# MANAGEMENT OF OBSOLETE CHEMICALS

**By**

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## DECLARATION

I hereby declare that this submission is my own work towards the MSc and that, to the best of my knowledge, it contains no material 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

*With love and affection; gratitude and appreciation; I humbly dedicate this thesis to my uncle and his wife,* ***Mr. & Mrs. Baidoo*** *of Adom Mbroso Cold stores Ltd.*

*May God replenish all that you have spent on me.*


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To the Most High God I say; *blessing, and glory, and wisdom, and thanksgiving, and honour, and power, and might, be unto our God for ever and ever. Amen (Rev. 7:12)*

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## ABSTRACT

Most educational institutions in Ghana have hundreds of chemicals in their stores, but few of them know what they have and where they are located. Hazardous chemicals accumulate when there is no tracking system and no disposal plan or when there are changes in staff and /or in curriculum. Industrial donations can compound the problem. 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 along side old stocks. Other personnel resort to dumping of chemicals at one corner on the store floors, thus reeking the stores.

In this study, quantities of current and obsolete chemicals were inventoried from the stores of Biological Department, Chemistry Department and Pharmacy Department, all of KNUST and also from Anglican Senior High School, Kumasi High Senior High School, and Technology Senior High school in Kumasi. Qualitative analysis and melting point determination were conducted on some of the chemicals to ascertain their chemical and physical properties. The melting point determination was done using Electro-thermal melting point apparatus.

Of the total weight of 1,082.7 kg of chemicals inventoried, 886.9 kg representing 81.9% was found to be obsolete and were grouped as; products requiring further testing and products that were definitely obsolete. The total weight of products requiring further testing was 42.7 kg and comprised of; 22.3 kg of acids, 10.7 kg of base and 5.4 kg neutral products. The remaining 4.4 kg could not be opened by hand due to the rusty nature of the caps. The total weight of products that were definitely obsolete was 844.2 kg and consisted of; 101.8 kg of corrosive chemicals, 28.8 kg of explosives, 102.0 kg of flammable/combustible, 61.5 kg of oxidizing materials, 19.0 kg of reactive, 235.1 kg of toxic/poison, 171.3 kg of non-hazardous, and 124.0 kg of unclassified products.

The results revealed that the generation of obsolete chemicals for the tertiary level on average was about 6 times higher than that for the senior high schools. Another finding was that the obsolete chemicals found in the stores could be classified as toxic, corrosive, reactive, explosive, oxidizing, highly inflammable or non-hazardous in nature. Due to the hazardous nature of the chemicals found, the quantities and economic considerations, proper disposal method of these chemicals have been proposed in this work.

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## LIST OF ABBREVIATION

| | |
|---|---|
| **ADEM** | Alabama Department of Environmental Management |
| **DAC** | Development Assistance Committee |
| **DRE** | Destruction and Removal Efficiency |
| **EPA** | Environmental Protection Agency |
| **FAO** | Food and Agriculture Organization of the United Nations. |
| **FDEP** | Florida Department of Environmental Protection |
| **FLS** | Front Line Staff |
| **LFG** | Landfill Gas |
| **GIFAP** | International Group of National Associations of Agrochemical Manufacturers |
| **MDEQ** | Montana Department of Environmental Quality |
| **MSDS** | Material Safety Data Sheet |
| **NFPA** | National Fire Protection Association |
| **NHDES** | New Hampshire Department of Environmental Service |
| **OECD** | Organisation for Economic Co-operation and Development |
| **OSHA** | Occupational Safety and Health Administration |
| **PPRSD** | Plant Protection and Regulation Services Department |
| **SMS** | Subject Matter Specialists |
| **UNEP** | United Nations Environmental Programme |
| **UNITAR** | United Nations Institute for Training and Research |
| **US-EPA** | United State Environmental Protection Agency |
| **VDEC** | Vermont Department of Environmental Conservation |
| **WHO** | World Health Organization |

# CHAPTER ONE

## 1.0 INTRODUCTION

Dealing with obsolete chemical stocks is far-reaching, global and urgent. Most developing countries including Ghana are facing problems with stocks of obsolete chemicals whose long-term effects may have widespread implications and incalculable adverse effects on human health and the environment. Safe and environmentally sound disposal facilities of these chemicals are rarely available in these countries. Governments wishing to address this problem often lack standards and directions (FAO, 1995a).

Obsolete chemicals are defined by the Food and Agriculture Organization (FAO) as stocked chemicals that can no longer be used for their original purpose or any other purpose and therefore require disposal. In some publications, obsolete chemicals could be described as *chemical waste* and covers unneeded, outdated or expired, and unknown chemicals, which are normally contained in aged and decrepit containers. All these are considered hazardous (GIFAP, 1985).

The accumulation and bad management of obsolete chemicals including hazardous pesticides constitute a threat to human health and the environment, locally, regionally and globally (Kasrstensen, 2005). Storage facilities and conditions in developing rarely meet internationally accepted standards. For example, containers are often stored in the open exposed to harsh weather conditions which accelerate the wear and tear of containers. Many containers deteriorate and leak their liquid contents into the soil, eventually contaminating groundwater and the environment while the powder contents of worn or broken containers are often dispersed into the environment by wind or rain causing several health problems (FAO, 1995a).

Estimates indicate that more than 500,000 tons of obsolete pesticides are accumulated globally, especially in developing countries (FAO, 2001a). A considerable amount of the accumulated obsolete pesticides are persistent organic pollutants (POP's). These chemicals possess toxic properties, resist degradation, bio-accumulate and are transported, through air, water and migratory species, across international boundaries and deposited far from their place of release, where they accumulate in terrestrial and aquatic ecosystems (Jones and de Voogt, 1999; Vallack *et al*, 1998).

Several international conventions have been established to protect human health and the environment through measures which will destroy and irreversibly transform stockpiled hazardous chemicals and reduce and/or eliminate emissions and discharges of chemicals (UNEP, 2001). Of special relevance is the Aarhus Protocol, the Stockholm Convention which entered into force on the 17$^{th}$ of May 2004 and the Basel Convention on the Control of Transboundary Movements of Hazardous Wastes (Basel Convention, 1989) which aim at stimulating local treatment of hazardous wastes.

These conventions acknowledge that there is an urgent need for environmentally sound disposal of the hazardous chemicals and that developing countries and countries with economies in transition, in particular the least developed among them, need to strengthen their national capabilities on sound management of chemicals (UNEP, 2001).

The Food and Agriculture Organization (FAO) of the United Nations has been addressing this issue and has disposed of approximately 3,000 tons of obsolete chemicals in more than 10 countries in Africa and the Near East since the beginning of the 1990's (FAO, 2001b). This means less than 1% of the accumulated amounts in a period of more than 10 years - if the rate of accumulation and the speed of disposal of these chemicals remain the same, this problem will "never" be solved (Karstensen, 2005).

In schools and other research institutions, scores of science teachers and laboratory personnel across the country are struggling with a legacy they have inherited from their predecessor - a stockpile of old, unlabeled, potentially hazardous chemicals sitting on their laboratory shelves and stores. The cause of accumulation of these chemicals has been attributed to lack of appropriate management practices including: poor stock keeping, uncoordinated donations, lack of expertise and financial resources. These chemicals pose a lot of risk to students, staff and the total environment, creating an unsafe environment for learning.

According to Venkataraman (2006), twenty departments in the University of Singapore generated 3 tons of obsolete chemicals. In Ghana, 20,326g (20.326Kg) of chemicals were identified as obsolete chemicals in Chemistry Department of Kwame Nkrumah University of Science and Technology which needed to be disposed of (Boakwah, 2006).

Obsolete chemicals are drawbacks to the developmental effort of many developing countries mainly because of the lack of both resources and expertise. The removal of waste chemicals and their disposal in an environmentally safe manner may not be considered development-oriented. On the other hand, if people engaged with chemicals are affected, if the environment becomes hazardous and uninhabitable, if human life and animals are at risk, if water and soil are contaminated, development schemes are also bound to fail (FAO, 1995a).

In view of the urgency, the global importance and the magnitude of the problem, there is the need for obsolete chemical management to be given a global attention to save our resources. This project seeks to encourage removal and safe disposal of obsolete chemicals and the need to prevent their future accumulation.

## 1.1 STATEMENT OF PROBLEM

The problem of obsolete chemicals remains extremely serious and that action is urgently needed to identify and secure or dispose of existing stocks and prevent the accumulation of new ones. The total quantity of obsolete chemicals held in developing countries and countries with economies in transition is thought to be huge. The amount can only be estimated because many stocks have not been inventoried or even located (OECD/FAO/UNEP, 2000).

In Africa alone, up to 20,000 - 30,000 tonnes of obsolete pesticides are estimated to exist (FAO, 1995a). Many of the stocks continue to deteriorate thereby giving rise to an ever escalating source of severe pollution of our resources, posing threats to human health, and stand in the way of socio-economic development. The situation is most serious in almost all developing countries because there is little or no awareness of the inherent danger of chemicals. There is therefore the need to address this problem now because it will be far more expensive and difficult to solve later (OECD/FAO/UNEP, 2000).

Stocks of obsolete chemicals should therefore be regarded as chemical time-bombs that can cause environmental and human disaster and thus need proper management (FAO, 1995b)

## 1.2 OBJECTIVES OF STUDY

Chemicals are mainly used in the laboratory for doing research and teaching. Most of the chemicals have low shelf life, while the characteristics of the chemicals vary widely from flammable to corrosive to toxic. In schools and research institutions, chemicals are often purchased under separate project grant, and thus, central purchasing and storage is not practiced. Most of the projects do not consider for the disposal of chemicals should there be any excess. Over a period of time, the accumulation of chemicals in our National Universities and other institutions in Ghana, now to be termed as 'Obsolete chemicals' pose a serious threat to environment, besides safety and health of laboratory personnel (Venkataraman, 2006).

This thesis has a general objective of contributing to the management of obsolete chemical stocks by raising awareness of the potential risks posed to students, staff and other chemical users, and the need to prevent future accumulation.

**Specific Objectives**

The thesis has the following specific objectives;

- To conduct an environmental audit and management of obsolete chemical stocks in some selected chemical stores.
- To determine the identity of these chemicals where possible, classify them and suggest a proper method of disposal by evaluating various disposal methods.

## 1.3 JUSTIFICATION

Problems related to obsolete chemicals are quite common, widespread and alarming, particularly as most developing countries are seriously affected. Large quantities of concentrated obsolete chemicals leak into the environment - contaminating soils and groundwater. If the issue remains unresolved and action is delayed, the magnitude and severity of the problem will increase and it will be much more difficult to control. The damage will be long term and will have much wider implications and deleterious effects on the environment.

As a result of growing international environmental awareness and because of the seriousness and frequency of exposure and widespread chemical-related accidents, developing countries are under increasing pressure to look for assistance and technical guidance for the disposal of obsolete chemicals. Subsequently, and mainly because of the urgency of the problem, it has become important to compile the inventory of obsolete chemicals in Ghana; discuss the issue; to enhance understanding and to initiate harmonization; to encourage and motivate donors; to recognize collective responsibility; and to plan coordinated actions for the disposal of obsolete chemicals.

Moreover, it has also become imperative to seek a common position on ways and means to avoid further accumulation of obsolete and unwanted chemical stocks in the future (FAO, 1997).

## 1.4 SCOPE OF STUDY

This work in actual sense should have been conducted nationwide but due to some constraints and as the adage says “a journey of thousand miles begins with a step”, few Schools/Departments have been chosen for this project work.

The scope of this study is to conduct an environmental audit and management of obsolete chemicals in the store rooms of the following departments; Department of Theoretical and Applied Biology, Department of Chemistry and Department of Pharmaceutical Chemistry all of K.N.U.S.T. It also covers the obsolete chemicals of Kumasi Senior High School, Technology Senior High School and Kumasi Anglican Senior High School, all in Kumasi.

# CHAPTER TWO

## 2.0 LITERATURE REVIEW

Hazardous wastes management has become the most prominent environmental problem of late. Almost any chemical requiring disposal is a hazardous waste. It is difficult to get through a week without hearing something about another illegal dumping, fire, or scandal involving hazardous chemicals. But despite their notoriety, it is difficult to put one's finger on the "hazardous waste problem" since it is multi-dimensional. Scientists around the world are trying to solve "the problem". Many different groups like farmers, laboratory personnel etc are directly or indirectly involved with hazardous waste management (Harrasiddhiprasad *et al, 1983*).

Searching for cheaper ways to get rid of the waste, toxic trade began shipping hazardous waste to developing countries and Eastern Europe. When this secrete activity was revealed, international outrage led to the drafting and adopting of Basel and other Conventions which aim at eliminating such problem (Boakwah, 2006).

### 2.1 CONVENTIONS ON CHEMICAL PROLIFERATION

Over the past 30 years, the production, generation and trade of chemicals and chemical wastes has exponentially grown up, with the consequent concern of governments and people, especially on account of the risks at the time chemicals and/or their wastes are being transported, handled or disposed of. To solve the problems of dealing with chemicals the international community established various global legal instruments. In response to these concerns, during the last decades the United Nations Environment Programme (UNEP) has given special attention to chemicals and hazardous wastes.

Within this framework three multilateral agreements, currently in force are mentioned. They provide global measures put in place to protect human health and the environment. These agreements are the **Basel Convention** on the control of transboundary movements of hazardous wastes and their disposal, **Rotterdam Convention** on the Prior Informed Consent Procedure for Certain Hazardous Chemicals and Pesticides in International Trade and the **Stockholm Convention** on Persistent Organic Pollutants (Martinez, 2004).

### 2.1.1 Basel Convention

Basel Convention on the Control of Transboundary Movements of Hazardous Wastes and Their Disposal was adopted in Basel, Switzerland in 1989 and came into force in May 1992 becoming an international commitment of those national Parties to the Convention. The Basel Convention has become the most important multilateral agreement on hazardous wastes, establishing a global regulatory regime to minimize the generation, management of hazardous wastes in an environmentally sound manner and the control of their transboundary movements. It has a broad scope and has developed lists to classify wastes based upon their hazard characteristics and specific lists of wastes within its scope. By September 2004, the Basel Convention has 163 contracting Parties. Basel Convention aims at:

Minimizing wastes generation taking into consideration social, technical and economic aspects. Assuring the use of adequate facilities for disposal operations, wherever the activity take place, looking after people involved in wastes management and adoption of necessary measures to prevent pollution. Assuring transboundary movements are reduced to a minimum consistent with their environmentally sound management (Martinez, 2004 and Boakwah, 2006).

### 2.1.2 Rotterdam Convention

Rotterdam Convention on the Prior Informed Consent Procedure for Certain Hazardous Chemicals and Pesticides in International Trade started as a voluntary information exchange program in the 80s, and came into force in 2004, February 24 and by September that year, 77 countries were Parties to the Convention. Its objective is to protect human health and the environment from specified hazardous chemicals by promoting shared responsibility among Parties in the international trade. The convention tries to facilitate relevant and precise information exchange and includes procedures for formally obtaining and distributing decisions among import and export countries trading specific chemicals. Now 24 chemicals used as pesticides, 6 severely hazardous pesticides formulation and 11 industrial chemicals are subject to Rotterdam Convention and it is expected that the list will be enlarged (Martinez, 2004).

### 2.1.3 Stockholm Convention

Stockholm Convention came into force in May 2004, and it is considered as a major success because of its objective; to reduce and completely eliminate 12 persistent organic pollutants (POPs) considered particularly toxic. POPs are characterized by their long lifetimes (persistence) in the water, soils or sediments or air. The Convention establishes that a contaminant is persistent if its half-life in water is greater than two months or its half-life in soil is greater than six months, or that its half-life in sediment is greater than six months (Martinez, 2004).

In relation to stockpiles of wastes consisting of, or containing persistent organic pollutants (POPs), Stockholm Convention establishes that:

In order to ensure that stockpiles and wastes are managed in a manner protective of human health and the environment, each Party shall:

- Develop appropriate strategies for identifying stockpiles and wastes.
- Take appropriate measures so that the wastes, including products and articles upon becoming wastes are; handled, collected, transported and stored in an environmentally sound manner.

These three conventions show the international community is concern in relation to minimizing/avoiding risks deriving from an environmentally unsound management of chemicals and wastes. Nevertheless, even though the three conventions have an increasing number of Parties committed to meet the convention's objectives and conscious of the problem and needed measures, many countries, especially the developing ones, lack the necessary infrastructure, capacity or resources to deal with chemicals and wastes management in an integrated manner. Anyway each of the above mentioned conventions present challenges and give opportunities to move forward offering a wide range of tools, not only basic ones such as awareness raising but also opening doors to local, national and regional discussion and to coordinate proposals and finally leading countries to develop rules to regulate different aspects of chemicals and wastes life cycle and therefore reach the objective of protecting human health and the environment (Martinez, 2004).

## 2.2 OBSOLETE CHEMICAL GENERATION

In most developing countries, large stocks of obsolete chemicals have accumulated over the years as a result of prolonged storage or because they have been banned from use (FAO, 1995a). These stocks are often stored in poor conditions and pose a threat to human health and the environment (FAO, 1995b). Owing to the absence of environmentally sound disposal facilities in developing countries, the quantity of obsolete chemical stocks is constantly on the increase (FAO, 1995a).

The total quantity of obsolete chemical stocks in non-Organization for Economic Co-operation and Development (OECD) countries is estimated to be well in excess of 100,000 tonnes (FAO, 1995a and FAO, 1995b) of which 20,000 to 30,000 tonnes are in Africa. A significant share of these stocks is leftovers of chemicals supplied under various aid arrangements. The problem is colossal and a concerted global effort is required to minimize the damage (FAO, 1995a).

The accumulation of obsolete stocks has continued unabated and continuously poses serious environmental and public health hazards. Lack of appropriate management, misuse of chemicals, uncoordinated chemical donations, substandard storage, poor storekeeping, lack of expertise and financial resources are major contributors to the problem. Developing countries are the most badly affected, mainly because of the lack of understanding of the inherent dangers of chemicals and the means to protect people. Urgent solutions are therefore needed (FAO, 1997).

Additionally, developing countries do not have adequate facilities to dispose of such stocks in a safe and environmentally sound manner. In many cases, therefore, the recommended disposal method would appear to be shipment of the chemicals to a country that has special hazardous waste incineration facilities. In view of the dangerous nature of these chemicals and the high costs of safe and environmentally sound disposal, the long-term solution to obsolete stocks lies in preventive measures: improved stock management and reduction of stocks (FAO, 1995a).

The issue of obsolete chemical stocks is increasingly receiving international attention. A growing number of developing countries are requesting aid agencies to provide assistance for disposal of obsolete stocks together with assistance aimed at preventing further accumulation of obsolete chemical stocks (FAO, 1995b). In response to that, FAO, UNEP, international donors, aid agencies, governments of countries with stocks, pesticide producers, and non-governmental organizations have taken on projects to track down, collect and dispose of existing stocks of obsolete pesticides and to prevent the accumulation of new ones. FAO has written guidelines and codes of conduct to help developing countries better manage pesticides, dispose of obsolete stocks, and avoid accumulating new ones. The OECD DAC has written guidelines for aid agencies that describe the problem and show how aid should be directed to avoid accumulation of obsolete chemicals. But these efforts have been able to address only a small part of what is a very large problem (OECD/FAO/UNEP, 2000)

### 2.2.1 Occurrence and state of obsolete chemicals in developing countries

In developing countries chemicals are often stored in unsuitable conditions and rapidly lose their potency. Modern chemicals have a shelf life of about two or more years when properly stored. But certain components in chemicals deteriorate more quickly if exposed to extreme heat or cold, or if their containers are damaged and thus expose the chemicals to air (UNEP, 2000). Such a situation exists in almost all developing countries especially in Africa and Near East (FAO, 1995a; FAO, 1995b).

Quantities of obsolete chemicals in individual countries range from a few tonnes to several thousands. In 1994, FAO conducted an inventory of obsolete pesticide stocks in Africa and the Near East. Results of this inventory indicated that the total of obsolete pesticides in Africa probably exceeds 15,000 tonnes. According to UNEP (2000), in Africa, a conservative estimate by the United Nations Food and Agriculture Organization (FAO) puts the total quantity of obsolete chemicals (pesticides) at about 20,000 metric tons. In Asia and Latin America, where less data has been gathered, perhaps another 80,000 metric tons are held, and in the Commonwealth of Independent States early estimates indicate stockpiles of at least 150,000 metric tons.

The combined result of these multiple failings in chemical supply and management has been the accrual of huge quantities of obsolete chemicals. In many cases these chemicals are escaping into the environment, contaminating soil, water, and air, and threatening wildlife and human health (UNEP, 2000). In most situations, obsolete chemicals are stored under conditions that do not meet the basic standards for safe and responsible storage of such hazardous materials. Stores are often poorly ventilated (FAO, 1995b).

### 2.2.2 Causes of accumulation of obsolete chemicals

Finding a solution to a problem without knowing it root causes would be difficult. Thus, it is important to identify and understand the factors that have contributed to the accumulation of the present stockpiles of obsolete chemicals in order to formulate preventive measures. This section provides a detailed analysis of the categories of causes of accumulation. There are many factors that have contributed to the accumulation of the present stockpiles of obsolete chemicals. These factors can be grouped into the following categories (FAO, 1995b).

#### *2.2.2.1* **Banning of Products**

Formerly, persistent organic pollutants (POPs) were the most commonly used chemicals because they were very effective and efficient. Presently, most POPs have been banned and can only be used under stringent conditions. This is because of their harmful effects on humans and the environment. The fate of existing stocks in a country is often given scare consideration. Stocks remain where they are stored and eventually deteriorate (FAO, 1995b). A considerable amount of the accumulated obsolete chemicals are persistent organic pollutants that possess toxic properties, resist degradation, bio-accumulate and are transported, through air, water and migratory species, across international boundaries and deposited far from their place of release, where they accumulate in terrestrial and aquatic ecosystems (Jones and de Voogt, 1999; Vallack et al., 1998).

#### *2.2.2.2* **Lack of chemical regulatory infrastructure in developing countries**

Lack of chemical regulatory infrastructure in developing countries leads to poor regulation of chemicals, absence or inefficient laws and law enforcement, and lack of co-ordination among relevant government agencies. Chemicals are sometimes banned without consideration of how to manage existing stocks. Illegal traffic or cross border smuggling of chemicals, sometimes from countries where a different language is spoken, can lead to confusion about the contents and appropriate use of products and eventual stockpiling (OECD/FAO/UNEP, 2000).

#### *2.2.2.3* Inadequate stores and poor stock management

##### *2.2.2.3.1 Inadequate chemical storage facilities*

Most developing countries do not have sufficient and well designed storage capacity to store all its chemicals safely. Many stores are poorly constructed, have insufficient ventilation and do not have concrete floors. Because of space constraints, chemicals are often not properly stacked, thereby reducing access to products and making it difficult to monitor the condition of containers. At several locations, chemicals are even stored in the open for prolonged periods of time. Poor storage conditions accelerate the degradation of chemicals and their containers. New products are sometimes stored inappropriately because obsolete products are occupying the limited storage space (FAO, 1995b).

##### *2.2.2.3.2 Lack of expertise in chemical management*

Storekeepers of major stores and those responsible for national stocks are often not familiar with the guidelines for good stock management (proper stacking, product segregation, principle of "first in - first out", etc.). Leakage and spills may not be cleaned up immediately because staff have not been trained how to handle them, or because the necessary materials and protective gear are not available. Contamination and improper stacking may affect the condition of other products and may impede a consistent application of the principle of "first in - first out". Stock records may not be regularly updated and communicated to the central authority responsible for establishing the country's chemicals requirements (FAO, 1995b).

#### *2.2.2.4 Inappropriate handling during transport*

Drums and other packaging materials are often damaged through rough handling or in transport. When drums are battered, their inner and outer coatings may be damaged, which will accelerate corrosion and shorten their life. Long periods of exposure to direct sun during transit are another important factor that affects both the container and its contents reducing if potency (FAO, 1995b).

#### *2.2.2.5* **Unavailability of analytical facilities**

Because laboratory facilities for chemical quality control are not available in most developing countries, it may be difficult to determine whether a chemical may still be used after its indicated shelf-life has expired (FAO, 1995b).

#### *2.2.2.6* **Unsuitable packaging**

##### *2.2.2.6.1 Poor container quality*

Chemicals are sometimes delivered in containers of poor durability that soon start leaking. Once drums have corroded or leak, they can no longer be transported, which makes it considerably more difficult to use their contents. The same applies to torn bags and other damaged packaging. If the container quality is not specified in tender documents, bidders may be tempted to reduce their price by compromising on the quality of containers (FAO, 1995b).

##### *2.2.2.6.2 Missing or incomplete labels*

Labels are inscriptions on a sheet of paper which serves as a means of communication between the manufacturer and the user that provide information on the chemical. In some cases, chemicals are not used because the potential user does not know the specifications of the product, or how to apply it, since labels are missing or incomplete, or are in a language alien to the user. Inadequate labeling and the absence of a date of manufacture/release on labels or on the container may complicate the matter. For this reason, there is often an understandable tendency to deviate from the principle of "first in - first out" and to use a newer product to be certain of its effectiveness; this practice leads to prolonged storage of older products (FAO, 1995b).

#### *2.2.2.7* Insufficient communication between supplier and user

In several cases, the quantity, active ingredient or packaging of donated chemicals are inappropriate for the intended use. Such mistakes occur because of a lack of detailed specifications in requests for chemical donations and/or a lack of background information and justification. On their part, aid agencies often make insufficient efforts to obtain such information before processing requests for chemical donations (FAO, 1995b).

#### *2.2.2.8* Keeping large strategic stock of chemicals

The possible extent of an expected pest outbreak is sometimes difficult to forecast. A lower pest incidence than expected may result in unused chemical stocks. In the past, this was particularly true for outbreaks or invasions of migratory pests. Countries that established large strategic chemical stocks in preparation for possible upsurges or invasions often ended up with large quantities of unused products. The risk was further increased by decentralizing such stocks. Monitoring of locust outbreaks has greatly improved with the FAO Emergency Centre for Locust Operations programme. Internationally coordinated control strategies based on the monitoring of developments in locust outbreaks have demonstrated that chemicals can be flown in on time and that large strategic stocks are therefore no longer necessary (FAO, 1995b).

#### *2.2.2.9* Overstocking of products with a short shelf-life

Most currently used chemicals have a short shelf-life. Tropical conditions characterized by excessive heat, high humidity and/or strong fluctuations in temperature may reduce this already short life span. During medium- or longer-term storage periods, these products degrade and become unusable. Overstocking of such products is a common cause of chemicals becoming obsolete (FAO, 1995b).

#### *2.2.2.10* Excessive and inappropriate chemical donations from aid agencies

This can occur for a variety of reasons, including the following:

Donations are not always driven by demand and in some cases turn to be waste. The result is that donated chemicals are sometimes unsuitable for the application equipment that is locally available, are unsuitable for the pest problem, are packed in inappropriate containers, have an inadequate shelf life, or are not registered in the receiving country. Donations may respond to the articulated demand, but developing countries may not have the expertise or infrastructure to accurately assess their pest control needs. Donated chemicals may not be subject to quality control, and their chemical and physical quality may be questionable. Developing countries may wish to accumulate precautionary stockpiles (“strategic stocks”), acquiring excess chemical so as to have a stock on hand in case of emergency such as locust attacks (OECD/FAO/UNEP, 2000).

