Survey of Pesticide Wastes in South Africa and Review of Treatment Options

Report to the

Water Research Commission

by

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EXECUTIVE SUMMARY

1. Background

The old testament mentions the locust plague in Egypt which, …*covered the face of the whole earth, so that the land was darkened and they did eat every herb of the land*…, (Exodus 10:15). It was common belief that pests appeared as divine punishment and therefore no steps were taken to combat them until the end of the 18^{th} century. In the early days locust control measures included digging of eggs, trampling, driving hoppers into pits, contact killing by spraying with paraffin oil, soap solution and carboxylic acid. Cyanide fumigation was a popular insect control measure in the late 18^{th} century until the introduction of organophosphate insecticides in the 1940's. The discovery of DDT in Switzerland, BHC in Britain and the organophosphates in Germany during World War II created a new era in chemical control of pests. The advent of chemical control has gone a long way in increasing agricultural production.

Unfortunately, the use of pesticides can come at a cost if irresponsibly applied, or disposed. The hazards associated with pesticide use are real. With the strong lobbying power of environmental groups pesticides are now viewed as a sensitive issue. In South Africa there are several laws protecting humans and the environment from the dangers of pesticides. These laws are regulated by 14 Acts and administered by 7 government departments and a non-statutory committee (Rother and London, 1998). Examples are the National Water Act no. 36 of 1998, the Atmospheric Pollution Prevention Act no. 45 of 1965, the Environment Conservation Act no. 73 of 1989 and the Fertilizers, Farm Feeds, Agricultural Remedies and Stock Remedies Act of 1947. The latter controls the sale and registration of veterinary and agricultural remedies and sets certain standards for pesticide residues on the export of fruit (GCIS, 2001a ; GCIS, 2001b).

Recent trends in public opinion and the adoption of cleaner production and sustainability strategies by governments suggest that reduction in pesticide use is the best option. However, no matter how efficiently pesticides are managed there will always be some generation of pesticide waste. Since the disposal of obsolete stocks has gained particular attention from environmental groups, which oppose transboundary movement of pesticide wastes, it is necessary for the government to have the framework in place for the safe disposal of obsolete pesticides. Several methods for waste disposal have also been criticized as environmentally harmful due to their end product formation or the lack of treatment. In South Africa, the National Waste Management Strategy report (1999) has highlighted the need for better hazardous waste disposal facilities and improved standards on existing facilities.

2. Objectives

The objectives of this project were to:

- Provide a comprehensive schedule of pesticide use and waste generation in Southern Africa.
- Provide a comprehensive survey of existing technologies for the disposal of pesticides.

3. Approach

A general overview of pesticides is provided and includes a brief review of hazard classification of pesticides and their dangers. Toxicology information is also provided for certain pesticide groups. This report also lists some options, which may be used to reduce pesticide use, or to minimize some of the dangers that pesticides may provide. The subject of pesticides is an extensive field and not all aspects could be comprehensively discussed in this report.

Pesticides are used by the agricultural, forestry, government, domestic, and industrial sectors. This report provides information of pesticide sales (as volume active ingredient) in the agricultural and forestry sectors, which form the major users of pesticides in South Africa. Pesticide sales have been provided from 1994 to 1998 and include total sales as well as sales of the different categories of pesticides viz:, insecticides, herbicides, fungicides, nematicides, ascaracides, and plant growth regulants. The Crop Protection and Animal Health Association (AVCASA) of South Africa provided majority of the information on pesticide use that has been presented in this document. Information from the governmental, domestic and industrial sectors are not included since no information was forthcoming from these sectors. In addition, no information was obtained from the various government departments contacted in Southern Africa. The Food and Agricultural Organization (FAO) and AVCASA provided information on obsolete pesticide stocks in Southern Africa. The inventories provided by FAO in 2000 require updating. The retrieval and disposal process in South Africa, which was completed in November 1999, is also discussed.

A comprehensive survey on existing technologies is provided. It includes well-established technologies, which have been used to dispose pesticides and more advanced methods that are currently being funded in the United States under the Superfund Programme. In addition, the survey deals with some of the options available for the clean-up of contaminated soil and groundwater sites.

4. Conclusions

South Africa has the necessary laws governing pesticide use in the country and recently has adopted laws protecting the environment. It is equally important that South Africa have the capability of enforcing its legislation in a controlled manner without placing undue costs on the manufacturer/supplier and the user.

It is necessary to prevent the mis-use of pesticides whether in agriculture or industry. South Africa has an active agriculture sector, which uses considerable amounts of pesticides in order to increase crop yields and prevent crop failure. Persistent pesticides when found in soil or groundwater are difficult and expensive to remove. Therefore government and industry need to make a concerted effort to prevent contamination of the environment and risk to human health. A programme of education, training, regulation, monitoring and the use of integrated pest management can do this.

In the case of pesticide waste disposal, it is necessary that the South African government provide its users with all the tools necessary to use, store, transport and dispose pesticides in a responsible manner. Whether final disposal of waste falls under the jurisdiction of the manufacturer, end-user or government is still a subject of debate. However, this debate should not prevent the establishment of a disposal programme. Several technologies have been discussed under disposal options. No one technology will solve all of South Africa's past or future contamination woes. However, it is necessary that contingency plans be in place to deal with pesticide waste. It is possible that incineration may be the best available control technique for the destruction of hazardous waste if designed, built and operated specifically for hazardous waste. However, adequate training and cleaner production techniques will reduce the generation of obsolete pesticides and may result in the operation and maintenance of an incinerator becoming unfeasible. It is also necessary that treatment options like bioremediation are accessible for soil and groundwater contaminated sites. It is highly probable that an integrated hazardous waste disposal approach will be necessary to handle pesticide wastes.

5. Recommendations

The main aim should be to reduce pesticide use and achieve sustainability while catering for the food demand. This can be achieved by:

- Create a lead agency to deal with pesticide (hazardous chemicals) use and disposal. Lead agencies provide the advantage of consolidation of expertise and knowledge on the national situation. Such experts must be able to liaise productively with the different government departments. In addition, they could be seconded to regional offices for short periods to deal with specific problems.
- Training / workshops in the field of pesticide application.
- Promotion of Integrated Pest Management.
- Training for the evaluation of exposure and risks.
- Providing incentives to the farmer for using fewer pesticides.
- Controlling pesticide quality and quantity.

- Adoption of stringent monitoring programs to evaluate soil and groundwater contamination. This must include standardization of analytical techniques and a system of accreditation for laboratories in South Africa. The latter has a major implication on regulation and enforcement.

- Provision of disposal options to the user. In South Africa, waste is disposed by specific companies which either co-dispose on landfills or truck the waste to sea out-falls. If additional technologies such as thermal or chemical treatments are to be used, then a strict auditing system needs to be in place.

- Creation of a hazard ranking system for contaminated sites in South Africa. Such a system could prioritize contaminated sites based on type of contaminant and location of contamination.

- Provision of options for treatment of soil or groundwater contamination. While it is clear from the DWAF interim generic process that the responsibility of remediation is placed on the polluter, it is necessary that the government personnel have the necessary expertise on best available techniques (BAT) or best possible environmental option (BPEO).

6. Capacity building

Internet searches were conducted by two 4th year chemical engineering students, Mr Dinesh Naidoo and Mr Anban Moodley. The project leader, Dr V Naidoo, has gained tremendous experience in managing the project, which will assist her in the management of future projects.

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GLOSSARY

Active Ingredient	The biologically active part of the pesticide present in a formulation.
Banned	A pesticide for which all registered uses have been prohibited by a final government regulatory action, or for which all requests for registration or equivalent action for all uses have, for health or environmental reasons, not been granted.
Biodegradation	A process of breaking down chemicals into simpler forms using bacteria.
Biotechnology	A new field of research using living organisms (bacteria) to make or modify commercial products, to improve plants or animals or to develop new microorganisms for specific uses. Sometimes referred to as genetic engineering.
Carbon Adsorption	A physical treatment method that removes low concentrations of organics from a waste mixture by passing the waste through an activated carbon "bed". The organics are removed as they "stick" to the carbon. Eventually the carbon becomes saturated (or full) and must be replaced.
Carbonaceous	Any material which contains or is composed of carbon.
Catalyst	A material that either speeds up or improves the output of a chemical reaction without being used up in the process.
Degradation	The process of breaking down a chemical into simpler chemicals or elements until nothing further will change.
Disposal	Encompasses the various thermal, chemical, physical and biological methods available for the destruction or containment of pesticides.

Ecotoxicology	It is the science devoted to the study of the production of harmful effects by substances entering the natural environment, especially effects on population, communities, and ecosystems.
Ecosystem	Grouping of organisms interacting together, with and through their physical and chemical environments, to form a functional entity.
Encapsulation	A process of completely surrounding a waste/material by sealing it in a specific material (such as an organic resin).
Environment	The aggregate at a given moment of all external conditions and influences to which a system under study is subjected.
Environmental fate	Destiny of a chemical or biological pollutant after release into the natural environment.
Formulation	The combination of various ingredients designed to render the product useful and effective for the purpose claimed; the form of the pesticide as purchased by users.
Hazard	It is a general term for anything which has the ability to cause injury or for the potential to cause injury.
Integrated Pest Management	A pest management system that, in the context of the associated environment and the population dynamics of the pest species, utilizes all suitable techniques and methods in as compatible a manner as possible and maintains the pest populations at levels below those causing economically unacceptable damage or loss.
In -situ	Occurring in place. Generally refers to a cleanup activity or treatment that can be applied at a site without having to excavate or remove the waste. An example is the treatment of contaminated soil using bioremediation methods that enhance natural degradation.
Ion Exchange	A physical removal process in which inorganic ions are removed from a waste stream by passing the solution over a "resin" bed, or material which exchanges ions in the bed for ions in the waste.

Inorganic	Chemical substances which are not organic (made with carbon) and are generally obtained from minerals. All metals are inorganic.
Intrinsic Remediation	The use of natural biological, chemical, or physical processes instead of engineered methods to clean up a contaminated site. It must be shown by extensive monitoring of soil and groundwater that these natural process are in fact degrading the contaminants at a site and that the lowering in concentrations in monitoring wells is not due to dilution, dispersion, evaporation or any other process that simply transfers contamination from one medium to another or from one location to another.
Microbes	Microorganisms or bacteria.
Mutant Strains	Unusual and undesirable bacteria which result from genetic damage or alterations.
Natural Attenuation	The use of natural biological, chemical and physical processes to contain the spread of contamination from chemical spills and to reduce the amount of pollutants at contaminated sites. According to EPA, dilution, dispersion, adsorption and evaporation are all acceptable natural processes. This approach is considered by most grassroots community based groups to be a "do nothing" approach.
Poison	A substance that can cause disturbance or structure or function, leading to injury or death when absorbed in relatively small amounts by human beings, plants or animals.
Prior Informed Consent	The principle that international shipment of a pesticide that is banned or severely restricted in order to protect human health or the environment should not proceed without the agreement, where such agreement exists, or contrary to the decision of the designated national authority in the participating importing country.
Pyrolysis	Burning in the absence of oxygen (also referred to as reduction).
Reagent	A substance that causes a chemical reaction to take place. The reagent chemical usually reacts with and changes another substance. Reagents are often used to detect or measure the presence of another substance.

Residence Time	The amount of time a material/waste is burning in an incinerator, ranging generally from 2-6 seconds.
Residues	Materials left after a treatment process is completed. Often the residue needs to be disposed of and should be tested for toxicity and leachability.
Risk	This term must not be confused with hazard. It is most correctly applied to the predicted or actual frequency of occurrence of an adverse effect of a chemical or other hazard.
Safety	It is the practical certainty that injury will not result from exposure to a hazard under defined conditions, i.e. the high probability that injury will not result.
Sludge	According to the Resource Conservation and Recovery Act of 1976, the term "sludge" means "any solid, semisolid, or liquid waste generated from a municipal, commercial or industrial waste water treatment plant, water supply plant or air pollution control facility, or any other such waste having similar characteristics and effects."
Slurry	A mixture of solid or semi-solid waste with a liquid to form a solid-liquid matrix; primarily prepared as a waste medium to aid in several treatment processes.
Toxic	Any substance able to cause injury to living organisms as a result of physicochemical interaction.

CHAPTER ONE

Introduction

Pesticides are an evil necessity (Richardson, 1996)

Headlines such as '*Poisonous containers pose threat*', '*Matola stews over Danish plans to burn pesticides*', '*Herbicide debate crops up again*', '*Zambian farmers face illness from pesticides*', '*Danida denies dirty-waste trade*', and '*Bad pesticides threaten health in poor nations*' often leads to panic and fear in the general public (Appendix A) (Schjerbeck, 1999 ; Sayagues, 1999 ; Cook, 2000, and Mpeta, 2000). In general, pesticides fall within the hazardous waste category. A waste is considered to be hazardous if it possesses a substantial present or potential danger to human health or the environment. The potential for toxicity, particularly carcinogenesis, has been the greatest fear expressed by the public and environmental groups. A waste may also be considered hazardous if it exhibits any of a variety of characteristics such as flammability, reactivity, explosivity, corrosivity, radioactivity, infectivity, irritation, or bioaccumulation (La Grega et al., 1994 ; Dawson and Mercer, 1986).

Several pesticides have also been classed as *Persistent Organic Pollutants* (POP's). POP's are carbon based chemical compounds or mixtures, which are persistent in the environment since they resist degradation through physical, chemical, or biological processes. POP's are generally semi-volatile (i.e. evaporate relatively slowly) and have low water solubility (i.e. they dissolve easily in fats and oil). Compounds with these properties bioaccumulate in fatty tissues of living organisms. Furthermore, POP's have the potential to disrupt normal biological functions and trigger harmful effects even at low concentrations (IPEN, 2000).

