chemicals can be considered hazardous (IGNAAM, 1985).Obsolete chemicals are becoming a concern because of the improper management and widespread of chemicals (Ngowi, 2002). Substantial evidence has proven that when these chemicals and wastes are released into the environment, either intentionally or unintentionally, they cause severe adverse effects on humans and on the environment (Koloutsou-Vakakis and Chinta, 2011).These effects do not only occur at the local scale as these substances may be transported to far away distances from their sources. This has led to the enactment of international policies to foster sound management of chemicals (UNEP, 2001). The principal international agreement is the

Stockholm Convention, which frowns on the use of some selected number of POPs (Antonov *et al*., 2007).

1.2 Problem Statement

Stockpiles of obsolete chemicals have been identified in many educational institutions in Ghana, many in rusting containers and others in bags stored or thrown out for decades (Ephraim, 2013). The creation and upgrading of science laboratories of some second cycle institutions in Ghana into science resource centers led to the purchase of some new chemicals, thereby abandoning the old stock. Again poor importation control measures coupled with inappropriate procurement and purchasing policies, untimely distribution, inadequate stock management, improper coordination between donor partners and acceptance of chemical products that are outdated and/or mislabeled or labeled in a language that users cannot read and understand are some of the major contributing factors in the stock pile of obsolete chemicals in second cycle schools (Woode, 2008). Obsolete chemicals if not managed could pose serious threat and danger to people who work and/ or live near stocks of such chemicals (Ephraim, 2013). Again, the improper disposal of obsolete chemicals can lead to pollution of the environment. These pollutants can bio-accumulate through the food chain thus causing destruction to organisms and interrupting biodiversity (FAO, 1995b).

Certain compounds have the capability to initiate spontaneous combustion, which can cause fires. Obsolete chemicals exposed to the environment can leach into water bodies hence contaminating them. They can permeate through the soil to contaminate it leading to serious health and environmental risk to nearby communities. The contaminated area and portion cannot be used for human occupation, crop cultivation and grazing by livestock (Bakanga, 2012). With the increasing negative impacts of obsolete chemicals on human and the environment, the efforts by the nation to effectively deal with its obsolete chemicals issues are grim; especially in chemical stores of our educational institutions. These facts, coupled with the little or no information about the type and quantity of chemicals left in these institutions makes it essentially critical to seek a common position on ways and means to avoid further accumulation of obsolete and unwanted chemical stocks in the future.

1.3 General Objectives of the study

The general objective of the research is to identify and measure quantities of obsolete chemicals and management practices in place at second cycle institutions in Ghana.

1.4 Specific Objectives

The research has the following as specific objectives;

- To measure quantities of obsolete chemicals in Afua Kobi Ampem Girls' Senior High, Nkawie Senior High Technical and Toase Senior High Schools
- Identify them qualitatively and classify them as acids, bases, organics and inorganics

1.5 Justification

The improper management and disposal of obsolete chemicals in the environment may result in prolonged exposure of humans to pollutants, which cause adverse effects to health (Boakwah, 2006). The scope of this study is to find and identify the various chemicals that are kept as obsolete and to find out if they are potent for re-use. This will help to reduce the volumes of such chemicals that will have to be disposed off. It has become important to compile the inventory of obsolete chemicals in second cycle institutions in Ghana and to initiate plans to control them.

CHAPTER TWO

2.0 LITERATURE REVIEW

Most educational institutions in Ghana have hundreds of chemicals in their stores, (Woode, 2008). Obsolete chemicals accumulate when there is no tracking system and no disposal plan. Donations can compound the problem (Bakanga, 2012). With gradual increase of unused chemicals, space and sorting of chemicals becomes a problem in the stores and as a result, newly acquired chemicals are either kept on shelves or benches alongside old stocks. Other personnel resort to dumping of chemicals at one corner on the store floors, thus wrecking the stores (Woode, 2008).

In the search for easier and cheaper ways to discard obsolete chemicals, agents and companies started shipping these chemicals to developing countries and parts of Eastern Europe. When these activities were revealed, an international outreach led to the drafting and adoption of the Basel and other conventions, which aims to eliminate such problems (Boakwah, 2006). The potential dangers of obsolete chemicals, however, would be reduced if plans and measures are adopted to avoid their accumulation (Ephraim, 2013). According to Venkataraman (2006), twenty departments in the University of Singapore generated 3 tons of obsolete chemicals. In Ghana, 20.326 kg of chemicals were identified as obsolete in the chemical stores of the Chemistry Department of Kwame Nkrumah University of Science and Technology, which needed to be disposed off (Boakwah, 2006). Pile ups of obsolete chemicals should be seen to be chemical time-bombs that can cause disaster to humans and the environment and thus need proper management (FAO, 1995b). Quantities of obsolete chemicals from countries range from a fewer tonnes to many thousands. The FAO report in 1995 revealed that an inventory of obsolete pesticide stocks in Africa estimates the total of obsolete pesticides to far higher than 15,000 tonnes.

According to a UNEP report in 2001, a conservative estimate by the United Nations Food and Agriculture Organization (FAO) categorizes the total quantity of obsolete pesticides in Africa at about 20,000 tonnes. The same report puts that of Asia and Latin America around 80,000 metric tonnes (Baba, 2008).

International Hexachlorocyclohexane and Pesticides Association (IHPA) puts the bulk sum of obsolete pesticides around 260,000 tonnes to 265, 000 tonnes in central and Eastern Europe and that of the former Soviet Socialist Republics. Estimated amounts in 25 Member States of the European Union hovering around 22,000 tonnes to 24,000 tonnes and that of south-east Europe 36,000 tonnes to 41,000 tonnes (FAO, 2001 b). South-East Asia is having 6500 tonnes while Central and South America has close to 30,000 tonnes (FAO, 2001 b). In order to render obsolete chemicals less hazardous and of smaller quantity, it can be treated so as to reduce its disposal costs, so that the threat that it poses in the environment can be minimized (Ephraim, 2013). Greater numbers of chemicals donated or imported into the country have short lifespan and may be classified mainly as poisons, hazardous or toxic (Woode, 2008). A major problem of concern that arises is that if the quantities of the chemicals purchased exceed that required, little or no considerations are made on how to store these chemicals (Ephraim, 2013). This situation leads to an accumulation of excess chemicals over a period of time. The excess chemicals for which no immediate use is required are noted as Obsolete Chemicals (Bakanga, 2012). In most cases, laws and legislative instruments are used to ban and terminate the use of some chemicals that have negative impact on health and the environment. Such banned chemicals subsequently tends to go "obsolete" because they are not used (Ephraim, 2013).

2.1 Conventions on chemical proliferations

Knowing the potential threats and dangers connected with obsolete chemical stocks in conjunction with the high costs of treatment to make it safe environmentally and sound for disposal, it has become imperative to seek a common position on ways and means to avoid the accumulation of stocks of chemicals, which may eventually go obsolete in the near future. Keeping preventive measures gives a lasting solution to stock-piles of obsolete chemicals (FAO, 1995b). International treaties and initiatives outline policies which aim to regulate the exposure or emission limits of some chemicals (Boakwah, 2006). The United Nations Environment Programme (UNEP) is given much priority and attention to chemicals and hazardous wastes where multilateral agreements which stipulate measures to protect human health and the environment (Boakwah, 2006). Among these agreements is the Basel Convention, which seeks to control the transboundary movements of hazardous wastes and their disposal. The Basel Convention is a global environmental agreement on hazardous and other wastes which came into force in 1992 (Vijgen*et al.*, 2009).

The Rotterdam Convention on the Prior Informed Consent Procedure for some Hazardous chemicals and Pesticides in International Trade which was adopted in 1998 seeks to; • to promote cooperative efforts among countries in the trade of certain hazardous chemicals so as to protect human health and the environment from potential harm

- to control the sound use hazardous chemicals, by creating awareness on their characteristics (W.H.A, 2010). The Stockholm Convention on Persistent Organic Pollutant (POPs) seeks to protect human health and the environment from POPs. It came into existence, on 17th May 2004 (Martinez, 2004). Other international agreements on regulation of waste and toxic chemicals include the International Conference on Chemicals Management (ICCM), which defines policies to promote the secured way of managing chemicals and the assessment of risks that chemicals may exhibit (W.H.A., 2010). The proposal from the Globally Harmonised System of Classification and Labeling of Chemical (GHS) describes how hazardous chemicals must be communicated through their labels and safety data sheets so as to protect human health and the environment (Vijgen *et al.*, 2009). Signatories to the Bali declaration on waste management for human health and livelihood reaffirmed their commitment to the principles of the Basel convention by adopting strict control measures to protect human health and the environment against the adverse effects from the generation, movement and management of hazardous wastes (W.H.A., 2010). These conventions indicate the level of seriousness the international community attaches to reducing if possible avoiding the risks from improper management of obsolete chemicals and wastes.

2.2 Causes of obsolete chemicals accumulation

Identifying the factors that contributes to the accumulation of obsolete chemicals helps in formulating measures to prevent and address the problem. Many factors can be attributed to the accumulation of stockpiles of obsolete chemicals, which can be grouped into several forms (FAO, 1995b).

2.2.1 Banning of chemicals

Appreciable quantities of obsolete chemicals accumulating in the country are persistent organic pollutants that are toxic, resist degradation, bio-accumulates and are transported through air, water and can migrate through international boundaries far from their place of origin (Jones and de Voogt, 1999; Vallack *et al*., 1998). Most POPs are banned form the markets and their use require stringent conditions due to their negative effects on humans and the environment at large. (FAO, 1995b).

2.2.2 Poor chemical regulation in developing countries

Most developing countries impose a ban on chemicals without making efforts to consider procedures to handle and manage those already in the system. Smuggling and illegal trafficking of chemicals across borders of countries may create unnecessary friction and tension about the contents and the use of some chemicals (OECD/FAO/UNEP, 2000). Inefficient implementation of laws on chemical importation and use in a country can lead to the accumulation of these chemicals.

2.2.3 Inadequate chemical storage facilities

Most developing countries do have insufficient and well-designed safe-keeping facilities for storing all its chemicals. Most of these are poorly ventilated and are not properly designed. In most instances the chemicals are on floors making it very difficult for movement in the stores which reduces accessibility to some chemicals. This makes the monitoring of chemicals a very difficult task (Ephraim, 2013). Again, poor storing conditions increases the rate at which the chemicals and their containers degrade. Newly purchased chemicals are in some cases improperly stored due to the fact that they will be competing with the old and obsolete ones for space (FAO, 1995b).

2.2.4 Lack of expertise in chemical handling and management

In most cases the storekeepers and attendants lack the pre-requisite skills to enable them follow the guidelines for management of chemicals (Woode, 2008).The improper stacking of where contaminated chemicals are mixed together with other products may affect the condition of these products, thereby hindering the basic principles where old chemicals are used before new ones. Stock records may not be regularly updated and communicated to the central authority responsible for establishing the country's chemicals requirements (FAO, 1995b).

2.2.5 Lack /Inadequate analytical equipment

Most developing countries lack or have little access to equipment and materials for proper analysis of chemicals to find out if a particular chemical product can still be used even though it's expiration date might have been elapsed (FAO, 1995b).