Aid agencies have sometimes provided chemical donations far in excess of requirements. In several cases this has involved products manufactured in the home country of the aid agency or funding government. Under some agricultural input supply programmes that last for a number of years, the provision of chemical is automatic until notice is given to stop. This system, depending on feedback, does not always work effectively. In some cases, it has led to an accumulation of chemicals when demand dropped and supply was not adjusted (FAO, 1995b).

#### *2.2.2.11* Removal of subsidies

Many countries are reducing or removing subsidies on chemicals. The rationale behind the adjustment of pricing policies is both technical and economic. Direct and indirect subsidies on chemicals are not desirable because they stimulate overuse and over-reliance on chemicals and frustrate the introduction of Integrated Pest Management (IPM). Moreover, structural adjustment programmes require the removal of subsidies from agricultural inputs to establish rational market mechanisms. This often causes a temporary or structural drop in demand. As a result, stocks may remain in store longer than planned and are at increased risk of becoming obsolete (FAO, 1995b).

#### *2.2.2.12* Coordination among and within aid agencies

##### *2.2.2.12.1 Poor coordination among aid agencies and recipients*

Insufficient coordination among aid agencies providing chemicals, especially for locust and other migratory pest control operations, has been a major factor in causing excess donations of chemicals. Recipient governments do not usually have any guarantee that the required chemicals will be provided by the donor agency they first contact. In emergency situations, this may lead to simultaneous requests for assistance to various agencies, with the hope that at least one will react in time. In the end, the requested amount may be received from more than one donor. Given this undesirable situation, FAO is enhancing donor coordination in emergency situations, both at the international level and the national level in recipient countries (FAO, 1995b).

#### *2.2.2.12.2 Administrative procedures within aid agencies*

Slow processing of requests for chemicals, in some cases, has meant that the chemicals have arrived too late. Project or programme funds are often allocated for spending within a certain period. Consequently, timing for the procurement of chemicals is sometimes determined by budgetary factors, rather than by actual requirements. This means that recipient countries may be pressed to accept chemical supplies on a "now or never" basis, which in many cases conflicts with the principle of providing chemicals only when they are actually needed (FAO, 1995b).

Several aid agencies have not yet assigned responsibility for the appraisal and processing of requests for chemicals to a specific technical office within the agency. Instead, such requests are processed by the country desk concerned. There may be little coordination among country desks themselves, or among country desks, technical departments and procurement departments. Without a specifically designated technical office to appraise requests for chemicals, it may be difficult to build up an institutional memory to avoid repetition of supplies (FAO, 1995b).

### *2.2.2.13 Commercial interests and hidden factors*

Agrochemical companies, or their local agents, often take the initiative to advise plant protection services and other large-scale users on their pesticide requirements. Sometimes such advice forms the basis for requests to donors. However, companies may not always likely to put the public interest above their own commercial interest and assessments may be in excess of actual requirements. Moreover, the recommended product will probably be one the company supplies and therefore may not necessarily be the most appropriate.

Large sums of money are involved in chemical supplies. As a result, a variety of hidden interests may play a role in decisions concerning chemical procurement or donations. Often these interests are not strictly related to the best technical solution to pest problems. Companies may use a range of aggressive marketing methods that result in procurement of quantities in excess of actual requirements, or of low-quality products. Some individuals involved in chemical procurement may have personal interests. Donor countries may place increased emphasis on supply of chemicals because of the spin-off for the national chemical industry, thereby increasing the risk of donations being supply- rather than demand-based. Supply-based donations of chemicals are more likely to become obsolete. Tied aid may restrict the range from which products can be selected. Such hidden factors often complicate a sound technical approach to pest and chemical management and should be identified and addressed in policy decisions (FAO, 1995b).

## 2.3 EFFECTS OF OBSOLETE CHEMICALS

Leaking drums and torn bags can seriously affect the health of staff working at the storage site and of others who happen to come in contact with the chemicals (FAO, 1995a; FAO, 1996). Obsolete chemical stocks not only present a hazard to public health but can also contaminate natural resources and stand in the way of socio-economic development (FAO, 1995a). The types of hazards encountered with obsolete chemicals include:

### 2.3.1 Hazard to human health

Hazard is the potential of any substance or situation to cause harm (Hember *et al*, 2001). Unmanaged obsolete chemical stocks can pose a serious health hazard, especially to people living near stocks. Comprehensive information about the impact on public health is not available. However, conditions of certain stocks, and their proximity to human habitations, leave no doubt about the danger and the need to apply the Precautionary Principle (OECD/FAO/UNEP, 2000).

### 2.3.2 Contamination of water sources

Obsolete chemical stocks, especially when located near water sources; pose a high risk of contaminating drinking water sources and water used for irrigating agricultural crops. As an example of how obsolete chemical stocks can hamper economic development in addition to threatening local resources, contaminated irrigation water might introduce pesticide residues into crops and fish, making them unfit for trade as well as local consumption (OECD/FAO/UNEP, 2000).

### 2.3.3 Contamination of soil and other natural resources

Leaking of chemical stocks can contaminate a significant land area making it unfit for human habitation, cultivation of crops, or any other kind of development. Cleanup of such areas is prohibitively expensive and is currently technically impossible (OECD/FAO/UNEP, 2000).

### 2.3.4 Escalating costs of clean ups.

Delay in cleaning up existing stocks and failure to prevent new stocks from accumulating would have severe financial consequences in the future. A small amount of chemical can contaminate water and soil in a surprisingly short time, multiplying by many times the cost and the difficulty to clean up (OECD/FAO/UNEP, 2000).

## 2.4 MECHANISMS FOR MANAGING CHEMICALS IN GHANA

The law in the management and control of the risks posed by chemicals to man and the environment is well established (UNITAR, 1997). The variety of controls that seek to respond to the myriad of threats by the use or misuse of chemicals include principal acts and subsidiary legislation, guidelines, import and export procedures and codes of conduct or practice (UNITAR, 1997).

Currently, Ghana has no comprehensive legislation devoted to chemicals, though one could deduce aspects of chemicals management from various laws in existence. The next best solution has been an administrative procedure which has been implemented by the Environmental Protection Agency (EPA) since 1989 titled "Chemical Import Procedures." It covers consumer, industrial and agricultural chemicals.

The procedures involve a permit clearance mechanism which allows screening and therefore monitoring of all chemicals that are imported into Ghana. The purpose is to prevent the importation of toxic wastes or chemicals that are either banned or severely restricted so as to protect human health and the environment and enhance the sound management of all types of industrial, commercial and agricultural chemicals (UNITAR, 1997).

With specific reference to pesticides however, the Pesticides Control and Management Act, 1996 (Act 528) comes to fill an important vacuum in Ghana's overall effort at minimizing the dangers that arise from the misuse of pesticides (UNITAR, 1997).

### 2.4.1 Institutions that Manage Chemicals in Ghana

#### *2.4.1.1 Environmental Protection Agency*

The Environmental Protection Agency is the institution under the Ministry of Environment, Science and Technology (established in 1994) which is at the forefront in the implementation of legislation designed to manage chemicals and generally to control pollution and protect Ghana's environment (UNITAR, 1997).

#### *2.4.1.2 Ministry of Food and Agriculture*

The Ministry is responsible for all policy issues on Ghana's food and agricultural production and practices. A number of Departments fall under the Ministry including Fisheries, Veterinary Services and Plant Protection and Regulatory Services Department (PPRSD). The Ministry and its institutions have an important role to play in the management of chemicals due to the large proportion of the population involved in the food and agricultural sector. The Plant Protection and Regulatory Services is responsible for educating farmers on the safe use of pesticides. This function will now continue within the context of the inter-institutional Pesticides Technical Committee. The Fisheries Department is also responsible for implementing the fisheries law which among other things prohibits the use of chemicals in fishing (UNITAR, 1997).

There is a high level of well-trained officers including Subject Matter Specialists (SMS) who train Front Line Staff (FLS). The FLS in turn train the farmers who are the main users of the chemicals (UNITAR, 1997).

#### *2.4.1.3 Ministry of Mines and Energy*

The Mines Department of the Ministry is responsible for the enforcement of the provisions of the Mining and Minerals Law and regulations made which cover inter-alia, health and safety in the mining environment. The Department also monitors the use and storage of explosives in the mining sector (UNITAR, 1997).

## 2.5 OBSOLETE CHEMICALS IN INSTITUTIONS

Hazardous chemicals can be found in many programs within schools (FDEP, 2007) and other research institutions. Many chemical repositories and laboratories in schools contain a wide variety of dangerous chemicals that are outdated, inappropriate, toxic, reactive, explosive and unknown (ADEM, 2002). Often, these chemicals are not well managed: they are purchased in excessive amounts. They are stored incorrectly in wrong places in decrepit containers, alongside other chemicals putting students, staff, and the environment at risk (ADEM, 2002, FDEP, 2007). Because staff often does not know what to do with old chemicals that are no longer used, the chemicals are kept, sometimes for decades, after which time many chemicals deteriorate, become contaminated or even unstable (FDEP, 2007).

Unfortunately, mismanagement and improper storage of hazardous chemicals in school laboratories and stores has become an important nationwide safety issue (MDEQ, 2005). Incidents involving hazardous chemicals are a common cause of problems in schools and have resulted in serious injury, property damage and schools being shut down for weeks to be decontaminated (FDEP, 2007). In 1998, two Vermont schools in the United State were closed as a result of mercury releases from vandalism. In 1999, a Vermont school was traced as the source of high levels of cadmium in the local wastewater treatment plant. Also in Idaho, the combined EPA and Department of Environmental Quality (DEQ) funds provided 22 schools with assistance in identifying, categorizing, and disposing chemicals. The program resulted in the removal of 29.1 kg of hazardous chemicals (Benoit, 2002).

Hazardous chemicals accumulate when there is no tracking system and no disposal plan, especially when there are changes in staff and/or changes in curriculum. Few schools have the resources or expertise needed to manage highly toxic or otherwise hazardous chemicals. Most staff is not trained to recognize and manage the risks of hazardous chemicals and very few schools have a budget for proper chemical storage space and equipment, staff time for chemical management activities, or even hazardous waste disposal (Lynn *et al*, 2006).

Disposing of unneeded, outdated, and excessive chemicals is critical to creating safe schools and an important step in achieving proper chemical management. It is essential that schools develop and implement responsible chemical management and waste minimization practices to decrease the risk of accidents and exposures and the need for cleaning out future chemical accumulations (U.S EPA, 2006). Once these chemicals are removed, it is much easier to set up and maintain systems to purchase track and store the remaining chemicals. The necessary storage facilities and personal protective and emergency response equipment and supplies are much easier to determine after the school has reduced the volume and toxicity of the chemical inventory to the amount and types required for safely running the school facility and its programs (Lynn *et al*, 2006).

### 2.5.1 Managing chemicals in schools

Managing hazardous chemicals is the process of controlling chemicals that can even in low concentration, have a significant adverse effect on the environment and/or public health (Boakwah, 2006). Proper management of chemicals is essential since schools can save huge sums of many for other projects.

#### *2.5.1.1 General strategies*

The number of sites where chemicals are stored in schools and research institutions should be minimized. It is difficult to keep track of all chemicals if the numbers of sites are many. Chemicals should be stored based on the hazard classification, which is based upon a chemical's compatibility and reactivity. All school staff that routinely works with hazardous chemicals must receive proper training in all phases of chemical management, including safe storage, proper use, potential hazards and proper methods of disposal to help create accident free environment (Benoit, 2002).

Periodic inspection of stored chemicals for signs of leakage, rusting, peeled labels, and expiration date must be conducted. Degraded labels should be immediately replaced to prevent unknowns (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 accessible to any one who uses the chemical. The files should be kept near where the chemicals are stored and a copy should be maintained in the main office (FDEP, 2007, NHDES, 2002).

#### *2.5.1.2 Classification of chemicals*

Material Safety Data Sheets (MSDS), comprehensive fact sheets prepared by chemical manufacturers, describe the physical properties, health effects, and other characteristics of chemicals, as well as procedures for handling, storing, and disposal of these substances. In many countries, manufacturers, suppliers and importers of substances are responsible for providing MSDS (Lunn and Sansone, 1994).

Chemicals can be grouped based on the type of hazard they pose. Knowing the different types of chemicals in a store is important for developing an effective chemical management policy. Hazardous substances in schools may fall into one or more of the following categories: 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*. Examples of hazard identification symbols are shown below.

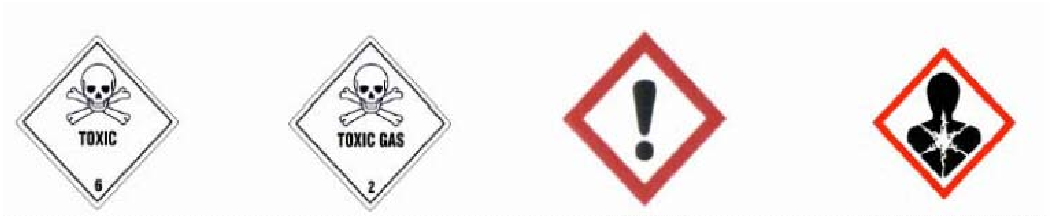

| | | | |
|---|---|---|---|
| HSNO Class 1.1, 1.2, 1.3 (UN Classes 1.1, 1.2, 1.3) | HSNO Class 1.4 (UN Class 1.4) | HSNO Class 1.5 (UN Class 1.5) | HSNO Class 1.6 (UN Class 1.6) |


| | | | |
|---|---|---|---|
| HSNO Class 2.1.1A flammable | HSNO Class 2.1.1B Flammable gases | HSNO Class Gases under pressure | HSNO Class Gases flammable liquids |


Flammable Liquid

Flammable Solid


| | | | |
|---|---|---|---|
| HSNO Class 4.3 | HSNO Class 5.1 | HSNO Class 5.2B | HSNO Class 5.2G (Organic) |



Toxic

Chronic Toxic


HSNO Class 8.1A Corrosive to metals

HSNO Class 8.3 Eye corrosive

HSNO Class 9.1A, B & C Aquatic ecotoxicity

**Figure 2.1: shows hazard group symbols.**

The degree of hazard associated with a particular substance ranges between 0 to 4 with 4 being extremely dangerous and 0 indicates no harm. The degree and types of hazard are summarized in as follows;

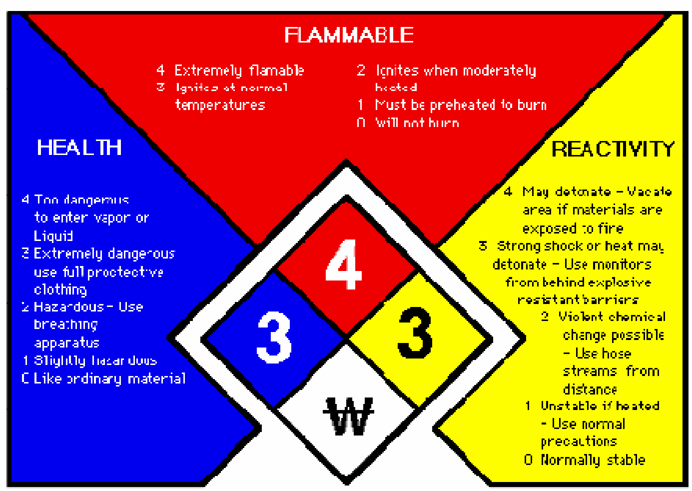



**Figure 2.2: shows the degree and types of hazard.**

**Health Hazard**

0. Material offers no health hazard.
1. Material only slightly hazardous to health. Exposure could cause irritation if not treated.
2. Exposure could cause injury. Appropriate protective equipment should be worn.
3. Exposure could cause serious injury. Appropriate protective equipment should be worn.
4. Could cause serious injury or death. Only special protective equipment designed specifically to protect against the specific hazard should be worn.

**Flammable Hazard**

0. Will not burn
1. Ignites after considerable heating
2. Ignites if moderately heated
3. Can be ignites at all normal temperature
4. Very flammable gases or very volatile flammable liquid

**Reactive Hazard**

0. Normally stable. Not reactive with water
1. Normally stable. Unstable at high temperature and pressure. Reacts with water.
2. Normally unstable but will not detonate. Materials can undergo chemical change with rapid release of energy.
3. Can detonate or explode, but requires strong initiating force or heating under containment.
4. Readily detonate or explodes.

#### *2.5.1.3 Standards for chemical store rooms*

- The room should have adequate ventilation separate from the general ventilation system.

- An inventory of the chemicals present is maintained in each room where chemicals are stored.
- Hazardous material storage cabinets are anchored to the walls.
- Doors on storage cabinet are closed and latched.
- Secondary containment tubs are provided for liquid chemicals stored on counters and near drains. Volatile chemicals are stored in well-ventilated areas that exhaust outside the building to maintain indoor air quality (FDEP, 2007).

#### *2.5.1.4 Storage systems*

Institutions can have numerous toxic, corrosive, reactive and flammable materials in storage. If these are stored close together, there is a risk of contact if the containers fail due to deterioration or leakage. The resulting spills could cause a reaction or a release of poisonous substances into the environment. The proper storage of chemicals will minimize this risk (FDEP, 2007).

#### *2.5.1.5 Systematic storage for laboratory chemicals*

Many universities publish diagrams of recommended chemical storage system on their websites. Two chemical supply companies, J.T. Baker and Flinn Scientific, Inc., also have popular systems for chemical storage. All incorporate the concept of "related and compatible storage groups" found in Prudent Practices.

These systems are based on a series of codes for functional classes of chemicals. Organic and inorganic chemicals are separated, with sub-groups further separated. The "related and functional storage groups" listed in Prudent Practices and the shelf storage codes often assigned to these groups are listed below (FDEP, 2007).

**Table 2.1: Prudent Practices and the Shelf Storage Codes**

| COMPATIBLE GROUPS | CHEMICALS | STORAGE COLOR CODE |
|---|---|---|
| Inorganic #1 | Metals, hydrides | Green Glow |
| Inorganic # 2 | Acetates, Halides, Iodides, Sulfates, Thiosulfates, Phosphates, Halogens | Coral |
| Inorganic # 3 | Amides, Nitrates (except Ammonium Nitrate), Nitrites, Azides | Yellow Glow |
| Inorganic # 4 | Hydroxides, Oxides, Silicates, Carbonates, Carbon | Red glow |
| Inorganic # 5 | Sulfides, Selenides, Phosphides, Carbides, Nitrides | Black |
| Inorganic # 6 | Chlorates, Perchlorates, Perchloric Acid, Chlorites, Hypochlorites, Peroxides, Hydrogen peroxide, Bromates | Tan |
| Ionrganic # 7 | Arsenates, Cyanides, Cyanates | Orange |
| Inorganic # 8 | Borates, Chromates, Manganates, Permanganates | White |
| Inorganic # 9 | Acids (except Nitric, which is isolated and stored by itself) | Acid Cabinet |
| Inorganic # 10 | Sulfur, Phosphorus, Arsenic, Phosphorus Pentoxide | Dark Blue |
| Organic # 1 | Acids, Anhydrides, Peracids | Green |
| Organic #2 | Alcohols, Glycols, Amine, Amides, Imines, Imides | Orange Glow |
| Organic # 3 | Hydrocarbons, Esters, Aldehydes | Red |
| Organic # 4 | Ethers, Ketones, Ketenes, Halogenated Hydrocabons, Ethylene Oxide | Yellow |
| Organic # 5 | Phenols, Cresols | Light Blue |

Source: FLINN Chemical Catalog Reference Manual 1991

### 2.5.2 Conducting a chemical inventory

An inventory is the starting point for the identification of management options to deal with obsolete chemical stocks. A complete chemical inventory will identify chemicals whose containers and contents have deteriorated over time. By conducting chemical inventories, schools and other research institutions can identify unneeded, out-of-date chemicals and arrange to have these chemicals disposed of before they cause problems. Up-to-date chemical inventories should be available in every School/Department prior to the ordering of any new chemicals (FAO, 1995b).

Conducting a chemical inventory may pose significant risks to the individuals taking the inventory; therefore, only those who have technical knowledge about the chemicals should be involved. Students should never participate in inventories. Before starting work at each site, basic steps should be taken to protect the health and safety of individuals involved in taking the inventory. It may be necessary to open doors and windows of stores for some time before starting work inside, to allow adequate ventilation to remove vapours built up inside (FDEP, 2007).

#### *2.5.2.1 Suggested inventory procedure*

1) Work in pairs, never alone. It is best if one team does the entire inventory.
2) Be sure the areas in which you are working have adequate lighting and ventilation.
3) Wear appropriate Personal Protective Equipment (PPE). This should include gloves, chemical splash goggles, a laboratory apron, and closed-toed shoes.
4) Be sure that you have quick access to a phone and a recently tested eyewash and safety shower.
5) Have a written response plan nearby in case of a spill or accident and verify that all participants have read it in advance. One person should act as the recorder and

the other person should read the names of the chemicals. The reader should be sure to pronounce the names correctly and confirm that they have been recorded accurately.

The inventory can be used to generate a disposal list and to decide which chemicals to retain. Hazardous waste removal companies require very specific information, so it is important to include sufficient information about the chemical to avoid unexpected price changes. For example, anhydrous aluminum chloride is much more expensive to dispose of than hydrated aluminum chloride. A disposal list should include the proper chemical name, the size of the container and the approximate amount present (FDEP, 2007).

## 2.6 DISPOSAL ROUTES AND OPTIONS

Products that cannot be used for their intended purpose(s) or a permitted alternative, and that cannot be reconditioned to become usable again, should be considered for disposal (FAO, 1995a, OECD/FAO/UNEP, 2000). By law, regulated hazardous wastes must be properly handled from their initial generation to their final point of disposal under a concept commonly known as "cradle to grave" responsibility (FDEP, 2007).

There is no doubt that disposal of obsolete chemicals can be expensive. The cost of disposal ranges from as little as $500 to as high as over $100,000. Costs are variable and depend on the types and condition of the chemicals to be disposed (MDEQ, 2005). Due to the high cost involved in disposal of obsolete or hazardous chemicals, most developing countries resort to stockpiling chemicals until funds are raised for such purposes.

Economics, while extremely important, are not the only criteria by which a disposal options should be assessed, however, a hierarchy of options may be established in which protection of the environment and safety of the public are given priority. One of such hierarchy consist of the following stages (Porteous *et al*, 1993),

(a) *Waste minimization*. Modification to a process, or changes in the nature of product, can reduce the quantities of hazardous potential wastes generated. Such modifications can yield economic benefits to the companies concerned. For example, the 3M Company (in UK) established a Pollution Prevention Pays' programme in 1975 which include ***waste minimization*** measures and this saved some $482 million world wide in its first 14 years of operation (Porteous *et al*, 1993).

(b) *Reuse and recycling of materials*. Hazardous wastes produced by one process may be usable as raw materials in another. There are instances where one company's waste could be of use to another firm. In USA waste materials exchanges have been set up in many areas to match waste with materials requirements. In the UK projects of this type exist: for example, waste slag used as cement; ash from power stations used for breeze block (Porteous *et al*, 1993).

(c) *Energy production*. Virtually all organic compounds have an energy content which can be utilized if they are burned under appropriate conditions. In both energy and financial terms, it is more advantageous to recycle solvents than to burn them for energy production since their manufacture uses more energy than can be recovered and their selling price allows a profit to be made.

> However, there are many instances where combustible materials cannot be recycled and their energy content become more valuable. Some materials may pose problems when they are burned owing to the production of corrosive *hydrogen chloride or dioxins* (Porteous *et al*, 1993).

The above option can result in economic gain or at least a recovery of some costs. If none of these is feasible, consideration must be given to other procedures like landfill, chemical treatment or incineration, all of which involve expenditure with little, if any, return;

### 2.6.1 Disposal options

There are many methods to dispose of hazardous waste, such as chemical or biological treatment, landfilling, and incineration (Hester and Harrison, 1994). Disposal methods are divided into three categories and are evaluated on their suitability for the disposal of bulk quantities of obsolete chemicals in developing countries.

The main criteria are:

- environmental soundness of the technology
- occupational safety for operators
- technical feasibility for destruction of bulk quantities of obsolete chemicals
- suitability for common circumstances in developing countries, and
- cost-effectiveness

The suitability of individual disposal techniques generally depends largely on the type and quantity of product to be disposed of. A particular technique may be acceptable for one group of products, but absolutely unsuitable for another group.

This means that it is essential always to consider the combination of the technology and the product on a case-by-case basis (UNEP/FAO/WHO, 1996)

#### *2.6.1.1 Chemical or Biological Treatment*

The hazardous nature of some wastes can be reduced by a wide range of chemicals and biological treatments. Cyanide for instance, are readily destroyed by oxidation with hypochlorite while a wide range of dilute organic materials can be treated by microorganisms (Porteous *et al*, 1993).

Chemical treatment of large quantities of obsolete chemicals would require: special reactor tanks; process control devices; analytical facilities to test chemicals and residues; continuous expert supervision; and disposal facilities for residues. Chemical treatment may offer a solution to relatively small quantities of chemicals, provided that the operation is guided by a chemical expert. Under certain circumstances, treatment with lime or alkaline liquid may be used to detoxify soil contaminated with organophosphorus chemicals. Chemical treatment can only be applied to a very few groups of compounds and thus is not frequently used of late (FAO, 1995b).

#### *2.6.1.2 Landfill*

Landfilling, which has been used for many years, has become increasingly inappropriate. This is due to the use of landfill sites for other purposes are increasing. As a result, the availability of landfill sites is decreasing dramatically, especially in populated areas, where huge municipal waste is generated. This means that if landfilling is still to be used, municipal waste must be transported to remote areas. Increasing the disposal cost arising from the cost of transportation makes landfilling less attractive than other disposal methods. In addition, landfilling may not be suitable for some types of hazardous waste (Hester and Harrison, 1994).

Other problems associated with landfill are as follow;

#### *2.6.1.2.1 Reactive hazards*

Certain wastes, when mixed together, can react to produce new materials which may be much more dangerous than the original wastes. At one site, in Essex, a consignment of dilute acid was dumped on sulphide wastes already present in the trench: the resulting cloud of hydrogen sulphide gas killed the tanker driver making the delivery (Porteous *et al*, 1993). In December 1982 a landfill near Edinburgh containing fireworks waste exploded, probably as a result of reaction between various wastes leading to the production of hydrogen gas. One such reaction is the reaction of water and magnesium, a common component of fireworks, according to the equation (Porteous *et al*, 1993).

$$Mg + H_2O \rightarrow MgO + H_2$$

This reaction and others which probably occur at the same time, is exothermic and provided a source of activation for an explosive reaction.