1.1. The Dirty Dozen

There is currently a shortlist of 12 POP's which are also referred to as the *dirty dozen*. These include dioxins, furans, polychlorinated biphenyl's (PCB's), DDT, chlordane, heptachlor, hexachlorobenzene (HCB), toxaphene, aldrin, dieldrin, endrin, and mirex. The pesticides DDT, chlordane, heptachlor, aldrin, dieldrin, and endrin are currently banned in South Africa. However, for different social and economic reasons such substances are still in use and / or released to the environment. For example, substances, like DDT, are still in use in South Africa but use is restricted to government. DDT is an effective insecticide for controlling malaria mosquitoes since the mosquitoes have not developed resistance to it. According to the National Department of Health, South Africa, the mosquitoes have developed resistance to the synthetic pyrethroid group of insecticides that has been used to control their spread in rural areas. In South Africa, the recent use of DDT to control malaria was strictly controlled by the National Department of Health (SAPA, 2000). Thus, the risk of contamination and waste accumulation of DDT is still prevalent if incorrectly administered and controlled. In May 2001, it was reported that the chemical chlordane was still being manufactured and sold in South Africa. This was one week after South Africa signed the United Nations treaty, which pledged to remove the *dirty dozen* from use. According to Gulf Chemicals, the company accused of selling the chemical, chlordane is mostly being sold to neighbouring African countries to control termites (Macloed, 2001). The Department of Agriculture had agreed to stop registering this product about 2 years ago but this report suggests that this is not the case. South Africa shares natural resources with its neighbours and therefore, should not propagate a NIMBY (not in my back yard) policy. There is therefore a need for government, industry, public and consumers to fulfil their obligations of protection and responsibility.

1.2. Environmental Laws

In South Africa, there are laws such as nature and conservation laws, water laws and air pollution laws, which protect the environment. These laws are regulated by 14 Acts and administered by 7 government departments and a non-statutory committee (Rother and London, 1998). Examples are the National Water Act no. 36 of 1998, the Atmospheric Pollution Prevention Act no. 45 of 1965, the Environment Conservation Act no. 73 of 1989 and the Fertilizers, Farm Feeds, Agricultural Remedies and Stock Remedies Act of 1947. The latter controls the sale and registration of veterinary and agricultural remedies and sets certain standards for pesticide residues on the export of fruit (GCIS, 2001a ; GCIS, 2001b).

South Africa has taken several steps to implement Agenda 21, a global strategy for sustainable development at national and local level. This has included the reformation of environmental policies, ratifying international agreements and participation in global and regional sustainable development initiatives. In 1994 the new constitution created the right to the environment as a fundamental right and this has led to the National Environment Management Act (NEMA) no 107 of 1998. NEMA lays down principles for effective management of the environment which all organs of the state have to comply with in decision-making (Anon, 2001b). Rother and London (1998) discuss in their report the various laws and regulations in place in South Africa. The report also provides information on the various bodies (governmental and non-governmental) that play a part in the pesticide web from registration to distribution and use.

1.3. International Treaties

South African is also a signatory of several international treaties concerning the environment and has recently signed the Basel Convention, 3 August 1994, which regulates the transboundary movement of hazardous wastes such as pesticides and makes obligations for ensuring the environmentally sound management and disposal of hazardous wastes. The Convention recognizes that the most effective way of protecting human health and the environment from the danger posed by such wastes, is the reduction of their generation to a minimum and the environmentally sound management of the hazardous wastes. The Basel convention stipulates three main goals:

- Reduction in transboundary movement of hazardous waste by employing good environmental management procedures.

- Hazardous wastes should be treated and disposed of as close as possible to their source of generation.
- Hazardous waste generation should be reduced and minimized at source (UNEP, 2000).

1.4. FAO Code of Conduct for Pesticide Use and Disposal

The Food and Agricultural Organization (FAO) has formulated a code of conduct for pesticides. The code which is currently under review describes the shared responsibility of governments, industry, trade and international institutions to work together so that pesticides are used without significantly affecting people or the environment. The code advises that governments have the overall responsibility of pesticide management but that manufacturers should retain an active interest in following their products to the ultimate consumer by accumulating knowledge of the major uses and the occurrence of problems i.e. *cradle to grave* policy. In addition the code provides information on testing of pesticides, reducing health hazards, regulatory and technical requirements, availability and use, distribution and trade, information control and prior informed consent (PIC), labelling, packaging, storage and disposal, advertising and monitoring the observance of the code (FAO, 1990).

1.5. Hazardous Waste Management in South Africa

In South Africa, according to the Green Paper on disaster management, the main areas of focus for hazardous waste such as pesticides are accidental and unauthorized release of hazardous material. The areas of vulnerability are:

- Environmental media such as air, water and soil,
- Industrial areas and all major transport routes,
- The marine environment including coastline, and
- Human life (GCIS, 2001a).

Disaster management for hazardous waste falls under the responsibility of the Department of Environment Affairs and Tourism (DEAT), Department of Water Affairs and Forestry (DWAF) and the Department of Transport (DoT). These organs should deal with the generation, transport and disposal of waste and pollution and clarify who has responsibility over particular areas (GCIS, 2001b). This has culminated in the White Paper on Integrated Pollution and Waste Management in South Africa. Pesticides are singled out in the National Waste Management Strategy (NWMS) report for special attention because of their particular danger to the environment (NWMS, 2000). Similarly, a mission fielded in July 2000 by Denmark, identified obsolete pesticides as a problem in the region and found that there may be scope for a regional project which included: (a) inventories, (b) storage, and (c) handling and destruction of obsolete pesticides. Such a project could also include training and stewardship, capacity building, chemical profiles, phasing out of POP’s, and integrated pest management.

1.6. Treatment and Disposal Options in South Africa

Incineration is one of the proposed treatment options for the disposal of waste pesticides. However, the National Waste Management Strategy report has indicated that incineration of hazardous waste is not considered a suitable option due to the poor operation of many existing facilities. Incineration is also not considered to be economically feasible due to the warmer climate that limits the market for energy derived from the process. The National Waste Management Strategy reports that the development of hazardous waste treatment facilities and the high capital costs to be incurred will require special funding mechanisms in place. However, the financial burden of treatment technologies and the associated treatment costs could result in an increase in illegal disposal to the natural environment or sewer or force the closure of small and micro – businesses that cannot afford to treat or dispose their waste properly (NWMS, 1999). While other thermal, physical and chemical treatment options may be available for the disposal of pesticides; biological processes have the potential to degrade the waste with a lower environmental burden. This process can be undertaken near the point of origin and thus reduce the potential hazards of transportation to a central facility either in southern Africa or abroad.

The neighbouring countries to South Africa which share water resources, have a similar problem with pesticide waste disposal (Northoff, 2000). Access to suitable physical and biological disposal options would assist them in the responsible treatment of these wastes and also protect international rivers, which may flow through South Africa. It would also protect marine resources, which may be seen by users as an easy disposal option. Chapter 5 discusses some options that would allow government and industry to deal with obsolete pesticides and associated contamination problems effectively.

1.7. Project Objectives

The original project was entitled ' A survey of pesticide wastes in the RSA and a preliminary study of their biodegradation'. Due to budgetary changes, this project was limited to a desk-type study dealing with pesticide use, waste and a review of disposal options that are or may be available to South Africa. Consequently, the project title was changed to *A survey of pesticide use and waste in South Africa and a review of existing technologies for the disposal and treatment of pesticide waste or contamination*. This project was initiated with the overall aim of scoping the current issues relating to pesticide use and disposal in Southern Africa. The specific objectives of this project are to:

- Provide a comprehensive schedule of pesticide use and waste generation in the Southern Africa region.
- Provide a comprehensive survey of existing technologies for the disposal of pesticides.

1.8. Report Outline

This report was divided into 5 chapters.

Chapter 1 introduces the subject of pesticides and briefly discusses the problems and perceptions posed by pesticides to the public and environmental groups. Some of the national and international laws governing pesticides are also discussed. The objectives are outlined in the introduction.

Chapter 2 provides an overview on pesticides and includes a brief historical background and classification of pesticides. Some toxicological problems posed by pesticides are also highlighted. Several options are provided for the reduction in pesticide use and consequently, the reduction in pesticide use, which will ultimately lead to a reduction in pesticide contamination of land and water.

Chapter 3 covers pesticide use in South Africa. In this report, pesticide sales are synonymous with pesticide use since it is difficult to acquire data on the amount of pesticide applied by the final end-user. There is no single database that monitors the latter in South Africa on any level. There are 5 sectors that use pesticides, agricultural, industrial, governmental and public sector. The agricultural sector is the largest user of pesticides while the public sector is the smallest. In addition, pesticide use data from neighbouring countries were requested via faxes but no response was obtained.

Chapter 4 deals with pesticide waste, which is also, termed obsolete pesticides. It reports on obsolete pesticide inventory data and covers stocks that were present until 1999 or are present today in South Africa and several Southern African countries. The recent pesticide retrieval and disposal drive undertaken by the Animal and Crop Protection Association (AVCASA) with Department of Agriculture funding is discussed.

Chapter 5 reviews some of the existing technologies that are available for the treatment and disposal of hazardous waste like pesticides. A distinction is made between technologies that can be used to dispose obsolete pesticide stocks and those technologies that can be used to treat or remediate contaminated land or water.

Chapter 6 discusses the current pesticide situation in South Africa in terms of use and waste accumulation. It also highlights the various technologies that can be use in South Africa to alleviate some of the pesticide problems currently and in future. Recommendations on changes in attitude and policy by the various stakeholders are suggested. In addition, future research initiatives are provided.

1.9. Stakeholders

It is envisaged that this survey and review will be of benefit to government, industry, consumers, public and environmental groups. A list of the stakeholders is tabulated in Table 1. It is clear that government is making several policy changes with regard to the environment. This report will serve to highlight areas of concern as well as suggest ways in which pesticide pollution may be managed in future. The role of government should not only be directed at policy and legislation but should be one of education and enforcement. The agro-chemical industries and umbrella bodies such as AVCASA and CAIA can limit some of the peripheral problems associated with pesticides by continually striving to market, sell and distribute pesticides responsibly. There is a need for the users of pesticides to be vigilant about the dangers that pesticides pose if irresponsibly used. The public is generally is silent player in the pesticide web and expects its government to be vigilant in alleviating and managing pesticide pollution. A more vocal group of the public sector is environmental groups who serve as watchdogs for the protection of the public and environment. Environmental groups are often accused of *chemo-phobia*.

Table 1: List of stakeholders for pesticides

Stakeholder	***Problems***	***Interests***	***Potential***
Agro-chemical Industries (including AVCASA and CAIA	*Image* *Spills / contamination* Environmental/Health risks – mis-use Lack of information to general public Lack of disposal options Lack of funds for disposal	*Information* Protection of sector through responsibility *Information dissemination* Disposal options Responsible use	*Co-operation* Information Advice *Expertise / Advice* Co-operation Information
User (includes public, government, farmers and industry)	*Lack of information* Lack of disposal options Lack of funds	*Information* Support Disposal options Responsible handling of pesticides and waste Funding	*Co-operation* Responsible use
Government	*Mis-use* Inappropriate use Accumulation of waste Spills/contamination leading to environmental and human risks	*Responsible use of pesticides* *Responsible handling of pesticides* Responsible disposal of pesticides Effective management of spills Remediation of contaminated land/water	*Information* Advice / education Policy Enforcement of laws and regulations
Public	*Environmental contamination* Health risks	*Effective policy and implementation* Effective disaster management Protection of health and environment	*Awareness* Responsibility
Universities and Research Institutions	*Research direction* Funds	*Creation and testing of innovative technologies for clean-up* Information	*Expertise* Advice
Waste Disposal Companies	*Lack of disposal options*	*Identify options available*	*Highlight potential problems* Expertise in handling of disposal
Water Research Commission	*Spills/Contamination of rivers and groundwater*	*Water protection* Remediation of land / water	*Finance research in key areas to protect water sources*

CHAPTER TWO

Overview

A pesticide may be defined as: (i) any substance or mixture of substances intended for preventing, destroying, repelling or mitigating any pest; and (ii) any substance or mixture of substances intended for use as a plant regulator, defoliant, or desiccant. A pest is defined as: (i) any insect, rodent, nematode, fungus, weed, or (ii) any other form of terrestrial or aquatic plant, or animal life or virus, bacteria, or other microorganisms (Andersen and Milewski, 1999). In other words, a pest is any living life form that is undesirable.

2.1. History

Pesticide usage is not new. Homer mentioned the fumigant value of burning sulfur in his *Illiad and Odyssey* during the 8th century BC (Richardson, 1986). The old testament mentions the locust plague in Egypt which, …*covered the face of the whole earth, so that the land was darkened and they did eat every herb of the land* , (Exodus 10:15). It was common belief that pests appeared as divine punishment and therefore no steps were taken to combat them until the end of the 18th century. In the early days locust control measures included digging of eggs, trampling, driving hoppers into pits, contact killing by spraying with paraffin oil, soap solution and carboxylic acid. Cyanide fumigation was a popular insect control measure in the late 18th century until the introduction of organophosphate insecticides in the 1940's. The discovery of DDT in Switzerland, BHC in Britain and the organophosphates in Germany during World War II created a new era in chemical control of pests. The use of liquid insecticide sprayed directly onto grain before final storage replaced the costly fumigation techniques of the past. Thus, the advent of chemical control has increased agricultural production (Wiese and Bot, 1983). More information on the history of specific groups of pesticides is discussed in subsequent sections in this chapter.