2.2.6 Missing or incomplete labels

Labels are inscriptions on a sheet of paper that serve as a means of communication between the manufacturer and the user that provide information on the chemical. Most often than not, the labels are written in languages alien to the users and therefore may find it difficult to know it's content, it's application mode and methods (Woode, 2008). Absence of labels and manufacturing dates on the labels of some chemical containers worsen the case (FAO, 1995b).

2.2.7 Overstocking of products with a short shelf-life

Significant numbers of some chemicals have their shelf lives very short or may have shorter expiration dates from the time that they were manufactured. Extreme atmospheric and weather conditions can adversely affect chemicals by reducing their shelf lives (Woode, 2008).

2.2.8 Excessive and inappropriate chemical donations from aid agencies

In some cases most donated chemicals turn to be waste because they may not be needed or are of low demand. Some donated chemicals may not be applicable in the tropical zone where most developing countries that receive the bulk of the donated chemicals are located (Bakanga, 2012). Donated chemicals may respond to the demands of a country but may lack the experts with the requisite knowledge and skills on how to use and transform them into other products (OECD/FAO/UNEP, 2000).

Donations from donor agencies at some points exceed far what is required and when demand is not adjusted it may lead to an accumulation of such chemicals (FAO, 1995b).

2.2.9 Poor communication between donor agencies and recipients

The interaction between the donor agencies and their recipients in terms of communication is very weak and poor. Donor agencies do not inform their partners about the type and nature of the chemicals they intend to give out. Countries receive the requested chemicals on time or do not receive them at all and begin to look for so many avenues of getting the chemicals with the hope that at least one will react in time. When more than one of these agencies responds to the request made, the rest becomes surplus and unused thereby adding to the stockpile of chemicals (Woode, 2008).

2.3 Effects of Obsolete Chemicals

Leaking containers of chemicals can affect the health of those who work on them at their places of storage and of others who may come in contact with these chemicals (FAO, 1995a; FAO, 1996). Obsolete chemical pileups in a country are not only a health hazard but also contribute to the contamination of natural resources and may serve as obstacle to socioeconomic development (FAO, 1995a). Types of hazards encountered with obsolete chemicals include**:**

2.3.1 Hazard to human health

Improper management of obsolete chemical stocks can cause serious health problems to people living near pileups. Even though detailed report and information about such impacts is lacking, conditions and the nature of some stocks, and their closeness to human habitations, leave no doubt and questions about the dangers they may pose

(OECD/FAO/UNEP, 2000).

2.3.2 Contamination of soil

Leaking of chemical stocks can significantly contaminate a large area of land making it unfit for human habitation, cultivation of crops, or any other kind of development. More resources and money are spent on cleaning up such areas which sometimes yields no prudent results (OECD/FAO/UNEP, 2000).

2.3.3 Contamination of water sources

Obsolete chemical stocks located near water bodies contaminates them rendering them unsafe for drinking and for irrigation purposes. In addition to threatening local resources, contaminated water meant for irrigation can introduce residues of toxic chemicals into crops and fish, thereby making them unsafe for trade consumption by humans and livestock (OECD/FAO/UNEP, 2000).

2.4 Mechanisms for managing chemicals in Ghana

There is no comprehensive legislation and laws in Ghana specifically for chemicals but some portions of chemicals and their management can be obtained from various laws. Since 1989 the Environmental Protection Agency has introduced a way of monitoring the importation of chemicals for consumption, industries and for agricultural purposes captioned “Chemical Import Procedures”. The procedures demands screening of all chemicals that are imported into the country before issuing a permit for clearing at the ports. This aims to prevent the import of toxics and chemicals, which are more harmful to human health and the environment (UNITAR, 1997).

2.4.1 Institutions that manage chemicals in Ghana

The Environmental Protection Agency, which is an institution under the Ministry of Environment, Science and Technology, has been championing the implementation of legislation designed to manage chemicals and the general control of pollution in Ghana's environment (UNITAR, 1997).

2.5 Obsolete chemicals in institutions

Toxic and dangerous chemicals can be found in the laboratories of schools offering science and related programmes and other research institutions (FDEP, 2007). Most of these chemical repositories and laboratories in schools have a wide variety of chemicals that are toxic, reactive, explosive, unknown and expired (ADEM, 2002).

These chemicals are usually not well kept and properly managed: they are stored incorrectly at improper positions and places in worn-out and uncovered containers along with other chemicals putting students, staff, and the environment at risk (ADEM, 2002, FDEP, 2007). Having difficulties with what to do with left-over and unused chemicals, they are kept in the laboratories and stores for several years, sometimes decades, leading to deterioration and contamination of the chemicals (FDEP, 2007).

The management and proper storage of toxic and hazardous chemicals in school laboratories and stores has become an important safety matter in the country (MDEQ, 2005). Accidents caused by these chemicals are many and may even results in serious injuries and damages to valuable properties. Hazardous chemicals may accumulate when there is non-availability of tracking system and disposal methods, due to frequent changes in staff and/or changes in the school's curriculum. Most of the staffs are not well trained to recognize and manage the risks of hazardous chemicals and very few schools have a budget for proper chemical storage space and equipment, activities for chemical management, or even hazardous waste disposal (Lynn *et al.*, 2006).

Disposing of excess and expired chemicals is critical in maintaining and establishing safer environmental conditions in schools. It is essential that schools adopt and implement responsible and reasonable chemical management and waste minimization practices. This will go a long way to decrease exposures and the need for flushing out future chemical accumulations (U.S EPA, 2006). The necessary storage facilities, personal protective and emergency response equipment are easily determined when the school reduces the volume of chemicals to the amount and types required for the safe running the school facility and its programs (Lynn *et al.*, 2006).

2.6 Managing chemicals in Schools

Proper management of chemicals is essential since Schools can save huge sums of money for other developmental projects**.** A lot of funds goes to waste if chemicals purchased are not used. Managing hazardous chemicals is the process of controlling chemicals that can have an adverse impact on the environment and public health even in lower concentrations (Boakwah, 2006).

2.6.1 General strategies Of Managing Obsolete Chemicals

Chemicals should be stored based on their compatibility and reactivity. School laboratory attendants and other staffs who work frequently with chemicals must be trained properly in all aspects of managing and handling of chemicals, including safe storage, proper use, potential threats and hazards and proper methods of disposal to help create accident free environment (Benoit, 2002). Stored chemicals must be regularly and routinely checked and inspected for leakages, peeled and torn-out labels, and expiration date to avoid wastage. Worn-out labels must immediately be replaced to prevent unknowns and accidents (Benoit, 2002).

Material Safety and Data Sheet (MSDS) files should be maintained for all chemicals and chemical products in the school. These files should be readily available and accessible to any visitor and stranger who intend to use the chemical, and must be kept near where the chemicals are stored with copies kept in the main office (NHDES, 2007).

2.7 Classification of chemicals

Material Safety Data Sheets (MSDS) are prepared by the manufacturers of chemicals and it indicates the properties, effects, and other characteristics of the chemicals. In many countries, manufacturers, suppliers and importers of chemicals are responsible for providing MSDS (Lunn *et al.*, 1994). The Occupational Safety and Health Administration (OSHA) classifies hazardous chemical as those which can cause physical hazard and health hazard. Chemicals that cause physical hazards are those known to be explosives, flammable ,a combustible liquid, an oxidizer, a compressed gas, selfreactive, self-heating, pyrophoric, and reactive with water, an organic peroxide, or corrosive to metal while the health hazard refers to chemicals which are carcinogens, toxic or highly toxic, reproductive toxins, irritants, corrosives, sensitizers, target organ toxins or aspiration hazards (UCLA, 2014). Chemicals categorizations may be based on the form of threat and danger the chemical can cause or create. Knowledge on these classifications is important for developing an effective storage practices. Examples of such categories may include: flammables/explosives, corrosives (the majority of which in high school laboratories are acids and bases), oxidizers/reactive, toxics/poison, and compressed gases. For easy identification purposes, each of these categories has been given a symbol known as *hazard classification symbol* (Teresa, 2011).

Examples of hazard identification symbols are shown below.

Explosive: a chemical that rapidly and spontaneously releases pressure, gas, and heat when a little shock, pressure or high temperature is applied (Lehto, 1998). Among the categories are division 1.1 which are substances that gives massive explosions, division 1.2 (projection hazards), not as massive explosion like 1.1, division 1.3 which refers to fire hazards and they could be hazard from a minor blast or a minor projection hazard or both, but not a massive explosion hazard. Division 1.4 refers to hazards from blasting agents, very insensitive explosions are categorized as division 1.5 and extremely insensitive and no mass explosions are classified as division 1.6 (Wallace *et al.*, 1999).

Figure 2.1: Explosive chemical symbols found on reagent bottles.

Flammable: chemicals within any of the following criteria:

(i) Aerosol, they are flammables that yield a flame when ignited.

(ii) Gas, are flammables that at ambient temperature and pressure, forms a range of flammable mixtures with air greater than 12% by volume, regardless of the lower limit (Bluff, 1997).

(iii) Flammable liquid is any liquid with a flashpoint below temperatures of 100°F (37.8°C).

(iv) Flammable solids are capable of causing fire through friction, absorption of moisture, spontaneous chemical change, or retained heat from manufacturing or processing and can be ignited readily to burn so vigorously and continuously so as to cause a serious accident.

Figure 2.2: Flammable gas symbols found on gas canisters

Oxidizer: they are chemicals or substances that begin and promote combustion in other materials, hence causing fires to it or by the releasing oxygen and other gases that may support combustion (Wogalter *et al.*, 1987).

Figure 2.3: Oxidising agent symbols found on chemical containers

Toxic: chemicals are regarded as toxic if they are able to cause harm or injury when a reasonable amount enters the body. In order to limit the definition , the OSHA therefore defines toxic as chemicals which have an average lethal dose (LD50) or lethal concentration (LC50), indicating the average lethal inhalation exposure (Boelhouwer *et al.*, 2013).

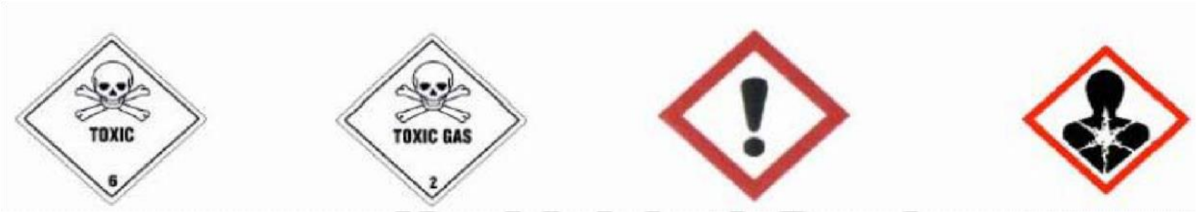


Figure 2.4: Toxic labels on chemical containers.

Corrosives: are chemicals that are capable of causing physical destruction to living tissues or can cause an irreparable and irreversible damages and changes to living tissue through chemical reactions at their first point of contact (ANSI, 2002).

Figure 2.5: Corrosive signs found on chemical containers.