#### *2.6.1.2.2 Air pollution*

Many organic materials are malodorous and can cause a smell nuisance. Toxic substances (including dioxins) produced by reactions can escape off-site, and dust containing heavy metals or asbestos could present a health risk if allowed to blow around. Presence of volatile organic compounds (VOCs) can initiate photochemical reaction and produce PAN.

##### *2.6.1.2.3 Water pollution*

Materials leaking from hazardous waste sites, especially some of the older ones may pose serious threats to water supplies. Organic solvents have contaminated aquifers in the UK and, on a much more widespread basis, in the USA. Cleaning of such contamination is difficult and expensive – and may not always be possible (Porteous *et al*, 1993).

Most modern landfills are classified according to the type(s) of waste material disposed of into them. Landfills can be engineered to a high standard in order to contain liquid leachate or landfill gas produced by decomposing organic waste (Porteous *et al*, 1993).

#### ***2.6.1.3*** **Specially engineered landfill (lined landfill)**

In general, land filling is not an acceptable option for the disposal of chemicals, because the chemicals can migrate and contaminate ground or surface water. In addition, there is a risk of them being dug up for unauthorized use. However, there are some exceptions. A properly lined landfill may be suitable for final disposal of incinerator ashes and slag, soils contaminated with chemicals, and/or powder formulations with low active ingredient content. Special attention must be paid to the selection of landfill sites. Landfills in areas with high groundwater tables or significant rainfall are not suitable. The landfill should be a designated landfill under the authority of the government. Authorization should be obtained before land filling the product concerned (FAO, 1995b).

Though specially engineered landfilled may be suitable for the disposal of incinerator ashes and slag, however, landfilled without pre-treatment is regarded as a 'last resort' for hazardous waste. This is no longer an option for some wastes (Porteous *et al*, 1993).

#### *2.6.1.4 Incineration*

Incineration is the most popular method for disposing of hazardous waste, and, as a result, has been applied extensively for handling a wide variety of waste (Siritheerasas and Lawrence, 1998). Incineration is feasible for most organic wastes although some may need pretreatment (e.g. water reduction). This method is generally only used for the more dangerous organic materials. The specific benefits of incineration include:

1. A reduction in the volume and mass of wastes (up to 90% of the volume and up to 75% of the mass).
2. Destruction of some wastes and detoxification of others, to render them more suitable for final disposal.
3. Destruction of organic components of biodegradable waste that may generate Landfill Gas (LFG).
4. The recovery of energy from organic wastes with sufficient calorific value.
5. The replacement of fossil fuels for energy generation with consequent beneficial impacts in terms of the greenhouse effect (Hester and Harrison, 1994).

##### *2.6.1.4.1 Selection of chemicals for incineration*

Whether or not chemicals can be properly incinerated depends on the type of chemical, the kind of incinerator, and the gas cleaning system. Inorganic materials are not normally incinerated and organic chemicals containing mercury and other heavy metals should also not be incinerated since their toxicity often results from the presence of elements, such as heavy metals, which are not destroyed by combustion

(FAO, 1996). Furthermore, excessive levels of toxic metals in the incineration ash or wastes from emission control equipment render them hazardous, thus requiring more expensive disposal (Porteous *et al*, 1993).

There are many types of incinerators, such as mass-burn incinerators, cement-kiln incinerators; mobile incinerators, and large-scale incinerators. The efficiency of these incinerators can be evaluated by various means. However, the following criteria are widely used (Siritheerasas and Lawrence, 1998):

1. Destruction and removal efficiency (DRE).
2. Combustion efficiency.
3. The emission levels of pollutants (*e.g.,* $NO_x$, $SO_2$, particulates).

*2.6.1.4.2 Cement kiln incineration*

A cement kiln is an oven that slowly rotates to expose limestone, sand and clay evenly to extremely high temperatures to make cement clinker. Only certain types of kilns (rotary kilns with electrostatic precipitator and bypass system) can be used for chemical incineration. Chemicals can be fired with the fuel by mixing them with the fuel, or by injecting them into the flame. Special adaptations need to be made to inject the chemicals, which can be costly. If the chemicals have a high calorific value they can, in part, replace the fuel. Cement kilns can destroy chemicals because temperatures inside range from 1,400 $^{o}$C to 2,000 $^{o}$C. The residence time of the gas phase is between 6 and 10 seconds. They can handle liquid or semi-liquid wastes and save on fuel costs. Acidic gases resulting from organochlorine chemicals are neutralized by the alkaline cement and therefore it is not necessary to have a scrubber (FAO, 1996).

#### *2.6.1.4.3 Mobile incinerator*

There are several models of mobile waste incinerators, ranging from small-scale to medium-scale. They are mainly used in the United States to deal with on-site clean-up of hazardous waste dumps. They handle large amounts of liquid, solid and sludge waste and contaminated soil at standards of destruction and emissions similar to those of large-scale fixed incinerators. Mobile incinerators are transported on two or three standard trailers and may have a gross weight of between 50 and 80 tonnes (FAO, 1996). Capacities of the smaller models range from 2 to 20 tonnes per day. These incinerators can achieve DREs of 99.999 percent and meet most standards for air emissions.

Bringing the incinerator to the waste avoids legal problems of international transportation of waste. However, use of a mobile incinerator does not eliminate the need to move products because chemicals still have to be brought to the incineration site.

#### *2.6.1.4.4 Large-scale fixed incinerator*

Large-scale dedicated hazardous waste incinerators are the preferred method of disposal for most obsolete chemicals. They are purpose-built to incinerate hazardous waste. Generally, they will be rotary kiln incinerators with an afterburner and various air pollution control devices. They maintain a temperature of 1,100°C to 1,300°C and the residence time in the afterburner is at least two seconds. The DRE is over 99.99 percent up to 99.99995 percent. The capacity varies according to model and ranges from 0.5 to 7 tonnes per hour at 24-hour operation. Such incinerators can handle solids and liquids, as well as contaminated soil, materials, containers and packed waste (FAO, 1996).They can handle all kinds of organic chemicals (including organochlorinated pesticides).

Because of the high initial investment cost ranging from US$10,000,000 to $200,000,000 and high operating costs (which include: large quantities of scrubber liquid; transport of waste to the plant; disposal of ashes and slag in a landfill; highly trained technicians; regular maintenance and servicing of plant; and intensive control procedures, including analytical facilities) they are only found in advanced industrialized countries (FAO, 1996).

#### *2.6.1.5 Impacts of incineration*

Existing data shows that burning hazardous waste, even in "state-of-the-art" incinerators, will lead to the release of three types of dangerous pollutants into the environment (Greenpeace, 2001):

1. Heavy metals
2. Unburned toxic chemicals
3. New pollutants - entirely new chemicals are formed during the incineration process.

##### *2.6.1.5.1 Toxic Metals*

Metals are not destroyed during incineration and are often released into the environment in even more concentrated and dangerous forms than in the original waste. High-temperature combustion releases toxic metals such as lead, cadmium, arsenic, mercury and chromium from wastes that contain these substances, including batteries, paints and certain plastics. They are released in the form of tiny particles or gases, increasing the risk of inhalation. An average-sized commercial incinerator

(32,000 tonnes per year) burning hazardous waste with average metals content emits these metals into the air at the rate of 92 tonnes a year (total for lead, cadmium, arsenic, mercury and chromium); another 304 tonnes a year will be found in residual ashes and liquids. Pollution control equipment can remove some but not all heavy metals from stack gases. But even then the metals do not disappear; they are merely transferred from the air into the ash, which is then landfilled (Greenpeace, 2001).

Subsequently, metals in the ash may leach into and contaminate soils and potentially groundwater. Presently, ash from incinerators is sometimes being used for construction purposes such as in asphalt, cement and for making paths. This practice can also have implications for the environment and for human health. For instance, metals can leach out of such construction materials. Ash from a municipal waste incinerator in Newcastle, UK, was used on local allotments and paths between 1994 and 1999. All of it had to be removed recently after it was found to contain unacceptably high levels of some heavy metals and dioxins.

##### *2.6.1.5.2 Unburned toxic chemicals*

No incinerator process operates at 100 per cent efficiency. Unburned chemicals are emitted in the stack gases of all hazardous waste incinerators. They also escape into the air as fugitive emissions during storage, handling and transport. While incinerators are designed to burn wastes, they also produce them in the form of ash and effluent from wet scrubbers and/or cooling processes. Incinerator ash carries many of the same pollutants that are emitted as stack gases. Studies have identified as many as 43 different semi-volatile organic chemicals in incinerator ash, and at least 16 organic chemicals in scrubber water from hazardous waste incinerators. Ash is commonly buried in landfill, while effluent is often treated before being discharged into rivers or lakes (Greenpeace, 2001).

#### *2.6.1.5.3 New pollutants - dioxins and furans*

One of the most insidious aspects of incineration is the entirely new and highly toxic chemicals that can be formed during the combustion process. When fragments of partially burned waste chemicals recombine within incinerator furnaces, smokestacks, and/or pollution control devices, hundreds, even thousands, of new substances are created, many of which are toxic than the original waste itself. Among these are dioxins and furans a class of chemical compounds widely recognized to contain many highly toxic compounds. Dioxins are created when chlorine-containing materials are burned. They have no useful purpose and are associated with a wide range of health impacts including, cancer, altered sexual development, male and female reproductive problems, and suppression of the immune system, diabetes, organ toxicity and a wide range of effects on hormones (Greenpeace, 2001)

## 2.7 PREVENTING ACCUMULATION OF OBSOLETE CHEMICAL STOCKS

Due to the harmful effects of obsolete chemical stocks and the high costs of safe and environmentally sound disposal method, it has become imperative to seek a common position on ways and means to avoid further accumulation of obsolete and unwanted stocks in the future. The long-term solution to obsolete stocks lies in preventive measures (FAO, 1995b). Table 2.2 gives a summary of some recommendation ways to avoid accumulation of obsolete chemicals.

**Table 2.2: Summary of some recommended measures to avoid accumulation of obsolete chemicals.**

| CAUSES OF ACCUMULATION | PREVENTIVE MEASURES |
|---|---|
| 1. Insufficient storage capacity | Upgrading of old stores. Procuring quantities of chemicals that will exceed storage capacity must be avoided. |
| 2. Staff not trained in stock management | Train staff in stock management. Ensure compliance with "first-in, first-out principle. |
| 3. Improper handling of chemicals | Train staff in proper handling of chemicals during transport. Transit periods should be shortened as much as possible. |
| 4. Overstocking of products with a short shelf-life. | Do not stock up large quantities of products with a short shelf-life. Chemicals should be stored for at most two years. |
| 5. Excessive donations | Donation in excess requirement should not be accepted. Donated chemicals should be well scrutinized before acceptance. |

# CHAPTER THREE

## 3.0 MATERIALS AND METHODS

## 3.1 MATERIALS

### 3.1.1 Apparatus and Equipment

All glassware (test tubes, beaker, volumetric flask, etc) used were soaked in detergent solution for about six hours; rinsed; washed; and dried before analysis. The list of apparatus and equipment used include the following; test tubes, beakers, capillary tubes, thermometer, litmus paper, funnel, volumetric flask, measuring cylinder, melting point apparatus (Electrothermal melting point apparatus) and pH-meter.

### 3.1.2 Reagents

Distilled water was used for the preparation of all solutions. All reagents used were products from BDH Company (England) and were of analytical grade. The reagents used include the following; 0.1M NaOH, $NaHCO_3$, 0.1M $H_2SO_4$, 0.1 M HCl and 0.1 M $AgNO_3$.

0.1M solutions of NaOH, $NaHCO_3$ and $AgNO_3$ were prepared by measuring 1.0 g, 2.1 g, and 4.25 g respectively of each compound and dissolving it with distilled water to the 250 mL volumetric flask. 5% HCl solution was also prepared by diluting 5 mL of concentrated HCl in a 100 mL volumetric flask. All solutions were transferred into reagent bottles and sealed for use.

## 3.2 EXPERIMENTAL METHODS

### 3.2.1 Selection of Schools

There are many schools or educational institutions in Ghana. Obsolete chemicals exist in almost every school across the country where chemicals are used. Due to the large number of schools/departments across the country, and the pilot scale on which this project is based, it was very prudent to select some of these schools to work on.

Several factors were considered during the selection of school/department and these included: quantity and type of chemicals used, the closeness of the department/school to the Chemistry laboratory of KNUST; and the willingness of the department to give out their chemicals for examination.

Based on the above factors, six department/schools were selected. Chemicals were collected from the chemical storerooms of; Departments of Theoretical and Applied Biology, Department of Chemistry, Department of Pharmaceutical Chemistry, all of K.N.U.S.T; and that of Anglican Senior High School, Kumasi Senior High School and Technology Senior High School, all in Kumasi.

### 3.2.2 Sorting and Inventory Taking

Most laboratories visited had their newly purchased and old chemicals sitting on the same shelves. It was then necessary to sort the old chemicals from the newly purchased ones. With the help from the store keepers, these chemicals were first sorted out. For the sake of this project chemicals that have been in stocks for ten or more years were sorted out and inventoried.

The urgency of removing outdated, extremely hazardous, unusable, and unknown chemicals from the chemical storerooms was very much appreciated after taking a good look at the stores under study.

Each of the stores visited had a variety of dangerous chemicals that were obsolete, unlabeled, toxic, reactive, and even explosive on their shelves which they no longer use. These chemicals have been kept for decades, and according to laboratory personnel, some have even been in stocks since the inception of the department/school. This was the legacy laboratory personnel inherited from their predecessors and has been a big problem for them.

Most of the chemicals have been degraded due to prolonged storage. Degradation was detected by changes in their physical state such as liquefaction, colour changes (which may be used as a guide to determine if a material has deteriorated) and the chemicals were contained in aged and decrepit containers; some of which were leaking whiles others were in containers with no caps. The leaking of chemicals in aged containers and the non-availability of caps had led to contamination and reeking of the store rooms.

Common problems found in the stores under study were as follows: incompatible chemicals were found next to each other on shelves but arranged alphabetically rather than locked in approved safety storage cabinets making them inappropriate and unsafe. Chemicals were stored above eye level on shelves, others kept on the floor or under sinks. Some reagent bottles were unlabeled, and others with warning or storage code omitted from the label. In some cases, chemicals were stored in the offices of laboratory personnel. Chemical inventories were non-existing or incomplete in most stores in all except for Department of Pharmaceutical Chemistry.

The Department of Pharmaceutical Chemistry was the only place which had inventory of all chemicals in stocks. The floors have been coloured by spilled chemicals and the storage rooms reek due to poor ventilation system. These practices may result in serious injury to students and staff.

The ever increasing nature of obsolete chemicals had created and continues to create problems for laboratory personnel. The method of storage of these chemicals varied from one department to another and from school to school especially for the unknown chemicals. Some laboratory personnel had packed these obsolete chemicals so closely to each other on the shelves, others for lack of space on the shelves dumped theirs at one corner on the floor of the store rooms, whiles another group of personnel also packed theirs on the corridors of the building due to lack of space both on the shelves and in the stores. All these practices were done without considering the incompatible nature of these chemicals. Each group of personnel admitted that the kind of storage is not the best, but lacked funds or the know how for disposal of these chemicals.

Detailed inventories were taken on all the chemicals that were kept in the stores to determine which of the chemicals were obsolete and which might still be usable, identify the chemical name (using the label), the quantities (Kg) and the condition or state of their packaging; and to identify suitable disposal options for those that are not usable. Individual products were later classified as:

a) ***Products that are definitely obsolete and require disposal:*** These are older chemicals, past guaranteed shelf-life, that have not yet visibly deteriorated and have their labels intact. They were then classified into solid and liquid, then into organic and inorganic, and finally into their various hazard classification groups.

b) ***Products requiring further testing:*** These chemicals do not have labels on them and most of which are caked and contaminated. They were then separated into liquid and solid compounds and qualitative analysis was performed on them to ascertain whether each of them is an acid, neutral or basic compound.

### 3.2.3 Melting Point Determination

Melting point determination was conducted to test for the purity of the *products that are definitely obsolete and require disposal.*

A total of 25 different chemicals were selected; 15 chemicals from Department of Chemistry, 5 chemicals from Department of Theoretical and Applied Biology and 5 from Department of Pharmaceutical Chemistry. Two samples of each type of chemical were picked and their melting points were determined.

A ground sample of each of the selected chemicals was fetched with the open end of a capillary tube and was then inserted into the capillary hole and a thermometer was also inserted into other hole of the Electrothermal Melting Point Apparatus. The apparatus was then switched-on to supply heat to the sample whiles the sample was observed carefully through the observing lens. Initial temperature was recorded just when the sample started melting while the final reading was also taking just when the entire sample had completely finished melting. This gave the range for the melting point.

### 3.2.4 Solubility test

The solubility of each of the unlabeled samples was tested in distilled water, $NaOH_{(aq)}$, $HCl_{(aq)}$, $H_2SO_{4\,(aq)}$ and $AgNO_{3\,(aq)}$ for identification purposes.

For the liquid sample, about 2 mL of each sample was used for the analysis. For the solid samples, about 0.2 g was dissolved in each of the above reagents.
Litmus test was also conducted where the samples dissolved in water.

### 3.2.5 *Determination of pH*

pH values were determined for *products requiring further testing* to ascertain whether the samples were strong acid, weak acid, strong base, weak base or neutral compounds. The pH meter was calibrated with buffer solutions of pH - 4 and pH-9 before using for the pH determination.

For the liquid samples portion of the chemical was used for the determination by dipping the electrode of the pH meter into the solution and allowing the reading to stabilize before recording.

For the solid samples, 5.0 g was dissolved in 20 mL of distilled water and portion of this solution was used for the determination.

### 3.2.6 Interaction with Store Managers

Interaction was made with store managers to find out how chemicals are purchased, stored and disposed of. Questions on the causes of accumulation of unused chemicals were also asked. Opinions on how this problem could be solved were sought for. There questions asked varied from store to store depending on how chemicals are being managed.

## 3.3 FLOW CHART OF EXPERIMENTAL PROCEDURE

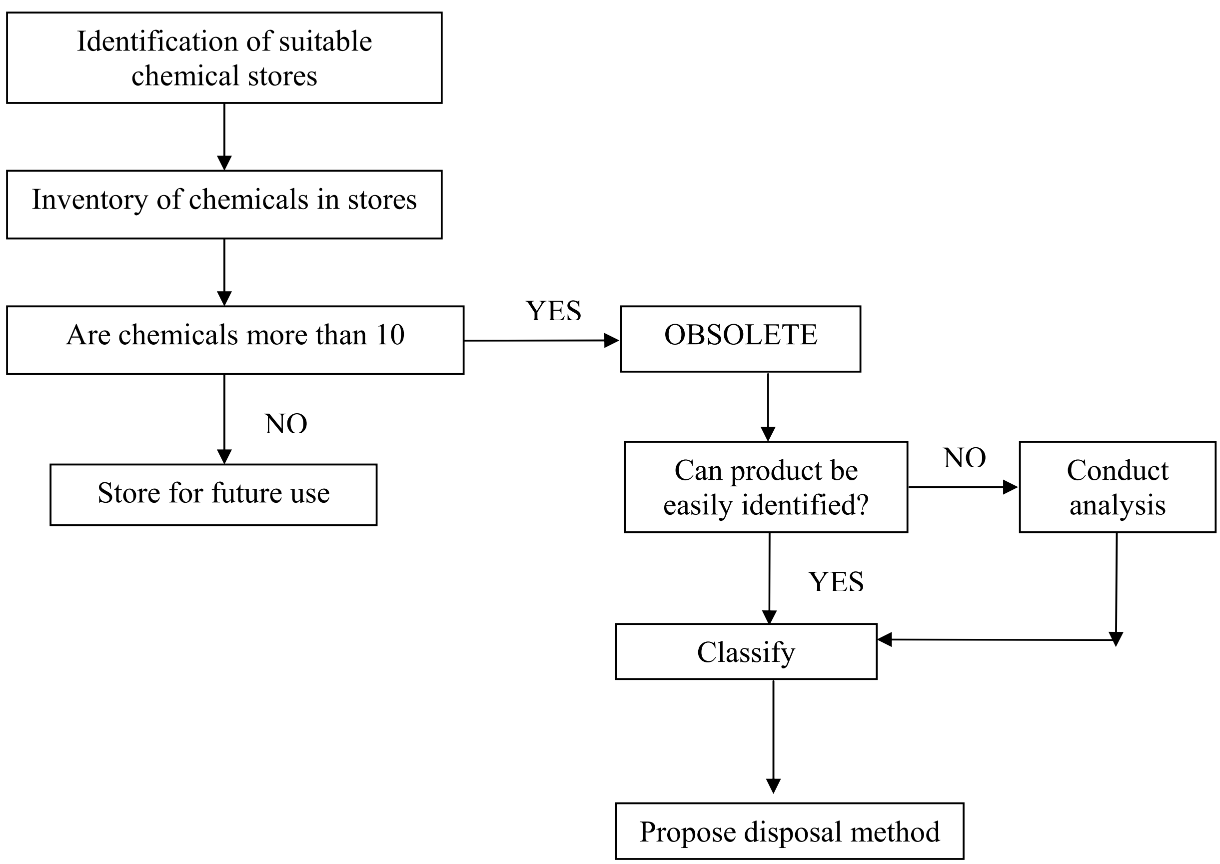



**Fig 3.1 Flow chart of experimental procedure**

## CHAPTER FOUR

### 4.0 RESULTS AND DISCUSSION

Table 4.0 below presents the total weight of currently in use and obsolete chemicals from all the six stores under study. The total weight of currently in use chemicals from all the stores was 195.7 kg. Kumasi Senior High School recorded the least value of 12.2 kg whiles Technology Senior High School recorded the highest value of 26.6 kg. Among the tertiary institutions, Department of Theoretical and Applied Biology recorded the least amount of chemicals in use (34.7 kg) whiles Department of Chemistry recorded the highest of 58.4 kg. The over all weight of both currently used and obsolete chemicals was 1,082.6 kg.

**Table 4.0: Total Weight of Currently Used Chemicals versus Obsolete Chemicals**

| LOCATION | WEIGHT OF USE CHEMICALS/ Kg | WEIGHT OF OBSOLETE CHEMICALS/ Kg | TOTAL WEIGHT /Kg |
|---|---|---|---|
| Department of Theoretical and Applied Biology, K.N.U.S.T | 34.7 | 258.8 | **293.5** |
| Chemistry Department, K.N.U.S.T | 58.7 | 224.9 | **283.6** |
| Pharmaceutical Chemistry Department, K.N.U.S.T | 39.5 | 283.3 | **322.8** |
| Anglican Senior High School, Ksi. | 24.0 | 20.5 | **44.5** |
| Kumasi Senior High School, Ksi. | 12.2 | 58.5 | **70.7** |
| Technology Senior High School. Ksi. | 26.6 | 40.9 | **67.5** |
| **TOTAL** | **195.7** | **886.9** | **1,082.6** |

With the exception of Anglican Senior High School which had it's currently used chemicals to be more than the obsolete chemicals, the rest of the schools had their obsolete chemicals exceeding the currently used chemicals. This can be attributed to the fact that the Anglican Senior High School is either managing their chemicals well or does not receive large quantities of chemicals.

The total weight of the currently used chemicals was less than the total weight of obsolete chemicals. On average, the total quantity of obsolete chemicals inventoried was about 5 times higher than the total quantity of currently used chemicals. This is an indication that the rate of accumulation of obsolete chemicals would decrease in the years to come, provided there are no frequent changes in curricula and/or equipment and also if industrial donations are also well scrutinized to reduce chemicals that are received at the stores. The small amount of chemical stock which are currently in use may be attributed either to the fact that schools are now managing their chemicals. Reduction of chemical stocks reduces the potential risk associated with chemicals.

In this study, much emphasis is laid on obsolete chemicals and thus the subsequent paragraphs deals more with accumulation of obsolete chemicals.

## 4.1 PRODUCTS THAT WERE DEFINITELY OBSOLETE AND REQUIRED DISPOSAL

Of all the chemicals encountered in the six chemical stores, 495 chemicals were identified as definitely obsolete and recorded a total weight of 844.2 kg, representing 95% of the over all total weight of 886.9 kg. For the senior high schools, the number of chemicals per store ranged from 19 to 73 with Anglican and Kumasi Senior High Schools recording the least and highest respectively. Similarly, the number of chemicals per store ranged from 154 to 179 for the tertiary level with the least and highest being recorded at Department of Theoretical and Applied Biology and Chemistry Department respectively. However, with the total weight Anglican Senior High School again recorded the least of 19.0 kg and Kumasi Senior High School recorded the highest of 54.6 kg for Senior High Schools. Chemistry Department and Pharmaceutical Chemistry Department recorded the least and highest weight of 206.3 kg and 280.3 kg respectively. The results are presented in Table 4.1. Detailed results can be found in the Appendix B.

**Table 4.1 Total weight of products that were definitely obsolete and required disposal**

| LOCATION | NO. OF CHEMICAL SAMPLES | WEIGHT OF ORGANIC PRODUCTS/kg | | WEIGHT OF INORGANIC PRODUCTS/kg | | **TOTAL WEIGHT/kg** |
|---|---|---|---|---|---|---|
| | | LIQUID | SOLID | LIQUID | SOLID | |
| Department of Theoretical and Applied Biology, K.N.U.S.T | 154.0 | 78.9 | 42.3 | 11.9 | 119.6 | **252.7** |
| Chemistry Department, K.N.U.S.T | 179.0 | 48.7 | 31.1 | 12.2 | 114.3 | **206.3** |
| Pharmaceutical Chemistry Department, K.N.U.S.T | 159.0 | 139.2 | - | - | 141.1 | **280.3** |
| Anglican Senior High School | 19.0 | 3.8 | 13.7 | - | 1.5 | **19.0** |
| Kumasi Senior High School | 72.0 | 1.2 | 13.6 | 0.3 | 39.5 | **54.6** |
| Technology Senior High School | 73.0 | 8.7 | 4.1 | 2.6 | 15.9 | **31.3** |
| **TOTAL** | **656.0** | **280.5** | **104.8** | **27.0** | **431.9** | **844.2** |

The 656 recorded in Table 4.1 as the total number of chemical samples comprised of 495 different chemicals. The difference of 161 is as a result of some chemicals appearing at more than one storage point. The total number of chemicals recorded depicts a wide variety of chemicals are used in our school systems. This practice is not healthy since most of the chemicals used in our schools are hazardous. The total number of chemicals recorded at the Senior High level was 143 and the total number recorded at the tertiary level was 352. Due to the varying nature of research works conducted at the tertiary level, the wide range of chemicals used at the tertiary level for intellectual excellence is due to the varying nature of the research works.

The total of 143 different types of chemicals reported for the 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. Thus, if 3 chemical repositories recorded 143 different chemicals while over 150 chemical repositories give 570, then, it is very clear that a wide range of chemicals is being used in our schools and this exposes students, staff and chemicals users to serious risk. Most of the chemicals used in school curricula are hazardous. The wider the variety of chemicals used, the greater the risk associated with it.

The total weight, 844.2 kg recorded is also an indication of the extent of danger posed to human health and the environment. Most of the chemicals are contained in aged and 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 of properly will eventually leak into the environment.