2.2. Pesticide Classification

Pesticides are classified by the World Health Organization (WHO) on the basis of their oral or dermal lethal dose (LD). South African classification is referred to as the RSA Classification Code and is based on the oral and dermal LD50 values from WHO. The RSA Classification Code takes cognizance of the SABS Code of Practice for the Identification and Classification of dangerous substances and goods (SABS 0228-1990).

A measurement called LD50 is calculated by measuring the number of milligrams of active ingredient per kilogram of body weight required to kill 50 % of a test sample of animals (e.g. rats) (FAO, 2000). LD50 values express the lethal dose in mg/kg body mass of the test animal. The lower the LD50 value the higher the toxicity. Liquid formulations are classified on acute oral and dermal toxicity data for rats as submitted. If such data is not available, the product will be classified on the data as applicable to the active ingredient. Generally pesticides are fall into 4 categories except in South where there are 5 categories (Table 2-1) (Kleynhans, 2000).

Table 2-1: Hazard classification for pesticides (Vermeulen et.al., 1997).

Group	LD50 for the rat (mg/kg body mass)				Distinctive label;	
	oral		Dermal		Hazard statement	Colour band
	Solids	liquids	Solids	Liquids		
Ia Extremely hazardous	5 or less	20 or less	10 or less	40 or less	Very toxic	Red
Ib Highly hazardous	5 – 50	20 - 200	10 – 100	40 – 400	Toxic	Red
II Moderately hazardous	50 – 500	200 - 2000	100 – 1000	400 – 4000	Harmful	Yellow
III Slightly hazardous	Over 500	0ver 2000	0ver 1000	Over 4000	Caution	Blue
IV Acute hazard unlikely in normal use[1]	*Over 2000*	*Over 3000*	-	-	-	*Green*

[1] – only in South Africa ; solids and liquids refer to the physical state of the product or formulation.

Risk is related to the degree of exposure to the pesticide. Risk and its magnitude are a function of 2 factors, exposure and toxicity and can be expressed mathematically as:

Risk = Exposure x Toxicity

If there is no exposure or zero toxicity, there is no risk. Pesticides can enter the body through:

- The skin (dermal or percutaneous route: Pesticides are generally absorbed by the outer most layer of skin. This is composed of dead, keratinized cells and acts as the main barrier against pesticides. Thus, changes in the outer skin layer such as abrasion and occlusion can increase the skin absorption.

- The mouth (oral route): Oral absorption of pesticides has been shown to be dependent on the carrier vehicle e.g. chlorinated hydrocarbons are more readily absorbed orally when a non-polar vehicle such as corn oil is used compared to an aqueous vehicle.

- Inhalation: The rate and extent of absorption of atmospheric pollutants via the respiratory tract is affected by meteorological conditions, the rate of breathing (e.g. strenuous exercise versus resting), and the route (e.g. mouth versus nose) (Kemppainen and Vodela, 1996).

The highest probability of exposure is by skin absorption and therefore, dermal toxicity is the most relevant in risk assessment.

According to London et al. (2000) the question of whether pesticide pollution in water is of concern can be directly linked to the standards that South Africa applies. The health-based approach adopted by the World Health Organization and the United States Environmental Protection Agency (USEPA) are based on current risk assessment methods such as acceptable dietary intake (ADI). However, the policy-based approach adopted by the European Union (EU) sets permissible levels of pesticides at the lowest limit of the analytical capability. Furthermore, studies by London et al. (2000) showed that water pollution by pesticides was a problem if EU policy-based standard is used. However, fewer pesticide detections were of concern when the health-based USEPA standard was applied.

2.3. Pesticides in the Abiotic Environment

Pesticides are toxic to the abiotic, i.e. non-living, component of the environment such as water soil, and air. Abiotic environmental problems associated with pesticides usage has intensified within the past three decades. Early environmental concerns in the USA and Europe were focussed primarily on the chlorinated hydrocarbons, especially DDT and BHC. At present in most countries DDT and BHC are banned. The impact of pesticides on the abiotic environment can be summarized as follows:

1. Pesticides can move from its target area due to drift / volatilization, leaching and runoff. Drift usually occurs during ground or aerial spraying and as much as 30 % of spray applications can move greater than 15 m from the intended site. Thus, pesticides can impregnate the soil, leach into groundwater and flow into water systems impacting on the soil / water fauna and flora (Baloch and Haseeb, 1996).

2. Leaching of pesticides to the soil can have a variety of negative effects. It may lead to the contamination of ground water and potable water making them unfit for human consumption. The contamination of groundwater can be more severe in areas with high rainfall. The leaching of herbicides is a serious problem as they are directly applied to soil and are water soluble, thereby rendering them more mobile (Baloch and Haseeb, 1996).

2.4. Pesticides in the Biotic Environment

Pesticides also impact on the biotic, i.e. living, component of the environment. The side effects attributed to the use of pesticides are the destruction of the natural biotic balance, suppression of biocontrol agents, insect resurgence, pesticide resistance, dangers to pollinators and soil and aquatic fauna and wildlife. Many of these effects are due to the lavish unplanned and indiscriminate use of pesticides, accidents during storage, transportation accidents and incorrect application in the field. There is a large body of evidence detailing the effects of pesticides on the biotic component of the world such as birds, mammals, fish and invertebrates. Human ailments such as cancer, liver diseases and hypertension have also been linked to the overuse or indiscriminate use of pesticides (Maroni, 1993 and Porter, 1999 cited in London et al., 2000 ; Richardson, 1996). Certain pesticides are believed to have estrogenic properties and have marked effect on the reproductive status of animals (Meintjies et al., 2000).

2.5. Toxicology of Major Pesticides

Most chemicals used are not selective and can be toxic to non-target species including man. Toxicology monitoring and evaluation of the hazards of handling and using pesticides have focussed primarily on preventing injury to man.

2.5.1. Organochlorine Pesticides

Organochlorinated insecticides include the chlorinated ethane derivatives such as DDT, the cyclodienes which include chlordane, aldrin, dieldrin, heptachlor, endrin and toxaphene, and the hexachlorocyclohexane (HCH) such as lindane. These chemicals were widely used from the 1940's through to the 1960's.

Dichlorodiphenyltrichloroethane (DDT) is the best known pesticide in this group. It was synthesized in 1874 in Germany but was recognized for its insecticidal properties in 1939. During this period DDT saved many lives from malaria and through pest control. However, due to its persistence in the environment, bioaccumulation in the adipose (fat) tissues of humans and wildlife and its biomagnification in the food chain, it is one of the most heralded pesticides and is banned in many countries and its use is severely restricted in others (WHO, 1984 ; Baloch and Haseeb, 1996). The major metabolite is via dehydrochorination to DDE or, alternatively, dehalogenates to DDD and after a series of reductive chlorinations and oxidative steps forms DDA (2,2-bis(4-chlorophenyl)acetic acid). The acute toxicity of DDT is affected by the solvent vehicle e.g. if administered in oil to the rat, a typical median lethal dose is 250 mg/kg of body weight. DDT is poorly absorbed through the skin (WHO, 1984). The primary toxic action of DDT is sensory and motor nerve fibres and motor cortex. Signs and symptoms of acute and sub-acute poisoning in man and animal resulting from higher doses of DDT include apprehension, hyper-susceptibility, irritability, dizziness, tremor and convulsions (Baloch and Haseeb, 1996).

The insecticides, aldrin (1, 2, 3, 4, 10, 10 - hexchloro - 1, 4, 4a, 5, 8, 8a – hexahydroendo - 1, 4 - exo-5, 8 - dimethanonaphthalene) and dieldrin (1, 2, 3, 4, 10, 10 – hexachloro - 6, 7 epoxy -1, 4, 4a, 5, 6, 7, 8, 8a-octahydro-endo-1, 4, exo-5, 8 - dimethanonaphthalene) are persistent and accumulate in the food chain. Aldrin is readily converted to dieldrin and therefore environmental samples rarely show aldrin. Currently, the largest use is for termite control. The primary site of action of dieldrin is the central nervous system (WHO, 1984).

Hexachlorobenzene (HCB) is a white solid with low water solubility but is soluble in organic solvents. HCB is used largely as a fungicide. Hexachlorobenzene has been shown to be carcinogenic. Studies reported that 10 % of unexposed hamsters developed tumors while 95 % of the HCB exposed hamsters developed tumors. Although, HCB has a low acute toxicity for most species (> 1000 mg/kg of the body weight), it has a wide range of biological effects at prolonged moderate exposure (WHO, 1984).

2.5.2. Organophosphorus Pesticides

The first organophosphorus insecticide was tetraethyl pyrophosphate (TEPP). This group of pesticides was developed in Germany prior to World War II. Important organophosphorus pesticides includes, TEPP, disulfoton, azinphosmethyl, parathion, methyl parathion, chlorfenvinphos, dichlorvos, diazinon, dimethoate, trichlofon, and malathion. These chemicals act as irreversible inhibitors of the cholinesterase enzymes of the neuromuscular system. The immediate cause of death is asphyxia resulting from respiratory failure. Parathion was one of the earliest organophosphorus pesticides used in agriculture. It is slightly soluble in water, exerts a pseudo-systemic action in insects, is moderately persistent and is stable for a shorter time at higher temperature (Baloch and Haseeb, 1996).

2.5.3. Carbamates

The carbamate group represents a unique class of diverse compounds. The mode of action of these chemicals is similar to the organophosphates and inhibits the acetylcholinesterase. The symptoms of poisoning are cholinergic, salivation, miosis, convulsions and ultimately death. They are reversible inhibitors and are rapidly detoxified and eliminated from animal tissues. Consequently, carbamates do not accumulate in fats and are not excreted in milk. Carbaryl (Sevin) was first introduced in 1956 and is a contact insecticide. It is only slightly soluble in water but highly soluble in organic solvents. The compound is mildly phytotoxic but toxic to fish (Richardson, 1996).

2.5.4. Pyrethroids

The use of pyrethrum, a species of flower, originated in Iran at the end of the 18th century. The active ingredients are a group of compounds commonly known as pyrethroids or pyrethrins which are synthetic mixed esters of pyrethrolone and cinerolone with chrysanthemic and pyrethric acid. Pyrethroids with the alpha-cyano group include deltamethrin, cypermethrin, fenvalerate and fenpropanate. Symptoms of poisoning are contact dermatitis, asthmatic like reactions and nervous system symptoms like excitation and convulsions leading to paralysis and muscular fibrillation. This group has low mammalian toxicity and is highly unstable in the presence of light, moisture and air. The pyrethroids do not accumulate in the environment but can be extremely toxic to fish and aquatic invertebrates. In South Africa, pyrethroids were recommended for use in the control of malaria. However, it has been found to be not as effective in the control of the disease. Consequently, the National Department of Health re-introduced the banned pesticide DDT to aid in the control of malaria (SAPA, 2000).

2.5.5. Herbicides

Herbicides can be extremely to moderately toxic to flora and fauna but most herbicides are highly selective and exhibit low to moderate toxicity to mammals. Most herbicides tend to inhibit photosynthesis. These compounds are highly water-soluble and can pose a threat where groundwater tables are high or soil flushing occurs. The bipyridium compound, paraquat, is one of the most effective herbicides but poses a major threat to the environment. The compound is water soluble and non-selective and acts as a defoliant, desiccant and plant regulator. Upon application, paraquat takes electrons from the plants photosynthetic processes to produce a superoxide radical like hydrogen peroxide, which is highly toxic to cellular processes and membranes. In animals, paraquat’s action is similar and acute toxicity is death by lung failure (Richardson, 1996).

2.5.6. Fungicides

Fungicides comprise an heterogenous group of compounds. These compounds are used to control fungal diseases of plants and seeds. Mercury based fungicides comprise the group that is most hazardous to the environment leading to neurological disorders. Toxicological research on fungicides is limited. Major classes of fungicides include organomercury (methoxyethyl mercury chloride and ethoxyethyl mercury hydroxide); dithiocarbamates (thiram, maneb, zineb, and mancozeb); and phathalimides (captan and captafol). Mercury containing compounds are reported to be neurotoxic and phathalimides are mutagenic, carcinogenic and tetragenic (Baloch and Haseeb, 1996).

2.6. *Pesticide Pollution*

Pesticide pollution can occur through:

- Use e.g. runoff, leaching through soil, use of incorrect doses, irresponsible application,
- Accidental contamination during transport or storage, and
- Contamination due to incorrect storage and disposal of obsolete (waste) pesticides.

In order to reduce the impact of pesticides on the environment it may be necessary to prevent accumulation of pesticides, use integrated pest management techniques, use alternative chemicals that are less hazardous and persistent and increase the use of biological control agents.

2.6.1. Prevention of Accumulation of Pesticide Stocks

One of the long-term solutions to pesticide disposal problems lies in preventing accumulation of obsolete pesticides. Therefore, stocks should be kept as small as possible and overstocking avoided. (Wodageneh, 1998b). In order to prevent future accumulation of obsolete pesticides, the FAO has suggested the implementation *of a pesticide bank*. Some of the aims of the pesticide bank are to:

- Continuously monitor use of pesticides on a daily, weekly, and a fortnightly basis on the end-user or supplier level,
- Continuously monitor pesticide shipments,
- Replenish pesticide stocks only when necessary.

Such a bank will allow for the close monitoring of consumption and shipment. It will prevent the oversupply of pesticides and therefore, the cost of disposal would be reduced. In addition, the cost of clean-up due to contamination and spills arising from stockpiles and transport, would be minimized (FAO, 2000). One of the biggest drawbacks of implementing a pesticide bank is the cost. However, the Crop Protection and Animal Association of South Africa (AVCASA) considers most of the aims of the pesticide bank to be impractical (Kleynhans, 2000).