Hazardous chemicals must be stored in isolation or separated from other chemicals and must be in accordance with their compatibility. This will prevent unintended contacts and reactions with each other to cause fires, explosion, or release of toxic or flammable gases or vapors. For example, flammables easily ignites, and oxidizers act as fuel for fire, therefore these two categories of chemicals should be kept away from another whenever possible to avoid causing fires (Byrum *et al.*, 2012). Vapors and stains of chemicals on containers can cause reactions that can degrade labels, shelves, cabinets, and containers themselves. At least, the following compounds should be stored separately from one another; strong acids kept away from strong bases, organic compounds must be separated from inorganics (UCLA, 2014).

2.8 Classification of chemicals by its Nature

Inorganic chemicals are a broad class of chemicals; it embraces all chemicals that do not contain carbon and its derivatives as their principal elements (Jerry, 1985). It however includes carbides, carbonates, cyanides, cyanates, and carbon disulfide, chlorides, fluorides, phosphates, nitride, the oxides, phosphates etc.

2.9 Types of Inorganic chemicals

2.9.1 Chlorides

The chloride ion (Cl^-), from its salt dissociation is soluble in water (Green *et al.*, 2001). It serves as an electrolyte in all the body fluids and it is responsible for establishing and maintaining an equilibrium between the body's acids and bases, disseminating nerve impulses and controlling the movement of fluids in and out of cells. Chlorides being an essential component of life are found in fresh and salty water. Chloride ions (Cl^-) are used during winters for de-icing roadways to prevent accidents (Napgal *et al.*, 2003).

Approximately, it constitutes about 0.05% of the earth's crust (Molly *et al.*, 2012). Chlorides in groundwater are as a result of leaching of fertilizers made with potash or mined salts into the soil (Napgal *et al.*, 2003).

Aquatic effects

Chloride occurs naturally in all type of water. In natural fresh water, however, its concentration is very low. The maximum permissible limit for chlorides in drinking water is 600p.p.m. (Dhangar, 2015). Higher concentrations and amounts of chloride in freshwater may be harmful to aquatic organisms through alterations in the biological processes of maintaining proper concentrations of salt and other solutes in the body fluids of organisms hindering their growth, survival and reproduction (Karraker, 2008). NaCl in water causes the water density to be higher and such water is found at the deepest part of the water body (rivers, lakes, oceans etc.) where current velocities are low (Eddy *et al.*, 2012). This can cause chemical stratification which prevents the diffusion of dissolved oxygen and nutrients within the water layers making it unfit to support aquatic life (Napgal *et al.*, 2003).

Environmental impacts

Chlorides in salts do not only affect the terrestrial roadside vegetation but it also has an impact on newly emerging aquatic plants. Chlorides in salt enters the environment from roadsides through splashing by vehicles and through spraying they are transported into the atmosphere by the wind, melting of snow can carry chloride into the soil (USEPA, N.H. Department of Environmental Service, 2007). Salt causes damage to foliage through dehydration and can also cause osmotic stress which results in distortions in the growth of plant root. It can cause disruptions in nutrient uptake during seed germination and flowering which may eventually lead to plant death (USEPA, 1988). Naturally there are no processes by which chlorides are broken down, metabolized, taken up, or removed from the environment (N.H. Department of Environmental Service, 2007).

Infrastructural impacts

According to a City of Madison Wisconsin Report in 2003, chloride ions increase the conductivity of water and accelerate corrosion. Chloride can penetrate and deteriorate concrete on bridge decking and parking garage structures, and damage reinforcing rods, compromising structural integrity. It damages vehicle parts such as brake linings, frames, bumpers, and other areas of body corrosion. The cost of corrosion damage and corrosion protection practices for highways and the automobile industry have been reported to cost a staggering 16-19 billion dollars a year (N H Environmental Service, 2007).

Effects on humans

Chlorides are not reported to be harmful to humans; however, its sodium portion of salts has been linked to heart and kidney related disease. Sodium chloride has a salty taste at 250 mg/L concentrations; however, calcium and magnesium chlorides are not detected until concentrations of 1000 mg/L is reached. Chlorides in water can lead to the formation of compounds known as trihalomethanes (THMs) in waters which when absorbed in the body can cause cancers.

2.9.2 Sulphates

Sulphates are distributed in nature and can be found in natural waters such as rivers and lakes. The main source of sulphur is rocks near water bodies and from anaerobic biochemical activities of bacteria (Sharma, 2011).

Sulphur is present in the environment in various chemical forms thus sulphides (S^{2-}, H_2S, HS^{-1}), sulphates (SO_4) and sulphites (SO_3) and are metabolize to amino acids by plants, animals and bacteria (Camacho, 2000). Sulphides can be assimilated biologically as sulphates and are the salts of a sulphuric acid. They are used as preservatives in medications and various foods and in some instances occur naturally in some foods like wines and other fermented beverages (Margaret, 2009). Apart from calcium sulfate, strontium sulfate, lead (II) sulfate, and barium sulfate, which are poorly soluble (Camacho, 2000), Many examples of sulfates are highly soluble in water and their presence in potable water can cause an unpleasant taste, and very high quantities can cause a purgative effect in new users of a product (Panduranga *et al.*, 2014). A ligand from the sulfate ion where it is attached by one oxygen atom is called a monodentate and when it is attached by two oxygen atoms it forms a chelate or a bridge, an example is the neutral metal complex $PtSO_4(P(C_6H_5)_3)_2$ where the sulfate ion is acting as a bidentate ligand (Greenwood *et al.*, 1997).

2.9.3 Uses of sulphates

Various forms of sulfates are used in the chemical industry and performs essential roles in our biological systems:

- Lead(II) sulfate is used in association with sulfuric acid to produce lead–acid accumulators (wet cell batteries)
- Sulfate-reducing bacteria, an anaerobic microorganisms which lives in sediment reduces sulfates oxidizes organic compounds or hydrogen which provides energy for chemosynthesis
- Copper sulfate is used as an algaecide to control the spread and multiplication of algae
- Iron sulfate provides iron in which serves as a supplements for humans, animals
- Magnesium sulfate commonly known as Epsom salts is added to water for bathing to cure some skin related diseases such as rashes
- Gypsum, a hydrated calcium sulfate serves as binder in cement used for making building blocks
- sodium lauryl ether sulfate (SLES), is used in manufacturing detergents and surfactants such as soaps, shampoos, toothpaste for cleaning and bathing

(Andrea, 2006).

Environmental Impacts

Sulfates are smaller particles (aerosols) which are obtained from burning fossil fuel and biomass. Sulphates can cause the pH of the atmosphere to decline through the formation of acid rain (Andrea, 2006).The effect of sulfate on climate is the scattering of light and radiations from the sun which increases the Earth's albedo leading to radiative warming from greenhouse gases which causes global warming (David, 1994).

2.9.4 Carbonates

Carbonates are salts formed from carbonic acid in the presence of the carbonate ion, CO^{2-}_3 and most of the salts are insoluble in water at normal temperatures (Kemper *et al., 2002*). According to Petrucci, *et al.,* 2007 bicarbonates can be used to prevent damages from acids; spreading bicarbonate powder in acid leakage zones neutralizes them to prevent possible accidents.

Biological significance

It acts as a buffer in the blood, thus it is able to resist changes in pH when small amounts of acid or bases is added. The pattern for the reaction is as follows: when pH is too low, the concentration of hydrogen ions is higher, so one exhales CO_2.

$H_2CO_{3(aq)} \rightarrow H_{+(aq)} + HCO_{3-(aq)}$

This causes the equation to shift to the left, causing a decrease in the concentration of H^+ ions, resulting in a sharp rise in the pH level to make it a base (Kemper *et al*., 2002). When pH is higher, the concentration of hydrogen ions in the blood becomes lower, so the kidneys excrete bicarbonate HCO_3^- (Petrucci *et al.,* 2007). Food additives containing magnesium carbonate known as E504, serves as laxative in higher quantities (Margarete *et al.*, 2005). Both calcium carbonate and hydroxyapatite, when given as supplements with a test meal, significantly reduces the retention of iron-59, a vital component in the body of animals which is the main constituent of hemoglobin, cytochrome, and other components of the respiratory system of the enzyme (Dawson-Hughes *et al*., 1986).

Environmental significance

$CaCO_3$ can be added to water body’s to neutralize the effects of acid rain in river ecosystems. It can be used to neutralize the acidic effects in soils and in water (Schreiber, 1988). The release of CO_2 from lakes is a substantial contribution to carbon balance in the continent (Cole *et al.,* 1994). Carbonate mineral reactions in groundwater are important for various applications, including carbon sequestration and in situ remediation and the precipitation of carbonate minerals in the groundwater can affect the physical properties such as porosity, permeability, and flow patterns, along with changes in its chemistry (Victoria, 2012).

2.9.5 Nitrates and nitrites

Among the compounds of nitrates and nitrites found in laboratories include sodium nitrite, sodium nitrate, potassium nitrate and ammonium nitrate (Butler and Feelisch, 2008). Potassium nitrite is an inorganic compound comprising of potassium ions K^+ and nitrite ions NO_2^-, forming a white hygroscopic crystalline powder which is soluble in water (Kim-Shapiro, 2005).

Uses of nitrates

Nitrates are mainly used as fertilizer in the production of crops, it is highly soluble and also biodegradable. Nitrates are mainly in the form of ammonium, sodium, potassium, and calcium salts and millions of kilograms are produced annually for agricultural purpose (Wolfgang *et al.*, 2006). Again nitrates are used as oxidizing agents in explosives; sodium nitrate is used for removing air bubbles from molten glass and ceramics (ISO, 1992). Nitrate and nitrite salts are used as food additives in meat to prevent the production and growth of *Clostridium botulinum* which causes botulism (Davidson *et al.*, 2002). This also improves the safety of foods by extending their lifespan (EFSA, 2003).

Effects on humans and the environment

High levels of nitrate can negatively affect the health of human, with infants being the vulnerable, methemoglobinemia from metabolizing some nitrates affects infants at early stages of development (Avery, 1999). Methemoglobinemia in infants which is called blue baby syndrome is caused by exposure of young infants to nitrates; it is a gastrointestinal disorder in infants (FAO/WHO, 1996). High intake of nitrites reacts with nitro stable compounds in the stomach to form *N*-nitroso compounds which is carcinogenic in humans (Speijers *et al.*, 2003; FAO/WHO, 1996, 2003a, b). Congenital malformations relating to high levels of nitrate in drinking water have been reported in Australia (Manassaram *et al.*, 2007). As well, Höring, Nagel &Haerting (1991), reports that nitrate in drinking-water causes goitre. The effect of nitrate on thyroid function can worsen if there is a deficiency of iodine at the same time (Höring, 1992).

In freshwaters or estuarine, high levels of nitrates can cause the death of fish and other aquatic organisms (Romano *et al.*, 2007).

2.9.6 Hyroxides

Hydroxides are diatomicanions with the formula OH^- acts as a base in chemical reactions, a ligand, a nucleophile and a catalyst. Hydroxide ions can form salts, some of which break up in aqueous solution to give out hydroxide ions (Geissler *et al.*, 2001). Large quantities of sodium hydroxide (NaOH) is produced annually (estimated worldwide demand about 44 million tonnes) for several industrial and domestic uses (Kurt *et a*l., 2006). Sodium hydroxide is mostly used as the raw material for producing industrial chemicals and it may also be used in the pulp, paper, metal, food and textile industries, in water treatment and for making various household detergents (CMAI, 2000). Sodium hydroxide (NaOH) is also used by the breweries to clean non-disposable bottles (Keskin *et al.*, 1991). It is used for purification and cleaning purposes example aluminium hydroxide forms a gelatinous precipitate with mud and debris in water which settles at the bottom of treatment systems for filtration (Cetin *et al.*, 2005).