The total weight of chemicals recorded for the senior high schools ranged from19.0 kg to 54.6 kg with Anglican Senior High School and Kumasi Senior High School recording the lowest and the highest respectively. The tertiary level also ranged from 206.3 kg to 280.3 kg with Chemistry and Pharmacy departments recording the lowest and highest respectively. The number and/or quantity of organic and inorganic compounds varied from school to school and from department to department. This may be due to the differences in the course structure and also the type of management policies in existence.

For instance, there were no organic solid and inorganic liquid compounds in the store of Pharmaceutical Chemistry Department.

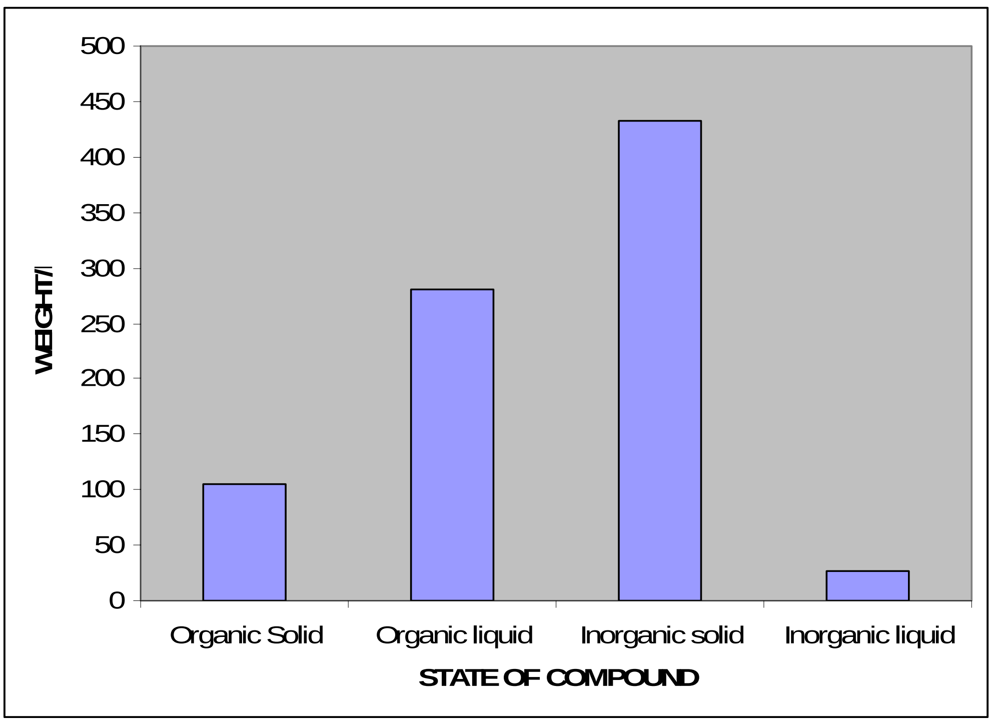



**Figure 4.1: Graphical representation of solid and liquid forms of both organic and inorganic compounds.**

From Table 4.1, the 27.0 kg of inorganic liquids 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 (HCl, $H_2SO_4$, HOCl, $AgNO_3$, etc) are frequently used in most of the school laboratory works. Due to the high demand for such chemicals, cases of excessive purchases are not experienced and thus prevent chemicals of such nature from becoming obsolete.

The 104.8 kg of organic solid recorded in the six stores is quite significant. Its accumulation may be due to the fact that, most of these chemicals are mostly used for identification purposes which requires very little amount/quantity (about 0.2g) of the compound. Thus, if large quantities are purchased, it will require a longer time to use all and the longer the chemicals stay in the stores, the higher the potential to become contaminated.

Most organic solvents are used in the laboratory mainly for extraction purposes. Ethanol, diethylether, tetrachlorocarbon, methanol, etc are solvents mostly used for extraction. Solvents like trichloroethane, dibromobenzene, chlorobutane, are not frequently used in the laboratory and have contributed greatly to the accumulation of the 280.5 kg as shown in Table 4.1.

The 431.9 kg obtained for inorganic solids shows that more of these compounds are left to go waste. It is very difficult to understand why huge amounts of these chemicals have become obsolete. Accumulation of inorganic solids may therefore be attributed to the fact that chemicals were formerly purchased without any prior measures. Purchasing chemicals that have no bearing on the course structure can contribute to the accumulation of such chemicals. Compounds like Strontium chloride, Strontium bromide, Manganous chloride, Mercuric thiocyanate were found among the stock but are not normally used. Industrial donations play a major role in the accumulation of such chemicals.

Most schools do not evaluate the health and safety criteria, or storage requirements before purchasing chemical products. Thus, schools often end up with chemicals that are very toxic, reactive and even explosive which they are not adequately prepared to use and store. 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 (Lynn *et al*, 2006). Surplus stock can also result from the following;

- Changes in curricula,
- Changes in staff or
- Donations

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 Educational 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. Organic compounds which are not mostly needed in the senior schools were sent to them from this source. Some of these compounds have not been touched since the time of distribution and are still sitting on shelves. Practical work for senior high schools is mostly direct and/or indirect titrations which normally do not require the use of organic compounds.

A number of surveys have been conducted to ascertain obsolete chemicals in schools around the world. A school chemical cleanout campaign program conducted to address chemical risk in schools for a number of states in the United States (US EPA, 2006) recorded the following results. The results represented in Table 4.2

**Table 4.2: Summary of quantities of chemicals removed as a result of the program.**

| STATE | NUMBER OF SCHOOLS | TOTAL WEIGHT/pounds | AVERAGE WEIGHT/kg |
|---|---|---|---|
| Alabama | 3 | 455 | 68.796 |
| California | 47 | 3283 | 31.684 |
| Idaho | 22 | 1411 | 29.092 |
| Iowa | 200 | 222446 | 504.508 |
| Montana | 7 | 3000 | 48.028 |
| Michigan | 34 | 3600 | 194.400 |

From Table 4.2 above, the average quantities ranged form 29.092 kg to 504.508 kg. The average for the three senior high schools (34.926 kg) in Ghana is quite close to the lowest value recorded in Table 4.2. With the exception of Idaho and California which had their averages below 34.926 kg, the remaining four states recorded averages above 34.926 kg. The value recorded in the Iowa state is too far above 34.926 g which is quite surprising comparing with other values in Table 4.2.

The weight (kg) presented in Table 4.2 are averages of chemicals in all the departments within the school, including chemicals in the science labs, art rooms, shop, classes, and maintenance areas. The 34.926 kg recorded would definitely increase, should chemicals of all these sources be inventoried in addition to chemicals in science laboratories.

A research conducted in Singapore by Venkataraman (2006), revealed that 3 tonnes of hazardous chemicals were generated as obsolete by 20 departments at the

University of Singapore. The average, 150,000 kg for the 20 departments is far less when compared with the average, 246.383 kg of the three departments in the KNUST. This huge value can result in worst scenario like fire outbreak and should therefore be dealt with as quickly as possible.

One could argue that, beside all these huge quantities of chemicals in our schools, there have not been any incidents of explosion or fire out breaks. What has to be remembered is that, the greater the quantities of chemicals, the greater would be the difficulty to solve the problems associated with such chemicals should there be a worst scenario.

| HAZARD GROUP | BIO. | CHE. | PHA. | ANG. | HIGH | TECH. | **TOTAL WEIGHT(kg)** |
|---|---|---|---|---|---|---|---|
| Non hazardous | 87.191 | 26.140 | 29.600 | 3.428 | 13.208 | 11.683 | **171.250** |
| Unclassified | 20.994 | 39.323 | 54.837 | 0.629 | 7.119 | 1.050 | **123.952** |
| Corrosives | 19.679 | 40.085 | 35.425 | 1.281 | 2.383 | 2.961 | **101.814** |
| Explosives | 28.194 | - | 0.536 | - | - | 0.037 | **28.767** |
| Flammables/Comb. | 22.723 | 22.637 | 45.173 | 3.646 | 2.034 | 5.836 | **102.049** |
| Oxidizers | 10.343 | 11.897 | 28.100 | - | 8.711 | 2.456 | **61.507** |
| Reactive | 1.125 | 1.730 | 15.450 | - | 0.304 | 0.388 | **18.997** |
| Toxic/Poison | 62.326 | 64.501 | 70.629 | 10.005 | 20.791 | 6.828 | **235.080** |

**Table 4.3 Hazard groups and their respective quantities found in all the six storerooms.**

Chemicals can be grouped or classified based on the type of hazard they pose (US EPA, 2006b). "Hazardous Chemicals" are those which pose health hazard. It is defined by OSHA as any substance for which there is statistically significant evidence, based on at least one scientific study, showing that acute or chronic harm may result from exposure to that chemical. Health hazards include carcinogens, toxic or highly toxic agents, reproductive toxins, irritants and corrosives (Trapp, 2002). Hazardous substances in schools may fall into one or more of the categories mentioned in the definition. Each of the characteristics associated with chemicals mentioned in the definition could stand as a group called, ***Hazard Group***. A hazard group is made up of a range of organic and inorganic chemicals.

Table 4.3 presents eight hazard groups for all the chemicals inventoried. These include corrosives, oxidizers, toxic/poison, flammables/combustible, reactive, non-hazardous and unclassified. The risk associated with this wide range of hazard groups is enormous and could result in unpleasant situations. Many hazardous materials require expensive storage cabinets, protective equipment and training to safely store, use and dispose of. In addition, these items require greater administrative tracking than non-hazardous chemicals. The schools liability (property damage, environmental contamination, personal injury, etc.) is greater relative to the quantity and toxicity of materials (Lynn *et al*, 2006). Lack of proper chemical management increase the range of hazard groups which apart from increasing cost, increases other liabilities and the extent of risk pose to students and staff.

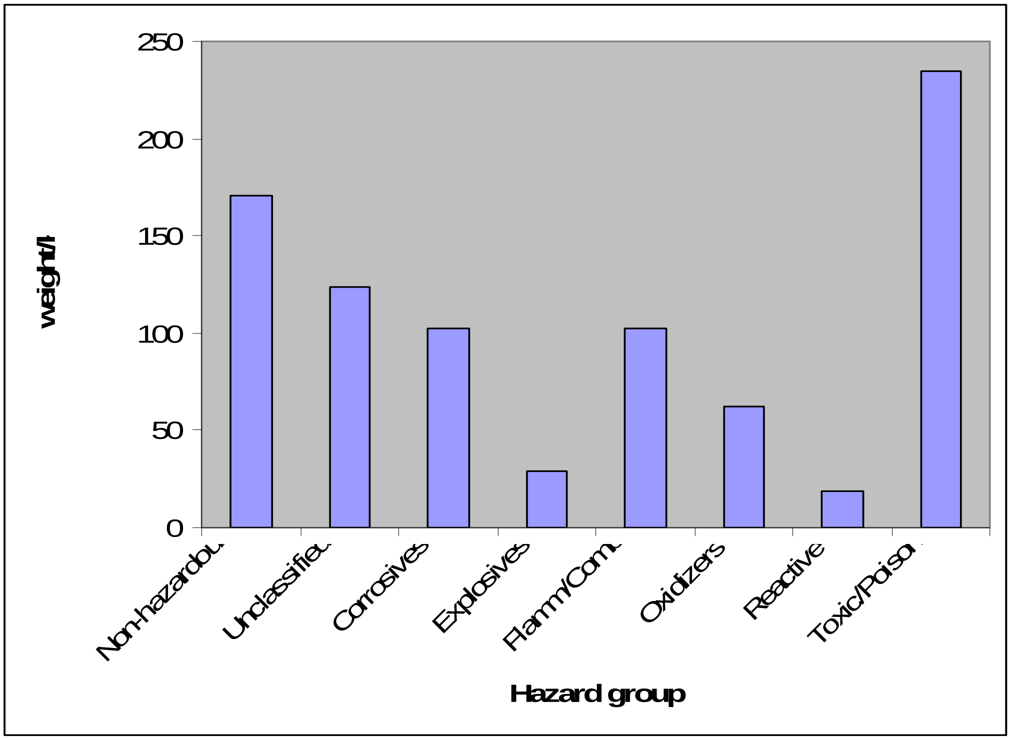



**Figure 4.2: Graphical representation of the weight versus hazard groups.**

From Table 4.3, 124 kg of chemicals was found to be unclassified (their hazard symbol were omitted) and thus becomes very difficult to say whether they are hazardous or not. It is also very dangerous when working with unclassified chemicals. This is because one may not know the kind of protective gear to wear when working with such chemicals and thus such person becomes vulnerable to any risk associated with the chemical. In countries like U.S.A, the Federation does not permit the use of such chemicals. Proper keeping of MSDS can help reduce the hazard one may be exposed. But in all the six stores that were studied, MSDS were not properly managed. Department of Chemistry, Department of Theoretical and Applied Biology, Technology Senior High School and Kumasi Senior High School provided a half-torn MSDS. It is therefore reasonable to properly manage MSDS.

The 171 kg of non-hazardous chemicals obtained depicts that relatively very small amount of such chemicals are employed in our laboratory work. Using more hazardous chemicals in our schools is not a good practice and puts the lives of students and staff at risk. Most of our laboratory wastes are washed down the drains which though in small quantities can accumulate with time and contaminate the environment. Aniline, methanol, naphthalene (very poisonous compounds) are used in the laboratory as part of the curriculum but students use these compounds without any strict adherence to laboratory rules - Gloves are not worn; besides, these chemicals are discarded into sinks and are washed down into the drains unknowingly to the laboratory instructor.

Many organic compounds are volatile and evaporate even at room temperature and because most students are not aware of the dangers associated with these compounds, they leave the containers open after working with them. Both students and staff should be very well trained on the dangers associated with chemicals to equip them in their laboratory work.

The primary hazard associated with flammable compounds, especially flammable liquids is their ability to readily ignite and burn. Flammable materials are very treacherous. In general, the vapour of many flammables is irritating to mucous membranes of the respiratory system and eyes, and in high concentration is narcotic *(Lynn et al, 2006)*. The 102 kg of flammable/combustible compounds obtained, is quite alarming must be dealt with to dispose of the existing quantity in order not to experience any fire out-break. Proper storage cabinet can also be used to prevent evaporation of flammable liquids and thus prevent explosion.

The 235 kg recorded as Toxic/Poison is alarming. Most of these chemicals recorded were heavy metals and/or their compounds. Very few of these compounds are used in the curricula for cation and anion identification. Cadmium, lead and mercury compounds are all poisonous and potential contaminants to the environment but were found in the stores. These chemicals when kept for a longer period and in large quantity pose a lot of risks to staff and students as well as the environment. Because of the hazardous nature of such chemicals, substituting by less toxic ones can go a long way to help both the public and the environment.

Because some of these chemicals are highly dangerous, the curriculum should therefore be scrutinized to seek ways to minimize the storage and use of highly hazardous chemicals (Lynn *et al*, 2006). Thus, incorporation of micro-scale or green Chemistry into school curricula can help solve these problems. Small-scale or green chemistry is a cost-effective, pollution prevention program that reduces waste and eliminates the accrual of future wastes in schools (US EPA, 2006).

## 4.2 PRODUCTS REQUIRING FURTHER TESTING BEFORE DISPOSAL

Chemicals that could not be identified because their labels have deteriorated or peeled off, were considered as *unknown*. These chemicals have lost their labels due to prolong storage and poor management. Most of such chemicals were liquefied. Some powdery substances are hardened and caked, while others have changed in colour and were contained in broken containers. The accumulation of these chemicals has created and continues to create problems (with spacing) for laboratory personnel beside the problem of disposing them.

Unknown chemical wastes cannot be legally transported or disposed. In order to dispose of them safely and properly, 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 need to be done include, IR, MS, GC and UV. Since these equipments are not within our reach besides the high cost involved in conducting such analyses, preliminary tests like solubility and pH analyses were performed to help classify the compounds into acids, bases or neutral.

Of 576 different chemicals recorded, 81 chemicals were found to be unknown and recorded a weight of 42.7 kg representing 5% of the total weight. The results are presented in Table 4.4.

**Table 4.4 Total weight of products requiring further testing**

| LOCATION | NO. OF CHEMICAL SAMPLES | WEIGHT OF LIQUID SAMPLES/kg | WEIGHT OF SOLID SAMPLES/kg | **TOTAL WEIGHT/kg** |
|---|---|---|---|---|
| Department of Theoretical and Applied Biology, K.N.U.S.T | 12.0 | 3.9 | 2.2 | **6.1** |
| Chemistry Department, K.N.U.S.T | 38.0 | 16.6 | 2.0 | **18.6** |
| Pharmacy Department, K.N.U.S.T | 6.0 | 1.7 | 1.3 | **3.0** |
| Anglican Senior High School | 5.0 | 0.8 | 0.7 | **1.5** |
| Kumasi Senior High School | 7.0 | 2.9 | 1.0 | **3.9** |
| Technology Senior High School | 13.0 | 6.8 | 2.8 | **9.6** |
| **TOTAL** | **81.0** | **32.7** | **10.0** | **42.7** |

With 38 chemicals, Chemistry Department recorded the highest number of unknowns whiles Anglican Senior High School recorded the least number of 5 chemicals. Most of the unknowns were solids (salts) but had absorbed water to become liquid. Each of the chemical recorded was subjected to qualitative analysis, testing it solubility in

$H_2O$ and solutions of HCl, NaOH, $AgNO_3$, and conc. $H_2SO_4$. Litmus test and pH were also determined. The details of the results are presented in Appendix C.

From Appendix C, 40 out of the total chemicals were classified as acids (turned blue litmus paper to red), 22 were classified as bases (turned red litmus paper blue) whiles 12 were classified as neutral (had no effect on litmus paper). The remaining 7 chemicals could not be opened by hand due to rusty nature of the caps. The pH of the acids ranged from 0.49-6.86; that of bases ranged from 8.34-13.85; whereas the neutral compounds had theirs ranged from 7.01-7.07.

Out of the 40 acids, 25 had their pH ranged from 3.19-6.86 which is indicative of weak acid whiles 15 had their pH ranged from 0.49-2.80 which is an evidence of strong acid. Examples of weak acids use in schools are; HCOOH, $C_6H_5COOH$, $CH_3COOH$, $C_6H_5OH$, HClO, HBrO, $H_2S$, $H_3PO_4$ etc. From Appendix B, some of the weak acids formed precipitate with $AgNO_3$ and are suspected to be one of the weak inorganic acids whiles those that did not form precipitate with $AgNO_3$ were suspective of weak organic acid. All strong acids are inorganic. Examples are; HCl, HBr, HI, $H_2SO_4$, $HNO_3$ and $HClO_4$. The strong acids mostly used in schools are HCl, $HNO_3$, $H_2SO_4$ and $HClO_4$.

Only two (2) out of twenty-two (22) basic chemicals recorded a pH of 13.85 which is characteristic of strong bases. Strong bases mostly used in schools are KOH, NaOH and $NH_3$. The remaining 20 chemicals had their pH ranged from 8.34-11.91 which is usually normal of weak bases. Evolution of gas and precipitate formation during the reaction of compound with conc. $H_2SO_4$ and $AgNO_3$ solutions are indicative of inorganic bases like KF, KBr, $Na_2CO_3$, $CaCO_3$, etc. Compounds that did not form precipitate with $AgNO_3$ are suspected to be organic compounds; $(CH_3)_2NH$, $C_6H_5N$, $C_6H_5NH_2$.

Neutral salts normally used in schools are; NaCl, KBr. KCl, $Ba(NO3)_2$, thus the compounds having their pH ranged from 7.01-7.07 may be one of the above compounds.

### 4.3 MELTING POINT DETERMINATION

Melting point is one of the physical properties useful in identification of organic compounds. Melting point is a valuable criterion for the determination of purity of organic compounds. A sharp melting point is usually indicative of high purity of a substance. A pure crystalline has a sharp and definite melting point range which does not exceed 0.5-2.0 $^{o}C$. The presence of impurities produces a remarkable increase in melting point range and causes the commencement of the melting point to occur at temperature lower than the melting point of the pure substance (Vogel, 1989).

In this project, melting point was determined to ascertain whether the chemicals have been contaminated. The presence of impurities will contaminate the chemical and definitely cause a change of melting point. Melting points of some chemicals were determined. The results are presented in Table 4.5 below.

**Table 4.5 Literature and experimental melting point value for some selected products that are definitely obsolete.**

| COMPOUND | LITERATURE VALUE/°C | EXPERIMENTAL VALUE/°C |
|---|---|---|
| 1-Naphthol | 94-96 | 89-95 |
| 2-Aminopyridine | 56-59 | 50.8-54 |
| 2-Naphthol* | 121-123 | 121.5-123 |
| 3-Nitroaniline | 112-114 | 95-101 |
| 4-Aminobenzoic acid | 187-189 | 157-166.5 |
| 8-Hydroxyquinoline* | 72.5-76 | 72-74 |
| Anisic acid | 183-185 | 169-175.5 |
| Anthrone | 152-158 | 148-151 |
| Myristic acid* | 53.5-55 | 54-55 |
| Quinol | 170-174 | 178-183 |
| Resorcinol | 110-112 | 113-116 |
| 1,4-Dichlorobenzene | 54-56 | 48-52 |
| 2,4-Dichlorophenol | 42-43 | 39-41 |
| 2-Methyl naphthalene | 34-36 | 30-33 |
| 4-Aminophenol* | 188-189 | 187-189 |
| Acetamide | 84-89 | 78-81 |
| 3-Amino benzoic acid | 178-180 | 170-178 |
| Acetylsalicylic acid | 138-140 | 133-139 |
| Benzamide | 128-129 | 120-125 |
| Benzoic acid | 122-123 | 115-120 |
| Methylene blue | 190 | 182-189 |
| Naphthalene | 80-82 | 71-76 |
| p-Amino benzoic acid | 188-189 | 176-178 |
| p-Amino phenol | 188-190 | 185-189 |
| p-Anisidine | 57-60 | 35-41 |

From Table 4.5, only four (marked by asterisk) out of twenty-five compounds were found to have their melting point fallen within their literature range. The four represents 16% of the total, thus 84% had their melting points fallen aside the literature range. This may be an indication of the presence of impurities in the compound. This shows that chemicals in these stores have not been handled well by the store keepers.

## 4.4 CAUSES OF ACCUMULATION

The causes of accumulation of chemicals in schools and research institutions are enormous, ranging from the time of purchase through to disposal. But after interacting with the store managers of various store rooms, the following causes became the most prominent.

- Improper purchasing policies and donations from agencies.
- Inadequate chemical storage facilities
- Poor chemical inventory management
- Lack of proper auditing
- Lack of routine training for relevant administrators, teachers and school personnel.
- Change in curricula and/or equipment
- Lack of funds for disposal

### 4.4.1 Lack of proper purchasing policies

This was present almost in all cases where chemicals have accumulated. According to US EPA (2006) and Benoit (2007), this was found to be the cause of accumulation in many schools in the United State.

According to the store managers for the tertiary level, purchasing of chemicals was formerly centralized. Chemicals were purchased by the university on a large scale and were later distributed to the departments. For this reason chemicals were purchased to cover a period of 2-5 years after which new purchase was made. Distribution through departments was also in large amounts and this contributed to the accumulation of these chemicals.

For the senior high schools, purchasing and distribution of chemicals was done yearly by Ghana Educational Service (GES). According to teachers and personnel in charge of stores, GES do the supply without considering the course structure. They did not even go round to check for surplus neither do they ask them to submit their request. For this reasons, organic chemicals which are less used were sent to the schools. This has contributed to the accumulation of these chemicals in Table 4.1.

In order to prevent future accumulation, departments and schools now buy their own chemicals. Chemicals are now purchased by the departments/schools with government subvention. According to laboratory personnel, since the beginning of such practice, accumulation of excess chemicals has reduced considerably.

### 4.4.2 Lack of proper chemical storage

After distribution of chemicals to the departments/schools, these chemicals were not well stored. Chemicals were and are still stored alphabetically, labels are in a deteriorable state, leaking containers with broken caps are found on shelves in the stores.

Deterioration of labels on containers and breaking of caps can be prevented by conducting a walk-through inspection at least once a week to check on chemicals that are not in good condition. Additionally, alphabetical storing of chemicals could also be avoided by storing according to hazard group as suggested by Flinn Scientific Inc. (1991). This can prevent any fire outbreak or explosion due to reaction of incompatible chemicals from leaking containers.

### 4.4.3 Chemical inventory management

Hazardous chemicals accumulate when there is no tracking system, no disposal plan and when there are changes in staff and/or changes in curriculum (Lynn *et al*, 2006). Inventory of all the chemicals in stocks were non-existing in all the chemical stores with the exception of Pharmacy department, Laboratory personnel are reluctant to conduct inventory of all the chemicals in stocks due to the failure on the part of the enforcers to enforce the implementation of the storage procedures. Besides, frequent changes of personnel have played a major role to the mismanagement of chemical inventory and thus lead to chemical accumulation (most of the laboratory personnel who could not provide inventory of their chemicals said that their predecessors did not do them and that they are now trying to take the task).

By conducting chemical inventories, schools can identify unneeded, out-of-date chemicals and arrange to have these chemicals disposed of before they cause problems. Accurate inventories will also help prevent the purchasing of chemicals already in stock (FDEP, 2007). It is therefore a necessity that, up to date chemical inventories be available in every school department prior to the ordering of any new chemicals.

### 4.4.4 Lack of proper auditing

Proper auditing can help prevent accumulation. In schools and universities, chemicals are only audited when they are freshly purchased. Even with that, laboratory personnel have to carry the freshly purchased chemicals to the auditor's office. Chemicals usually taken to the auditor's office are done by hand which is inappropriate and unsafe.

### 4.4.5 Lack of routine training for relevant administrators, teachers and school personnel

In the majority of cases**,** adequate training about responsible chemical management is not part of the schools curriculum for both teachers and store keepers (US EPA, 2006). "School administrators and staff are often unaware of the quantity and toxicity of hazardous chemicals accumulating in their school buildings, or of the proper use and storage procedures necessary to maintain product stability and occupant safety". "Most staff are not trained to recognize and manage the risks of hazardous chemicals". This according to Lynn *et al* (2006) has been the cause of accumulation in many schools in Massachusetts.

Therefore, it is important to provide routine training for teachers and store keepers to help institute responsible chemical management activities such as inventory taking and assisting with chemical cleanouts. Offering training opportunities at little or no cost to teachers acts as an incentive for participation. Training will allow relevant school staff to:

- Prepare chemical inventories;
- Identify hazards; and
- Institute responsible chemical management practices (US EPA, 2006).

This scenario (problem) manifested itself after interacting with the personnel. It was observed that most of the personnel have little or no knowledge about the hazards of most of the chemicals they have in stock.

### 4.4.6 Change in curricula and/or equipment

Changes in curricula and/or equipment could lead to accumulation of chemicals in the stores. This though, a minor problem needs to be addressed before it becomes a major contributory factor. The severity of the situation comes in when there are frequent changes in curriculum.