2.6.2. Organic Farming

Organic farming is suggested as an alternative form of agriculture. This type of farming operates on the principle of non-chemical use. It uses inter cropping, organic manure and biological botanical control of pest infestation. Green manure and compost production and important indigenous knowledge for crop production such as the use of selected nitrogen fixing leguminous crops to improve soil fertility are all applicable in organic farming (Baloch and Haseeb, 1996). While this type of farming can be successfully implemented, it is not a viable option for the increased crop yields necessary to supply food for the increasing population (Richardson, 1996).

2.6.3. Chemical Alternatives

Certain environmental groups have suggested that using other chemical formulations, which are less persistent and toxic in the environment, can reduce the threat of persistent pesticides. The United Nations Environment Programme has a website, POP's Database on Alternatives, which lists possible substitutes for 11 persistent organic pollutants, aldrin, chlordane, DDT, dieldrin, endrin, heptachlor, hexachlorobenzene, mirex, PCB, dioxins (PCDD), furans (PCDF's), and toxaphene. For example, hexaclorobenzene which is used to control *Helminthosporium maydis* on maize, bunt and dwarf bunt of wheat and fungi can be replaced with alternate chemicals or a biological control agent (Table 2-2) (UNEP, 2000b). The USEPA also issues alternatives for pesticides like chlorpyrifos, which are considered to be hazardous (USEPA, 2000).

Table 2-2: Chemical alternatives to the persistent organic pesticide, hexachlorobenzene.

Specific Use and Application	Socio-economic sector	Alternative
Helminthosporium maydis control on maize	Agriculture and forestry	carboxin
Bunt and dwarf bunt control on wheat	Agriculture and forestry	Guazatine Bitertanol and Fuberidazole Biological control
Fungi control	Agriculture and forestry	Carboxin Fuberidazole

2.6.4. Biological Control of Pests

Until powerful synthetic pesticides became freely available after World War II, pest control depended on the application of a combination of cultural, mechanical, chemical and biological methods. Over the last 30 years, the dominance of chemical control stifled the development of and application of other approaches. The rise in resistance to chemical pesticides and the growing concern of their environmental impact has led to renewed interest in biological control (Greathead and Waage, 1983). Another option to the use of chemical pesticides is biological control, which are also termed biopesticides by the USEPA. These biological control agents are derived from such natural materials as animals, plants, and bacteria (USEPA, 1998).

Biological pesticides are based on beneficial insect and weed pathogens, and entomopathogenic nematodes, which include fungi, bacteria, viruses and protozoa. Biological control has the advantage of being target specific, i.e. it affects only the target pest and other related organisms. Biocontrol is also effective in small quantities and decomposes quickly, thereby reducing the pollution problems posed by conventional pesticides. However, the biggest advantage, is that biopesticides can greatly reduce the reliance on conventional pesticides while maintaining high crop yields.

One of the most widely used forms of biocontrol belongs to the species *Bacillus thuringiensis* (Bt) which effectively controls insect pests in cabbage, potatoes and other crops. *Bacillus thuringiensis* is a naturally occurring bacterial disease of insects common in soil throughout the world. Another type of Bt kills mosquitoes but is ineffective for crop pest control. The toxic crystal Bt protein in commercial formulations is only effective when eaten by insects with a specific (usually alkaline) gut pH and the specific gut membrane structures required to bind to the toxin. Bt genes have been transferred into other microorganisms to produce more active formulations. In addition, researchers have genetically engineered varieties of plant species to express the Bt toxin. Bt cotton has a gene transferred from the bacterium Bt that allows plants to produce a natural insecticide, thus reducing reliance on chemical insecticides. Bt cotton was first grown commercially in the US in 1996 and has accounted for more than half of the cotton acreage in Arizona since 1997 (McGinley, 2000). Monsanto, a pesticide supplier, added the Bt gene to the cotton plant to control pests and consequently, found that the use of chemical insecticides on cotton were reduced by 1 million gallons (ca. 4.5 Ml) (USEPA, 1999 ; Anon, 2000). Success with this technique has led to Bt transformed lines of tobacco, corn, tomatoes, potatoes and others.

A microbial pesticide, which is currently in the experimental stage, is *Aspergillus flavus* AF36, which is being used to control aflatoxin on cotton seed. Aflatoxins are powerful, tasteless, odourless and colourless myco-toxins, which inhibit the immune systems of the body. Although, many fungi are controlled with chemicals, the *Aspergillus* fungi have proven largely immune to tested pesticides (Wicklow, 2000). The *Aspergillus flavus AF36* strain is a non-aflatoxin producing strain, which competes with the carcinogenic producing strains (USEPA, 1999; USEPA, 1998).

2.6.5. Integrated Pest Management

Integrated Pest Management (IPM) is probably one of the best ways in controlling pesticides since it recognizes field crops as an agro-ecosystem. IPM is an effective and environmentally sensitive approach to pest management that relies on a combination of common-sense practices. It draws on biological control measures (natural predators and parasitoids of pests), cultural practices (agronomic practices), genetic manipulation (pest resistant varieties), and judicious use of selective pesticides to stabilize crop production while reducing the hazards to humans and the environment. The philosophy of IPM is not to eliminate pests but to maintain their use below economic injury level (Greathead and Waage, 1983 ; Baloch and Haseeb, 1996). Integrated Pest Management use current comprehensive information on the life cycles of pests and their interaction with the environment (USEPA, 2000). The 4 steps to IPM include:

Set Action Thresholds – IPM first sets an action threshold i.e. a point at which pest populations or environmental conditions indicate that pest control action must be taken. The level at which pests will become an economic threat is critical to guide future pest control decisions.

Monitor and Identify Pests – Not all insects, weeds, and other living organisms require control. IPM programmes work to monitor for pests and identify them accurately, so that appropriate control decisions can be made in conjunction with action thresholds. This monitoring and identification removes the possibility that pesticides will be used when they are not really needed or that the wrong kind of pesticide will be used.

Prevention – As a first line of pest control, IPM programmes work to manage the crop, lawn, or indoor space to prevent pests from becoming a threat. Cultural methods such as crop rotation, selection of pest resistant varieties, and planting pest-free rootstock can be implemented for agriculture.

Control – Once monitoring, identification, and action thresholds indicate that pest control is required and preventative methods are no longer effective, IPM then evaluates the proper control method for effectiveness and risk. Effective less risky pest controls such as biocontrol, use of pheromones to disrupt mating or mechanical control, are chosen first after which additional pest control measures such as the use of pesticides may be employed. Broadcast spraying of non-specific pesticides is a last resort (EPA, 2000).

Some aspects of integrated pest management is currently being used by the Department of Agriculture to control pests. The Department of Agriculture was involved in research to develop an early warning system to predict locust outbreaks, which was completed in 1999. The Department of Agriculture is also actively spreading biological control agents of weed species like *Harissa martinii* and *Sesbania punicea* (NDA, 2001). However, the extent to which a complete IPM programme has been adopted in South Africa is not known.

CHAPTER THREE

Pesticide Use

Pesticides are widely used in agriculture and public health for the control of pests and insect vectors responsible for crop damage and disease. Although pesticides are highly beneficial to man, they are one of the most biologically active groups of chemicals. Their manufacture is generally well controlled by internationally based companies but their use is susceptible to mal-, mis-, and over-usage by the end-user. Pesticides are a powerful weapon against all agricultural pests, insects, weeds and rodents. The use of pesticides enhances and stabilizes crop yield, protects the nutritional integrity of foodstuffs, facilitates storage to ensure year-round supplies and provides for attractive and appealing food products (Richardson, 1996 ; Rother and London, 1998). As discussed in Chapter 1, pesticide use is synonymous with pesticide sales for this chapter since no data is available on the amount of pesticides used per year by the various users.

3.1. Trends in Pesticide Sales

Based on population growth and subsequent food demand, the need for pesticides will increase. Worldwide sales of pesticides has increased substantially both in 1995 and 1996 (Wodageneh, 1998a). It is predicted that pesticide sales will continue to increase by 1.6 % per year over the next few years (cited in Rother and London, 1998). Despite the adverse publicity to which pesticides have been subjected in recent years, the need to use modern pesticides will increase. Whilst organic farming has its attractions, and should be encouraged as part of integrated pest management initiatives, it is not a viable alternative for mass production of high quality fruit and vegetables (Richardson, 1996).

Africa purchases only about 3 % of the all the pesticides sold per year around the world (Figure 3-1). However, South Africa is the leading agricultural force in sub-Saharan Africa and forms about 60 % of the pesticide market. Thus, the potential of environmental hazards in South Africa brought about by pesticide use is real. The major users of pesticides are the United States of America and Western Europe who collectively can make up about 60 % of the market (Wodageneh, 2000). From Figure 3-1, it is clear that the industrialized nations are the primary users of pesticides. However, due to the lack of adequate pesticide management, control, funding and enforcement frameworks in developing and undeveloped countries, the potential for health and environmental disasters is significant. The lack or inefficiency of disaster management strategies can leave some countries with a legacy of contaminated land and water systems that may be difficult to eradicate.

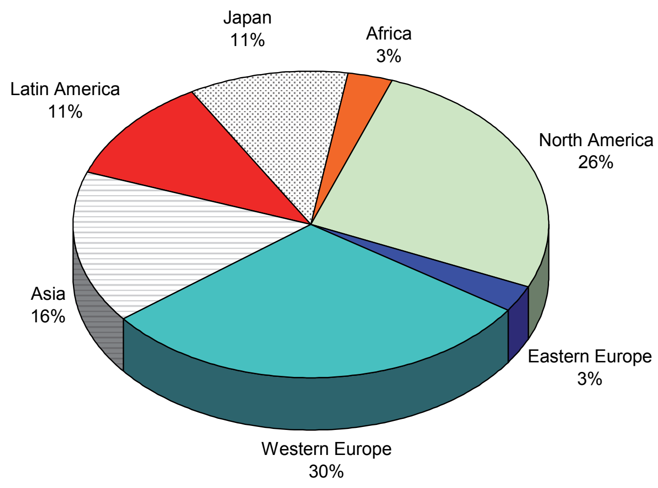

Figure 3-1: View of the pesticide value imported by region (1993-94)

3.2. Agro-chemical Industry

There are 165 chemical companies in South Africa (Rother and London, 1998). Majority of these companies fall under the Crop Protection and Animal Health Association (AVCASA) and the Chemical and Allied Industries Association (CAIA). AVCASA and CAIA are umbrella organizations which co-ordinate and monitor these companies. Most of the large transnational pesticide companies are represented by AVCASA. However, some of these companies, especially smaller companies, are not represented at all.

Smaller companies are often blamed for illegal importation and sale of pesticides. For example, in a recent newspaper article published in the Daily Mail and Guardian in May 2001, the chemical company Gulf Chemicals was accused of still selling chlordane, a persistent organic pesticide even though South Africa recently signed the treaty banning it (Macloed, 2001). Smaller companies are more difficult to regulate because they are not represented by a chemical association and do not comply to present controlling forces of peer pressure, product stewardship and self-regulation. According to Rother and London (1998) this is largely because there are gaps in the legislation, lack of enforcement and the assumption that self-regulation of companies is a viable option.

The South African government should work towards ensuring that all chemical companies (large and small) fall under a single umbrella body or a federation of bodies. This would allow government to access pesticide sales data, which would allow government to designate high-risk areas based on sales and intended use.

3.3. Pesticide Users in South Africa

There are four major sectors within the South African community that uses pesticides. These include the agricultural, governmental, industrial and domestic sectors.

1. Agricultural sector

This sector includes

- Co-operatives i.e. food plots or farm groups
- large scale commercial farmers
- Small-scale subsistence farmers
- Emerging farmers

The agricultural sector is a major user of pesticides in South Africa and account for a large percentage of the sales (Kleynhans, 2000). Due to South Africa's export driven economy, farmers see the use of pesticides as important in order to compete with export quality and yield demands.

2. Government sector

Various government departments use pesticides. The National Department of Health uses pesticides to control diseases or pests like malaria, lice and rats. Various municipalities use pesticides for the control of pests for public amenities such as schools and the clearing of vegetation on the shoulders of roads and pavements. The Minister of Water Affairs and Forestry announced a R 200 000 partnership with three herbicide companies, Cyanamid, Dow Agro-sciences SA, and Zeneca Agrochemicals. This is due to alien plants which have been spreading and growing at an average of 5 % per year with a doubling period of 14 years (Streek, 2000). Pesticides are also used by the Department of Defense to clear vegetation and for research by government laboratories. Data on government purchases of pesticides were not available.

3. Industrial sector

Businesses use pesticides for sterilization and control of pests. These are important to maintain quality standards for their products and processes. Pest control companies use pesticides for fumigation purposes and farmers contract aerial spray operators to spray fields.

4. Public Sector

This small sector includes the home and garden users. The home and garden users generally purchase from supermarkets and in small quantities. The public sector are often guilty of dumping redundant pesticides down the drain due to ignorance or apathy.

3.4. Management of Pesticide Use

A major aspect of the use of pesticides is the effective and efficient application techniques, coupled with the knowledge of the effects of different sprays and their deposits. Inappropriate use of pesticides may lead to:

- environmental impact on water quality
- contamination of land
- impact on wildlife habitat
- pesticide residues in non-targeted species
- application / harvester health and safety problems, and
- consumer exposure to pesticide residues in food.

Some of the problems with pesticides arise from the consumers not using pesticides in accordance with the procedures laid down by the supplier. The farmer should not spray a crop more than once if the recommended dose is one application and neither should they use pesticides in unauthorized mixtures. However, the manufacturer/suppliers are not entirely blameless for such mal-use since their products have a high biological activity and they need to adopt a *cradle to grave* policy. Furthermore the regulators in each country need to ensure that the end-user, whether it is a major farm or a subsistence small farm, uses pesticides correctly and responsibly (Richardson, 1996).