Environmental and Health Issues of Hydroxide

Hydroxides are corrosive substances and are very irritating when it gets in contact with the skin, eye and through inhalation. Hydroxides such as sodium hydroxide can cause burns and damages to tissues of the body (Hnizdo and Vallyathan, 2003). When sodium hydroxide is opened and exposed to the atmospheric air, it readily reacts with the air to produce substances which are toxic to humans if inhaled (De Groot *et al.*, 2002). It can react with water vapour in the air to produce aerosol and mist, which are very corrosive and irritating to the skin (UNEP, 1995). Concentrated aerosols such as silica and asbestos can cause a number of diseases such as silicosis and black lung when inhaled or swallowed (Hnizo *et al.*, 1990). A fatal burn to the dermal tissue of the skin of a worker through contact with NaOH has been reported (Lee *et al.*, 1995). Cello *et al.*, 1980, reports of nine cases of liquid NaOH ingestion, which resulted in oesophageal and gastric injuries. Drinking a solution of 10 g NaOH in water caused the death a man through transmural necrosis of the esophagus and stomach, also swallowing 30 ml of 16 % NaOH caused the death of a 42-year-old female (Hugh and Meagher,1991). Inhaling aerosol of 5 % NaOH by a woman resulted in obstructive lung injury while working in a poorly ventilated room (Hansen and Isager, 1991).

2.9.7 Organic chemicals

Organic solvents are compounds used routinely for research and in the industries (OHSU, 2010). They can be grouped into aliphatic; which has straight chain or branch chain of carbons but do not form ring, such as *n* -hexane, and aromatic compounds with a 6-carbon ring, such as benzene (Chang, 2008). Aliphatics and aromatics can have a halogen as substitute for one of its hydrogen atoms, such as bromoethane and carbon tetrachloride (Carey, 2003). Alcohols, ketones, esters, ethers, aldehydes, and pyridines are substituents in place of hydrogen on aliphatic and aromatic hydrocarbons (Chang, 2008). Organic solvents are considered to be very useful because they are capable of dissolving substances such as oils and fats, resins, paints, dyes and plastics (Orsi *et al.*, 2010). Organic solvents are used for a variety of purposes and applications including: degreasing of substances such as bolts and nut in workshops, cleaning and sterilization of tool and materials for operations in laboratories, paint solvents and thinners, and as pesticide carrier solvents (OHSU, 2010). Chlorinated hydrocarbons, alcohols and the carbonyl solvents are mostly used as the raw materials for the manufacture of other chemicals or drugs or in mixtures with other substances (Orsi *et al.*, 2010).

Health and environmental effects

Working in industries that uses organic chemicals may be exposed to so many hazards; inhalation, ingestion, and absorption of such chemicals into the skin are among the ways in which one can be exposed to the negative effects of these chemicals (Gargouri *et al.*, 2011). The health implications of organic substances on humans depend on its exposure to the neurological system of the body and can be described as either acute or chronic (Gargouri *et al.*, 2010). The acute exposure causes harmful effects to the part of the body with which it gets into with or alters the function of that organ (Kelsall *et al.*, 2005). The vapour from organic substances can be irritating to the respiratory tract, affecting the throat and lungs and skin contacts causes dry and cracks to the affected part (Morb Mortal Weekly Report, 2012). Most organic solvents are harmful to the liver and the kidneys (Longstreth *et al.*, 1994). Trichloroethane and petroleum ether are among the toxic organic chemicals, which causes harmful effects on the heart (Iregren, 1988). Organic solvents are harmful to the central and the peripheral nervous systems (Johnson *et al.*, 1983). The acute effect ranges from intoxication and insensibility, unconsciousness and may even lead to death through failure of the respiratory system. Exposure to n-hexane and methyl n-butyl ketone for long periods causes the

degeneration of nerve cells in the peripheral nervous system which results in restless and pains in legs, muscle cramps, pains, weakness and loss of sensation in the limbs (CDC, 2001). Continuous exposure may also affect the central nervous system causing frequent tiredness and fatigue, difficulty in concentrating, loss of memory, changes in personality and loss of motivation (Seppalainen *et al.,* 1978).Benzene is a common solvent known to cause cancer in humans from industrial use and the extended exposure to it can cause blood cancer in humans (Vrca and Karacic, 1995). Organic solvent exposure may affect male fertility, irregular menstrual flows, increasing rate of spontaneous abortion, congenital malformations and tumours, and other teratogenic effects (OHSU, 2010).

Carbon disulfide has been identified and reported as an occupational reproductive hazard (Johnson, 1983). Reactions of organic solvents in the atmosphere under ultraviolet light or the presence of sunlight produce ground-level ozone, an air pollutant which seriously affect human, animal and plant health when in higher concentrations and can also be destructive to buildings and other materials (OSHA, 2010).

CHAPTER THREE

3.0 MATERIALS AND METHODS

3.1 Selection of Schools

The schools were selected so as to cover all category of second cycle schools in the region that are science biased. Afua Kobi Ampem Girls Senior High school is a model school for science with modern science resources. Toase senior high is a school offering science programme for quite a long time and Nkawie senior high technical being a less endowed school were selected.

3.2 Sorting and Inventory

Oral interviews were conducted with the store keepers and the laboratory attendants to ascertain the number of years that the chemicals have been kept in their chemical store. Obsolete chemicals in the store were sorted into groups as elapsed expiry date, unlabeled and worn out labels.

3.3 Determination of weights of obsolete chemical stock in kilogrammes

The chemicals were weighed with the aid of a measuring/chemical balance.

3.4 sorting into labels and lost labels and inventory

The chemicals were sorted and categorized into those with labels and those that has lost its labels. Lost labels sorted into liquids and solids

3.5 Determination of pH

Litmus test was carried out on each of the groups to confirm their status as acidic or basic. Aslso, pH values were determined on the chemicals to ascertain whether the samples were acidic, basic, neutral chemicals and salts. The pH meter was calibrated with buffer solutions of pH 4 and 9 before using it for the determinations. Prepared liquid portions of chemicals were used for the determination by placing the electrodes of the pH meter into the solution and allowing readings to stabilize before recording. For the powdered or crystal samples, 4.0 g of each were dissolved in 1000 mL of distilled water and portions of the solutions prepared were used for the pH determinations

3.6 Qualitative /confirmatory analysis

Aqueous solutions of the compounds suspected to be salts after the litmus and pH test was prepared by diluting 4g portion of each with distilled water in 1000 cm^3 volumetric flask. Those that had already dissolved into liquids because they were deliquescent, 4ml of their solutions were taking and dissolved with 1000cm^3 of distilled water.

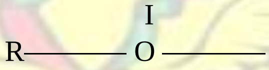
Table 3.1: Qualitative analysis for obsolete chemical cations

Cation	Dilute NH_3 in drops and in excess	Further tests, observations and confirmatory tests
$Na_{(aq)}^{+}$	No ppt, no gas, clear solution forms	Confirmatory test: solution of zinc uranyl ethanoate is added Observation: Yellow ppt forms
Ca^{2+}	No ppt, no gas, clear solution forms	Conc. H_2SO_4 solution is added Observation: White ppt of $CaSO_4$ forms
$Cu^{2+}_{(aq)}$	Light blue ppt of $Cu(OH)_2$ forms on addition of drops. Ppt dissolve in excess to form $[Cu(NH_3)_4]^{2+}$	formation of deep blue $[Cu(NH_3)_4]^{2+}$ upon addition of ammonia solution in excess
$Zn^{2+}_{(aq)}$	White gel ppt of $Zn(OH)_2$ forms ppt dissolves in excess to form $[Zn(NH_3)_4]^{2+}$ complex	
$Fe^{2+}{(aq)}$	pale green ppt of $Fe(OH)_2$ forms ppt insoluble in excess but turns brown on standing for sometime	Confirmatory Test: Few drops K_4 Fe CN $_6$ aq potassium hexacyanoferrate II was added Observation: White ppt forms which turns dark blue on standing
$Fe^{3+}{(aq)}$	Rust or red brown ppt of $Fe(OH)_3$ Forms,ppt insoluble in excess	Confirmatory test: $KSCN_{(aq)}$ is added Observation: Deep "blood" red solution of $Fe(sCN)_3$ $forms$

Table 3.2: Qualitative analysis for obsolete chemical anions

Anion	Dilute HCl or H_2SO_4	Further/Confirmatory Test
$Cl^-_{(aq)}$	Clear solution, no gas , no ppt forms	Aq AgNO_3 added the excess dil HNO_3 Observation: White ppt of AgCl insoluble in excess forming sol complex [Ag(N
Br^-	Clear solution, no gas , no ppt forms	Aq AgNO_3 added the excess dil HNO_3 Observation: cream ppt of AgBr insoluble in excess dil. HNO_3;ppt insol in excess NH_3 but darkens on standing in light
I^-	Clear solution ,no gas , no ppt forms	Aq AgNO_3 added the excess dil HNO_3 Observation :Yellow ppt of AgI forms
SO_4^{2-}	Clear solution, no gas , no ppt forms	Aq $BaCl_2$ is added then excess dil HCl Observation: White ppt of $BaSO_4$ insol in excess HCl
CO_3^{2-}	Effervescence of colourless, Odourless gas CO_2 forms; gas turns limewater milky	Confirmatory test: same as with dilute acid
NO_3^-	Clear solution, no gas, no precipitate	Confirmatory test: add freshly prepared aq Iron (II) tetraoxosulphate (VI) to sample. OBSERVATION: formation of brown ring between the layers

Table 3.3: Qualitative analysis for organic functional groups

TEST	OBSERVATION	INFERENCE
Add Aq $\boldsymbol{Na_2CO_3}$ to samples solution in a test tube	Evolution of colourless odourless gas which turns lime water milky	Gas is CO_2 $Na_2CO_3 + 2CH_3COONa + H_2O + CO_2 \uparrow$
Add Tollen's reagent to sample solution in a test tube	Formation of silver mirror on sides of test tube	Tollen's reagent is made up of Ag$(NH_3)^+$ Ag^+ is reduced to Ag^0 and the aldehyde is oxidized to carboxylic acid anion ($RCOO^-$) sample contains an aldehyde
Add acidified $K_2Cr_2O_7$ to sample solution in a test tube	Yellowish-orange colour turns greenish	Sample contain an alcohol. The chromium in the dichromate ion is reduced from +6 to +3 (Cr_2O_7) $16H^+ + 2Cr_2O_7^- + 3CH_3CH_2OH \rightarrow 4Cr^{3+} + 3CH_3COOH + H_2O$
Add iodine crystals to sample solution in a test tube	Deep Red brown colour forms	The nucleophilic oxygen in the ether redraws an iodine to form a complex  $R—\overset{I}{O}—R$

CHAPTER FOUR

4.0 RESULTS

The sorting and inventory was not an easy task because store-keepers and the laboratory attendants of the selected schools were not at post at the time most of these chemicals were being purchased. The problem was worsened by the absence of proper documentation on the chemicals. Nkawie senior high technical and Toase senior high schools had their new and obsolete state of chemicals kept at the same storeroom. The situation at Afua Kobi is different because they have separated their new stock of chemicals from the obsolete ones and kept them in separate rooms. A total of 439 obsolete chemicals were recorded in this study, of which 398 were identified and 41 were unidentified. Out of the 398 whose identity were detected and classified, 179, representing 44.97 % of the identified were unlabeled while 219 representing 55.03 % were labeled. From Figure 4.1, Afua Kobi Girls' S.H.S was observed to have the highest number of obsolete chemicals (183) while Nkawie S.H.T.S had the least number of 91.