This situation has been a minor cause of accumulation over the past years. For instance, the laboratory work of Chemistry department has not seen much change in the curricula for over 5 years and has contributed less to the accumulation of chemical stocks.

### 4.4.7 Accumulation from donations

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 H2SO4) 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.

Additionally, most of these chemicals are irrelevant and can not be used for the curricula. This, according to laboratory personnel has been one of the major contributing factors to the accumulation of chemicals in stocks. Staff and personnel should scrutinize donated chemicals very well before accepting them in order to prevent future accumulation.

### 4.4.8 Lack of funds for disposal

Chemical users become hesitant when it comes to disposal. This is due to the exorbitant charges involved in disposing of the chemicals. The best way to manage these chemicals is to stockpile them in the stores. To prevent that, government should provide funds or solicit for funds to dispose them of and also educate people on the need for proper management of chemicals.

## 4.5 COMPARISON OF OBSOLETE CHEMICALS AND CURRENTLY USED CHEMICALS

To support the removal of obsolete chemical from the stores, comparison was made between the currently used chemicals and the obsolete chemicals. This was done to find out number of obsolete chemicals that are still employed in our curricula. Three laboratory manuals for undergraduate practical work in the Department of Chemistry were used. In all, 145 chemicals were recorded and compared with 179 obsolete chemicals. The list of these chemicals as well as the list of the obsolete chemicals in the department is shown in Appendix D.

Comparing the two lists, only six (6) chemicals (marked by asterisk), representing 3.35% were still in use for the undergraduate practical work. The remaining 173 obsolete chemicals (representing 96.65%) were no longer in use and should therefore be disposed of. Also the probability that these chemicals will be used again is very slim. This is because for the past 8 -10years, the course structure (or laboratory manuals) of Chemistry Department has not seen any change of curricula and if this should continue, then the faith of these obsolete chemicals will only lie in disposing them of but not in keeping them.

## 4.6 PROPOSAL OF PROPER DISPOSAL METHODS

Disposal of hazardous waste is dangerous and expensive even when the contents of the waste are identified. Fortunately, most of the chemical wastes produced by the Departments/Schools were identifiable. However, when the contents of a reagent bottle or reaction flask are not identified, the process of disposal is much more dangerous, expensive and difficult. Without mitigating information, all unknown materials have to be treated as if they were potentially lethal and hazardous (FAO, 1995a).

The obsolete chemicals found vary in characteristics and were either toxic, corrosive or highly inflammable in nature. The chemicals include aromatic chlorinated compounds, heavy metals, solvents and hydrocarbons. Storage of such chemicals poses serious safety and health hazards. Disposing of obsolete chemicals effectively is critical to creating safety in schools and is an important step in achieving proper chemical management.

Though none of the disposal methods; incineration, landfill and chemical treatment discussed in section **2.6.1** is safe, however, due to economic considerations, the quantities and the wide range of hazardous waste produced; *incineration* would be the preferred one among the three methods discussed. Incineration actually perpetuates the use of landfills because of the large quantities of leftover ash produced by incinerators. This ash is very toxic, containing concentrated amounts of heavy metals and dioxins which, when buried, will eventually leach into the soil, potentially polluting groundwater.

Notwithstanding the fact that incineration is the best among the three options, incineration should be coupled with landfill due to the fact that heavy metals and compounds containing heavy metals cannot be incinerated. Therefore heavy metals and their compounds should therefore be segregated and landfill in addition to the ash produce by the incinerator.

### 4.7 PREVENTIVE MEASURES

In view of the hazards associated with obsolete chemical stocks and the high costs of safe and environmentally sound disposal method, it has become imperative to seek a common position on ways and means to avoid further accumulation of obsolete and unwanted stocks in the future. The long-term solution to obsolete stocks lies in preventive measures (FAO, 1995b).

**Table 4.6: Causes and Preventive Measures to Avoid Future Accumulation of Chemicals.**

| CAUSES OF ACCUMULATION | PREVENTIVE MEASURES |
|---|---|
| 1. Improper purchasing policies | Careful consideration should be given to purchasing chemicals for storage to avoid common problem of chemicals and excess stocks. |
| 2. Improper chemical storage | Chemicals should not be stored alphabetically. They should be stored by their chemical hazard group to keep incompatible chemicals from each other (but in each group, they should be stored categorically). Appropriate measures include separation by shelves or by secondary containment.<br>Chemicals should also not be stored above eye level. Thus, shelves should not be built so high that one will have to overreach before picking a chemical from the top shelf. |
| 3. Chemical inventory management | Proper management of inventories can help determined existing chemicals, its location, and approximate shelf life, thus helping to control purchasing of already existing chemicals to reduce congestion in stores. |
| 5. Lack of routine training for relevant administrators, teachers and school personnel. | Intermittently, training should be given to relevant administrators, teachers and store keepers. Training can be in the form of seminars, etc. This will help store keepers to manage their stock well by practicing “First in, First out” in order not to accumulate chemicals till they expire. |
| 6. Change of curricular and/or equipment. | Changes of curricula and/or equipment should be a long term plan. This will pave way to clear |

| | |
|---|---|
| | the back log of chemicals in stock. Regular changes of curricula and/or equipment can be a major contributor to chemical accumulation. |
| 7. Accumulation from donations | Most of the donated chemicals near expiration date. Others too are irrelevant to the curricula activities. Thus donated chemicals should be well checked before acceptance. |
| Lack of funds | Disposal of hazardous chemicals (wastes) is very costly and because funds for disposal are non-existing, government and other aid agencies should provide funds for disposal of existing chemicals. This will enhance the implementation of proper chemical management. |

# CHAPTER FIVE

## 5.0 CONCLUSION AND RECOMMENDATION

### 5.1 CONCLUSION

- Chemical inventories were taken on both currently used and obsolete chemicals from six chemical stores within our school system. Based on the results obtained in this research, it can be concluded that;

- Of the total weight of 1,082.7 kg of chemicals inventoried, 886.9 kg representing 81.9% was found to be obsolete and were grouped as; products requiring further testing and products that were definitely obsolete.

- The total weight of products requiring further testing was 42.7 kg and comprised of; 22.3 kg of acids, 10.7 kg of base and 5.4 kg of neutral products. The remaining 4.4 kg could not be opened by hand due to the rusty nature of the caps. The total weight of products that were definitely obsolete was 844.2 kg and consisted of; 101.8 kg of corrosives, 28.8 kg of explosives, 102.0 kg of flammable/combustible, 61.5 kg of oxidizer, 19.0 kg of reactive, 235.1 kg of toxic/poison, 171.3 kg of non-hazardous, and 124.0 kg of unclassified products.

- The total weight of obsolete chemicals for the tertiary level on average was 6 times that of the senior high schools level. This showed the extent of research work at the tertiary level.

- Most of the chemicals found in the stores were hazardous and vary in characteristics. Due to economic consideration, the nature and quantity of chemicals found, it is proposed that the method of disposal of these chemicals be incineration coupled with landfill.

## 5.2 RECOMMENDATION

The following recommendations were based on the outcome of the research:

- Government agencies like EPA should solicit for sponsorship to do this nation-wide to help quantity.

- Schools and other research institutions should practice micro-scale or green chemistry and also use less toxic chemicals in order to prevent future accumulation.

- A national chemical procurement body should be established to control purchasing and supplies of chemicals to schools, universities and research institutions. This body should also be task with the responsibility of ensuring that excesses are minimized if not eliminated.

- Changes of curricula and /or equipment should be a long term plan in order not to create a backlog of chemicals.

- Intermittently, training should be given to relevant administrators, teachers, school personnel and other chemical users to upgrade their knowledge on chemical management. The training can be in the form of seminars, etc.

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# APPENDICES

**Appendix A**

| INVENTORY OF CURRENTLY USED CHEMICALS | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | WEIGHT/ kg | | | | | | |
| CHEMICAL NAME | QTY | PHYSICAL STATE | | BIO | CHEM | PHARM | ANGL. | K. HIGH | TECH. | **TOTAL WEIGHT/ kg** |
| 1,10- Phenanthroline hydrate | 1 | solid | | | | 0.495 | | | | **0.495** |
| Acetamide | 1 | liquid | | | | | | | 0.28 | **0.28** |
| Acetic acid glacial | 7 | liquid | | 0.625 | 0.428 | 1.27 | 0.8 | 0.5 | 0.573 | **4.224** |
| Acetic anhydride | 1 | liquid | | | 0.217 | | | | | **0.217** |
| Acetone | 6 | liquid | | 0.749 | 0.228 | | 0.5 | 0.481 | | **1.927** |
| Acetophenone | 1 | liquid | | | | | | | 0.153 | **0.153** |
| Agar | 1 | solid | | 0.5 | | | | | | **0.5** |
| Alumina | 1 | solid | | | 0.158 | | | | | **0.158** |
| Aluminum chloride | 1 | solid | | | | | | | 0.247 | **0.247** |
| Aluminum foil | 2 | solid | | 1.5 | | | | | | **1.5** |
| Aluminum nitrate | 2 | solid | | | 0.261 | | | | 0.5 | **0.761** |
| Amino acid | 1 | solid | | | 0.141 | | | | | **0.141** |
| Ammonia | 8 | liquid | | | 0.304 | 0.874 | 1.7 | 0.622 | 0.096 | **3.637** |
| Ammonium carbonate | 2 | solid | | | 0.981 | | | | | **0.981** |
| Ammonium chloride | 4 | solid | | 0.664 | 0.247 | 0.627 | | 0.341 | 0.762 | **2.641** |
| Ammonium metavanadate | 1 | solid | | | 0.212 | | | | | **0.212** |
| Ammonium molybdate | 1 | solid | | | 0.164 | | | | | **0.164** |

| | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Ammonium nickel sulphate | 1 | solid | | | 0.627 | | | | | **0.627** |
| Ammonium Sulphate | 4 | solid | | | | 0.502 | 0.9 | 0.217 | 1 | **2.636** |
| Ammonium sulphide | 1 | liquid | | | | | | | 0.314 | **0.314** |
| Amyl alcohol | 4 | liquid | | | 0.585 | 0.756 | | | 0.405 | **1.746** |
| Aniline | 2 | liquid | | | 0.823 | | | | | **0.823** |
| Antimony trichloride | 1 | solid | | | 0.05 | | | | | **0.05** |
| Aspartic acid | 1 | solid | | 0.1 | | | | | | **0.1** |
| Barium chloride | 2 | solid | | | 0.136 | | | | 0.05 | **0.186** |
| Beef extract | 1 | solid | | 0.454 | | | | | | **0.454** |
| Benedict solution | 1 | liquid | | | | | 0.5 | | | **0.498** |
| Benzaldehyde | 1 | liquid | | | | | | | 0.609 | **0.609** |
| Benzene | 2 | liquid | | | 1.418 | | | | | **1.418** |
| Benzoic acid | 2 | solid | | | | 0.265 | 0.6 | | | **0.838** |
| Benzophenone | 1 | liquid | | | 0.609 | | | | | **0.609** |
| Bleaching powder | 1 | solid | | | 0.402 | | | | | **0.402** |
| Borax | 2 | solid | | 1 | 0.817 | | | | | **1.817** |
| Boric acid | 3 | solid | | 0.744 | 0.73 | | | | | **1.474** |
| Bromobenzene | 1 | liquid | | | 0.274 | | | | | **0.274** |
| Bromocresol green | 1 | solid | | | 0.037 | | | | | **0.037** |
| Butanol | 1 | liquid | | | | 0.643 | | | | **0.643** |
| Calcium carbonate | 5 | solid | | | 1.406 | | 0.5 | | 1.908 | **3.814** |
| Calcium chloride | 3 | solid | | | 0.498 | 0.438 | 0.7 | | | **1.608** |
| Calcium hydroxide | 2 | solid | | | | | 0.8 | | 0.349 | **1.149** |
| Carbon tetrachloride | 3 | liquid | | | 0.562 | | 1.6 | | | **2.181** |
| Cerric ammonium sulphate | 1 | solid | | | | 0.6 | | | | **0.6** |

| | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Cerrium ammonium sulphate | 1 | solid | | | | 0.275 | | | | **0.275** |
| Charcoal | 1 | solid | | | 0.942 | | | | | **0.942** |
| Chlorobenzene | 1 | liquid | | | 0.251 | | | | | **0.251** |
| Chloroform | 4 | liquid | | 0.649 | 0.536 | 1.103 | | | | **2.288** |
| Cinnamic acid | 1 | solid | | | | | | | 0.102 | **0.102** |
| Copper | 1 | solid | | | 0.215 | | | | | **0.215** |
| Copper (II) chloride | 1 | solid | | | | | | | 0.05 | **0.05** |
| Copper nitrate | 3 | solid | | | 0.203 | | 0.7 | | | **0.932** |
| Copper sulphate | 1 | solid | | | 0.25 | | | | | **0.25** |
| Crystal Violet | 1 | solid | | 0.02 | | | | | | **0.02** |
| Cupric oxide | 1 | solid | | | | | | | 0.1 | **0.1** |
| Cyclohexane | 1 | solid | | | | 0.718 | | | | **0.718** |
| Cyclohexanol | 1 | liquid | | | | 0.95 | | | | **0.95** |
| di-Ammonium iron (II) sulphate | 1 | solid | | | | | | | 0.303 | **0.303** |
| Diethylether | 2 | liquid | | | 0.372 | 0.403 | | | | **0.775** |
| Diglyceride | 1 | liquid | | | 0.183 | | | | | **0.183** |
| Dimethylglyoxime | 1 | solid | | | 0.649 | | | | | **0.649** |
| Diphenylamine | 1 | solid | | | 0.425 | | | | | **0.425** |
| di-sodium hydrogen orthophosphate | 1 | solid | | | | 0.247 | | | | **0.247** |
| Dragendorf's reagent | 1 | solid | | | 0.025 | | | | | **0.025** |
| Endo agar | 1 | solid | | 0.5 | | | | | | **0.5** |
| Eriochrome black | 1 | solid | | | 0.025 | | | | | **0.025** |
| Ethanol | 11 | liquid | | | 4.625 | 2.426 | 1 | | 0.256 | **8.333** |
| Ethyl acetate | 2 | liquid | | | 0.595 | | | | 0.792 | **1.387** |

| | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Ethylenediaminetetra-acetic acid | 2 | solid | | | 0.761 | 0.265 | | | | **1.026** |
| Fehlings solution | 3 | liquid | | | 0.187 | | 0.6 | | 0.159 | **0.95** |
| Ferric chloride | 2 | solid | | 0.144 | | 0.664 | | | | **0.808** |
| Ferric hydroxide | 1 | solid | | | 0.13 | | | | | **0.13** |
| Ferric sulphate | 2 | solid | | 0.5 | | | | | 1 | **1.5** |
| Ferrous ammonium sulphate | 1 | solid | | | 0.179 | | | | | **0.179** |
| ferrous oxalate | 1 | solid | | | 0.066 | | | | | **0.066** |
| Ferrous sulphate | 3 | solid | | | 0.078 | 0.781 | | | 0.03 | **0.889** |
| Folic acid | 1 | solid | | 0.1 | | | | | | **0.1** |
| Formaldehyde | 4 | liquid | | 2.55 | | | 0.5 | | | **3.046** |
| Glucose | 2 | solid | | 0.5 | | | | | 0.253 | **0.753** |
| Glycerol | 2 | liquid | | 1.03 | | | | | | **1.03** |
| Heptane | 1 | liquid | | | 0.489 | | | | | **0.489** |
| Hexane | 2 | liquid | | 0.652 | | 1.266 | | | | **1.918** |
| Hydrochloric acid | 13 | liquid | | 2.265 | 2.551 | 1.153 | 1.1 | | 0.975 | **8.06** |
| Hydrogen carbonate | 1 | solid | | | 0.211 | | | | | **0.211** |
| Hydrogen peroxide | 4 | liquid | | 2.198 | 0.803 | | | | | **3.001** |
| Hydroxylammonium chloride | 1 | solid | | | 0.276 | | | | | **0.276** |
| Iodine | 7 | solid | | 0.4 | 0.62 | 0.634 | | | 0.012 | **1.666** |
| Iron | 1 | solid | | | 0.348 | | | | | **0.348** |
| Iron  sulphide | 1 | solid | | | | | | | 0.973 | **0.973** |
| Iron (II) nitrate | 1 | solid | | | 0.219 | | | | | **0.219** |
| Iron (III) chloride | 3 | solid | | | | | 0.7 | 0.614 | 0.5 | **1.793** |
| Iron ammonium sulphate | 1 | solid | | | 0.159 | | | | | **0.159** |
| Iron sulphate | 2 | solid | | | 0.373 | | 0.7 | | | **1.091** |

| | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Isopropyl alcohol | 1 | liquid | | | 0.586 | | | | | **0.586** |
| Kavacs reagent | 1 | solid | | 0.1 | | | | | | **0.1** |
| Lactic acid | 1 | liquid | | 0.337 | | | | | | **0.337** |
| Lead acetate | 1 | solid | | | | | 0.5 | | | **0.462** |
| Lead nitrate | 2 | solid | | | | 0.498 | 0.8 | | | **1.345** |
| Lead sulphite | 1 | solid | | | | | | | 0.1 | **0.1** |
| Leishmans stain | 2 | solid | | 0.05 | | | | | | **0.05** |
| Mac. Conkey broth | 1 | solid | | 0.2 | | | | | | **0.2** |
| Magnesium oxide | 1 | solid | | | 0.072 | | | | | **0.072** |
| Magnesium sulphate | 1 | solid | | | 0.246 | | | | | **0.246** |
| Magnesium turnings | 1 | solid | | | 0.643 | | | | | **0.643** |
| Manganate (II) oxide | 1 | solid | | | 0.049 | | | | | **0.049** |
| Manganese sulphate | 3 | solid | | 0.25 | | 0.835 | | | 0.15 | **1.235** |
| Mayer's reagent | 1 | solid | | | 0.05 | | | | | **0.05** |
| Mercuric chloride | 1 | solid | | | | 0.25 | | | | **0.25** |
| Methanol | 4 | liquid | | 0.237 | 0.986 | 0.649 | | | | **1.872** |
| Methyl orange | 3 | solid | | 0.1 | 0.038 | 0.544 | | | | **0.682** |
| Methyl red | 2 | solid | | | 0.075 | 0.059 | | | | **0.134** |
| Methyl violet solution | 1 | liquid | | 0.5 | | | | | | **0.5** |
| Methylene blue | 1 | liquid | | 0.5 | | | | | | **0.5** |
| Methylene chloride | 1 | liquid | | | | 0.348 | | | | **0.348** |
| Metol | 1 | solid | | 0.5 | | | | | | **0.5** |
| Monoglyceride | 1 | liquid | | | 0.17 | | | | | **0.17** |
| Naphthalene | 1 | solid | | | 0.728 | | | | | **0.728** |
| n-butanol | 3 | liquid | | | 1.72 | | | | | **1.72** |

| | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Nessler reagent | 1 | solid | | | 0.025 | | | | | **0.025** |
| Nickel | 1 | solid | | | 0.275 | | | | | **0.275** |
| Nickel sulphate | 1 | solid | | | 0.32 | | | | | **0.32** |
| Ninhydrin spray | 1 | liquid | | | 0.1 | | | | | **0.1** |
| Nitric acid | 9 | liquid | | 1.917 | 1.079 | 1.278 | 0.9 | | 0.6 | **5.741** |
| n-propanol | 2 | liquid | | | 1.349 | | | | | **1.349** |
| Nutrient agar | 1 | solid | | 0.028 | | | | | | **0.028** |
| Oil immesion | 1 | liquid | | 0.05 | | | | | | **0.05** |
| Orthophosphoric acid | 1 | solid | | | 0.47 | | | | | **0.47** |
| Oxalic acid | 4 | solid | | | 0.5 | | 0.8 | | 0.271 | **1.534** |
| Paraffin liquid | 1 | liquid | | | 0.5 | | | | | **0.5** |
| Perchloric acid | 2 | liquid | | | 1.197 | | | | | **1.197** |
| Petroleum ether | 5 | liquid | | 0.32 | 0.749 | 0.492 | | | | **1.561** |
| Phenol red | 4 | solid | | 0.02 | 0.05 | | | 0.125 | | **0.195** |
| Phenolphthalein | 8 | solid | | 0.049 | 0.1 | 0.046 | | 0.076 | | **0.271** |
| Phospholipid | 1 | solid | | | 0.206 | | | | | **0.206** |
| Phosphoric acid | 2 | solid | | | 0.18 | | 0.7 | | | **0.883** |
| Potassium aluminum sulphate | 1 | solid | | | | | | | 0.417 | **0.417** |
| Potassium bromate | 1 | solid | | | | 0.792 | | | | **0.792** |
| Potassium bromide | 5 | solid | | 0.25 | 0.5 | 0.646 | | | 0.436 | **1.832** |
| Potassium carbonate | 1 | solid | | | | | | | 0.266 | **0.266** |
| Potassium chromate | 3 | solid | | | 0.435 | 0.649 | | | 0.25 | **1.334** |
| Potassium dichromate | 4 | solid | | 0.328 | 0.673 | 0.429 | | | 0.231 | **1.661** |
| Potassium ferricyanide | 2 | solid | | | | | 0.6 | | 0.496 | **1.13** |
| Potassium ferrocyanide | 1 | solid | | | | | | | 0.5 | **0.5** |

| | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Potassium dihydrogen phosphate | 3 | solid | | 0.878 | 0.248 | 0.604 | | | | **1.73** |
| Potassium hydrogen phthalate | 1 | solid | | | | 0.314 | | | | **0.314** |
| Potassium hydroxide | 7 | solid | | | 0.5 | 0.882 | 1.6 | 0.582 | 1.113 | **4.691** |
| Potassium Iodate | 2 | solid | | 0.495 | | 0.274 | | | | **0.769** |
| Potassium iodide | 6 | solid | | 1.113 | 1.423 | 0.491 | 1 | | 0.732 | **4.759** |
| Potassium nitrate | 3 | solid | | 0.506 | 0.472 | | | | | **0.978** |
| Potassium oxalate | 2 | solid | | | 0.489 | | | 0.205 | | **0.694** |
| Potassium permanganate | 4 | solid | | | 0.891 | 0.717 | | 0.719 | | **2.327** |
| Potassium sodium tartrate | 2 | solid | | | | 0.426 | | | 0.022 | **0.448** |
| Potassium sulphate | 2 | solid | | | | 0.702 | | 0.409 | | **1.111** |
| Propanol | 1 | liquid | | | | 0.917 | | | | **0.917** |
| Pyridoxine hydrochloride | 1 | solid | | 0.005 | | | | | | **0.005** |
| Salicylic acid | 2 | solid | | | 0.612 | 0.789 | | 0.673 | | **2.074** |
| Silica gel | 2 | solid | | | 0.35 | 0.426 | | | | **0.776** |
| Silver chloride | 1 | solid | | | 0.478 | | | | | **0.478** |
| Silver nitrate | 5 | solid | | | 0.879 | 0.736 | | 0.372 | 0.015 | **2.002** |
| Slanett Bartley agar | 1 | solid | | 0.4 | | | | 0.345 | | **0.745** |
| Sodium | 3 | solid | | | 1.258 | 0.879 | | | | **2.137** |
| Sodium acetate | 5 | solid | | 0.335 | | 0.371 | | | | **0.706** |
| Sodium carbonate | 6 | solid | | | 0.27 | 0.876 | 0.7 | 0.678 | 1.912 | **4.471** |
| Sodium chloride | 7 | solid | | | 1.541 | 0.916 | | 0.611 | 0.483 | **3.551** |
| Sodium hydrogen carbonate | 4 | solid | | | 0.752 | 0.502 | | 0.742 | | **1.996** |
| Sodium hydrogen phosphate | 1 | solid | | | 0.495 | | | | | **0.495** |
| Sodium hydroxide | 11 | solid | | 0.32 | 0.764 | 1.714 | 0.1 | 0.741 | 1.4 | **5.064** |
| Sodium nitrate | 4 | solid | | | 0.38 | | | 0.406 | 0.907 | **1.693** |

| | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Sodium nitrite | 1 | solid | | | | 0.5 | | | | **0.5** |
| Sodium phosphate | 1 | solid | | | 0.265 | | | | | **0.265** |
| Sodium sulphate | 3 | solid | | | 0.32 | | 0.9 | 0.742 | 1 | **2.941** |
| Sodium sulphite | 1 | solid | | | | | | | 0.5 | **0.5** |
| Sodium thiosulphate | 4 | solid | | 0.184 | 0.185 | | 0.6 | | 0.372 | **1.39** |
| Solochrome dark blue | 4 | solid | | | 0.2 | | | | | **0.2** |
| Styrene | 1 | solid | | | 0.328 | | | | | **0.328** |
| Sulphuric acid | 13 | liquid | | 2.097 | 1.328 | 0.694 | 0.7 | 0.548 | 0.967 | **6.375** |
| Thymol | 1 | solid | | 0.43 | | | | | | **0.43** |
| Tin (II) chloride | 1 | solid | | | 0.5 | | | | | **0.5** |
| Tryton brote | 1 | solid | | 0.25 | | | | | | **0.25** |
| Urea | 2 | solid | | | | | | 0.413 | 0.473 | **0.886** |
| Vanadate-molybdate | 2 | solid | | | 0.426 | | | | | **0.426** |
| Xylene | 2 | liquid | | 3.634 | | | | | | **3.634** |
| Zinc carbonate | 3 | solid | | | | | | 0.498 | 0.096 | **0.594** |
| Zinc chloride | 2 | solid | | | | 0.152 | | | 0.182 | **0.334** |
| Zinc sulphate | 4 | solid | | 0.495 | 0.25 | 0.762 | | 0.569 | | **2.076** |