In South Africa, the registration of pesticides is done through the National Department of Agriculture However, according to London (2000), the National Department of Agriculture is poorly placed to ensure end-user safety. The only provision through which the Department of Agriculture can claim to regulate end-use is through application of the legislation that makes it an offence to use a pesticide in contravention of the label.

3.4.1. Pesticide Guides

In South Africa the National Department of Agriculture provides annual guides on pesticides and their uses. There are currently 4 guides:

- A Guide to the Use of Plant Growth Regulants, Defoliants and Desiccants,
- A Guide for the Control of Plant Pests,
- A Guide to the Use of Herbicides, and
- A Guide for the control of Plant Diseases.

These guides provide the user (the farmer) with information such as the type of pesticides that can be used to control pests, plant diseases, fungal diseases affecting specific or non-specific crops. It also provides a hazard classification of the various pesticides, pesticide properties, application of pesticides, dosage, formulation and treatment against poisoning. The guides also briefly provide information for the storage, or disposal of empty containers (Vermeulen et.al., 1997 ; Vermeulen et.al., 1998 ; Nel et.al., 1999a ;Nel et.al., 1999b). In addition, the Crop Protection and Animal Health Association (AVCASA) provides the farmer with a 'Manual on Responsible Use of Crop Protection and Animal Health Products'. AVCASA also produces a Crop Protection Compendium CD-ROM which an electronic manual designed to give the user access to product registration and use

3.4.2. Training and Education

According to Rother and London (1998) the education and training programmes are scattered and uncoordinated. At the moment there are three non-governmental groups and one government department involved in pesticide training and education programmes. The Chemical and Allied Association is involved in a Safe Use and Responsible Care Programme while AVCASA has adopted the Train-the-Trainer Programme for emerging farmers. The Poison Working Group has also been working with farmers and has provided information through radio and television. The Department of Health initiated a STOP (Safety towards out people) Programme in 1994. It appears that a central government office should co-ordinate the training and education programmes since other departments such as DWAF, NDH and DEAT are also affected by irresponsible handling and disposal of pesticides.

3.5. Pesticide Sales in South Africa

The pesticide sales figures were provided by AVCASA and include sales to the agricultural, ornamentals and forestry sector but do not include sales to industry, government and home and garden users. Since the agricultural sector is a major user of pesticides, much of the regulatory aspects regarding pesticides falls under the control of the National Department of Agriculture.

Figure 3-2 shows the sales as volume of active ingredient of the different pesticide groups. The category *other* in Figure 3-2 represents a variety of chemicals, which are not bought in any significant quantity in South Africa. Most of the sales are for triazines, organometallic compounds, carbamate / thiocarbamate, organophosphates, hydrocarbons, aniline / acetanilide, and organochlorine pesticides. Triazine is the most commonly used pesticide in South Africa by the agricultural and forestry sector. A significant proportion of the sales for 1997 and 1998 are for organochlorines and organophosphates. Some pesticides, which fall within these groups of chemicals, are considered highly hazardous due to their bioaccumulative and persistence properties. Figure 3-2 also shows that biological agents represent a small proportion of the total sales for 1998. It is likely that biological control agents may increase since the current trend appears to be moving towards a reduction in the use of chemicals through the employment of integrated pest management. More detailed information on the sale of different classes of pesticides are contained in Appendix B.

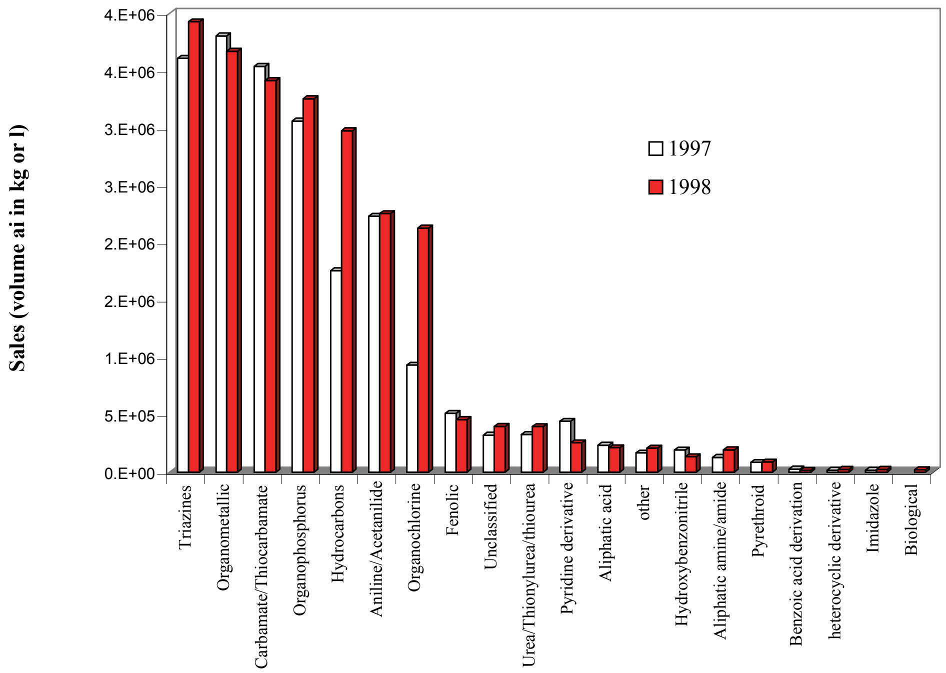

Figure 3-2: Sales for various groups of pesticides for 1997 and 1998.

Figure 3-3 shows the total sales in herbicides, insecticides, fungicides, nematicides, acaracides, defoliants and Plant Growth Regulators (PGR's) in South Africa from 1994 to 1998 (as volume active ingredient in kg or l). Figure 3-3 shows that majority of the sales of pesticides were for use as herbicides. Since 1994 there has been a general increase in pesticide sales (Figure 3-4) and it is unlikely that this trend will change significantly in the near future.

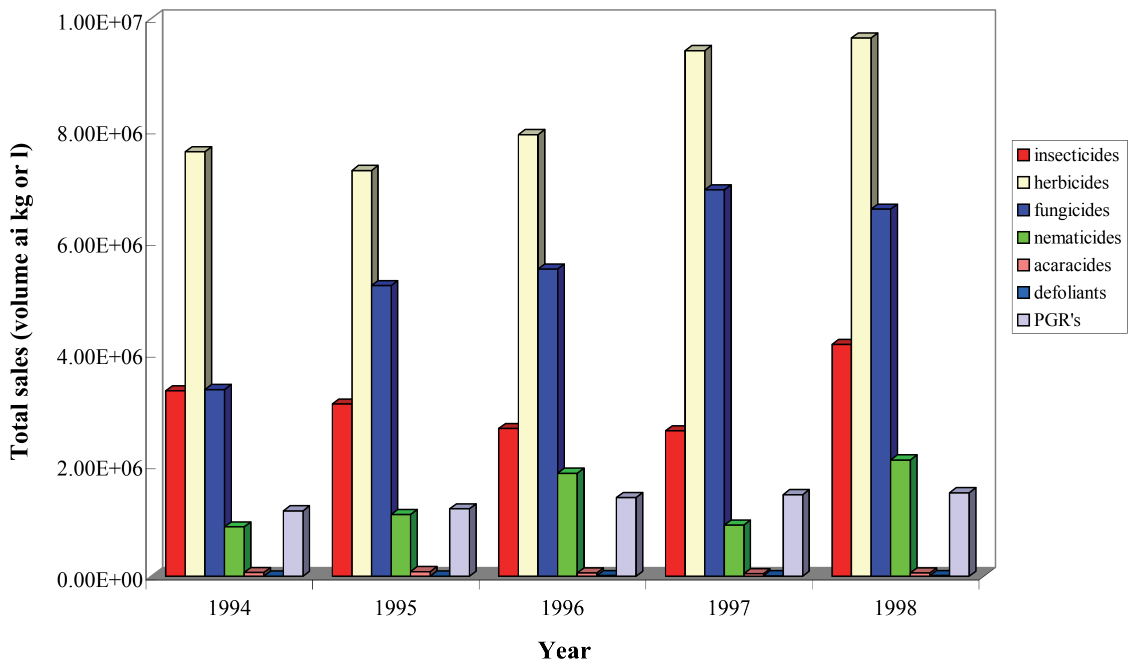

Figure 3-3: Total sales (as volume active ingredient in kg or l) for individual groups of pesticides for South Africa from 1994 to 1998.

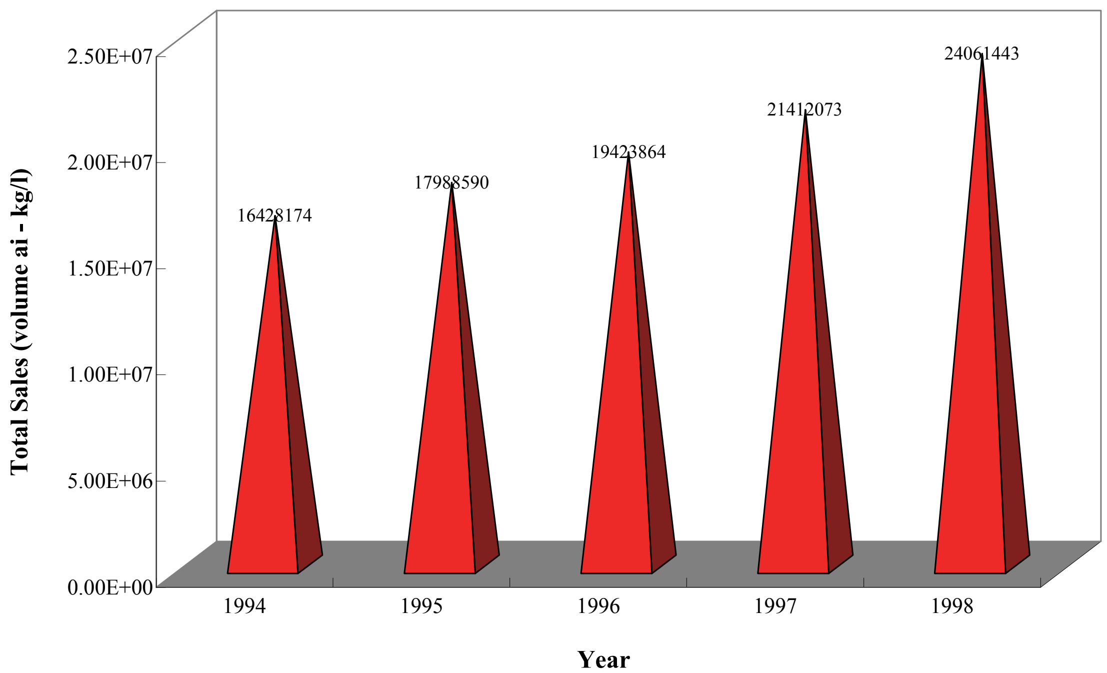

Figure 3-4: Total sales of pesticides from 1994 to 1998 excluding pesticides used by industry, government and in the home and garden.

CHAPTER FOUR

Obsolete Pesticides

Many stockpiles of obsolete pesticides are a source of severe pollution and a threat to human health, environment and development. In 1998, the FAO estimated that approximately 15 000 to 20 000 tons of obsolete pesticides required disposal in Africa and several countries in the Middle East. Due to the absence of environmentally sound disposal facilities obsolete pesticide stocks are constantly increasing. Mr Niek Van der Graaf, Head of the FAO's Plant Protection Service, has labelled these pesticide stocks as *potential time-bombs* (Wodageneh, 1998a).

4.1. What are Obsolete Pesticides?

An obsolete pesticide includes:

- Pesticides that have been banned or are no longer registered for use e.g. DDT and toxaphene.
- Unwanted pesticides, which have lost their labels or other markings and are considered to be unknown.
- Pesticides not in a usable form i.e. formulations have broken down (Wilson, 1993).
- Pesticides for which the expiry date has been passed i.e. products have expired (AVCASA, 2000).

Figure 4-1 shows the criteria that the FAO uses to class pesticides as obsolete. Figure 4-1 shows that the product first has to be identified either by label or analysis before it can be classed as obsolete or usable. Once a product has been classified as obsolete, it is necessary to determine if the manufacturer is prepared to take back the product either for disposal or recycling. This may require repackaging for international transport. If this route is not possible, then it important for governments to have the necessary infrastructure in place to deal with hazardous pesticides responsibly

The problem of obsolete pesticides is perceived to be widespread and common. Some obsolete pesticide stocks in Africa are over 30 years old. Obsolete pesticide stocks include large quantities of banned organo-chlorine compounds (Dieldrin, and DDT) that are highly persistent in the environment. Also included in the pesticide stocks are highly toxic organo-phosphorus compounds such as parathion, methyl-parathion, dichlorvos and monocrotophos (Wodageneh, 1998a).

Some of the banned or severely restricted pesticides in South Africa are provided in Table 4-1. Pesticides such as dieldrin, BHC and DDT have been banned from use in South Africa. DDT is only used under regulated conditions by the National Department of Health to control malaria. Aerial application has been banned for several of the pesticides used in South Africa and in some cases, the registrar of pesticides has restricted use to certain agricultural problems.