The highest number of unlabeled chemicals was however encounted at Toase S.H.S.

Afua Kobi Girls' S.H.S and Nkawie S.H.T.S recorded 60 and 33 unlabeled obsolete chemical containers respectively and Toase S.H.S recorded 86.

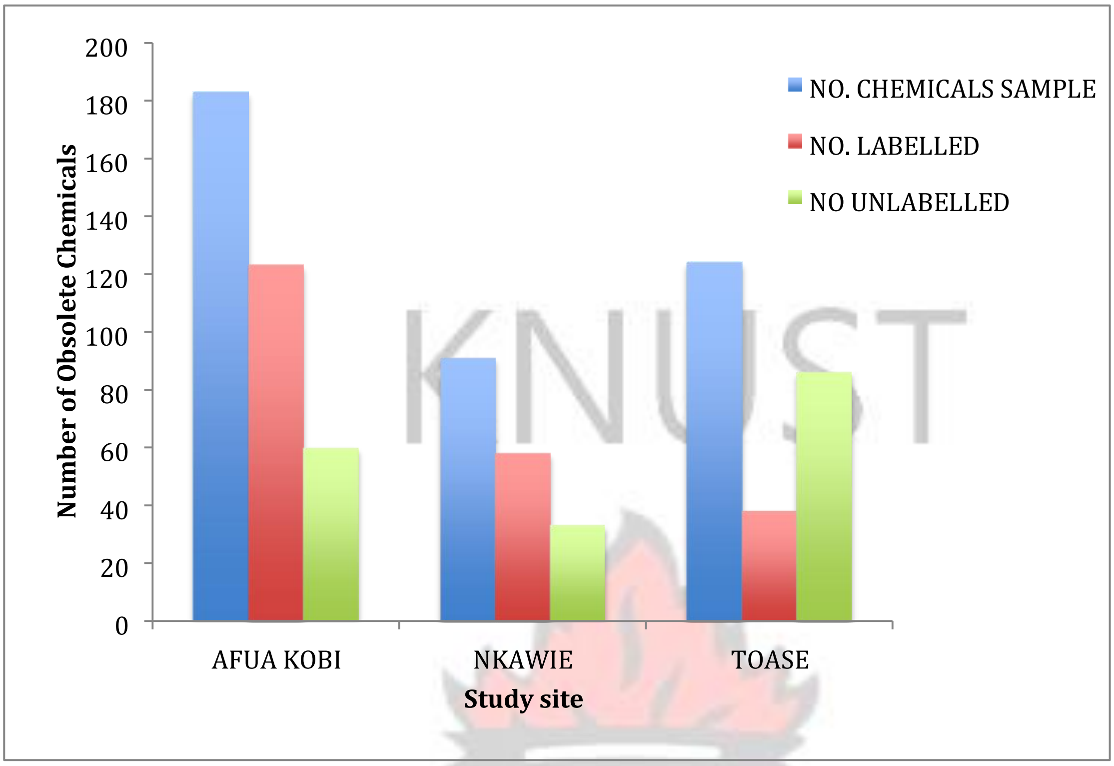


Figure 4.1: Number of obsolete chemicals encountered at the various S.H.S

4.1 Weight of Obsolete Chemicals

The total weight of identified obsolete chemicals from all the schools was 168.2 kg. Nkawie Senior High Technical School recorded the least value of 32.32 kg whiles Afua Kobi Ampem Girls' Senior High School recorded the highest value of 102.5 kg (Figure 4.2). The total weight of unlabeled chemicals was 53.9 kg and that of labeled obsolete chemical containers was 114.3 kg. The unidentified obsolete chemicals had a total weight of 22.5 kg.

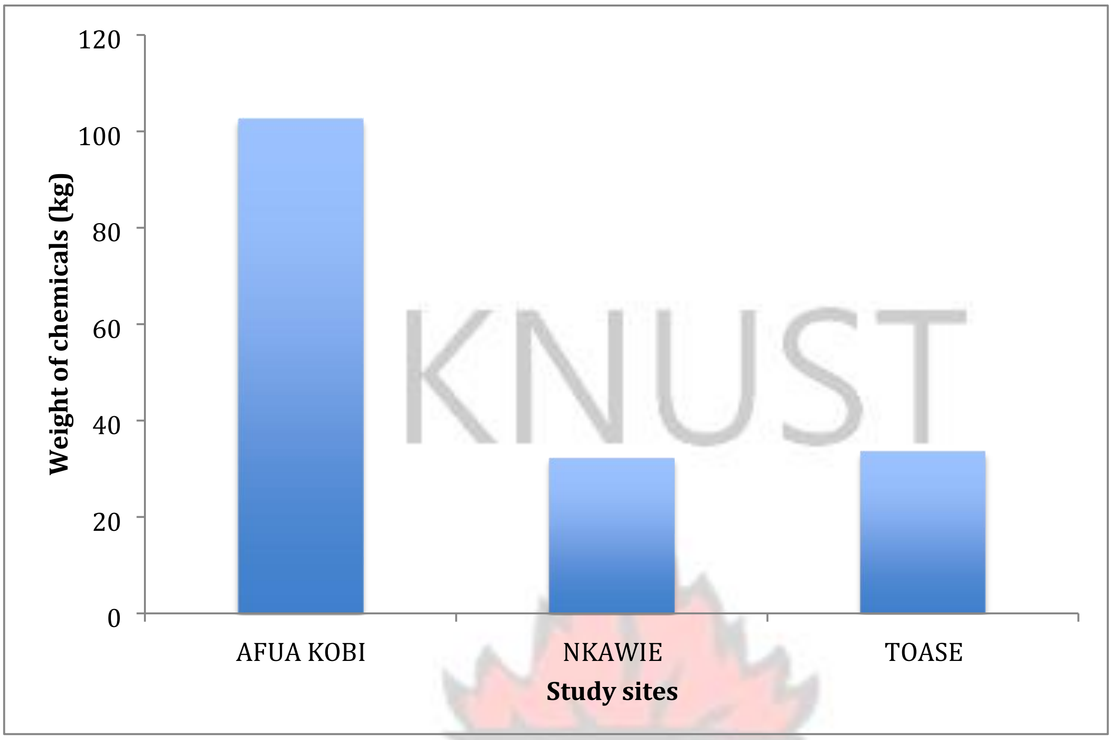


Figure 4.2: Weight distribution of obsolete chemicals from the three Senior High Schools

4.2 Organic and inorganic obsolete chemicals

From Figure 4.3, the weight of inorganic obsolete chemicals present in the schools far exceeded that of organic chemicals. The total weight of inorganic chemicals was 130.5 kg while that of organic compounds was 37.7 kg. Out of the 130.5 kg of inorganic compounds, 96 kg were solids and 34.5 kg were solvents. 27.6 kg of the 37.7 kg organic compound were solvents while 10.1 kg were solids. Afua Kobi Ampem Girl' S.H.S recorded the highest quantity of inorganic chemicals (93 kg) but the least organic chemicals (9.5 kg). Nkawie S.H.T.S had as much inorganic chemicals as organic compounds (16.1 kg). Again Nkawie recorded the least quantity of inorganic compounds while Toase S.H.S had the least amount of organic compounds.

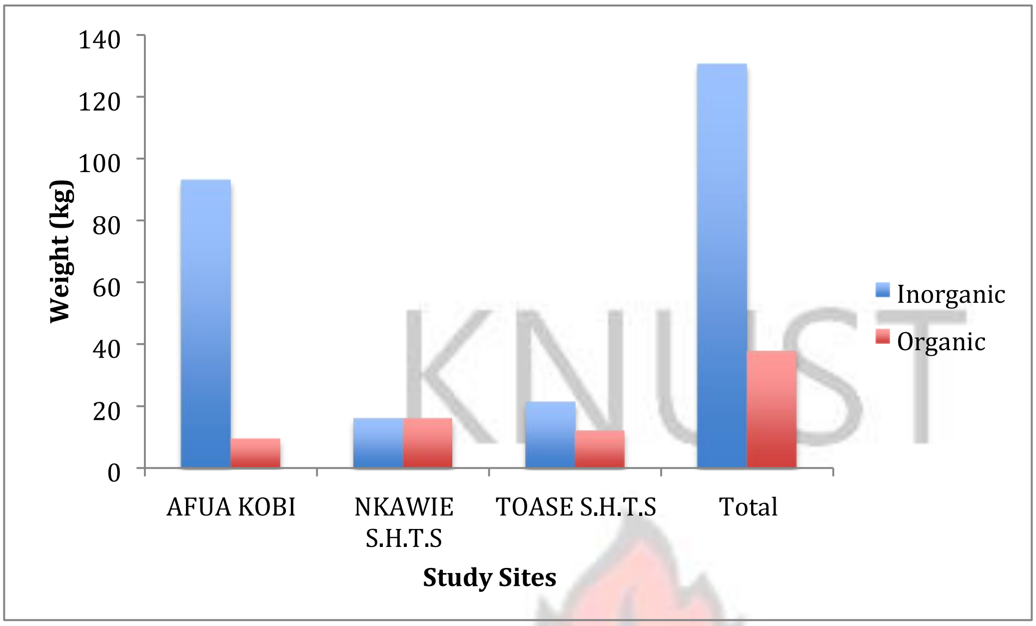


Figure 4.3: Comparison of amount of organic and inorganic compounds

4.3 Quantity of the types of inorganic compounds

From the graph representing the total of the specific ions and functional groups, the sulphates recorded the highest value in terms of weight representing 15.5 kg followed by the chlorides with a weight of 11.7 kg. The carbonates, nitrates and iodates recorded 11.2 kg, 7.0 kg and 7.5 kg weights respectively.