**Appendix B**

| Chemical Inventory | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| CHEMICAL NAME | QTY | PHYSICAL STATE | HAZARD CLASSIFICATION | WEIGHT/Kg | | | | | | **TOTAL WEIGHT/Kg** |
| | | | | BIOLOGICAL | CHEMISTRY | PHARMACY | ANGLICAN | KUMASI HIGH | TECHNOLOGY | |
| 1,1,1-trichloro ethane | 7 | liquid | Toxic. Ozone depleting chemical. Bioaccumulative pollutant. | | | 7.784 | | | | **7.784** |
| 1,2-dibromoethane | 1 | liquid | Toxic. Carcinogen. Skin irritant | | 0.246 | | | | | **0. 246** |
| 1,2-dichlorobenzene | 1 | liquid | Toxic. Severe irritant. | | 0.250 | | | | | **0.250** |
| 1,2-dichloroethane | 2 | liquid | Flammable. Toxic. Bioacuumulative pollutant | | 4.000 | | | | | **4.000** |
| 1,2-Epoxypropane | 1 | liquid | Extremely flammable | 0.536 | | | | | | **0.536** |
| 1,4-Dichlorobenzene | 3 | solid | Toxic. Severe irritant. | | | | | 6.000 | | **6.000** |
| 1-Chloro butane | 2 | liquid | Flammable. Irritant | | | 2.042 | | | | **2.042** |
| 1-Chloro butane | 1 | liquid | Flammable | | | 0.092 | | | | **0.092** |
| 1-Chloro butane | 11 | solid | Corrosive. Skin irritant | | 5.000 | | | | 0.051 | **5.051** |

| | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| 2,4-Dichloro-phenol | 7 | solid | Poison | 0.689 | | | | | | **0.689** |
| 2,4-Dinitrophenyl hydrazine | 1 | solid | Explosion risk | | | | | | 0.037 | **0.037** |
| 2,6-Lutidine | 1 | liquid | Flammable. Toxic. | | 0.373 | | | | | **0.373** |
| 2-Aminopyridine | 4 | solid | Toxic. Irritant. | | 0.350 | | | | | **0.350** |
| 2-Bromo phenol | 1 | liquid | Toxic. Persistent pollutant. | | | 0.051 | | | | **0.051** |
| 2-Bromo propane | 2 | liquid | Flammable | | | 2.026 | | | | **2.026** |
| 2-Chloro benzyaldehyde | 1 | liquid | Corrosive | | | 0.097 | | | | **0.097** |
| 2-Ethoxy ethanol | 2 | liquid | Inflammable | 5.450 | | | | | | **5.450** |
| 2-Methoxy ethanol | 1 | liquid | Flammable. Irritant | | | 1.225 | | | | **1.225** |
| 2-Methyl napthalene | 2 | solid | Combustible | | 0.500 | | | | | **0.500** |
| 2-Methyl propan-1-ol | 1 | liquid | Flammable | | 0.500 | | | | | **0.500** |
| 2-Napthol | 9 | solid | Corrosive. Skin irritant | | 4.500 | | | | | **4.500** |
| 3,5-Dinitrosalicylic acid | 1 | solid | Corrosive | 0.049 | | | | | | **0.049** |
| 3-Amino benzoic acid | 1 | solid | Corrosive | | 0.100 | | | | | **0.100** |
| 3-Nitroaniline | 5 | solid | Corrosive | | 1.250 | | | | | **1.250** |
| 4-Amino benzoic acid | 11 | solid | Corrosive | | 1.100 | | | | | **1.100** |
| 4-Amino diphenyl hydrochloride | 1 | solid | Corrosive | | 0.050 | | | | | **0.050** |
| 4-Aminophenol | 1 | solid | Poison | | 0.389 | | | | | **0.389** |
| 4-Picoline | 1 | liquid | Flammable | | 0.243 | | | | | **0.243** |
| 8-Hydroxyquinoline | 7 | solid | corrosive | 0.210 | 1.608 | | | | | **1.818** |
| Acetanilide | 2 | solid | Toxic | | | | | 0.047 | 0.472 | **0.519** |
| Acetamide | 1 | solid | Not regulated as hazardous | | | | | 0.293 | | **0.293** |
| Acetic anhydride | 2 | liquid | Corrosive, flammable | 0.709 | | | | | | **0.709** |
| Acetyl acetone | 1 | liquid | Flammable. Severe irritant. | | | 1.307 | | | | **1.307** |

| | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Acetylsalicylic acid,aspirin | 1 | solid | corrosive | | | | | | 0.407 | **0.407** |
| Acrolein | 1 | liquid | Flammable. Inhalation toxin. Severe irritant. | 0.213 | | | | | | **0.213** |
| Acrylamide | 2 | solid | Toxic by absorption, suspected carcinogen | 0.498 | | | | | | **0.498** |
| Acrylonitrile | 2 | liquid | Flammable. Poison by inhalation, skin absorption. Carcinogen | | | 1.842 | | | | **1.842** |
| Activated charcoal | 2 | solid | Combustible. | | | | 1.000 | | 0.236 | **1.236** |
| Adipic acid | 1 | solid | Corrosive; absorbs through skin, lachrymator | | 0.500 | | | | | **0.500** |
| Alizarin | 27 | solid | Toxic. Severe irritant | 0.600 | | | | 0.191 | | **0.791** |
| Aluminum ammonium sulphate | 7 | solid | Not regulated as hazardous | 0.908 | 1.368 | | | 0.937 | | **3.213** |
| Aluminum bromide anhydrous | 2 | solid | Corrosive | | 0.672 | | | | | **0.672** |
| Aluminum cerric sulphate | 1 | solid | Unclassified | | 0.050 | | | | | **0.050** |
| Aluminum chloride, hydrate | 1 | liquid | Not regulated as hazardous | | 0.098 | | | | | **0.098** |
| Aluminum hydroxide | 6 | solid | Toxic. Irritant | 0.898 | 2.000 | | | | | **2.898** |
| Aluminum lithium hydride | 5 | solid | Reacts violently with water | | 0.230 | | | | | **0.230** |
| Aluminum nickel sulphate | 2 | solid | Toxic. Carcinogen | | | | | 0.402 | | **0.402** |
| Aluminum oxide | 32 | solid | Not regulated as hazardous | 1.952 | 8.023 | | | 1.905 | | **11.880** |
| Aluminum phosphate | 3 | solid | Unclassified | | 1.367 | | | | | **1.367** |
| Aluminum potassium sulphate | 8 | solid | Not regulated as hazardous | 2.536 | 4.609 | | | 0.997 | | **8.142** |
| Aluminum silicate | 1 | solid | Not regulated as hazardous | | 2.879 | | | | | **2.879** |
| Aluminum sodium hydrogen orthophosphate | 5 | solid | Unclassified | | 2.462 | | | | | **2.462** |

| | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Aluminum sulphate | 4 | solid | Not regulated as hazardous | 1.213 | | | | 0.418 | 0.781 | **2.412** |
| Aluminum, powder | 2 | solid | Highly flammable as dust. | | | 0.250 | | 0.250 | | **0.500** |
| Amino-diphenylamine | 1 | solid | Unclassified | | 0.100 | | | | | **0.100** |
| Ammonii oxalas | 1 | solid | Unclassified | 0.979 | | | | | | **0.979** |
| Ammonium acetate | 1 | liquid | Not regulated as hazardous | 0.382 | | | | | | **0.382** |
| Ammonium Acetate | 1 | solid | Not regulated as hazardous | | | | | | 0.397 | **0.397** |
| Ammonium bromide | 5 | solid | Toxic. Irritant. | | 1.003 | 6.000 | | | | **7.003** |
| Ammonium carbonate | 2 | solid | Not regulated as hazardous | 2.451 | | | | | | **2.451** |
| Ammonium ceric sulphate | 8 | solid | Not regulated as hazardous | | | 0.600 | | 0.196 | | **0.796** |
| Ammonium chloride | 1 | solid | Corrosive | | | | | 0.078 | | **0.078** |
| Ammonium citrate | 1 | solid | Not regulated as hazardous | 0.056 | | | | | | **0.056** |
| Ammonium cobalt sulphate | 2 | solid | Unclassified | | 1.208 | | | | | **1.208** |
| Ammonium dichromate | 13 | solid | Powerful oxidizer, toxic, carcinogen | 0.496 | 4.832 | 0.350 | | 0.365 | | **6.043** |
| Ammonium dihydrogen orthophosphate | 6 | solid | Not regulated as hazardous | 2.429 | | 0.500 | | | | **2.929** |
| Ammonium ferric chloride | 1 | solid | Unclassified | | | 0.750 | | | | **0.750** |
| Ammonium ferric citrate | 2 | solid | Not regulated as hazardous | 0.959 | | | | | | **0.959** |
| Ammonium ferric sulphate | 4 | solid | Not regulated as hazardous | 3.633 | | 3.500 | | | | **7.133** |
| Ammonium ferrous sulphate | 1 | solid | Not regulated as hazardous | | | | | 0.005 | | **0.005** |
| Ammonium hydrogen difluoride | 1 | liquid | Corrosive | | 0.242 | | | | | **0.242** |
| Ammonium hydrogen sulphate | 2 | liquid | Not regulated as hazardous | 1.002 | | | | | | **1.002** |
| Ammonium hydrogen tetraborate | 2 | liquid | Corrosive. Combustible | 3.712 | | | | | | **3.712** |
| Ammonium iodide | 2 | solid | Not regulated as hazardous | 0.907 | | | | | | **0.907** |

| | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Ammonium iodide | 2 | liquid | Not regulated as hazardous | | | | | 0.099 | | **0.099** |
| Ammonium magnesium chloride | 1 | solid | Toxic. Irritant | | | 1.000 | | | | **1.000** |
| Ammonium magnesium sulphate | 1 | solid | Unclassified | | | 0.280 | | | | **0.280** |
| Ammonium molybdate | 5 | solid | Irritant. Toxic by ingestion. | 0.428 | 1.516 | 2.750 | | | | **4.694** |
| Ammonium molybdo phosphate | 1 | solid | Unclassified | | | | | 0.053 | | **0.053** |
| Ammonium nickel sulphate | 22 | solid | Toxic. Carcinogen | | 9.284 | 2.200 | | | | **11.484** |
| Ammonium nitrate | 1 | solution | Powerful oxidizer, reactive with organic compounds. | | | | | | 0.058 | **0.058** |
| Ammonium nitrate | 1 | liquid | Powerful oxidizer, reactive with organic compounds. | | | | | | 0.500 | **0.500** |
| Ammonium nitrate | 1 | solid | Powerful oxidizer, reactive with organic compounds. | | | | | | 0.500 | **0.500** |
| Ammonium persulphate | 5 | solid | Oxidizer. Moderately toxic. Strong irritant. | | 2.471 | | | | | **2.471** |
| Ammonium sodium hydrogen phosphate | 9 | solid | Unclassified | 3.503 | 0.490 | 1.500 | | | | **5.493** |
| Ammonium sodium phosphate | 1 | solid | Unclassified | | 0.493 | | | | | **0.493** |
| Ammonium sulphate | 4 | solid | Not regulated as hazardous | 3.993 | | | | | 0.496 | **4.489** |
| Ammonium tetraborate | 1 | solid | Unclassified | | 1.000 | | | | | **1.000** |
| Ammonium thiocyanate | 6 | solid | Slightly toxic by ingestion. | 0.701 | | 2.750 | | 0.254 | | **3.705** |
| Ammonium thiocyanate | 2 | liquid | Slightly toxic by ingestion. | | 0.479 | | | | | **0.479** |
| Ammonium thiocyanate | 1 | solution | Slightly toxic by ingestion. | | | | | | 0.302 | **0.302** |
| Ammonium tungstate | 4 | solid | Unclassified | | 0.032 | | | | | **0.032** |
| Ammonium zinc sulphate | 2 | solid | Unclassified | | 1.612 | | | | | **1.612** |

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|---|---|---|---|---|---|---|---|---|---|---|
| Amyl acetate | 4 | liquid | Flammable. | | 0.203 | 7.373 | | | | **7.576** |
| Amyl alcohol | 4 | liquid | Flammable. Severe irritant. | 1.898 | | 3.360 | | | 0.104 | **5.362** |
| Amylopectin starch | 1 | solid | Not regulated as hazardous | 0.909 | | | | | | **0.909** |
| Aniline | 4 | liquid | Carcinogen, toxic, absorbs through skin | | | 6.570 | | 0.500 | | **7.070** |
| Aniline hydrochloride | 4 | solid | Poison | 1.968 | | | | | | **1.968** |
| Anisic acid | 1 | solid | Corrosive | | 0.100 | | | | | **0.100** |
| Anthracene | 3 | solid | Unclassified | | 0.500 | | | | | **0.500** |
| Anthraquinone | 1 | solid | Unclassified | | 0.100 | | | | | **0.100** |
| Anthrone | 2 | solid | Unclassified | 0.050 | | | | | | **0.050** |
| Antimony pentasulphate | 2 | solid | Poison | | 0.058 | | | | | **0.058** |
| Antimony powder | 6 | solid | Flammable solid. Toxic. | 0.497 | | 0.260 | | | | **0.757** |
| Antimony sulphide | 8 | solid | Toxic | | | | | 3.143 | | **3.143** |
| Antimony tri-iodide | 1 | solid | Toxic | | | 0.050 | | | | **0.050** |
| Antimony trioxide | 6 | solid | Toxic. Irritant | | 2.003 | 0.750 | | 0.962 | | **3.715** |
| Antimony trisulphide | 6 | solid | Toxic. Carcinogenic | 0.588 | | | | | | **0.588** |
| Arsenic trioxide | 6 | solid | Deadly poison & carcinogen. | | 0.268 | | | | | **0.268** |
| Arsenous oxide | 7 | solid | Deadly poison & carcinogen. | 0.503 | 0.248 | | | | | **0.751** |
| Barium bromide | 3 | solid | Poison | | 0.745 | | | | | **0.745** |
| Barium carbonate | 11 | solid | Toxic by ingestion. | 1.439 | 6.713 | | | | | **8.152** |
| Barium chlorate | 2 | solid | Oxidizer | | | 1.000 | | | | **1.000** |
| Barium chloride | 9 | solid | Deadly poison. | 1.500 | | 1.500 | | | | **3.000** |
| Barium fluoride | 2 | solid | Poison | | 0.703 | | | | | **0.703** |
| Barium hydroxide | 5 | solid | Toxic by ingestion. | 0.983 | 0.750 | 1.000 | | | 0.500 | **3.233** |
| Barium nitrate | 10 | solid | Oxidizer | 2.994 | | 0.100 | | 0.940 | | **4.034** |

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|---|---|---|---|---|---|---|---|---|---|---|
| Barium oxide | 1 | solid | Poison | | | 0.500 | | | | **0.500** |
| Barium peroxide | 10 | solid | Toxic by ingestion. Oxidizer. Corrosive. | 2.982 | | 1.000 | | | 0.500 | **4.482** |
| Barium sulphate | 2 | solid | Toxic by ingestion. | | | | | 1.896 | | **1.896** |
| Benzaldehyde | 2 | liquid | Combustible. Ingestion of small amount can cause convulsions | | 2.000 | | 0.500 | | | **2.500** |
| Benzylamide | 1 | solid | Unclassified | | | | | 0.112 | | **0.112** |
| Benzene sulphonyl chloride | 1 | liquid | Unclassified | | | 0.196 | | | | **0.196** |
| Benzene-sulphonic acid | 2 | solid | Corrosive | | | | | 0.450 | | **0.450** |
| Benzoic acid | 1 | liquid | Corrosive | 1.786 | | | | | | **1.786** |
| Benzoic acid | 2 | solid | Corrosive | 0.872 | | | | 0.191 | | **1.063** |
| Benzontrile | 1 | liquid | Toxic. Organic cyanide reacts with acids to produce poison gas. Combustible. | | | 0.090 | | | | **0.090** |
| Benzoyl chloride | 4 | liquid | Corrosive. Combustible. Inhalation hazard. | | | 5.804 | 0.531 | | | **6.335** |
| Benzyl alcohol | 21 | liquid | Explosive. Reactive. Poisonous | 28.184 | | 0.436 | | | | **28.620** |
| Benzyl benzoate | 14 | liquid | Unclassified | 8.120 | | | | | | **8.120** |
| Benzyl methyl ketone | 2 | liquid | Unclassified | 0.558 | | | | | | **0.558** |
| Benzylamine | 2 | liquid | Unclassified | | | 0.089 | | | 0.226 | **0.315** |
| Berylium oxide | 38 | solid | Poison | | 2.082 | | | | | **2.082** |
| Berylium sulphate | 3 | solid | Poison | | 0.198 | | | | | **0.198** |
| Bibenzyl | 2 | solid | Unclassified | | 2.000 | | | | | **2.000** |
| Bismuth arsenilate | 1 | solid | Unclassified | | | 0.200 | | | | **0.200** |

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|---|---|---|---|---|---|---|---|---|---|---|
| Bismuth hydroxide | 1 | solid | Unclassified | | | | | 0.500 | | **0.500** |
| Bismuth metal | 4 | solid | Not regulated as hazardous | | | 0.100 | | 0.300 | | **0.400** |
| Bismuth nitrate | 7 | solid | Oxidizer. Toxic | | 0.592 | | | | | **0.592** |
| Bismuth oxide | 1 | solid | Poison | | | 0.100 | | | | **0.100** |
| Bismuth oxycarbonate | 1 | solid | Unclassified | | | 1.000 | | | | **1.000** |
| Bismuth oxychloride | 1 | solid | Unclassified | | | 0.025 | | | | **0.025** |
| Bismuth oxynitrate | 5 | solid | Unclassified | | 0.600 | | | | | **0.600** |
| Bismuth sulphate | 1 | solid | Unclassified | | | 0.200 | | | | **0.200** |
| Bismuth tri-iodide | 1 | solid | Unclassified | | | 0.025 | | | | **0.025** |
| Bleaching powder | 3 | solid | Corrosive | | | 5.000 | | | | **5.000** |
| Boric acid | 1 | solid | Slightly toxic by ingestion. | | | | 0.500 | | | **0.500** |
| Boric anhydride | 1 | solid | Corrosive | | 2.000 | | | | | **2.000** |
| Bromoethane | 1 | liquid | Toxic. Irritant. Carcinogen. | | | 0.125 | | | | **0.125** |
| Bromobutane | 13 | liquid | Toxic. Persistant pollutant. Mixed with flammable alcohols. | | 4.641 | | | | | **4.641** |
| Butan-1-ol | 7 | liquid | Flammable. Moderately toxic. | | | 2.847 | | | 1.062 | **3.909** |
| Butane-1,3-diol | 4 | liquid | Unclassified | | 1.012 | | | | | **1.012** |
| Butane-1,4-diol | 2 | liquid | Unclassified | | 0.468 | | | | | **0.468** |
| Butane-2,3-diol | 3 | liquid | Unclassified | | 0.687 | | | | | **0.687** |
| Butanone | 1 | liquid | Flammable | | 0.256 | | | | | **0.256** |
| Cadmium acetate | 1 | solid | Toxic heavy metal, carcinogen | 0.095 | | | | | | **0.095** |
| Cadmium bromide | 2 | solid | Toxic heavy metal, carcinogen | 0.497 | | | | | | **0.497** |
| Cadmium carbonate | 5 | solid | Toxic heavy metal. Poison | 0.400 | | 0.200 | | | | **0.600** |

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|---|---|---|---|---|---|---|---|---|---|---|
| Cadmium chloride | 3 | solid | Toxic heavy metal, carcinogen | 0.349 | | 0.100 | | | | **0.449** |
| Cadmium iodide | 4 | solid | Toxic heavy metal, carcinogen | 0.219 | | 0.500 | | | | **7.019** |
| Cadmium nitrate | 1 | liquid | Toxic heavy metal, carcinogen. Oxidizer. | 0.100 | | | | | | **0.100** |
| Cadmium nitrate | 2 | solid | Toxic heavy metal, carcinogen. Oxidizer. | | | 0.200 | | | | **0.200** |
| Calcium acetate | 3 | solid | Not regulated as hazardous | | | | | 0.604 | | **0.604** |
| Calcium carbide | 1 | solid | Reacts with water to produce flammable acetylene gas. | | | 0.500 | | | | **0.500** |
| Calcium carbonate | 7 | solid | Not regulated as hazardous | 5.081 | | | | 2.000 | | **7.081** |
| Calcium chloride | 4 | solid | Not regulated as hazardous | | | 9.000 | | | 2.000 | **11.000** |
| Calcium chloride | 1 | liquid | Not regulated as hazardous | | | | | | 0.106 | **0.106** |
| Calcium citrate | 3 | solid | Unclassified | 1256 | | | | | | **1.256** |
| Calcium formate | 1 | solid | Unclassified | | | | | 0.500 | | **0.500** |
| Calcium hydrogen orthophosphate | 1 | solid | Unclassified | | | | | 0.500 | | **0.500** |
| Calcium hydroxide | 1 | solid | Moderately corrosive, especially to eyes | | | | | | 0.051 | **0.051** |
| Calcium iodide | 1 | solid | Unclassified | 0.492 | | | | | | **0.492** |
| Calcium nitrate | 3 | solid | Oxidizer | 0.948 | | | | | | **0.948** |
| Calcium nitrate | 2 | liquid | Oxidizer | 0.438 | | | | | | **0.438** |
| Calcium oxide | 8 | solid | Corrosive. Reacts with water. | | | 14.500 | | | | **14.500** |
| Calcium sulphate | 1 | solid | Not regulated as hazardous | | | | | 0.312 | | **0.312** |
| Calcium tetra hydrogen di-orthophosphate | 3 | solid | Unclassified | | | | | 0.877 | | **0.877** |

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|---|---|---|---|---|---|---|---|---|---|---|
| Camphor | 3 | solid | Combustible. Toxic. | | | | | 1.000 | 0.263 | **1.263** |
| Chloro acetyl chloride | 2 | liquid | Unclassified | | | 0.457 | | | | **0.457** |
| Chloro aniline | 1 | liquid | Poison | | | 0.089 | | | | **0.089** |
| Chloro benzene | 1 | liquid | Flammable, toxic via inhalation & contact. Bioacuumulative pollutant | | | 0.918 | | | | **0.918** |
| Chloroacetic acid | 1 | solid | Corrosive. Poison by inhalation | | | | 0.250 | | | **0.250** |
| Chloroacetic acid | 1 | liquid | Corrosive. Poison by inhalation | | | | | 0.400 | | **0.400** |
| Chloroform | 1 | liquid | Toxic. Carcinogen. If old forms deadly Phosgene gas. Bioacuumulative pollutant | | | | | | 0.937 | **0.937** |
| Chlorohexane | 1 | liquid | Unclassified | | | | 0.629 | | | **0.629** |
| Chloronaphthalene | 1 | liquid | Unclassified | | 0.100 | | | | | **0.100** |
| Cholesteryl acetate | 1 | solid | Unclassified | 0.087 | | | | | | **0.087** |
| Chromic carbonate | 1 | solid | Unclassified | | | | | 0.250 | | **0.250** |
| Chromic chloride | 1 | liquid | Unclassified | | | | | 0.100 | | **0.100** |
| Chromic potassium sulphate | 4 | solid | Unclassified | | | 3.500 | | 0.500 | | **4.000** |
| Chromium potassium sulphate | 6 | solid | Not regulated as hazardous | 2.450 | 0.250 | | | | | **2.700** |
| Chromium trioxide, chrome acid | 5 | solid | Oxidizer. Poison. Carcinogen. | 1.475 | 1.000 | 2.000 | | | | **4.475** |
| cinnamaldehyde | 6 | liquid | Unclassified | | 0.625 | 1.845 | | | | **2.470** |
| Citric acid | 1 | solid | Not regulated as hazardous | 0.418 | | | | | | **0.418** |
| Cobalt chloride | 1 | solid | Toxic. Possible carcinogen. | 0.583 | | | | | | **0.583** |
| Cobalt nitrate | 2 | liquid | Oxidizer. Suspect carcinogen. Toxic. | 0.506 | | | | | | **0.506** |

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|---|---|---|---|---|---|---|---|---|---|---|
| Cobalt sulphate | 2 | solid | Toxic by ingestion. | | 0.200 | 0.050 | | | | **0.250** |
| Cobaltous nitrate | 1 | solid | Oxidizer. Toxic | | | 0.500 | | | | **0.500** |
| Cobaltous sulphate | 1 | solid | Unclassified | | | | | 0.500 | | **0.500** |
| Congo red, amyloid | 2 | solid | Toxic | 0.250 | | | 0.005 | | | **0.255** |
| Copper carbonate | 2 | solid | Toxic by ingestion. | | 0.300 | 0.600 | | | | **0.900** |
| Copper II sulphate | 2 | solid | Toxic by ingestion | | | | | | 0.507 | **0.507** |
| Copper powder | 1 | solid | Flammable. Toxic | | 0.250 | | | | | **0.250** |
| Coumarin | 1 | solid | Unclassified | 0.100 | | | | | | **0.100** |
| Cumene, Iso-propylbenzene | 1 | liquid | Flammable. Central nervous system depressant. Peroxide former. Explosion risk. | | | 0.908 | | | | **0.908** |
| Cupric acetate | 1 | solid | Toxic by ingestion. | 0.202 | | | | | | **0.202** |
| Cupric arsenite | 1 | solid | Unclassified | | 0.250 | | | | | **0.250** |
| Cupric carbonate | 9 | solid | Toxic by ingestion. | 2.490 | 1.000 | 0.500 | | | | **3.990** |
| Cupric chloride | 5 | solid | Unclassified | 0.250 | | 0.250 | | 0.200 | 0.073 | **0.773** |
| Cupric nitrate | 2 | liquid | Oxidizer. Toxic | | | | | 0.100 | 0.107 | **0.207** |
| Cupric orthophosphate | 1 | solid | Unclassified | | | | | 0.167 | | **0.167** |
| Cupric oxide | 7 | solid | Toxic. Irritant to skin. | 2.994 | | | | 0.100 | | **3.094** |
| Cupric silicate | 1 | solid | Unclassified | | 0.250 | | | | | **0.250** |
| Cupric sulphate | 20 | solid | Toxic by ingestion | 21.952 | | | | | | **21.952** |
| Cuprous cyanide | 1 | solid | Toxic | | | 0.500 | | | | **0.500** |
| Cuprous oxide | 6 | solid | Toxic. Irritant to skin. | 3.000 | | | | | | **3.000** |
| Cyclohexane | 2 | liquid | Highly flammable. | 0.603 | | | | | 1.000 | **1.603** |
| Cyclohexanol | 5 | liquid | Combustible. Peroxidizable. Toxic by inhalation. | | | 6.312 | | | | **6.312** |

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|---|---|---|---|---|---|---|---|---|---|---|
| Cyclohexanone | 1 | liquid | Combustible. | 1.683 | | | | | | **1.683** |
| Cyclopentadiene | 12 | liquid | Unclassified | | | 19.602 | | | | **19.602** |
| D-arabinose | 1 | solid | Not regulated as hazardous | 0.025 | | | | | | **0.025** |
| D-fructose | 1 | liquid | Not regulated as hazardous | 0.015 | | | | | | **0.015** |
| D-Glucose anhydrous | 1 | solid | Unclassified | | | | | 0.500 | | **0.500** |
| D-Glucose monohydrate | 3 | solid | Unclassified | | 3.000 | | | | | **3.000** |
| Diacetyl | 2 | liquid | Flammable | 0.197 | | | | | | **0.197** |
| Diamminoethanetetra acetic acid | 1 | solid | Corrosive | 0.204 | | | | | | **0.204** |
| Di-Ammonium hydrogen orthophosphate | 12 | solid | Not regulated as hazardous | 1.877 | 0.788 | 2.000 | | 1.204 | | **5.869** |
| Dichloro benzene | 2 | liquid | Toxic. Severe irritant. | | | 1261 | | | | **1.261** |
| Dichloroethane | 3 | liquid | Flammable. Toxic. Bioacuumulative pollutant | 1381 | | | | | | **1.381** |
| Diethyl aniline | 2 | liquid | Poison | | 0.214 | 1.880 | | | | **2.094** |
| Diethyl ether | 2 | liquid | Flammable | | | | 0.100 | | 0.506 | **0.606** |
| Diethyl phthalate | 1 | liquid | Unclassified | | 0.500 | | | | | **0.500** |
| Diethyl sulphate | 3 | liquid | Poison. | | 1.207 | | | | | **1.207** |
| Digol | 2 | liquid | Unclassified | 0.224 | 0.491 | | | | | **0.715** |
| Di-Iso butylene | 1 | liquid | Unclassified | | 2.000 | | | | | **2.000** |
| Dimtheylgloxime | 5 | solid | Toxic by inhalation, ingestion, and skin contact. | 0.500 | | | | | | **0.500** |
| Di-n-Butyl phthalate | 1 | liquid | Unclassified | | | 0.196 | | | | **0.196** |
| Dioxane | 2 | liquid | Flammable. Peroxide former. Explosion risk. | 0.206 | 1.913 | | | | | **2.119** |