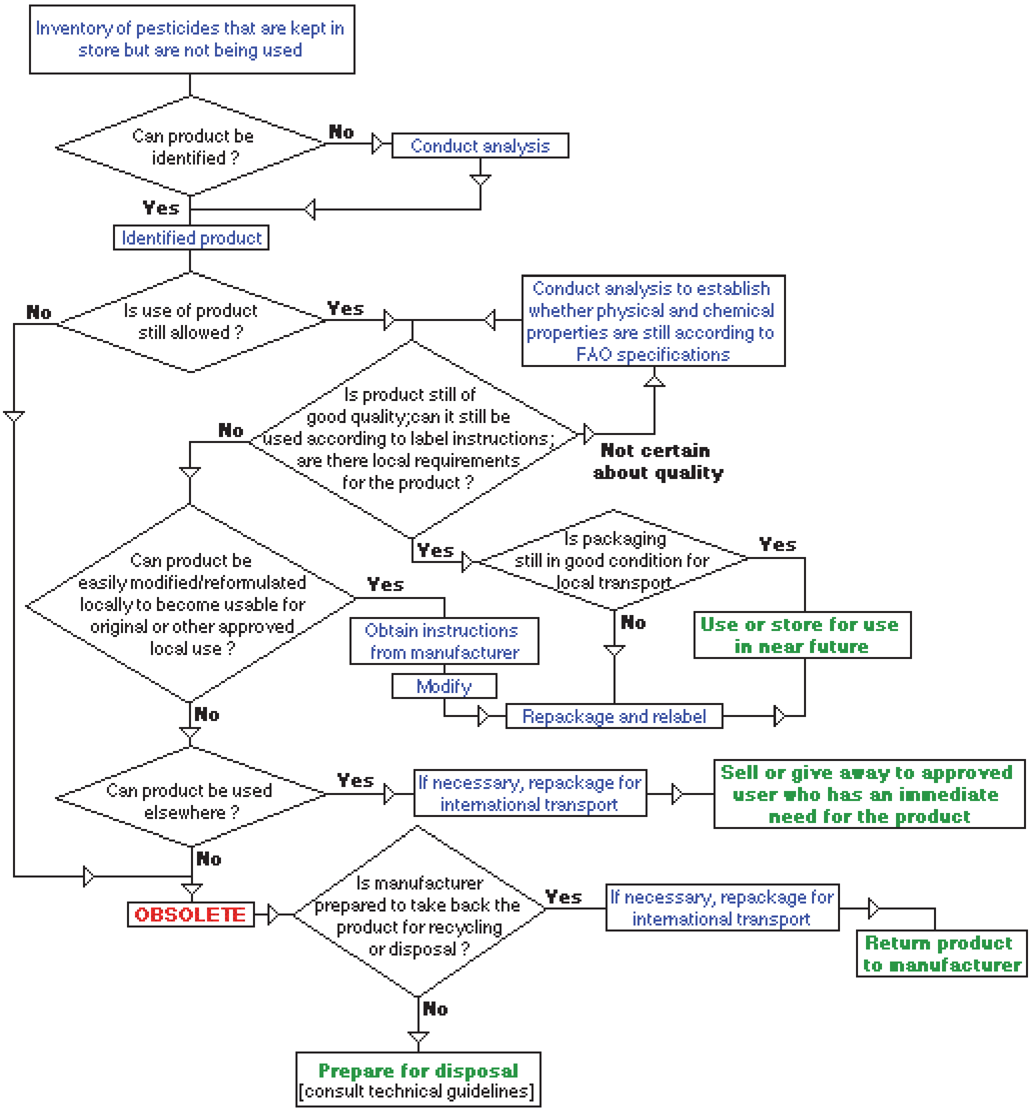

Figure 4-1: The obsolete pesticide tree (FAO, 2000).

Table 4-1: Banned or severely restricted pesticides in South Africa (Vermeulen et al., 1998).

Pesticide	Remarks
Aldrin (HHDN)	Withdrawn in 1992.
Arsenic	In 1983 it was totally prohibited as a stock remedy.
Atrazine	Industrial use withdrawn in 1995.
Azinphos-ethyl	Withdrawn as an agricultural remedy in 1997.
BHC	Banned in 1983.
Binapacryl	All registrations lapsed in 1988.
Camphechlor (CLC)	Withdrawn as agricultural remedy in 1970 and as a stock remedy in 1985.
Chlordane	In 1993 use restricted to stem treatment of citrus and vineyards.
Chlorobenzilate	Withdrawn as an agricultural remedy in 1978.
2,4-D (dimethylamine salt)	In 1991 aerial application in KwaZulu Natal was banned.
2,4-D esters	Withdrawn in 1980 from agricultural use in Western Cape; prohibited in 1991 in KwaZulu Natal.
2,4-DB (sodium salt)	In 1991 aerial application banned.
Dicamba	Aerial application banned in 1991 in Natal; prohibited in Camperdown, Richmond and Pietermaritzburg.
DDT	Banned in 1983 except for the control of malaria by the government.
Dibromochloropropane	Withdrawn in 1984.
Dieldrin	Banned in 1983.
Dinoseb	All registrations as agricultural remedy lapsed in 1995.
Endosulfan	Registration on fodder crops was suspended in 1970.
Endrin	Withdrawn in 1980.
Gamma-BHC (lindane)	All stock remedy registrations were withdrawn in 1971.
Heptachlor	Registration withdrawn in 1976.
Kepone	In 1971 a decision was taken not to register this product in SA..
Leptophos	Registration withdrawn in 1980.
MCPA (dimethylamine salt)	In 1991 aerial application banned in KwaZulu Natal.
MCPA (potassium salt)	In 1991 aerial application banned in KwaZulu Natal.
MCPB (sodium salt)	In 1991 aerial application was banned in KwaZulu Natal.
Mercury compounds	Withdrawn from all agricultural uses in 1974. In 1983 the use of mercury compounds on seed, bulb, tubers, stems or any other plant material was banned.
Methyl bromide	Small containers were withdrawn in December 1995.
Monocrotophos	In 1989 it was voluntarily withdrawn by industry for agricultural use in Western Cape.
Nicotine	Withdrawn as a stock remedy in 1971.
Parathion	Only certain uses allowed from June 1993.
Phosphorus containing formulations	All formulations containing phosphorus were withdrawn in 1979.
Propham	Withdrawn as an agricultural remedy in 1997.
2,4,5-T	All registrations lapsed in 1989.
Triclopyr	In 1991 aerial application was banned in KwaZulu Natal.
TDE	Withdrawn as an agricultural remedy in 1970.
Vinclozilin	Voluntarily withdrawn by registration holder in 1995

The obsolete pesticide situation is serious in several developing countries because there is little or no awareness of the inherent dangers of pesticides. These countries do not have the legislation, capacity, facilities or the finance to handle the disposal of waste pesticides or the problems associated with obsolete pesticides. In addition to the large quantities of obsolete pesticides, there are large quantities of heavily contaminated floor material, soil and empty containers, which should be regarded as environmentally hazardous (Wodageneh, 1998a; FAO, 1998).

4.2. Reasons for Accumulation

Some of the common reasons for the accumulation of pesticide waste in the past include:

- Stocks which have become banned.
- Prolonged storage of products with a short shelf life.
- Difficulties in forecasting outbreaks of pests such as locust.
- Excessive donation which can be inappropriate, untimely and uncoordinated.
- Late arrivals of pesticide donations.
- Aggressive sales practice.
- Inadequate storage facilities.
- Lack of trained staff (Wodageneh, 1998b).

Several of these factors which have contributed to the accumulation of obsolete pesticide stocks can be alleviated. For example, the FAO can promote the implementation of better management and monitoring structures by governments in developing countries. Donations should not be accepted if not required. Aggressive sales practices can be curtailed by promoting self-regulation and providing better training and education on pests and pest control.

4.3. Storage of Obsolete Pesticides

Pesticides should generally be kept in cool and dry conditions and should be stored in a secure location away from inhabitants and the waste containers should be placed in an area with concrete (impermeable) floors (Wilson, 1993). However, the obsolete pesticide stocks in Africa are kept in substandard stores or stored in the open. Many of these stores lack impermeable floors and are kept in containers that are deteriorating or leaking (Figure 4-2). Those containers that are kept outdoors are exposed to sunlight and rain which accelerates the deterioration process (Figure 4-3). This coupled with unfavourable climatic conditions, e.g. tropical conditions, and high temperature, exacerbates the situation. These pesticide stocks are often found in urban areas near water bodies such as rivers, irrigation systems or ports (Wodageneh, 1998a).

Figure 4-2: Pesticides stored in inadequate facilities

Figure 4-3: Pesticides stored outdoors

4.4. Cost of Obsolete Pesticide Disposal – Who pays?

In 1999 it was estimated that to remove obsolete pesticides in Africa would cost between US$ 3 500 and US$ 4 000 / ton. Based on these values, the FAO had estimated the cost for disposal of obsolete pesticides in Africa to be greater than US$ 100 million. According to AVCASA (2000), the cost is closer to US$ 1 500 to US$ 2 500 per ton for incineration in Europe, which is the most expensive route. The value quoted for by the FAO is probably for the whole operation, which includes retrieval, creation of inventory, packaging, transport, storage at collection points and disposal. A massive global mobilization of resources is needed to alleviate the situation and without financial support from agro-industries, governments and aid agencies, this enormous environmental threat cannot be resolved (Northoff, 1999).

According to Food and Agricultural Organization approximately 1 511 tons were disposed of from 10 countries (Niger, Madagascar, Mozambique, Zanzibar, Yemen, Tanzania, Zambia, Seychelles, Mauritania). These included highly toxic pesticides such as aldrin, DDT, dieldrin, lindane, malathion, and parathion. Most of the money spent for the disposal of these pesticides was financed by the Netherlands, Germany, and the Food and Agriculture Organization (FAO, 1998). Aid agencies are prepared to contribute to the disposal operation in Africa but they are unwilling to cover all costs without substantial contribution from the agro-chemical industry (Northoff, 1998). USAID has pledged US$ 1 million to help dispose obsolete pesticides in Ethiopia, which has 1500 tons of obsolete pesticides. In addition, the Dutch government has pledged a further US$ 2 million. However, this amount is insufficient to complete the disposal process (Wodageneh, 1999). The chemical industry has promised to pay at least a quarter of this or approximately US$ 1 for every litre/kg of obsolete pesticide in Africa (i.e. about to ¼ the estimated cost). However, this applies only for products that originated from the GCPF (Global Crop Protection Federation) member companies and not for products from countries like China and India.

It has been suggested that the obsolete stocks be retrieved and shipped by the producer (PANNA, 2000). In some cases, the lines of responsibility are clear. For example, Shell Chemical and its subsidiaries has been the world’s only producer of dieldrin. Consequently, Shell International contributed about US$ 300 000 towards clean-up of dieldrin in Mauritania. For other pesticides, however, the process of identifying responsible parties will be more difficult, especially since there are unknowns (Northoff, 1999 ; AVCASA, 2000). During an expert consultation on prevention and disposal of obsolete pesticides held at the FAO headquarters in Rome in March 1998, the industry talked of paying on a case by case basis. They stated that they would cover up to 30 % of disposal costs in countries such as Gambia, Madagascar and Senegal (Wodageneh, 1998b; FAO, 1998).

4.5. Current Disposal Options

The disposal of obsolete pesticides should encompass both the pesticide and the pesticide container. Pesticide containers can be classified as refillable or non-refillable and can be made of metal or plastic. The non-refillable plastic containers can be shredded and sent to landfills for disposal. The refillable plastic containers can be rinsed thoroughly and re-used. These containers could be used at the end-user level for mixing and storing pesticide formulations. They could also be sent back to the supplier for re-use. The latter is rarely implemented successfully. Metal containers could be crushed, washed and sold to steel mills for processing into products (Green, 1993).

The FAO considers incineration to be the best disposal option for hazardous pesticides. The International Group of National Associations of manufacturers of Agrochemical Products (GIFAP) lists the re-use of pesticides, high temperature incineration, chemical treatment, long term storage (encapsulation) and landfilling as possible disposal methods. None of the developing countries, except a few newly industrialized nations, have the facilities required for the safe and environmentally sound disposal of pesticides (Dalvie, 2001).

Incineration has been criticized has being unsafe because of the presence of products such as dioxins and furans in the emissions. It was found that Japan has about 10 times more dioxin than other industrialized nations. This is largely attributed to Japan's penchant for incineration. Japan contains nearly 70 % of the world's incinerators (Corliss, 1999). Initially, the FAO considered setting up cement kilns to incinerate the obsolete pesticides in countries within Africa but this option was dropped. It was feared that the standards of the incinerators would not be maintained resulting in greater atmospheric pollution and it would lead to trade in import of toxic waste. Therefore, the FAO decided to support the export of obsolete pesticides to industrialized nations, which have the facilities to deal with toxic waste safely. However, this policy has received opposition from communities receiving the waste and environmental groups (Wodageneh, 1998a; Corliss, 1999; Mail and Guardian, 1999).

Another waste disposal option is encapsulation. However, land disposal may not effectively contain the pesticides if not appropriately managed. It acts as a storage facility and can be described as an *out of sight, out of mind* policy. The threat of leakage is real and can contaminate the environment and threaten human and animal health especially in under-developed countries where management of obsolete pesticides is minimal or absent. Environmental groups have also suggested that the pesticide industry take voluntary responsibility for its product (PANNA, 2000). There is several waste disposal techniques that are available or are being developed. These will be discussed in detail in **Chapter 5**.

4.6. Hazardous Waste Disposal Options for South Africa

Hazardous waste includes a wide spectrum of materials with dangerous, explosive, flammable, reactive and toxic characteristics. South Africa generates < 5 % of the world's total hazardous waste production of about 400 Mt/yr. According to DEAT (2001), < 5 % of the 5 million m^3 of hazardous waste generated per year reaches hazardous waste disposal sites. Certain pesticides fall within the hazardous waste category. Furthermore, most of the 5 million m^3 of hazardous waste generated is in Mpumalanga and KwaZulu Natal. The Departments of Agriculture and Health mainly control the hazardous substances that are extensively used in agriculture and industry. The rate of increase of the production of hazardous waste is estimated to be 2.6 % per annum over the next 10 years (DEAT, 2001).