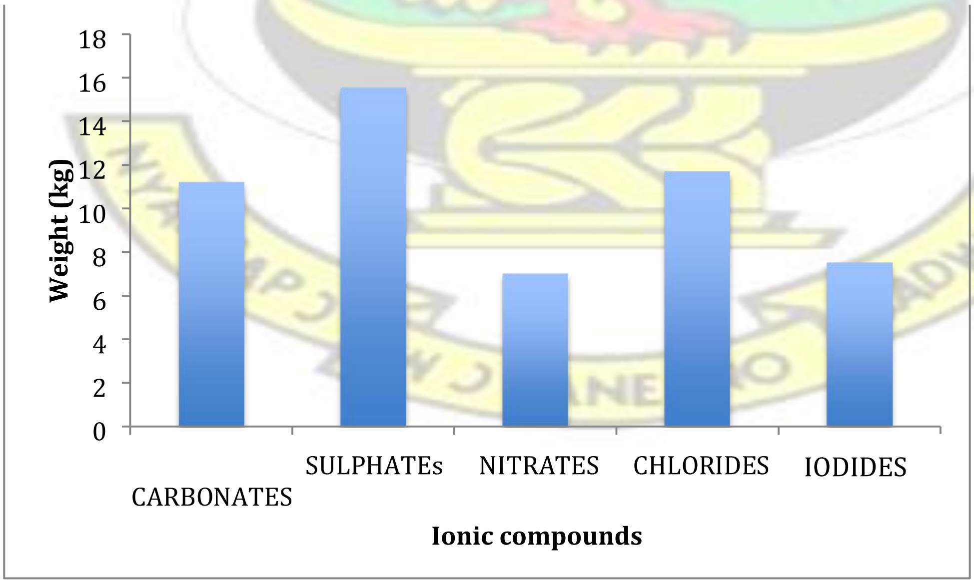


Figure 4.4: Weight of different categories of inorganic obsolete chemicals found

in the schools

4.3.1 Sulphates

From Figure 4.5, Toase S.H.S recorded the highest quantity of obsolete sulphates (6.0 kg). Afua Kobi Ampem Girl's S.H.S recorded the least amount of 4.0 kg and Nkawie S.H.T.S recorded an amount of 5.5 kg of sulphates.

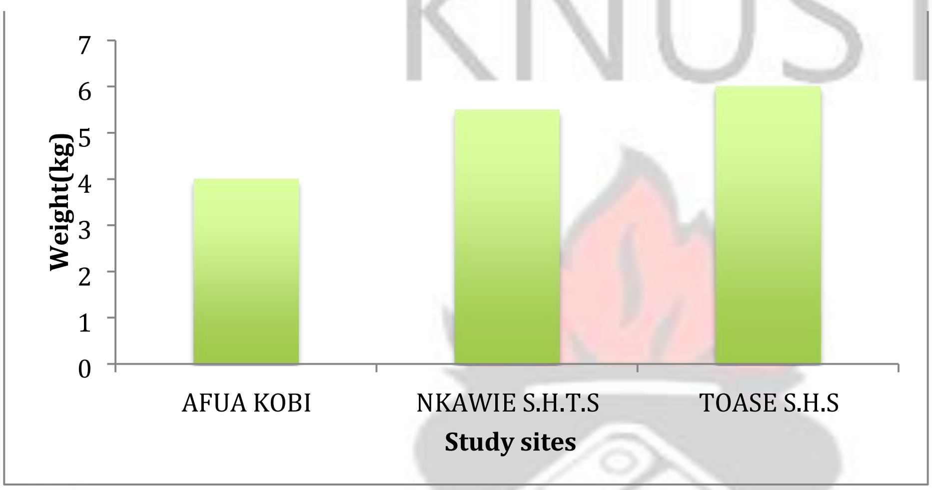


Figure 4.5: Weight of obsolete sulphate containing compounds in the three schools

4.3.2 Carbonates

Afua Kobi Ampem Girls' Senior High recorded the highest amount of carbonates (8.0 kg). Toase Senior High School recorded the second highest with an amount of 2.0 kg while Nkawie Senior High Technical School recorded the least amount of carbonates (1.0 kg) as shown in Fig. 4.6

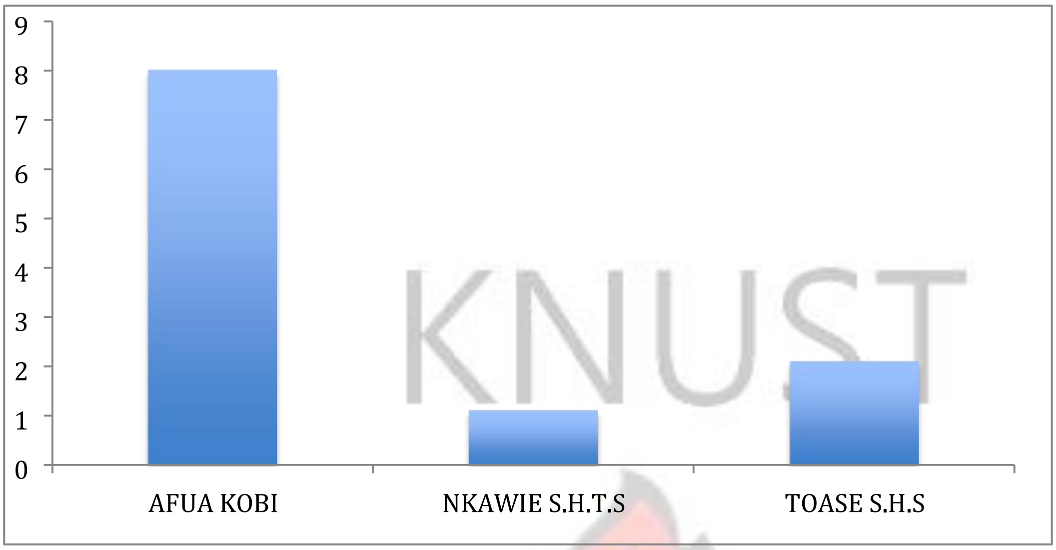


Figure 4.6: Weight of carbonate containing compounds

4.3.3 Chlorides

From Figure 4.7, it is obvious Afua Kobi Ampem Girls' S.H.S has the highest amount of obsolete chloride compounds (6.0 kg). Toase Senior High School recorded 3.2 kg and Nkawie Senior High Technical School recorded the least weight of 2.5 kg.

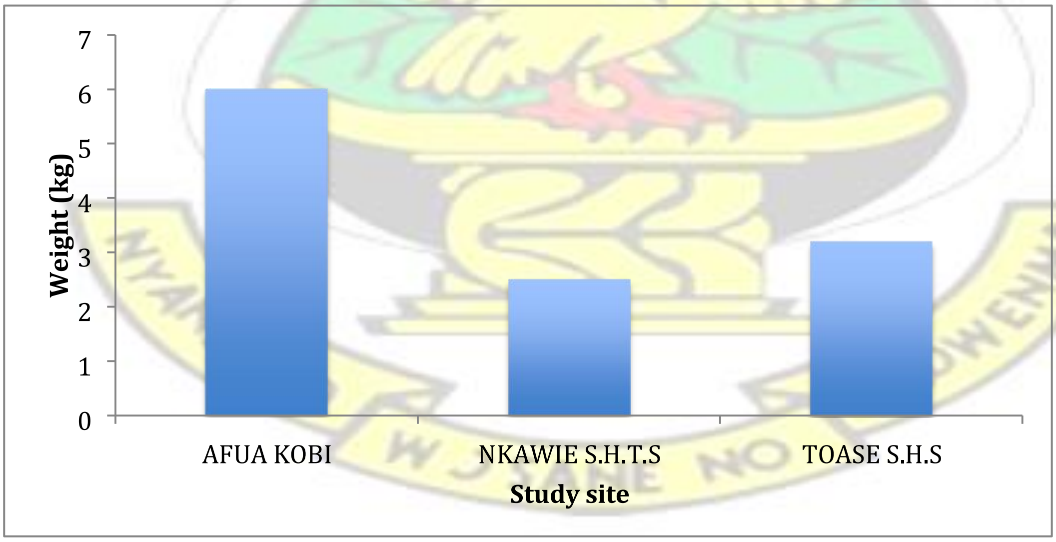


Figure 4.7: Weight of obsolete chloride compounds in three schools

4.3.4 Nitrates

From Figure 4.8 the amount of nitrate recorded at both Toase S.H.S and Nkawie Senior High Technical School was 1.0 kg. Afua Kobi Ampem Girls S.H.S recorded the highest amount of 5.0 kg.

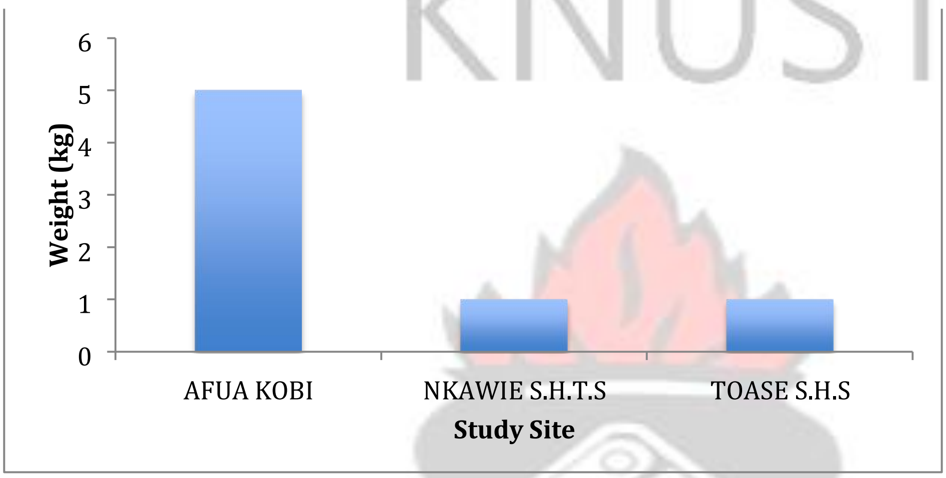


Figure 4.8: Weight of Obsolete Nitrate compounds in three schools.

4.3.5 Iodides

Toase S.H.S recorded 1.0 kg of iodates, Nkawie Senior High Technical School recorded a quantity of 1.5 kg and Afua Kobi again recorded the highest quantity of 5.0 kg as shown in Fig. 4.9

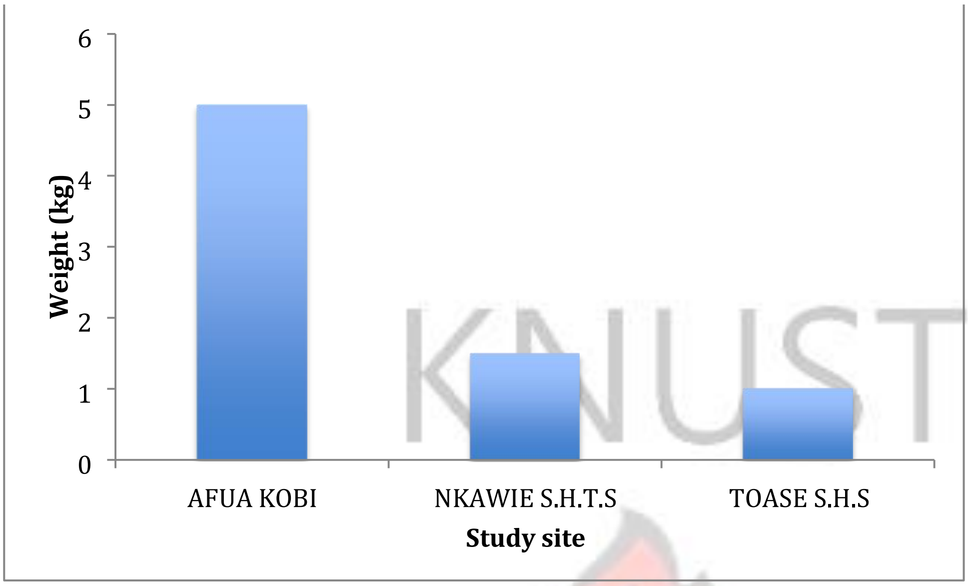


Figure 4.9: Weight of iodides from the three schools.