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|---|---|---|---|---|---|---|---|---|---|---|
| di-sodium hydrogen orthophosphate | 2 | solid | Unclassified | | | | | 0.500 | 0.373 | **0.873** |
| Di-Sodium tertraborate | 3 | solid | Unclassified | | | 0.750 | | 1.250 | | **2.000** |
| D-Maleic acid | 1 | solid | Corrosive | | 0.500 | | | | | **0.500** |
| EDTA | 1 | solid | Not regulated as hazardous | 0.500 | | | | | | **0.500** |
| Ethane diol | 1 | liquid | Toxic. Irritant. | | | 1.925 | | | | **1.925** |
| Ethyl acetate | 6 | liquid | Flammable. | 2.177 | | | 0.472 | | | **2.649** |
| Ethyl amine | 2 | liquid | Flammable. | | 0.423 | 0.977 | | | | **1.400** |
| Ethyl benzoate | 4 | liquid | Unclassified | | 0.536 | 1.012 | | | | **1.548** |
| Ethyl carbonate | 1 | solid | Unclassified | 0.500 | | | | | | **0.500** |
| Ethyl cyanoacetate | 2 | liquid | Unclassified | | | 0.819 | | | | **0.819** |
| Ferric chloride | 1 | liquid | Corrosive to skin & eyes. | 0.360 | | | | | | **0.360** |
| Ferric oxide | 4 | solid | Toxic. Severe irritant. | | | 1.000 | | | 0.500 | **1.500** |
| Ferric sulphate | 3 | solid | Not regulated as hazardous | | | 1.000 | | | 0.984 | **1.984** |
| Ferrous sulphate | 1 | solid | Slighty toxic by ingestion | 0.025 | | | | | | **0.025** |
| Ferrous sulphide | 1 | solid | Reacts with acids to form poisonous hydrogen sulfide gas | | | 1.000 | | | | **1.000** |
| Formaldehyde | 1 | liquid | Toxic. Carcinogen. Severe sensitizer | | | | | | 0.253 | **0.253** |
| Formamide | 1 | liquid | Unclassified | | | 1.240 | | | | **1.240** |
| Formate | 1 | solid | Corosive | | 0.030 | | | | | **0.030** |
| Formic acid | 2 | liquid | Corrosive. May degrade & pressurize sealed container. | 0.178 | | | | | 1.000 | **1.178** |
| Furfuraldehyde | 1 | liquid | Unclassified | | | 1.430 | | | | **1.430** |
| Glacial acetic acid | 1 | liquid | Corrosive. | 2.361 | | | | | | **2.361** |

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|---|---|---|---|---|---|---|---|---|---|---|
| Glucose | 1 | solid | Not regulated as hazardous | 0.495 | | | | | | **0.495** |
| Glycerol triacetate | 1 | liquid | Unclassified | | | 1.271 | | | | **1.271** |
| Glycerol tributyrate | 1 | liquid | Unclassified | 0.092 | | | | | | **0.092** |
| Hept-1-ene | 1 | liquid | Flammable | | 0.025 | | | | | **0.025** |
| Hexachloro butadiene | 18 | liquid | Unclassified | | | 0.548 | | | | **0.548** |
| Hexamine | 2 | solid | Unclassified | 0.873 | | | | | | **0.873** |
| Hydrobromic acid | 4 | liquid | Corrosive. Toxic fumes | | 8.000 | | | | | **8.000** |
| Hydroxy-ammonium chloride | 1 | solution | Unclassified | | | | | | 0.042 | **0.042** |
| Hydroxylamine | 1 | solid | Unclassified | 0.025 | | | | | | **0.025** |
| Iodic acid | 7 | solid | Corrosive | | 0.281 | 0.150 | | | | **0.431** |
| Iodine pentaoxide | 1 | solid | Unclassified | | | 0.250 | | | | **0.250** |
| Iodo ethane | 1 | liquid | Unclassified | | | 0.099 | | | | **0.099** |
| Iodo methane | 2 | liquid | Unclassified | | | 0.198 | | | | **0.198** |
| Iodo propane | 1 | liquid | Unclassified | | | 0.091 | | | | **0.091** |
| Iron (III) chloride anhydrous | 1 | liquid | Corrosive. Toxic by ingestion. | 0.048 | | | | | | **0.048** |
| Iron oxide | 1 | solid | Unclassified | | 0.050 | | | | | **0.050** |
| Iso amyl alcohol | 2 | liquid | Flammable. Can form explosive peroxides when concentrated | | | 2.240 | | | | **2.240** |
| Iso- butyl amine | 1 | liquid | Unclassified | | | 0.228 | | | | **0.228** |
| Iso-bromyl acetate | 1 | liquid | Unclassified | | 0.241 | | | | | **0.241** |
| Iso-butanol | 3 | liquid | Unclassified | 1.500 | | | | | | **1.500** |
| Iso-butyric acid | 3 | liquid | Corrosive; intense stench. Combustible. Theft risk. | 0.473 | | 0.485 | | | | **0.958** |
| Isophorone | 1 | liquid | Unclassified | | 2.297 | | | | | **2.297** |

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|---|---|---|---|---|---|---|---|---|---|---|
| Iso-propylamine | 5 | liquid | Highly inflammable | | 0.862 | | | | | **0.862** |
| Lactic acid | 8 | liquid | Corrosive. Toxic. | 1.517 | 0.782 | | | | | **2.299** |
| Lacto-phenol | 1 | liquid | Poison | | 0.312 | | | | | **0.312** |
| Lactose | 14 | solid | Not regulated as hazardous | 9.383 | | | 0.500 | | 0.500 | **10.383** |
| L-cystine | 1 | solid | Unclassified | 0.472 | | | | | | **0.472** |
| Lead acetate | 5 | solid | Poison | 2.470 | 0.050 | | | | 0.276 | **2.796** |
| Lead bromide | 1 | solid | Toxic. Irritant. | | 0.250 | | | | | **0.250** |
| Lead carbonate | 6 | solid | Poison | | 2.041 | | | | | **2.041** |
| Lead chloride | 3 | solid | Poison | 0.250 | 0.250 | | | | 0.100 | **0.600** |
| Lead dioxide | 7 | solid | Poison heavy metal. Oxidizer | 1.000 | 1.500 | 0.500 | | | | **3.000** |
| Lead fluoride | 1 | solid | Poison heavy metal. | | 0.250 | | | | | **0.250** |
| Lead foil | 9 | solid | Toxic when scraped into shavings or powder or if acidified. | | 4.500 | | | | | **4.500** |
| Lead metaborate | 1 | solid | Unclassified | | 0.250 | | | | | **0.250** |
| Lead monoxide | 4 | solid | Poison | | 0.150 | 0.500 | | | 0.250 | **0.900** |
| Lead orthophosphate | 1 | solid | Poison | | 0.050 | | | | | **0.050** |
| Lead oxide | 4 | solid | Poison. | | 0.100 | 0.500 | | | 7.44 | **1.344** |
| Lead peroxide | 3 | solid | Oxidizer. Toxic. | | 1.009 | | | | | **1.009** |
| Lead sulphate | 4 | solid | Poison. | 0.025 | 0.450 | | | | 0.500 | **0.975** |
| Lead tartrate | 6 | solid | Poison. | | 0.246 | | | | | **0.246** |
| L-glutamic acid | 1 | liquid | Corrosive | 0.974 | | | | | | **0.974** |
| Lithium carbonate | 4 | solid | Not regulated as hazardous | | 1.050 | | | | | **1.050** |
| Lithium chloride | 2 | solid | Not regulated as hazardous | | 0.550 | | | | | **0.550** |
| Lithium hydroxide | 3 | solid | Corrosive. | | 0.508 | | | | | **0.508** |

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|---|---|---|---|---|---|---|---|---|---|---|
| Lithium metal | 5 | liquid | Reacts with water & nitrogen in air. Flammable solid. | | 1.250 | | | | | **1.250** |
| Lithium metal | 2 | solid | Reacts with water & nitrogen in air. Flammable solid. | | | 0.050 | | | | **0.050** |
| Lithium tetraborate | 1 | solid | Unclassified | | 0.032 | | | | | **0.032** |
| L-leucine | 6 | solid | Unclassified | 0.375 | | | | | | **0.375** |
| Magnesium arsenate | 1 | solid | Toxic | | 0.920 | | | | | **0.920** |
| Magnesium dioxide | 1 | solid | Toxic | | | | | 4.000 | | **4.000** |
| Magnesium fluoride | 1 | solid | Corrosive | | 0.500 | | | | | **0.500** |
| Magnesium hydroxide | 2 | solid | Unclassified | | 1.000 | | | | | **1.000** |
| Magnesium metaborate | 2 | solid | Unclassified | | 0.500 | | | | | **0.500** |
| Magnesium metal | 4 | solid | Highly flammable. May spontaneously ignite when wet or if friction is applied. | | | 0.575 | | | | **0.575** |
| Magnesium sulphate | 1 | solid | Not regulated as hazardous | | | | | 0.849 | | **0.849** |
| Magnesium turnings | 3 | solid | Flammable solid. | | 0.350 | | | | 0.161 | **0.511** |
| Maleic acid | 6 | solid | Combustible. Moderately corrosive to eyes and mucosa. | 1.025 | 0.250 | | | 0.284 | | **1.559** |
| Maleic anhydride | 9 | solid | Corrosive. Irritant | | 4.000 | | | | | **4.000** |
| Maleic hydrazide | 4 | solid | Corrosive | 0.400 | | | | | | **0.400** |
| Maltose | 5 | solid | Not regulated as hazardous | 0.295 | | | 0.100 | | | **0.395** |
| Mandelic acid | 2 | solid | Corrosive | | 0.450 | | | | | **0.450** |
| Manganese chloride | 7 | liquid | Not regulated as hazardous | 3.788 | | | | | | **3.788** |
| Manganese chloride | 1 | solid | Not regulated as hazardous | | | 0.500 | | | | **0.500** |
| Manganese dioxide | 8 | solid | Oxidizer. Toxic. | 2.000 | | 2.000 | | 0.800 | | **4.800** |

| | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Manganese hydrogen orthophosphate | 1 | liquid | Unclassified | 0.500 | | | | | | **0.500** |
| Manganous carbonate | 6 | solid | Unclassified | | 1.791 | | | 0.110 | | **1.901** |
| Manganous chloride | 6 | liquid | Slightly toxic by ingestion. | | 1.983 | | | | | **1.983** |
| Manganous chloride | 1 | solid | Slightly toxic by ingestion. | | | | | 0.100 | | **0.100** |
| Manganous chloride | 2 | solution | Slightly toxic by ingestion. | | | | | | 0.337 | **0.337** |
| Manganous sulphate | 1 | solid | Unclassified | | | | | | 0.336 | **0.336** |
| Mercuric oxide | 1 | solid | Poison | | | 0.020 | | | | **0.020** |
| Mercuric thiocyanate | 1 | solid | Poison | | | 0.100 | | | | **0.100** |
| Methyl acetate | 4 | liquid | Flammable | | 6.000 | 0.980 | | | | **6.980** |
| Methyl benzoate | 6 | liquid | Combustible | 3.000 | | | | | | **3.000** |
| Methyl blue | 4 | liquid | Poison via ingestion. | 2.000 | | | | | | **2.000** |
| Methyl chlorohexane | 1 | liquid | Unclassified | | 1.000 | | | | | **1.000** |
| Methylated spirit | 1 | liquid | Flammable. Irritant. Carcinogen. | | | | | | 0.250 | **0.250** |
| Methylene blue | 7 | solid | Poison via ingestion. | | | | 7.000 | | | **7.000** |
| Metol | 1 | solid | Corrosive | 0.500 | | | | | | **0.500** |
| Morphiline | 5 | liquid | Inflammable | | 0.500 | 3.144 | | | | **3.644** |
| Myristic acid | 4 | solid | Corrosive | | 0.350 | | | | | **0.350** |
| N- ethylaniline | 2 | liquid | Poison | | | 0.178 | | | | **0.178** |
| Naphtha solvent | 1 | liquid | Flammable | | 1.879 | | | | | **1.879** |
| Naphthalene | 1 | solid | Combustible. Toxic. Irritant. | | | | | 0.500 | | **0.500** |
| Napthanic acid | 1 | liquid | Corrosive | | | 1.814 | | | | **1.814** |
| n-Butylaldehyde | 1 | liquid | Flammable. Toxic via skin absorption. | | | | 0.136 | | | **0.136** |

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|---|---|---|---|---|---|---|---|---|---|---|
| n-Butyric acid | 2 | liquid | Corrosive; intense stench. Combustible. Theft risk. | 3.824 | | | | | | **3.824** |
| n-Heptanol | 1 | liquid | Flammable. Irritant | | | 1.211 | | | | **1.211** |
| n-Hexanoic acid | 4 | liquid | Corrosive. Toxic. | | 1.000 | | | | | **1.000** |
| n-Hexanol | 3 | liquid | Unclassified | | | 2.157 | | | | **2.157** |
| Nitrobenzene | 20 | liquid | Toxic. Combustible. Oxidizer. Absorbs through skin. | | 2.652 | 15.840 | | | | **18.492** |
| n-Methylaniline | 2 | liquid | Poison | | | 1.956 | | | | **1.956** |
| NN-diethylaniline | 6 | liquid | Poison | | 2.402 | | | | | **2.402** |
| N'N'N'N'-tetra methyl ethylene | 1 | liquid | Flammable. Corrosive | 0.195 | | | | | | **0.195** |
| o-Anisidine | 2 | liquid | Poison | | | 0.876 | | | | **0.876** |
| o-cresol | 1 | liquid | Corrosive to skin & eyes. Toxic via ingestion, skin absorption. | 0.500 | | | | | | **0.500** |
| Orthophosphate acid | 1 | liquid | Corrosive. Toxic. | | | | | | 0.503 | **0.503** |
| o-Toluidine | 1 | solid | Combustible. Carcinogen | | | | | | 0.086 | **0.086** |
| o-Toluidine | 2 | liquid | Combustible. Carcinogen | | | | 0.438 | | 0.184 | **0.622** |
| Oxalic acid | 8 | solid | Toxic. Irritant. | 3.026 | | | | | 0.031 | **3.057** |
| p-Amino benzoic | 2 | solid | Unclassified | | 0.500 | | | | | **0.500** |
| p-Amino phenol | 2 | solid | Unclassified | | 0.350 | | | | | **0.350** |
| p-Amino-azo benzene | 1 | solid | Toxic. Carcinogen | | 0.100 | | | | | **0.100** |
| p-Anisidine | 2 | solid | Poison. Carcinogen | | 0.200 | | | | | **0.200** |
| Paraffin liquid | 5 | liquid | Not regulated as hazardous | | | | 0.500 | 0.250 | 1.061 | **1.811** |
| p-Benzoquinone | 8 | solid | Toxic | 1.984 | | | | | | **1.984** |
| p-Chlorotoluene | 2 | liquid | Toxic | | | 2.416 | | | | **2.416** |

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|---|---|---|---|---|---|---|---|---|---|---|
| p-cresol | 1 | liquid | Corrosive to skin & eyes. Toxic via ingestion, skin absorption. | 0.407 | | | | | | **0.407** |
| p-Cymene | 1 | liquid | Unclassified | | | 0.402 | | | | **0.402** |
| Pentanol | 2 | liquid | Flammable. Toxic. Irritant. | | | 2.244 | | | | **2.244** |
| Pentyl acetate | 1 | liquid | Highly flammable | | 0.701 | | | | | **0.701** |
| Pepsin | 4 | solid | Not regulated as hazardous | | | | 2.000 | | | **2.000** |
| Periodic acid | 4 | liquid | Corrosive | 0.100 | | | | | | **0.100** |
| Periodic acid | 1 | solid | Corrosive | | | 0.025 | | | | **0.025** |
| Petroleum ether | 1 | liquid | Flammable. | | | | | | 1.478 | **1.478** |
| Petroleum spirit | 2 | liquid | Flammable. | 0.624 | | | | | 0.506 | **1.130** |
| phenol | 1 | liquid | Poison. Corrosive. Readily absorbed through skin. | | | | | | 0.038 | **0.038** |
| Phloroglucinol | 14 | liquid | Unclassified | 0.336 | | | | | | **0.336** |
| Piperidine | 3 | liquid | Flammable. Toxic | | 0.659 | | | | | **0.659** |
| Polyethylene glycol | 1 | solid | Unclassified | 0.054 | | | | | | **0.054** |
| Potassium acetate | 2 | liquid | Not regulated as hazardous | 2.000 | | | | | | **2.000** |
| Potassium bicarbonate | 3 | solid | Not regulated as hazardous | 1.500 | | | | | | **1.500** |
| Potassium bromate | 1 | solid | Strong oxidizer. Toxic. | | | 1.500 | | | | **1.500** |
| Potassium bromide | 10 | solid | Slightly toxic by ingestion. Prolonged contact with moist skin can produce severe burns. | 2.500 | | 0.500 | | | | **3.000** |
| Potassium carbonate | 2 | solid | Not regulated as hazardous | | | | | | 0.420 | **0.420** |
| Potassium chlorate | 5 | solid | Powerful oxidizer. Theft risk. May explode if heated. | 1.000 | | 2.500 | | | | **3.500** |
| Potassium chloride | 7 | solid | Not regulated as hazardous | 2.934 | | 1.000 | | 0.052 | 0.216 | **4.202** |

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|---|---|---|---|---|---|---|---|---|---|---|
| Potassium chromate | 3 | solid | Powerful oxidizer. Toxic. Carcinogen | | | | | 0.500 | 0.442 | **0.942** |
| Potassium citrate | 1 | solid | Not regulated as hazardous | 0.500 | | | | | | **0.500** |
| Potassium cyanate | 1 | solid | Unclassified | | | 0.500 | | | | **0.500** |
| Potassium Dihydrogen orthphosphate | 1 | solid | Toxic. | | | | | | 0.019 | **0.019** |
| Potassium ferrocyanide | 7 | solid | Releases cyanide gas if heated or acidified. Toxic | 1.125 | | 0.600 | | | | **1.725** |
| Potassium hydrogen carbonate | 14 | solid | Not regulated as hazardous | 5.507 | | 1.800 | | | | **7.307** |
| Potassium hydrogen orthophosphate | 1 | solid | Not regulated as hazardous | 0.050 | | | | | | **0.050** |
| Potassium hydrogen phthalate | 4 | solid | Not regulated as hazardous | 1.037 | | | | | 0.050 | **1.087** |
| Potassium hydrogen sulphate | 11 | solid | Not regulated as hazardous | 4.126 | | 0.500 | | | | **4.626** |
| Potassium hydroxide | 1 | solid | Corrosive. Blisters skin on contact. | | | | | 0.264 | | **0.264** |
| Potassium iodate | 7 | solid | Oxidizer. Toxic. | | | 0.500 | | 5.248 | | **5.748** |
| Potassium iodide | 5 | solid | Not regulated as hazardous | | | | | 1.936 | | **1.936** |
| Potassium metal | 1 | solid | Water reactive, peroxide former (orange fog/crystals) | | | 0.200 | | | | **0.200** |
| Potassium nitrate | 3 | solid | Oxidizer | 0.486 | | | | 0.011 | 0.493 | **0.990** |
| Potassium orthophosphate | 1 | solid | Not regulated as hazardous | 0.486 | | | | | | **0.486** |
| Potassium periodate | 1 | solid | Oxidizer. Severe skin irritant. | | | 0.125 | | | | **0.125** |
| Potassium permanganate | 2 | solid | Strong oxidizer. Strong irritant. Can explode if quickly heated. | | | | | 0.247 | | **0.247** |
| Potassium salicylate | 1 | solid | Unclassified | 0.236 | | | | | | **0.236** |
| Potassium sodium tartrate | 13 | solid | Not regulated as hazardous | 8.298 | | | | | | **8.298** |

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|---|---|---|---|---|---|---|---|---|---|---|
| Potassium sulphate | 1 | solid | Not regulated as hazardous | 0.853 | | | | | | **0.853** |
| Potassium sulphide | 1 | solid | Unclassified | | | | | 0.500 | | **0.500** |
| Potassium tartrate | 1 | solid | Not regulated as hazardous | | | | | | 0.500 | **0.500** |
| Potassium thiocyanate | 6 | liquid | Toxic by ingestion. Reacts with acids to release cyanide gas. | 0.589 | | | | | | **0.589** |
| Potassium thiocyanate | 1 | solid | Toxic by ingestion. Reacts with acids to release cyanide gas. | | | 0.400 | | | | **0.400** |
| Propylene glycol | 1 | liquid | Not regulated as hazardous | 1.522 | | | | | | **1.522** |
| p-Toluidine | 2 | solid | Toxic | | | | | 0.196 | 0.074 | **0.270** |
| Pyridine | 4 | liquid | Flammable. Toxic by ingestion, inhalation, skin contact Vapor forms explosive mix with air | 3.038 | | | | | | **3.038** |
| Quinol | 2 | solid | Corrosive. | | 0.700 | | | | | **0.700** |
| Quinoline | 4 | liquid | Poison | | | 0.118 | | | | **0.118** |
| Resorcinol | 2 | solid | Toxic. Easily absorbed through skin. | 1.000 | | | | | | **1.000** |
| Salicyaldehyde | 2 | liquid | Unclassified | | | 0.382 | | | | **0.382** |
| Schiff's reagent | 1 | liquid | Corrosive. Carcinogen | | | | 0.500 | | | **0.500** |
| Sec- Butylalcohol | 3 | liquid | Flammable. Can form explosive peroxides on concentration. | | | 1.739 | | | | **1.739** |
| Selenium Powder | 1 | solid | Acute poison by inhalation of powder or ingestion. | | | 0.100 | | | | **0.100** |
| Silica gel | 4 | solid | Not regulated as hazardous | | | | | 0.553 | 0.500 | **1.053** |

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|---|---|---|---|---|---|---|---|---|---|---|
| Silicon | 1 | solid | Combustible. Irritant. | | 0.500 | | | | | **0.500** |
| soda lime | 14 | solid | Calcium oxide + sodium hydroxide. Corrosive solid. Generates heat in contact with water. | | 3.862 | 6.300 | | 1.000 | | **11.162** |
| Sodamide | 1 | solid | Flammable | | | 0.100 | | | | **0.100** |
| Sodium acetate | 2 | solid | Not regulated as hazardous | | | | | 0.252 | 0.449 | **0.701** |
| Sodium acetate | 1 | liquid | Not regulated as hazardous | | | | | | 0.083 | **0.083** |
| Sodium arsenite | 4 | solid | Deadly poison. Carcinogen. | | 1.750 | | | | | **1.750** |
| Sodium benzoate | 2 | solid | Toxic by ingestion. | | | | 2.500 | 2.500 | | **5.000** |
| Sodium bismuth | 2 | solid | Toxic by ingestion | | 0.500 | | | | | **0.500** |
| Sodium bismuthate | 1 | solid | Oxidizer. | | | 0.025 | | | | **0.025** |
| Sodium borohydride | 1 | solid | Flammable solid. Water reactive | | | 0.010 | | | | **0.010** |
| Sodium bromide | 1 | solid | Not regulated as hazardous | | | 2.500 | | | | **2.500** |
| Sodium carbonate | 2 | solid | Not regulated as hazardous | | | | | | 1.000 | **1.000** |
| Sodium cobalt nitrite | 2 | solid | Explosive. Reactive. Poisonous | 0.010 | | 0.100 | | | | **0.110** |
| Sodium cyanate | 1 | solid | Toxic. Carcinogen | | | 0.500 | | | | **0.500** |
| Sodium dichromate | 3 | solid | Powerful oxidizer. Toxic. Carcinogen | | | 1.500 | | | | **1.500** |
| Sodium dithionate | 2 | solid | Flammable. Toxic | | | 0.200 | | | | **0.200** |
| Sodium dithionite | 2 | solid | Water reactive. Toxic by ingestion & inhalation. An allergen. Powerful reducing agent. | | 0.250 | 0.700 | | | | **0.950** |
| Sodium ferrocyanide | 2 | solid | Toxic. Irritant. | | 2.000 | | | | | **2.000** |

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|---|---|---|---|---|---|---|---|---|---|---|
| Sodium fluoride | 1 | solid | Poison by ingestion or inhalation. Strong skin irritant. | | | 0.500 | | | | **0.500** |
| Sodium fluoroborate | 1 | solid | Corrosive. | | | 0.250 | | | | **0.250** |
| Sodium formate | 1 | solid | Toxic. Carcinogen. | | | | | | 0.437 | **0.437** |
| Sodium hexameta-phosphate | 4 | solid | Toxic. Irritant | | 1.987 | | | | | **1.987** |
| Sodium hydride | 1 | solid | Reacts with water. Flammable | | | 0.500 | | | | **0.500** |
| Sodium hydrogen sulphate | 1 | solid | Corrosive | | | 1.000 | | | | **1.000** |
| Sodium lime | 1 | solid | Corrosive | | | | | | 0.500 | **0.500** |
| Sodium metal, in paraffin liquid | 32 | solid | Water reactive. Corrosive | | | 11.900 | | | | **11.900** |
| Sodium nitrate | 6 | solid | Oxidizer. | | 1.520 | | | 0.500 | 0.356 | **2.376** |
| Sodium nitrite | 1 | liquid | Oxidizer. Toxic by ingestion. | | 0.100 | | | | | **0.100** |
| Sodium nitrite | 16 | solid | Oxidizer. Toxic by ingestion. | | | 16.000 | | | | **16.000** |
| Sodium nitro prusside | 1 | solid | Toxic. Irritant | | | 2.500 | | | | **2.500** |
| Sodium oxalate | 2 | solid | Poison. Corrosive. | | 1.711 | | | | | **1.711** |
| Sodium perborate | 1 | solid | Oxidizer. Toxic by ingestion. | | 0.373 | | | | | **0.373** |
| Sodium stannate | 2 | solid | Corrosive | | 1.000 | | | | | **1.000** |
| Sodium sulphate | 3 | solid | Not regulated as hazardous | 5.051 | | | | | 0.652 | **5.703** |
| Sodium thiosulphate | 2 | solid | Not regulated as hazardous | 1.524 | | | | 0.046 | | **1.570** |
| Sodium thiosulphate | 1 | liquid | Not regulated as hazardous | | | | | | 0.133 | **0.133** |
| Sorbitol | 1 | solid | Not regulated as hazardous | 0.403 | | | | | | **0.403** |
| Squalene | 2 | liquid | Unclassified | | 0.500 | | | | | **0.500** |
| Stannic Sulphide | 1 | solid | Unclassified | | 0.397 | | | | | **0.397** |
| Stannous bromide | 1 | solid | Unclassified | | 0.050 | | | | | **0.050** |
| Stannous oxide | 2 | solid | Unclassified | | 0.307 | | | | | **0.307** |