The most common forms of treatment of hazardous waste practiced in South Africa are:

- **Encapsulation** of extreme and hazardous waste. However, this is costly and while it isolates the waste from the environment, it must be classed as storage since it does not destroy or reduce the toxicity of the waste.

- **Chemical treatments** are used to reduce the toxicity of the waste before disposal e.g. ash blending and lime treatment.

4.7. Status of Obsolete Pesticide Stocks in Southern Africa

The FAO undertook to help Africa in its clean-up of obsolete pesticides. The first part of the progamme included the creation of an inventory of all obsolete pesticides. The inventory also included contaminated soil sites. The next step was to repackage the obsolete pesticides and store them safely until disposal (Figure 4-4). Table 4-2 provides a summary of the amount of obsolete pesticides found in Botswana, Madagascar, Malawi and Zimbabwe. Some countries are awaiting disposal e.g. Mozambique. South Africa, Mozambique and Botswana had the highest amount of obsolete pesticide stocks in the Southern Africa region. Table 4-2 shows that the Southern African regions contained 1 774 tons of obsolete pesticides which accounts for approximately 9 to 12 % of the obsolete pesticide stocks estimated for Africa and the Near East. Therefore, Southern African regions are relatively clean in comparison to the rest of Africa.

At a consultative meeting between South Africa and Denmark held in Pretoria in September 2000, DANCED identified the handling of obsolete pesticides as a problem in Southern Africa. The findings of this mission found that there may be a scope for regional project handling including inventories, storage, handling and destruction of obsolete pesticides. Furthermore such a project could also include training in stewardship, capacity building, chemical profiles, phasing out of POP's and preventative measures such as promotion of integrated pesticide management (IPM). Given Denmark's current support to the regional Basel Training Centre, it appeared possible to anchor activities relating to obsolete pesticides and POP's within the centre (Koefoed, 2000).

Table 4-2: Summary of obsolete pesticide stocks estimated, found and disposed as of 2000 in Southern Africa.

Country	**FAO estimate 1997– 1998 (ton)**	**GCPF figures – 2000 (ton)**	**Disposed- 2000 (ton)**
Botswana	255	165	Unknown
Madagascar	65	0	65
Malawi	127	111	Unknown
Mozambique	443	900	Unknown
Namibia	245	0	215
South Africa	603	0	775
Swaziland	9	60	Pending
Zimbabwe	27	0	Unknown
Total	*1774*	*1236*	*1055*

FAO – Food and Agricultural Organization; GCPF – Global Crop Production Federation ;

Figure 4-4: A typical clean-up operation for obsolete pesticides showing re-packaging of pesticides for disposal.

- **Botswana**

Botswana had 255 tons of obsolete pesticides (as of November 1997). Most of the pesticides were found in corroded drums. Heavily contaminated soil has been found and will require clean up. This will have an impact on the environment and human health, especially if these sites are located in urban areas. Class II and III (moderately and slightly hazardous) type pesticides were found but several mixtures are listed as unknown. However, in 2000, the GCPF reported only 165 tons of pesticides awaiting disposal. *The current state of disposal of the obsolete pesticides in Botswana is unknown* (Wodageneh, 2000).

- **Madagascar**

Madagascar has reported an obsolete pesticide stock of 65 tons. This value was last updated by the FAO in November 1998. The obsolete stocks in Madagascar range from extremely hazardous (class Ia) to slightly hazardous (class III). These pesticide wastes have been found at several different sites around the country.(Wodageneh, 2000). *By the year 2000, the 65 tons of pesticide waste had been disposed and the GCPF reported no additional obsolete pesticides stocks in Madagascar (AVCASA, 2000).*

- **Malawi**

Malawi has about 127 tons of obsolete pesticides. The FAO inventory for Malawi was last updated in November 1996. A countrywide survey has been undertaken and further results are expected. The pesticides listed come from 15 different sites and comprise about 69 different pesticides. The pesticides reported fall into class Ia (extremely hazardous), class Ib (highly toxic), class II (moderately hazardous), and class III (slightly hazardous) categories

(Wodageneh, 2000). In 2000, the GCPF found only 111 tons which is about 16 tons less than the FAO estimate (AVCASA, 2000). *The current state of disposal of the obsolete pesticides in Malawi is unknown*.

➢ **Mozambique**

Mozambique contains about 443 tons of obsolete pesticides and is second only to South Africa in Southern Africa (Wodageneh, 2000). This figure is significantly smaller than that reported by the GCPF in 2000 which placed the figure at about 900 tons (AVCASA, 2000) The pesticides belong to all 4 classes of hazardous chemicals. Approximately 1000 m^3 of contaminated soil in the Matola region needs to be cleaned. This clean up process is expected to cost about US$ 10 million. The total cost for disposal and clean-up of obsolete pesticides is estimated to be over US$ 13 million. Denmark has committed itself financially to the removal of pesticides from Mozambique. The disposal of obsolete pesticide stocks in Mozambique is being financed by DANIDA (Danish International Development Agency) (Wodageneh, 2000). Initially, DANIDA intended building cement kilns for the incineration of the waste in Mozambique at a cost of US$ 6 million. However, environmental groups and the local community have recently criticized DANIDA for setting up sub-standard cement kilns, which they believe will create *dangerous cancer causing compounds*. They have also accused DANIDA of planning to import waste from other parts of Africa for disposal in Mozambique (Sayagues, 1999). DANIDA has refuted these claims and reported that the decision to build the kilns in Mozambique was done to improve the environment and health of the Mozambican population and was done strictly according to Mozambican laws (Schjerbeck, 1999). *The current state of disposal of the obsolete pesticides in Mozambique is unknown.*

➢ **South Africa**

The South African government undertook to finance the collection and shipment of obsolete and banned crop protection and animal health products from Southern Africa to incinerator facilities in Wales. It was the first initiative of its kind in Southern Africa. The National Department of Agriculture appointed and funded the Crop Protection and Animal Health Association (AVCASA) to manage the project (NDA, 2001). To access unwanted farm stocks, the retrieval project relied on returns from a postal survey of farmers. Retrieval was completed in 1998 (Dalvie, 2001). In January 1999 the FAO records indicated that South Africa contained about 603 tons of obsolete pesticides (Table 4-2) (Wodageneh, 2000). In June 1999 after an intensive retrieval and disposal project was undertaken by AVCASA, the inventory volume increased from 603 to 1050 tons of obsolete pesticide (Table 4-2). These obsolete pesticides had accumulated over a 30-year period.

The obsolete pesticides had been retrieved from 45 bulk collection points around South Africa and included obsolete stocks from Namibia (60 tons) and Swaziland (215 tons). These obsolete pesticides were found in corroded containers and with labels missing. Significant proportions of the retrieved pesticides were unknowns and were classed as highly toxic. The pesticides were collected at bulk sites, repackaged and labelled. The obsolete pesticides could be categorized as organochlorine, various, organophopshorus, fungicides, arsenical compounds and herbicides (Table 4-3).

In November 1999, about 740 tons of highly toxic obsolete pesticides were exported to Wales at Shanks to be incinerated (Kleynhans, 2000; Boon, 2000). The remaining 250 tons (less toxic) of the pesticide waste was disposed by Enviroserv at the Holfontein landfill site, Gauteng. Three disposal methods were used, high-tech encapsulation (105 tons), ash-blending (80 tons) and lime treatment (65 tons). The encapsulation of the 105 tons of pesticide waste cost approximately R 9 million. At this point (November, 1999), South Africa was considered to be technically clean. The Department of Agriculture was the major financial contributor (R 13 million) to the retrieval and disposal drive. Overseas donor funds contributed R 300 000. The 60 tons of pesticide waste retrieved from Swaziland is pending disposal.

Table 4-3: Obsolete pesticide retrieval from 45 bulk collection sites in South Africa

Waste Category	Amount (tons)
Organochlorine	410
Various	265
Organophosphorus	220
Fungicide	80
Arsenical Compounds	50
Herbicide	25

In 2000, it was reported that approximately 50 tons of pesticides had become redundant. Further, reports were received by farmers who claimed to have had no knowledge of the previous disposal drive (Kleynhans, 2000). Two hundred and thirty three farms in the Stellenbosch region were surveyed for obsolete chemicals. About 205 of the farmers that were questioned indicated that they had no knowledge of the national retrieval project. According to Dr Vermeulen of the Department of Agriculture, the initial postal survey to compile the inventory for the national retrieval project had a low response rate (Dalvie, 2001). Furthermore, according to Dalvie (2001) the postal survey relied on returns from farmers but no mention is made of the other sectors that use pesticides e.g. governmental and industrial users. Therefore, it is expected that significantly more obsolete pesticide stocks will be found in South Africa. However, any further disposal drives will have to funded by Chemical Manufacturers and Importers (Kleynhans, 2000).

A second problem posed by pesticides is contamination of soil and water. In South Africa, the Department of Water Affairs and Forestry (DWAF) becomes aware of such problems if approached by industry or as a result of a complaint by the public. DWAF has an interim generic process for the determination of remediation strategies for contaminated land and water resources. This process entails 4 phases:

1. Investigation of site status and determination of future use and remediation objectives.
2. Alternative options to ensure future use and objectives are achieved after remediation.
3. Legal and impact assessment, and
4. Summarized application for appropriate authorization.

This is largely a reactive approach by government. Since the regional offices normally handle these problems, the head office may not be aware of all contamination sites in South Africa. Currently, the DWAF head office knows of only 1 site in Gauteng that is contaminated with pesticides such as dieldrin and aldrin. This contamination has been linked to bad practice i.e. the irresponsible manufacturing and storage of pesticides. Thus, DWAF does not have a clear understanding of the number of sites that may be contaminated with pesticides nationally (DWAF, 2002).

It may be useful for South Africa to create a hazard ranking system of contaminated sites in order to assess the national problem (Swanson and Socha, 1997). This system could prioritize sites that will require remediation based on type of contaminant and location of contamination. For example, contamination near groundwater sources or on prime agricultural or industrial land should be given the highest clean-up priority. One of the advantages of such a system is that national government will be able to assess re-occurring regional problems with time and thereby create the necessary mechanisms to assist municipalities in dealing with such problems adequately. It could also identify which regions are dealing with the problems efficiently and successfully, and thus, facilitate technology transfer to other regions in the country.

- **Swaziland**

Approximately 9 tons of obsolete pesticides had been estimated to be in Swaziland. The obsolete pesticide stocks comprise about 35 different pesticides and have been found at only 2 sites (Wodageneh, 2000). It was believed that more obsolete pesticides existed than was reported. In 2000, AVCASA reported the total volume of obsolete pesticides from Swaziland to be 60 tons. *These pesticides were not disposed of during the South African retrieval and disposal drive and the disposal of the obsolete pesticides in Swaziland is pending* (AVCASA, 2000).

- **Zimbabwe**

In August 1998, Zimbabwe reported that 27 tons of obsolete pesticides were found. It was reported that 15 sites were seriously affected. Pesticides belonging to all 4 classes were found. Some pesticides were found in corroded metal drums while pesticides in plastic containers were reported to be in good condition. *According to the FAO, the current state of disposal of the obsolete pesticides is unknown* (Wodageneh, 2000). However, recent GCPF reports show no pesticide stocks in Zimbabwe (AVCASA, 2000).

CHAPTER FIVE

Disposal Options for Obsolete Pesticides and Pesticide Contamination

Pesticides, when applied and handled correctly, have enormous benefits in increasing crop yields and improving the quality of agricultural produce. Unfortunately, there is considerable mal-, mis- and over-usage of pesticides. In addition, the irresponsible handling, storage and transport can lead to spills and contamination of the environment. Figure 5-1 shows the many hazards that the use of pesticides can pose to man and the environment if not regulated and controlled correctly by government, industry, and the end-user. The obsolete pesticide stocks need to be treated and disposed correctly in order to reduce their impact on the environment. It is essential to treat contaminated land and water sources to alleviate the environmental impact. This chapter discusses the various technologies that may be used to dispose obsolete pesticide stocks and clean-up land and groundwater sites contaminated by pesticides either through use, mis-use or accidents. It also introduces some advanced treatment options for the disposal of hazardous waste.

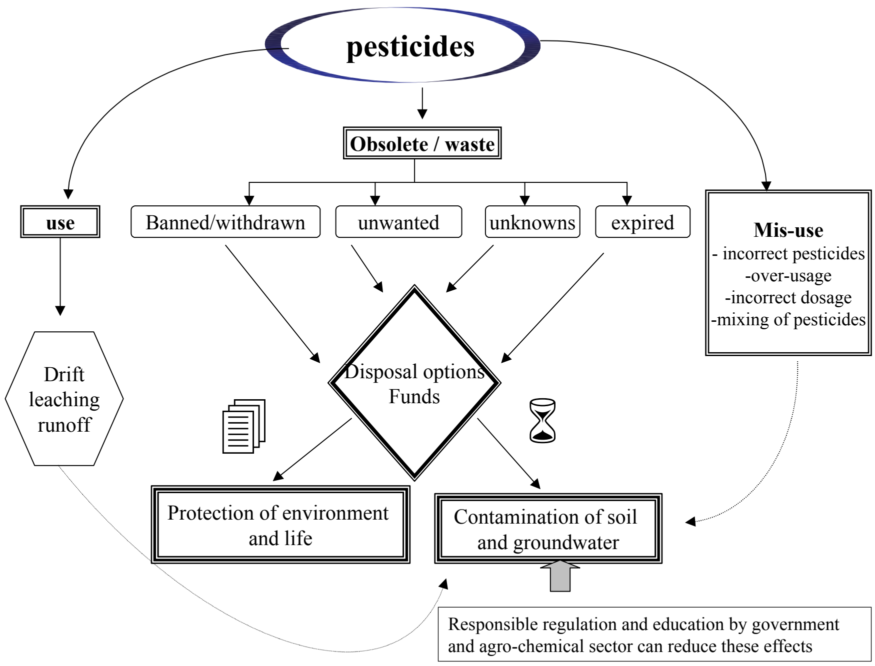

Figure 5-1: The hazards and potential hazards of pesticide use.