4.4 Organics

In all, a total of 37.7 kg was recorded for the organic compounds Nkawie S.H.T.S recorded the highest followed by Toase senior high and Afua Kobi Ampem Girls' S.H.S recording the least. From Fig. 4.10, a total of 18.8 kg being the highest was recorded for compounds having the carboxylic acid functional group. This was followed by the ether recording a value of 8.2 kg, the alcohol and the carbonyl (aldehyde) recorded values of 6.8 kg and 3.9 kg respectively.

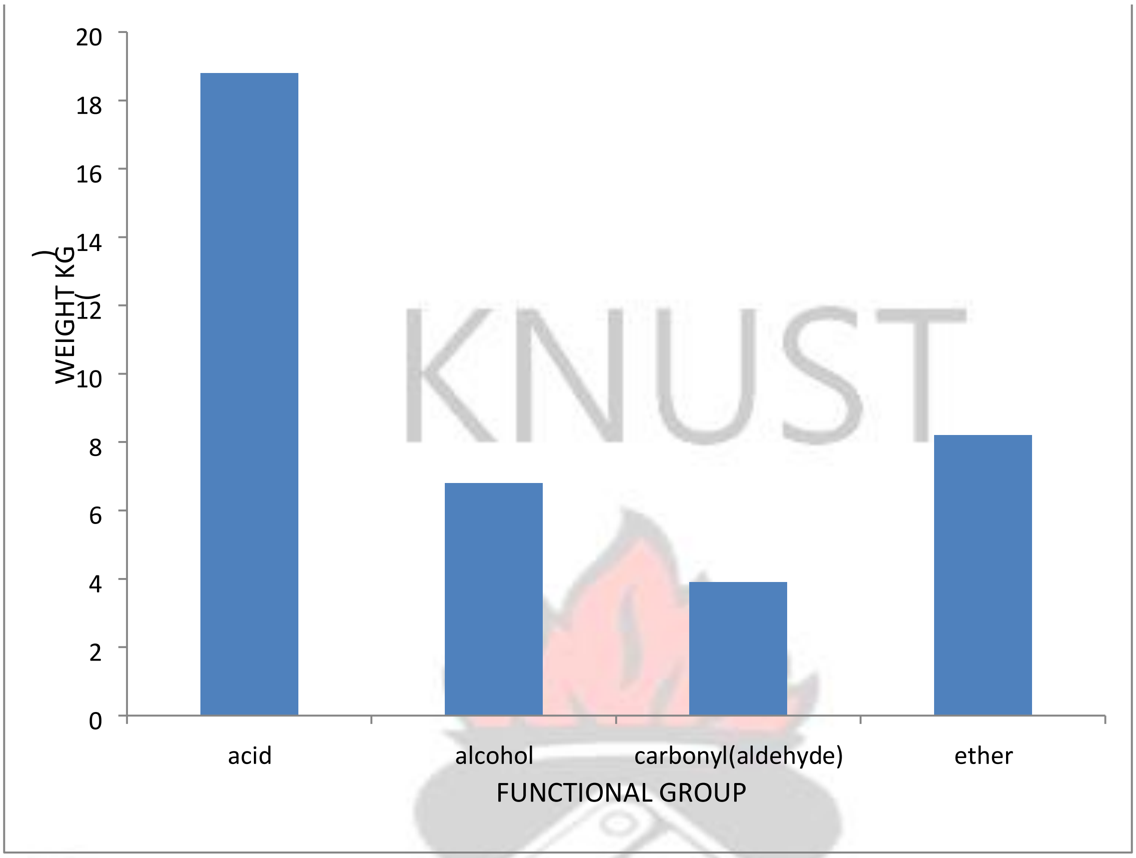


Figure 4.10: Weight of various organic functional groups from the three schools

4.5 Weights of obsolete acids, bases and salts after the litmus and pH meter test

From Fig. 4.11, 151.2 kg representing 39% of the inorganics were acids, 33.4 kg representing 26% were bases whilst 45.9 kg representing 35% were salts after testing for pH

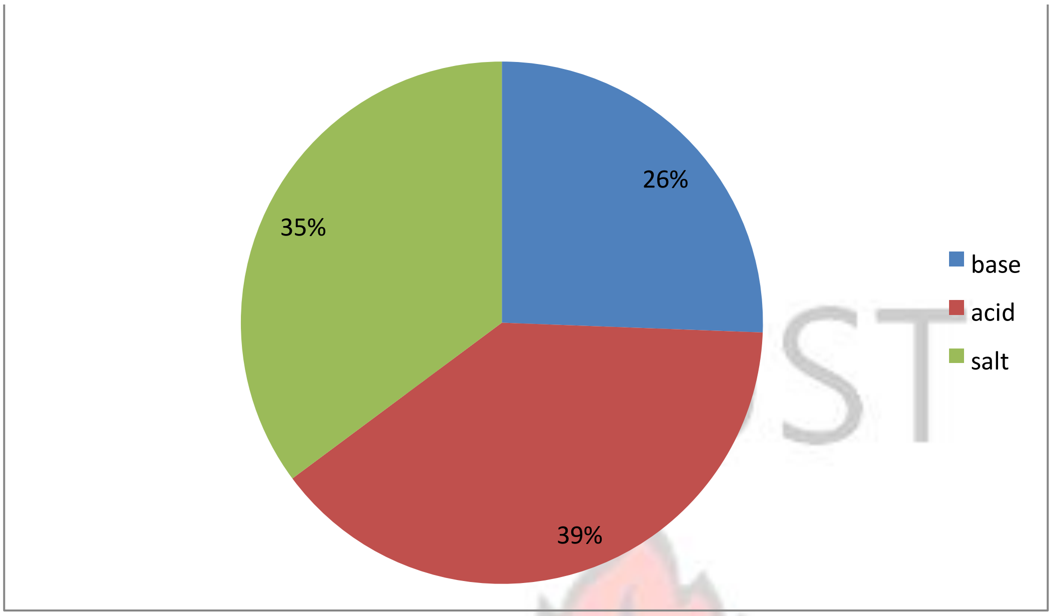


Figure 4.11: percentage weight distribution of inorganic compounds

CHAPTER FIVE

5.0 DISCUSSION

Chemicals are used in the laboratory for research work and practical demonstrations. Most of the chemicals have short shelf life with a wide range of physical and chemical properties. There is no agency present to monitor the availability and use of such chemicals in our secondary schools. The teachers and laboratory technicians are therefore left to decide what to do with such chemicals. The total of 439 different types of chemicals reported for these senior high schools stores is alarming and steps need to be taken to address this issue. According to MDEQ (2005) and US EPA (2006), a total of 570 different chemicals were reported in a survey conducted for over 150 high schools in Montana. These high numbers can be attributed to the ready availability of donors of such chemicals to the schools.

It is very clear that a wide range of chemicals is being used in our schools and this exposes students, staff and chemical users to serious risk. Most of the chemicals used in school curricula are hazardous and are contained in decrepit containers, which make them very difficult to remove. Some of the containers are broken whiles others do not even have caps on them. These quantities of chemicals if not disposed off properly will eventually leak into the environment. Schools often purchase more chemicals than they need to obtain lower bulk pricing and in some cases, they end up not purchasing the right or required chemicals for the curricula activities. Surplus stock can also result from the following; Changes in curricula, Changes in staff or Donations. Afua Kobi Ampem Girls' Senior High School had the highest weight of obsolete chemicals that is even more than the rest of the schools combined. This can be attributed to the fact that Nkawie S.H.T.S and Toase S.H.S are either managing their chemicals well or do not receive large quantities of chemicals. 179 representing 44.97 percent of the identified unlabeled chemicals in these schools is worrying. They do not have any information on them to tell the type of chemicals they are. This probably could be the reason why these chemicals were left unattended to making them go waste. Most schools do not evaluate the health, safety and reactivity criteria, or storage requirements before storing chemical products at a specific place. Thus, schools often end up parking chemicals that are very toxic, reactive and even explosive at one place due to the fact that most of such products have no labels on their containers. After the practical work, most of the chemicals are not returned to their right bottles and appropriate storage places. The chemicals are also tagged with letters written in ink, which may easily be deleted when the chemicals flow on the walls of the container when pouring for use. Most of the chemicals found to be obsolete were purchased or distributed without any proper purchasing control. Upon interaction with store managers, it was found that the Ghana Education Service (GES), who used to distribute chemicals to senior high schools, did so without taking measures to inquire from the schools the type and quantity of chemicals they would need.

In the case of Afua Kobi Ampem Girls' Senior High School, they often receive some quantities of chemicals from an N.G.O in the United States called zeta-Phy-Beta. This probably could be the reason for high quantity of obsolete chemicals in their storeroom. Donation is a good gesture, which should yield a progressive rather than a retrogressive result. In most cases, donation of chemicals to schools has yielded a retrogressive results leading to the accumulation of such chemicals in schools. Most of the chemicals donated by industries are near or have past their expiration date but because of the high cost involve for their disposal, donors deliberately add some of the frequently used chemicals (e.g. HCl, NaOH, and H_2SO_4) in schools to entice staff and personnel to accept their offer. Most staff and personnel do not take time to check the content but just skim through the list to find out whether some of the frequently used chemicals are there.

The 34.5 kg of inorganic liquids of the total 130.5 kg obtained shows that a very small proportion of inorganic liquids are left to become obsolete (waste). The reason is that most of the liquid inorganic compounds (nitric acid, sulphuric acid, hydrochloric acid etc.) are frequently used in most of the school laboratory works. The 96.0 kg of inorganic solid recorded in the three stores is quite significant. Its accumulation may be due to the fact that, most of these chemicals are unlabeled and as such it was very difficult in identifying these chemicals for use. The total weight of 37.7 kg for the organic obsolete chemicals may be due to the fact the curricula for the senior high schools does not demand most research and practical work in organic chemistry and as such they are of low purchase by the schools.

Out of the total 37.7 kg for obsolete organic chemicals in the three schools, Nkawie Senior High Technical School recorded the highest of 16.1 kg. This probably could be due to the fact that these chemicals were unlabeled and as such they were not easily identified for use in practical lessons. In addition, because the technical skills department of the school also uses some of the organic solvents for their practical work, the school usually purchases higher quantities of these organics, which ends up losing their labels, and later to be discarded as obsolete.

Results of the sampled t-test on the labeled and unlabeled weights, weights of organic and inorganic obsolete chemicals, weights of organic solid and organic solvents and weights of inorganic solid and inorganic solvents showed that there is no significant difference between any of them, the *p*-values were > 0.05. This means that these weights were occurring just by chance and as such there were external factors influencing the presence of the chemicals. It could probably be due to the fact that almost the same kind of experiments are conducted in these schools when it is getting to final examination periods that the students are taught practical work.