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|---|---|---|---|---|---|---|---|---|---|---|
| Strontium chloride | 2 | solid | Toxic | | 1.511 | | | | | **1.511** |
| strontium carbonate | 5 | solid | Unclassified | 412 | 1.318 | | | | | **1.730** |
| Strontium bromide | 1 | solid | Unclassified | | 0.227 | | | | | **0.227** |
| Strontium nitrite | 1 | solid | Unclassified | | 0.050 | | | | | **0.050** |
| Strontium orthophosphate | 1 | solid | Unclassified | | 1.000 | | | | | **1.000** |
| Strontium sulphate | 3 | solid | Unclassified | | 1.000 | | | | | **1.000** |
| Styrene monomer | 2 | solid | Flammable. Suspect carcinogen. | | | | 1.000 | | | **1.000** |
| Succinic acid | 1 | solid | Corrosive | 0.495 | | | | | | **0.495** |
| Succinic anhydride | 1 | solid | Corrosive | | 0.500 | | | | | **0.500** |
| Sucrose | 1 | solid | Not regulated as hazardous | | | | 0.328 | | | **0.328** |
| Sulfur precipitate | 1 | solid | Combustible. Releases poisonous sulfur dioxide gas when wet or acidified. | | 0.250 | | | | | **0.250** |
| Sulphuric acid | 1 | liquid | Corrosive. | | | | | | 0.500 | **0.500** |
| Tannic acid | 2 | solid | Toxic by ingestion. | 0.049 | 0.250 | | | | | **0.299** |
| Tetrahydrofuran | 5 | liquid | Unclassified | | | 12.373 | | | | **12.373** |
| Tetra-sodium pyrophosphate | 4 | solid | Not regulated as hazardous | | 2.000 | | | | | **2.000** |
| tetrachloroethane | 1 | liquid | Unclassified | | | 0.972 | | | | **0.972** |
| Tin, foil | 7 | solid | Not regulated as hazardous | | 1.500 | 0.600 | | | | **2.100** |
| Titanium dioxide | 1 | solid | Unclassified | | 0.030 | | | | | **0.030** |
| Tri-ammonium orthophosphate | 3 | solid | Not regulated as hazardous | 0.495 | 0.489 | 1.000 | | | | **1.984** |
| Triethyl orthoformate | 1 | liquid | Flammable | | | 0.991 | | | | **0.991** |
| Tri-n-butylphosphate | 2 | liquid | Unclassified | | 4.000 | | | | | **4.000** |
| Tri-potassium orthophosphate | 2 | liquid | Not regulated as hazardous | 0.723 | | | | | | **0.723** |

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|---|---|---|---|---|---|---|---|---|---|---|
| Tri-potassium orthophosphate | 2 | solid | Not regulated as hazardous | 1.572 | | | | | | **1.572** |
| Tri-Sodium orthophosphate | 2 | solid | Not regulated as hazardous | | 1.000 | 0.500 | | | | **1.500** |
| Urea | 2 | solid | Not regulated as hazardous | 0.953 | | | | | 0.096 | **1.049** |
| Wood's metal | 1 | solid | Poison. Contains cadmium & lead. | | | 0.100 | | | | **0.100** |
| Zinc borate | 1 | solid | Unclassified | | 0.500 | | | | | **0.500** |
| Zinc carbonate | 3 | solid | Not regulated as hazardous | | 1.536 | | | | 0.500 | **2.036** |
| Zinc fluoride | 1 | solid | Corrosive | | 0.500 | | | | | **0.500** |
| Zinc metal | 5 | solid | Not regulated as hazardous | | | 4.500 | | | 0.759 | **5.259** |
| Zinc oxide | 2 | solid | Moderately toxic by ingestion and inhalation | | 0.050 | | | 0.500 | | **0.550** |
| Zinc sulphide | 2 | solid | Reacts with acids to form poisonous hydrogen sulfide gas. | | | | | 0.304 | 0.388 | **0.692** |
| | | | | | | | | | | |
| **TOTAL** | | | | | | | | | | **843.927** |

**Appendix C: Analysis on all unknown chemicals at various storage points.**

| UNLABELED CHEMICALS IN DEPARTMENT OF CHEMISTRY -K.N.U.S.T. | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| SAMPLE CODE | WEIGHT/Kg | PHYSICAL STATE | SOLUBILITY IN | | | | | | LITMUS TEST | pH |
| | | | H2O | HCl | NaOH | AgNO3 | Conc. H2SO4 | | | |
| COC1 | 0.242 | Liquid | Misc. | No vis. Rxn | No vis. Rxn | white ppt. | white ppt. | | blue to red | 5.15 |
| COC2 | 0.604 | Liquid | Misc. | No vis. Rxn | turned voilet | No vis. Rxn | turned pink | | blue to red | 4.92 |
| COC3 | 0.482 | Liquid | Misc. | No vis. Rxn | No vis. Rxn | pale yellow | | | red to blue | 10.4 |
| COC4 | 0.499 | Liquid | Immisc. | Immisc. | Immisc. | white ppt. | thick wine | | blue to red | 5.35 |
| COC5 | 0.286 | Liquid | Misc. | No vis. Rxn | No vis. Rxn | white ppt. | evolution of gas | | red to blue | 8.84 |
| COC6 | 0.248 | Liquid | could not be opened | | | | | | | |
| COC7 | 0.389 | Liquid | could not be opened | | | | | | | |
| COC8 | 0.487 | Liquid | Misc. | No vis. Rxn | No vis. Rxn | white ppt. | evolution of gas | | red to blue | 9.43 |
| COC9 | 0.318 | Solid | Soluble | No vis. Rxn | No vis. Rxn | No vis. Rxn | evolution of gas | | no effect | 7.03 |
| COC10 | 0.500 | Liquid | could not be opened | | | | | | | |
| COC11 | 0.484 | Liquid | Misc. | No vis. Rxn | No vis. Rxn | white ppt. | white ppt. | | red to blue | 9.42 |
| COC12 | 0.223 | Liquid | Misc. | No vis. Rxn | No vis. Rxn | white ppt. | white ppt. | | blue to red | 3.57 |

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| COC13 | 0.418 | Liquid | Misc. | No vis. Rxn | No vis. Rxn | No vis. Rxn | white ppt. | blue to red | 6.85 |
| COC14 | 0.498 | Liquid | Misc. | No vis. Rxn | No vis. Rxn | white ppt. | No vis. Rxn | blue to red | 4.33 |
| COC15 | 0.497 | Liquid | Misc. | No vis. Rxn | No vis. Rxn | brown ppt. | white ppt. | blue to red | 6.51 |
| COC16 | 0.209 | Liquid | Misc. | No vis. Rxn | No vis. Rxn | No vis. Rxn | No vis. Rxn | blue to red | 0.6 |
| COC17 | 0.132 | Liquid | Misc. | No vis. Rxn | No vis. Rxn | white ppt. | No vis. Rxn | blue to red | 1.48 |
| COC18 | 0.135 | Liquid | Misc. | No vis. Rxn | pale blue | No vis. Rxn | white ppt. | blue to red | 1.08 |
| COC19 | 0.502 | Liquid | Misc. | No vis. Rxn | No vis. Rxn | No vis. Rxn | No vis. Rxn | blue to red | 0.66 |
| COC20 | 0.573 | Liquid | Misc. | No vis. Rxn | No vis. Rxn | white ppt. | evolution of gas | blue to red | 2.8 |
| COC21 | 0.499 | Liquid | Misc. | No vis. Rxn | No vis. Rxn | pale yellow | yellow | blue to red | 4.13 |
| COC22 | 0.486 | Solid | Soluble | white ppt. | No vis. Rxn | tan | evolution of gas | red to blue | 13.85 |
| COC23 | 0.482 | Liquid | Misc. | No vis. Rxn | No vis. Rxn | pale yellow | white ppt. | red to blue | 10.3 |
| COC24 | 0.061 | Liquid | Misc. | No vis. Rxn | No vis. Rxn | No vis. Rxn | bubbles | red to blue | 10.45 |
| COC25 | 0.379 | Liquid | Misc. | No vis. Rxn | No vis. Rxn | No vis. Rxn | white ppt. | blue to red | 0.49 |
| COC26 | 0.413 | Solid | Soluble | No vis. Rxn | No vis. Rxn | ppt. | evolution of gas | no effect | 7.07 |
| COC27 | 0.036 | Liquid | Misc. | No vis. Rxn | No vis. | No vis. | No vis. Rxn | blue to red | 5.13 |

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | | | | Rxn | Rxn | | | |
| COC28 | 0.500 | Liquid | Immisc. | Immisc. | Immisc. | Immisc. | thick dark brown | blue to red | 3.19 |
| COC29 | 0.500 | Liquid | Misc. | No vis. Rxn | No vis. Rxn | white ppt. | evolution of gas | red to blue | 9.38 |
| COC30 | 0.189 | Liquid | Misc. | No vis. Rxn | No vis. Rxn | creamy ppt | evolution of gas | red to blue | 10.7 |
| COC31 | 0.500 | Solid | Insoluble | No vis. Rxn | No vis. Rxn | white ppt. | No vis. Rxn | | |
| COC32 | 0.250 | powder | Insoluble | partially soluble | dark brown | insoluble | deep voilet | | |
| COC33 | 0.500 | Liquid | Misc. | No vis. Rxn | No vis. Rxn | No vis. Rxn | evolution of gas | blue to red | 6.78 |
| COC34 | 1.809 | Liquid | could not be opened | | | | | | |
| COC35 | 1.872 | Liquid | Misc. | No vis. Rxn | No vis. Rxn | white ppt. | evolution of gas | blue to red | 4.01 |
| COC36 | 2.000 | Liquid | Misc. | No vis. Rxn | No vis. Rxn | white ppt. | evolution of gas | blue to red | 5.15 |
| COC37 | 0.204 | Liquid | Misc. | No vis. Rxn | No vis. Rxn | No vis. Rxn | evolution of gas | red to blue | 8.34 |
| COC38 | 0.189 | Liquid | could not be opened | | | | | | |
| | | | | | | | | | |
| **TOTAL** | **18.595** | | | | | | | | |
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| **UNLABELED CHEMICALS AT DEPARTMENT OF THEOREICAL AND APPLIED BIOLOGY** | | | | | | | | | |
| BOC1 | 0.422 | Liquid | Misc. | No vis. Rxn | No vis. Rxn | white ppt. | white ppt. | red to blue | 9.15 |

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| BOC2 | 0.616 | Liquid | Misc. | No vis. Rxn | turned voilet | No vis. Rxn | turned pink | blue to red | 4.92 |
| BOC3 | 0.818 | Liquid | Misc. | No vis. Rxn | No vis. Rxn | pale yellow | | red to blue | 11.4 |
| BOC4 | 0.951 | Liquid | Immisc. | Immisc. | Immisc. | white ppt. | thick wine | blue to red | 5.35 |
| BOC5 | 0.328 | Liquid | Misc. | No vis. Rxn | No vis. Rxn | white ppt. | evolution of gas | no effect | 7.03 |
| BOC6 | 0.423 | Solid | Soluble | No vis. Rxn | No vis. Rxn | white ppt. | white ppt. | red to blue | 8.86 |
| BOC7 | 0.902 | Solid | Soluble | No vis. Rxn | No vis. Rxn | No vis. Rxn | evolution of gas | blue to red | 4.38 |
| BOC8 | 0.135 | Liquid | Misc. | No vis. Rxn | No vis. Rxn | white ppt. | evolution of gas | red to blue | 9.73 |
| BOC9 | 0.409 | Solid | Soluble | No vis. Rxn | No vis. Rxn | No vis. Rxn | evolution of gas | no effect | 7.01 |
| BOC10 | 0.501 | Solid | Soluble | No vis. Rxn | No vis. Rxn | white ppt. | evolution of gas | no effect | 7.02 |
| BOC11 | 0.484 | Liquid | Misc. | No vis. Rxn | No vis. Rxn | white ppt. | white ppt. | red to blue | 9.94 |
| BOC12 | 0.148 | Liquid | Misc. | No vis. Rxn | No vis. Rxn | white ppt. | white ppt. | blue to red | 3.57 |
| | | | | | | | | | |
| **TOTAL** | **6.137** | | | | | | | | |
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| **UNKNOWN CHEMICALS AT DEPARTMENT OF PHARMACEUTICAL CHEMISTRY** | | | | | | | | | |
| PHOC1 | 0.105 | Liquid | Misc. | No vis. Rxn | No vis. | No vis. | white ppt. | blue to red | 5.85 |

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|---|---|---|---|---|---|---|---|---|---|
| | | | | | Rxn | Rxn | | | |
| PHOC2 | 0.976 | Liquid | Misc. | No vis. Rxn | No vis. Rxn | white ppt. | No vis. Rxn | no effect | 7.02 |
| PHOC3 | 0.598 | Solid | soluble | No vis. Rxn | No vis. Rxn | brown ppt. | white ppt. | blue to red | 6.51 |
| PHOC4 | 0.329 | Liquid | Misc. | No vis. Rxn | No vis. Rxn | No vis. Rxn | No vis. Rxn | blue to red | 1.06 |
| PHOC5 | 0.682 | Solid | soluble | No vis. Rxn | No vis. Rxn | white ppt. | No vis. Rxn | blue to red | 0.78 |
| PHOC6 | 0.336 | Liquid | Misc. | No vis. Rxn | pale blue | No vis. Rxn | white ppt. | blue to red | 1.08 |
| | | | | | | | | | |
| **TOTAL** | **3.026** | | | | | | | | |
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| **UNLABELED CHEMICALS AT ANGLICAN SENIOR HIGH SCHOOL** | | | | | | | | | |
| AOC1 | 0.102 | Liquid | Misc. | No vis. Rxn | No vis. Rxn | No vis. Rxn | No vis. Rxn | blue to red | 0.66 |
| AOC2 | 0.312 | Liquid | Misc. | No vis. Rxn | No vis. Rxn | white ppt. | evolution of gas | blue to red | 2.18 |
| AOC3 | 0.098 | Liquid | Misc. | No vis. Rxn | No vis. Rxn | pale yellow | yellow | no effect | 7.02 |
| AOC4 | 0.651 | Solid | soluble | white ppt. | No vis. Rxn | tan | evolution of gas | red to blue | 13.85 |
| AOC5 | 0.295 | Liquid | Misc. | No vis. Rxn | No vis. Rxn | pale yellow | white ppt. | red to blue | 11.53 |
| | | | | | | | | | |
| **TOTAL** | **1.458** | | | | | | | | |
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| **UNLABELED CHEMICALS AT KUMASI SENIOR HIGH SCHOOL** | | | | | | | | | |
| KHOC1 | 1.173 | Liquid | Misc. | No vis. Rxn | No vis. Rxn | No vis. Rxn | bubbles | red to blue | 10.45 |
| KHOC2 | 0.413 | Liquid | Misc. | No vis. Rxn | No vis. Rxn | No vis. Rxn | white ppt. | blue to red | 0.49 |
| KHOC3 | 0.413 | Solid | soluble | No vis. Rxn | No vis. Rxn | ppt. | evolution of gas | no effect | 7.02 |
| KHOC4 | 0.613 | Liquid | Misc. | No vis. Rxn | No vis. Rxn | No vis. Rxn | No vis. Rxn | blue to red | 5.13 |
| KHOC5 | 0.503 | Liquid | Immisc. | Immisc. | Immisc. | Immisc. | thick dark brown | no effect | 7.02 |
| KHOC6 | 0.128 | Liquid | Misc. | No vis. Rxn | No vis. Rxn | white ppt. | evolution of gas | red to blue | 9.38 |
| KHOC7 | 0.648 | Solid | soluble | No vis. Rxn | No vis. Rxn | creamy ppt | evolution of gas | red to blue | 10.7 |
| | | | | | | | | | |
| **TOTAL** | **3.891** | | | | | | | | |
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| **UNLABELED CHEMICALS AT TECHNOLOGY SENIOR HIGH SCHOOL** | | | | | | | | | |
| TOC1 | 0.412 | solid | soluble | Soluble | insoluble | insoluble | white ppt. | red to blue | 4.87 |
| TOC2 | 0.501 | powder | soluble | partially soluble | dark brown | insoluble | deep voilet | blue to red | 7.86 |
| TOC3 | 0.554 | Liquid | Misc. | No vis. Rxn | No vis. Rxn | No vis. Rxn | evolution of gas | blue to red | 6.78 |
| TOC4 | 1.351 | solid | Soluble | No vis. Rxn | No vis. Rxn | white ppt. | white ppt. | red to blue | 9.65 |

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|---|---|---|---|---|---|---|---|---|---|
| TOC5 | 1.647 | Liquid | Misc. | No vis. Rxn | No vis. Rxn | white ppt. | evolution of gas | blue to red | 4.01 |
| TOC6 | 0.223 | Liquid | Misc. | No vis. Rxn | No vis. Rxn | white ppt. | evolution of gas | no effect | 7.01 |
| TOC7 | 0.239 | Liquid | Misc. | No vis. Rxn | No vis. Rxn | No vis. Rxn | evolution of gas | no effect | 7.03 |
| | | | | | | | | | |
| TOC8 | 0.534 | solid | Soluble | No vis. Rxn | white ppt. | No vis. Rxn | white ppt. | blue to red | 4.96 |
| TOC9 | 1.682 | Liquid | Misc. | No vis. Rxn | No vis. Rxn | white ppt. | No vis. Rxn | blue to red | 1.48 |
| TOC10 | 0.516 | Liquid | Misc. | No vis. Rxn | pale blue | No vis. Rxn | white ppt. | blue to red | 1.08 |
| TOC11 | 0.502 | Liquid | Misc. | No vis. Rxn | No vis. Rxn | No vis. Rxn | No vis. Rxn | blue to red | 1.66 |
| TOC12 | 0.483 | Liquid | Misc. | No vis. Rxn | No vis. Rxn | pale yellow | | red to blue | 10.4 |
| TOC13 | 0.951 | Liquid | Immisc. | Immisc. | Immisc. | white ppt. | thick wine | no effect | 7.03 |
| | | | | | | | | | |
| **TOTAL** | **9.595** | | | | | | | | |

**Appendix D**

**CURRENTLY USED CHEMICALS IN CHEMISTRY DEPARTMENT**

| | | |
|---|---|---|
| Acetic acid | Acetic anhydride | Acetone |
| Alumina | Amino acid | Ammonia |
| Ammonium carbonate | Ammonium chloride | Ammonium hydroxide |
| Ammonium metavanadate | *Ammonium molybdate | *Ammonium nickel |
| sulphate | | |
| Ammonium nitrate | *Ammonium thiocyanide | Amyl alcohol |
| Aniline | Antimony trichloride | Barium Chloride |
| Benzene | Benzophenone | Benzoyl peroxide |
| Bleaching powder | Borax | Boric acid |
| Bromine | Bromobenzene | Bromocresol green |
| Caffaine | Calcium carbonate | Calcium chloride |
| Carbon dioxide | Carbon tetrachloride | Charcoal |
| Chlorobenzene | Chloroform | Citric acid |
| *Copper | Copper nitrate | Copper sulphate |
| Diethylether | Diglyceride | Dimethylglyoxime |
| Diphenylamine | Disodium -magnesium | EDTADisodium salt of |
| EDTA | | |
| Dragendorf's reagent | Eriochrome black | Ethanol |
| Ether | Ethyl acetate | Fatty acid |
| Fehlings Solution | Ferric hydroxide | Ferrous ammonium |
| sulphate | | |

| | | |
|---|---|---|
| Ferrous oxalate | Ferrous sulphate | Glycine |
| Heptane | Hexane | Hydrochloric acid |
| Hydrogen carbonate | Hydrogen peroxide | Hydrogen sulphide |
| Hydroxylammonium chloride | Hydroxylammonium | hydrochloride |
| Iodine | Iron | Iron (II) nitrate |
| Iron ammonium sulphate | Iron sulphate | Isopropyl alcohol |
| Magnesium oxide | Magnesium sulphate | *Magnesium turnings |
| Manganate (II) oxide | Mayer's reagent (Potassium mercuric iodide) | |
| Methanol | Methanolic | potassium hydroxide |
| Methyl orange | Methyl red | Monoglyceride |
| Naphthalene | n-butanol | Nessler reagent |
| Nickel | Nickel sulphate | Ninhydrin spray |
| Nitric acid | n-propanol | Orthophosphoric acid |
| Oxalic acid | Paraffin liquid | Perchloric acid |
| Petroleum ether | Phenanthroline | Phenol red |
| Phenolphthalein | Phospholipid | Phosphoric acid |
| Picric acid | Potassium | Potassium bromide |
| Potassium chloride | Potassium chromate | Potassium dichromate |
| Potassium dihydrogen phosphate | Potassium hydroxide | Potassium iodide |
| Potassium hydrogen phosphate | Potassium nitrate | Potassium oxalate |
| Potassium permanganate | Potassium persulphate | Potassium thiosulphate |
| Salicyclic acid | Silica gel | Silver bromide |
| Silver chloride | Silver nitrate | Sodium |
| Sodium carbonate | Sodium chloride | Sodium fluoride |

| | | |
|---|---|---|
| Sodium Hydrogen carbonate | Sodium hydrogen phosphate | Sodium hydroxide |
| *Sodium nitrate | Sodium phosphate | Sodium sulphate |
| Sodium sulphide | Sodium sulphite | Sodium thiosulphate |
| Solochrome dark blue | Starch | Styrene |
| Sucrose | Sulphur dioxide | Sulphuric acid |
| Tin (II) chloride | Triglyceride | Vanadate |
| Vanadate-molybdate reagent | Zinc | Zinc sulphate |

**OBSOLETE CHEMICALS IN CHEMISTRY DEPARTMENT**

| | | |
|---|---|---|
| 1,2-dibromoethane | 1,2-dichlorobenzene | 1,2-dichloroethane |
| 1-Naphthol ` | 2,6-Lutidine | 2-Aminopyridine |
| 2-Methyl naphthalene | 2-Methyl propan-1-ol | 2-Napthol |
| 3-Amino benzoic | 3-Nitroaniline | 4-Amino benzoic acid |
| 4-Amino diphenyl hydrochloride | 4-Aminophenol | 4-Picoline |
| 8-hydroxyquinoline | Adipic acid | Aluminum ammonium |
| sulphate | | |
| Aluminum bromide | Aluminum cerric sulphate | Aluminum chloride |
| Aluminum hydroxide | Aluminum lithium hydride | Aluminum oxide |
| Aluminum phosphate | Aluminum potassium sulphate | Aluminum silicate |
| Aluminum sodium | hydrgen orthophosphate | Amino-diphenylamine |
| Ammonium bromide | Ammonium cobalt sulphate | Ammonium dichromate |

| | | |
|---|---|---|
| Ammonium hydrogen difluoride | *Ammonium molybdate | *Ammonium nickel sulphate |
| Ammonium persulphate | Ammonium sodium hydrogen phosphate | |
| Ammonium sodium phosphate | Ammonium tetraborate | *Ammonium thiocyanide |
| Ammonium tungstate | Ammonium zinc sulphate | Amyl acetate |
| Anisic acid | Anthracene | Anthraquinone |
| Antimony pentasulphate | Antimony trioxide | Arsenic trioxide |
| Arsenous oxide | Barium bromide | Barium carbonate |
| Barium fluoride | Barium hydroxide | Benzyaldehyde |
| Berylium oxide | Berylium sulphate | Bibenzyl |
| Bismuth nitrate | Bismuth oxynitrate | Boric anhydride |
| Bromobutane | Butane-1,3-diol | Butane-1,4-diol |
| Butane-2,3-diol | Butanone | Chloronaphthalene |
| Chromium ammonium sulphate | Chromium trioxide | Cinnamaldehyde |
| Cobalt sulphate | Cobaltous carbonate | Copper carbonate |
| | | |
| *Copper powder | Cupric arsenite | Cupric carbonate |
| Cupric silicate | D-Glucose monohydrate | D-Glucose monohydrate |
| Di-Ammonium hydrogen orthophosphate | | Diethyl aniline |
| Diethyl phthalate | Diethyl sulphate | Digol |
| Di-Iso butylenes | Dioxan | D-Malic acid |
| Ethyl amine | Ethyl benzoate | Ethylbenzoate |
| Formate | Hept-1-ene | Hydrobromic acid |
| Iodic acid | Iron oxide | Iso-bromyl acetate |

| | | |
|---|---|---|
| Isophorone | Iso-propylamine | Lactic acid |
| Lacto-phenol | Lead acetate | Lead bromide |
| Lead carbonate | Lead chloride | Lead dioxide |
| Lead fluoride | Lead foil | Lead metaborate |
| Lead monoxide | Lead orthophosphate | Lead oxide |
| Lead peroxide | Lead sulphate | Lead tartrate |
| Lithium carbonate | Lithium chloride | Lithium hydroxide |
| Lithium metal | Lithium tetraborate | Magnesium arsenate |
| Magnesium fluoride | Magnesium hydroxide | Magnesium metaborate |
| *Magnesium turnings | Maleic acid | Maleic anhydride |
| Mandelic acid | Manganous carbonate | Manganous chloride |
| Methyl acetate | Methyl chlorohexane | Morphiline |
| Myristic acid | Naphtha solvent | n-Hexanoic acid |
| Nitrobenzene | N, N-diethylaniline | p-Amino benzoic |
| p-Amino phenol | p-Amino-azo benzene | p-Anisidine |
| Pentyl acetate | Piperidine | Quinol |
| Silicon | Soda lime | Sodium arsenite |
| Sodium bismuth | Sodium dithionite | Sodium ferrocyanite |
| Sodium hexameta-phosphate | *Sodium nitrate | Sodium nitrite |
| Sodium oxalate | Sodium perborate | Sodium stannate |
| Squalene | Stannic Sulphide | Stannous bromide |
| Stannous oxide | Strntium chloride | Strontium bromide |
| Strontium carbonate | Strontium nitrite | Strontium orthophosphate |

| | | |
|---|---|---|
| Strontium sulphate | Succinic anhydride | Sulfur precipitate |
| Tannic acid | Tetra-sodium pyrophosphate | Tin metal |
| Titanium dioxide | Tri-ammonium orthophosphate | Tri-n-butylphosphate |
| Tri-sodium phosphate | Zinc borate | Zinc carbonate |
| Zinc fluoride | Zinc oxide | |

**Some obsolete chemicals at the Department of Theoretical and Applied Biology**

**Another section of obsolete chemicals also at the Department Theoretical and Applied Biology**

**Some obsolete chemicals being dump on the floor at the Department of Chemistry**

**Another section of obsolete chemicals at the Department of Chemistry**


**Some obsolete chemicals at the Department of Pharmaceutical Chemistry**