5.1 Products requiring further testing before disposal

A total weight of 22.5 kg from 41 obsolete chemicals could not be identified because their labels were deteriorated or off and did respond to any of the tests, namely the litmus test, pH test and qualitative analysis were considered as *unidentified*. These chemicals have lost their labels due to prolong storage and poor management. Most of such chemicals were liquefied and some were powdery substances while others were hardened and caked, some of them have completely changed in colour. The accumulation of these chemicals has created and continues to create problems (with spacing) for laboratory personnel beside the problem of disposing them.

Unidentified chemical wastes cannot be transported or disposed off without the necessary legal backing. To do this, it is important to have as much information about the material as possible. To identify an unknown compound, testing may be needed to determine the characteristics of the waste. Analyses that needs to be done include, IR, MS, GC and UV (Woode, 2008).

Disposal of waste chemicals goes along with its economic demerits and impacts on the environment even when these chemicals are identified. This problem is worsened when the chemicals are however not identified (FAO1995a). Fortunately, most of the obsolete chemicals in the schools were identifiable. Disposing obsolete chemicals off effectively is critical to creating safety in schools and is an important step in achieving proper chemical management.

5.2 Bad laboratory practices found in the schools

Among the common bad laboratory and storage practices found in almost all the schools included the following: dangerous solvents such as HCl and H_2SO_4 were kept above eye level on shelves, others kept on the floor, incompatible chemicals were found next to each other on shelves this was partly due to the arrangement of the chemicals based on their physical state that is whether a solid or liquid. In Toase senior high school, this problem could be attributed to the arrangement of the chemicals in alphabetical order. Chemical inventories were not found in all the storerooms and laboratories and some reagent bottles had their labels worn out partially or completely**.**

CHAPTER SIX

CONCLUSION AND RECOMMENDATIONS

6.1 Conclusion

Both organic and inorganic obsolete chemicals were identified from the study sites. It was also clear that there were no clear-cut management protocols in place at the study sites for the management of these chemicals.

6.2 Recommendations

1. There is the need to set up more effective monitoring and evaluation bodies to regulate quantities of chemicals at these schools.
2. There should be a policy and guidelines by the Ghana Education Service on chemical use in schools in order to prevent stockpiling of these chemicals in the schools.
3. Donor organizations should be advised to properly evaluate the use of chemicals they donate to schools in order to prevent the donation of excessive amounts to the schools.
4. There is the need to keep proper documentation (records) on all chemical stocks in the various school laboratories and store rooms so that in the absence of the storekeepers and technicians new comers can locate the exact positions of the chemicals without mixing old stock with new ones.

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APPENDIX

Table 1: Weight of obsolete organic and inorganic chemicals.

School	No. chemical samples	weight of inorganic/kg solvent(liquids)	Weight of inorganic solids/kg	Weight of organic solvents/kg	Weight of organic solids/kg	Total weight/kg
AFUA KOBI	183	15	78	6.3	3.2	102.5
NKAWIE S.H.T.S	91	16.1	-	12	4.1	32.2
TOASE S.H.T.S	124	3.4	18	9.3	2.8	33.5
TOTAL	398	34.5	96	27.6	10.1	168.2

Table 2: Weight of labeled and unlabeled obsolete chemicals.

SCHOOL	NO. CHEMICALS SAMPLE	NO. LABELED	NO UNLABELED	WEIGHT LABELED/Kg	WEGHT UNLABELED	TOTAL WEIGHT
AFUA KOBI	183	123	60	74.5	28	102.5
NKAWIE	91	58	33	20.6	11.6	32.2
TOASE	124	38	86	19.2	14.3	33.5
TOTAL	398	219	179	114.3	53.9	168.2

Table 3: Weight of specific inorganic ions.

SCHOOL	WEIGHT OF CARBONATES/Kg	WEGHT OF SULPHATES/Kg	WEIGHT OF NITRATES/Kg	WEIGHT OF CHLORIDES/Kg	WEIGHT OF IODATES/Kg	WEIGHT OF ORGANICS/Kg
AFUA KOBI	8.0	4.0	5.0	6.0	5.0	-
NKAWIE S.H.T.S	1.1	5.5	1.0	2.5	1.5	-
TOASE S.H.S	2.1	6.0	1.0	3.2	1.0	1.0
TOTAL	11.2	15.5	7.0	11.7	7.5	1.0

Table 4: ANOVA of the mean weight obsolete chemicals from the three schools.

Weight in kg

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	808.732	2	404.366	.900	.440
Within Groups	4042.505	9	449.167		
Total	4851.237	11			

Table 5: Multiple Comparisons of the mean weight of obsolete chemicals from the three schools.

Dependent Variable: Weight in kg Sidak

(I) Schools	(J) Schools	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
					Lower Bound	Upper Bound
AfuaKobi SHS	Nkawie SHS	17.57500	14.98611	.613	-26.2275	61.3775
	Toase SHS	17.25000	14.98611	.626	-26.5525	61.0525
Nkawie SHS	AfuaKobi SHS	-17.57500	14.98611	.613	-61.3775	26.2275
	Toase SHS	-.32500	14.98611	1.000	-44.1275	43.4775
Toase SHS	AfuaKobi SHS	-17.25000	14.98611	.626	-61.0525	26.5525
	Nkawie SHS	.32500	14.98611	1.000	-43.4775	44.1275

Table 6: ANOVA of the mean weight of obsolete chemicals by type (organic or inorganic).

Weight in kg

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	717.653	1	717.653	1.736	.217
Within Groups	4133.583	10	413.358		
Total	4851.237	11			

Table 7: ANOVA of mean weight of obsolete chemicals by nature (solutes or solvents).

Weight in kg

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	161.333	1	161.333	.344	.571
Within Groups	4689.903	10	468.990		
Total	4851.237	11			

Table 8: ANOVA of mean weight of different ionic compounds in the three schools.

Schools

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	7.333	10	.733	1.100	.505
Within Groups	2.667	4	.667		
Total	10.000	14			

Table 9: ANOVA of mean weight of obsolete ionic compounds between the three schools.

Weights

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	32.529	2	16.265	4.817	.029
Within Groups	40.520	12	3.377		
Total	73.049	14			

Table 10: Multiple Comparisons of mean weight of obsolete chemicals in the three schools

Dependent Variable: Weights
Sidak

(I) Schools	(J) Schools	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
					Lower Bound	Upper Bound
AfuaKobi SHS	Nkawie SHS	3.28000*	1.16218	.045	.0604	6.4996
	Toase SHS	2.94000	1.16218	.077	-.2796	6.1596
	AfuaKobi SHS	*	1.16218	.045		-.0604
	Toase SHS		1.16218	.989		2.8796
Nkawie SHS		-3.28000			-6.4996	
		-.34000			-3.5596	
	AfuaKobi SHS	-2.94000	1.16218	.077	-6.1596	.2796
Toase SHS	Nkawie SHS	.34000	1.16218	.989	-2.8796	3.5596

*. The mean difference is significant at the 0.05 level.

Table 11: ANOVA of mean weight of ionic compounds by type.

Weights

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	16.049	4	4.012	.704	.607
Within Groups	57.000	10	5.700		
Total	73.049	14			

Table 12: Multiple Comparisons of the mean weight of ionic compounds by type.

Dependent Variable: Weights
Sidak

(I) Ions	(J) Ions	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
					Lower Bound	Upper Bound
1.00	2.00	-1.43333	1.94936	.999	-8.3879	5.5212
	3.00	1.40000	1.94936	.999	-5.5545	8.3545
	4.00	-.16667	1.94936	1.000	-7.1212	6.7879
	5.00	1.23333	1.94936	1.000	-5.7212	8.1879
2.00	1.00	1.43333	1.94936	.999	-5.5212	8.3879
	3.00	2.83333	1.94936	.857	-4.1212	9.7879
	4.00	1.26667	1.94936	.999	-5.6879	8.2212
	5.00	2.66667	1.94936	.894	-4.2879	9.6212
3.00	1.00	-1.40000	1.94936	.999	-8.3545	5.5545
	2.00	-2.83333	1.94936	.857	-9.7879	4.1212
	4.00	-1.56667	1.94936	.997	-8.5212	5.3879
	5.00	-.16667	1.94936	1.000	-7.1212	6.7879
4.00	1.00	.16667	1.94936	1.000	-6.7879	7.1212

	2.00	-1.26667	1.94936	.999	-8.2212	5.6879
	3.00	1.56667	1.94936	.997	-5.3879	8.5212
	5.00	1.40000	1.94936	.999	-5.5545	8.3545
5.00	1.00	-1.23333	1.94936	1.000	-8.1879	5.7212
	2.00	-2.66667	1.94936	.894	-9.6212	4.2879
	3.00	.16667	1.94936	1.000	-6.7879	7.1212
	4.00	-1.40000	1.94936	.999	-8.3545	5.5545

1.00 Carbonates, 2.00- Sulphates, 3.00- Nitrates, 4.00- Chlorides, 5.00- Chlorides

Table 13: qualitative test for the nitrate ions and copper ion

Test	Observation	Inference
Sample + heat	Decompose to give brown fume	The brown fumes are NO_2 from NO_3
Sample + water	Dissolves to give a blue solution	Cu^{2+} is suspected
Sample solution +NH_3 (aq) in drops and in excess	Blue ppt Ppt dissolve to give deep blue solution	Cu^{2+} is confirmed.

Table 14: qualitative test for sulphates ions

Test	Observation	Inference
Sample solution + $AgNO_3$ (aq)	No visible change	Cl^-, CO_3^- absent
Dilute HCl is added to the solution	No visible change in colour	Cl^-, CO_3^- absent
Another sample solution + $BaCl_2$ solution	No visible change in colour and no ppt formed	SO_4^{2-} ion is absent
Dilute HCl is added to the solution	No visible change and no ppt formed	Confirms that SO_4^{2-} is absent

Table 15: Qualitative test for carbonates and chloride ions

Test	Observation	Inference

Sample+ water	Clear solution forms	
Sample solution +dilute NaOH solution in drops and then in excess	No visible change, no gas, no ppt forms	Na^+ may be present
Mixture + zinc uranylethanoate	Yellow ppt forms	Na^+ is confirmed
Sample solution + $AgNO_3$ (aq)	White ppt forms	Cl^-, CO_3^{2-} suspected
Dilute HCl added to the ppt	Ppt insoluble	CO_3^{2-} confirmed and Cl^- ion absent.
Dilute ammonia solution is added	Ppt insoluble	CO_3^{2-} Confirmed
Sample solution + $BaCl_2$ solution	No visible change(still clear solution)	SO_4^{2-} absent

Table 16: qualitative test for the alcohols

Test	Observation	Inference
Sample + ethanoic acid	Clear solution	
Mixture + 2 drops of conc. H_2SO_4 + Heat	Fruity smell produced	Alcohol may be resent
Sample +$K_2Cr_2o_7$ solution	Yellowish/orange solution	
Solution+ heat	Mixture turns turns greenish	Alcohol is confirmed

Figure 1: Obsolete chemicals on the shelf at the study site

Figure 2: Obsolete chemicals without labels on a shelf at the study site

Figure 3: Obsolete chemicals without labels on a shelf at the study site

Figure 4: Obsolete chemicals without labels on a shelf at the study site

Figure 5: Obsolete chemicals with labels on a shelf at the study site