5.1. Treatment and Disposal Technologies for Obsolete Pesticide Stocks

The ideal scenario would be for South Africa to create a central or regional collection point for hazardous wastes. From this point wastes can be sent to various sites for disposal. There are 4 different technologies available for the treatment of pesticide waste. These include:

- thermal destruction methods
- chemical treatment methods
- physical treatment methods, and
- biological treatment.

No single treatment technology is ideal for the disposal of pesticide waste. It is highly likely that a combination of treatment methods may be more applicable for the different chemicals that require disposal.

5.1.1. Thermal Destruction Methods

Most thermal destruction methods use high temperatures (416 – 1648 °C) to break down organic chemicals into more simple, less toxic forms in systems with oxygen (incineration) or without oxygen (pyrolysis) present. Incinerators are the preferred method of destruction of waste materials and are regarded by the USEPA as the Best Available Control Technique (BACT). However, this technique of disposal has received considerable opposition from environmental groups, the public and some governments. Environmental groups oppose incineration due to the formation and emission of toxic pollutants called *Products of Incomplete Combustion*. Many of these products of incomplete combustion are more toxic than the original compounds. Under certain conditions burning chlorine-containing pesticides like dieldrin and lindane leads to the production of extremely toxic, persistent, and bioaccumulative products of incomplete combustion such as dioxins and furans. The carcinogenic potency of dioxin is reported to be 140 000 and 7 800 times greater than that of lindane and dieldrin, respectively. Another aspect of incineration that has been criticized is the measurement of the Destruction and Removal Efficiency (DRE). The DRE is measured during a one-time only *trial burn* of selected substitute chemicals under carefully controlled conditions. The Environmental Protection Agency has expressed concern about the DRE during upset conditions (IPEN, 1999; Thornton, 1990). Other environmental groups oppose the quantities and types of chemicals in the incinerator stack emissions.

In general, well operated incinerators, designed for the destruction of hazardous waste will have lower emissions than older and less efficiently operated facilities. The opposition to incineration has led the United States Environmental Protection Agency (USEPA) and other European Environmental Agencies to search for alternatives to incineration or to improve existing incineration technologies. Technologies for the reduction of incomplete combustion include the optimization of the combustion process, after-burning of combustion processes, utilization of enriched oxygen, and catalytic oxidation. Technologies designed to remove chemicals from the flue gases include the scrubbing of the organic products of incomplete combustion, wet or dry spray sorption systems, which, are used for the removal of hydrochloric acid and other inorganics, and the sorption of the organic products of incomplete combustion onto beds of activated carbon or other effective sorptive material (EPA, 1994).

In addition, pyrolysis is considered to be a better option than combustion i.e. incineration. Wastes are typically combusted in 2 stages during pyrolysis. The first stage occurs in the main chamber. The next stage occurs in the secondary chamber, where gases formed in the main chamber are burned at 976 °C – 1648 °C. In theory, this second chamber burns off carbon monoxide and organic vapours generated in the first chamber, and avoids vaporization of inorganic material. Inorganics, which are include heavy metals, form an insoluble residue, which is not destroyed by incineration and has to be disposed of. One of the advantages that the pyrolysis process has over the incineration process, is the reduction in the production of unwanted by-products like dioxin (USEPA, 1998). A selected number of advanced thermal technologies are discussed below.

Closed Loop Detoxification

Closed loop detoxification (CLD) is a thermo-chemical reduction process based on the catalytic stream gasification of organic or carbon containing materials and is applicable to waste streams containing halogenated or chlorinated organic compounds. During the process, steam and carbonaceous material react to form carbon dioxide and hydrogen. Under the conversion conditions, the organic materials thermally decompose and chemically react. The material then flows into a reactor vessel to ensure complete conversion of the contaminants, before being cooled to about 472 °C and sent to a cyclone separator to separate the gases and solids. The gases, carbon dioxide and hydrogen, are then scrubbed and recycled. The liquid phase contains the sodium chloride, which is removed, and water, which can be recycled and used as steam. The ash residue can be sent to landfills or processed further (Hoffman, 1990).

Closed loop detoxification can operate when metallic (in)organic, radioactive substances, solvents or other chemicals, including herbicides and pesticides, or more toxic compounds such as trichloroethylene (TCE), various polychlorinated biphenyl's (PCBs), the herbicides 2,4-dichlorophenoxyacetic acid (2,4-D) and 2,4,5-trichlorophenoxyacetic acid (2,4,5-T), and possibly dioxin are present. Since the process occurs in a reducing environment, chlorine present in the waste is *completely converted into hydrogen chloride* producing neither side reactions nor products of incomplete production. In other words, the chlorine in the waste becomes unavailable for further chemical reactions, which may result in dioxin or furan formation. The process is intended to yield zero return or discharge of any toxic substance, reactant or product to the environment. However, if sulfur-containing fuels such as coal are used, stack-gas cleanup is necessary. There is no data, however, to either support or refute these claims. The lack of equipment and funds has prevented further experimentation on the system (Hoffman, 1990).

Texaco Gasification Process

The Texaco gasification process is a non-catalytic, partial-oxidation process in which carbonaceous substances react at elevated temperatures and pressure, producing a gas containing mainly carbon monoxide and hydrogen. The process treats the waste material at pressures above 20 atmospheres and temperatures between 1200 °C and 1452

°C. It is reported that these extreme conditions destroy hydrocarbons and organics in the feed, and inhibit the production of many of the undesirable by-products associated with other incineration methods. At such high operating temperatures the residual ash melts into inert glass-like slag particles which are disposed. According to Texaco, the gasification process can treat a variety of waste streams, such as solid or liquid wastes, contaminated soils, sludge, and sediments that contain both organic and inorganic constituents, as well as chemical wastes and petroleum residues. One of the major problems with this technology is that some organic compounds, such as dioxin, appear as products of incomplete partial oxidation reactions (PIRs) (USEPA, 1995).

ECO-LOGIC Gas Phase Chemical Reduction

This process treats organic hazardous waste in a hydrogen-rich atmosphere at approximately 864 °C under ambient pressure, converting aqueous and oily hazardous contaminants into a hydrocarbon-rich gas. The reduction reaction takes place within a specially designed reactor. A heat exchanger evaporates the contaminated aqueous feedstock to form steam and concentrated heated liquor. Separate nozzles inject the gaseous waste, steam, and hydrogen into the reactor. The temperature is raised to 864 °C, and the reduction reaction takes place as the gases enter the ceramic tube through inlets at the bottom of the tube and travel up toward the scrubber. The scrubber removes hydrogen chloride, heat, water, and particulate matter. The process is designed to treat liquid and oily waste streams including contaminated soils and landfill leachates, and wood treatment and pulp mill wastes contaminated with chemicals such as polyclorinated biphenyls, polynuclear aromatic hydrocarbons, pesticides, chlorinated dioxins and furans, chlorinated solvents, chlorobenzenes, and chlorophenols. The ECO LOGIC system is currently in use in Australia and Canada. ***The advantages of this system are that there is no formation of byproducts like dioxins and furans***, and maintaining the concentration of hydrogen greater than 50% can prevent the formation of polynuclear aromatic hydrocarbons. The disadvantages of this system are that excess methane is produced when treating highly concentrated wastes, and residues generated by the process have to be disposed (Casten, 1995; USEPA, 1996; USEPA, 1994). However, methane can be used as an alternate fuel source on site or could be captured for external uses.

PEAT's Thermal Destruction and Recovery Unit

PEAT's Thermal Destruction and Recovery (TDR) system is powered by an electric arc (plasma) from a plasma arc torch. The process is distinctly different from combustion (incineration) in that it uses energy from the plasma to thermally convert organic waste from a solid or liquid to a gas through a process called controlled pyrolysis or controlled gasification. The constant high operating temperature insures the destruction of all complex organic wastes and process control minimizes the possibility of reformation of complex pollutants.

The process chamber is heated to 900 °C to 1650 °C before feeding is started on a continuous basis. Organic materials rapidly dissociate into elemental constituents, mainly hydrogen, carbon, oxygen and frequently a halogen such as chlorine. The result is a pyrolysis product gas composed of hydrogen, carbon monoxide, and acid gas such as HCl. The gas products are piped to a quench and a gas scrubbing system where the gas is neutralized and the particulates removed. Inorganic constituents will melt in the processing chamber and if silicates or other glass formers are present will form a glassy slag which can be sent to landfills for disposal.

Photothermal Detoxification Unit

The photothermal detoxification unit (PDU) was developed by the University of Dayton, USA. The system uses photothermal (light and heat) reactions conducted at temperatures ranging between 80 °C and 304 °C. These temperatures are higher than conventional photochemical processes but lower than combustion temperatures. This temperature range provides photothermal reactions with enough energy to destroy waste quickly and efficiently, presumably without producing potentially hazardous by-products (thus far, there is no data to support this presumption). The photothermal detoxification system consists of an insulated reactor vessel illuminated with high-intensity UV lamps, which provide near-UV radiation and heat for the process. The system is designed to destroy certain hazardous organic wastes, and has been proven effective at destroying the vapours of PCBs, dioxins, dibenzofurans, aromatic and aliphatic ketones, aromatic and chlorinated solvents. The system has yet to be field-tested or commercialized. The advantage of this system is that it destroys the wastes at low enough temperatures to avoid combustion and the potential for the production of hazardous by-products. The disadvantage of this system is that it is not a stand-alone treatment technology, and is only designed as a secondary treatment step to clean and destroy organic wastes found in off-gases of primary treatment technologies (USEPA, 1996; USEPA, 1995b).

5.1.2. Chemical Treatment Methods

Chemical treatment methods use different properties of a chemical to alter its hazardous elements. Chemical reactions alter the chemicals, destroying the hazardous elements or producing new compounds that are easier to treat or dispose of. This process is useful primarily when a single chemical is involved (or a few with similar properties). When applied to waste mixtures, side reactions interfere with the desired reactions. Traditional chemical treatment methods include electrolysis, oxidation and reduction. Some new techniques improve on these methods, others use different chemical reactions. Two chemical treatment methods, chemical dechlorination and the Delphi Research DETOX System, are discussed. Both methods are primarily aimed at reducing or eliminating the formation of dioxins and furans.

Chemical Dechlorination

Chemical dechlorination is a chemical process that removes chlorine from a substance rendering the original chemical less toxic. Although dechlorination processes has been known for over 75 years, only in the past decade have researchers begun to look at its potential to treat polychlorinated biphenyl and dioxin contaminated materials. This application of dechlorination is designed to use glycols, alcohols, and water as their primary reagents. The two most common versions of chemical dechlorination are glycolate dehalogenation and base-catalyzed decomposition. During the dechlorination process of the glycolate dehalogenation, the alkali metal hydroxide portion of the reagent reacts with chlorine in the contaminant (PCB or dioxin) and forms a non-toxic salt. This process consists of five steps: preparation, reaction, separation, washing, and dewatering. (USEPA, 1996a, USEPA, 1990).

The second chemical dechlorination process, base-catalyzed decomposition, was developed by the USEPA as an inexpensive way to remediate liquids, sludge, soil, and sediment contaminated with chlorinated organic compounds especially PCBs, pesticides, and some herbicides and dioxins. In the process, contaminated soil is mixed with sodium bicarbonate and heated in a reactor where the chlorinated compounds are separated from the soil by evaporation. The dechlorinated reaction occurs when several chemicals including sodium hydroxide are mixed with the condensed contaminants and heated in a reactor (USEPA, 1996a).

The primary advantages of dechlorination processes include:

(i) the ability to treat on-site contaminated material,

(ii) the process works in an enclosed vessel at mild temperature and pressure conditions, so that no air emissions or water discharges occur,

(iii) off-gases that are produced are collected and recovered for treatment, and

(iv) some costs can be recovered by recycling reagents.

Disadvantages include the lack of information on the toxicity of the reagents, polyethylene glycol and dimethyl sulfoxide and the lack of extensive field testing. (USEPA, 1996a, USEPA, 1990).

Delphi Research DETOX System

The DETOX technology is a catalyzed wet oxidation process that chemically and non-thermally breaks down organic wastes into carbon dioxide and water. The basic process involves feeding waste and oxygen into a reactor where organic compounds are destroyed and toxic metals are concentrated and recovered, or disposed. The system is designed to handle soil, sludge (not municipal sewage sludge), solids, sediment, off-gases from primary treatment technologies, and mixed wastes. It can destroy all organics except for fluoropolymers. It is best applied to bulk organic wastes containing toxic and/or radioactive metals. Dioxins, polychlorinated biphenyls, volatile and semi-volatile organic compounds, heavy metals, radioactive metals, and pesticides can all be treated by this system. The advantages of this system are that the low temperature inputs and nature of the catalyst solution doesn't produce dioxins, furans, or volatile metals in the output. Therefore, there is less need for off-gas treatment and the process doesn't need fuel to operate. ***The disadvantages of this system are that it is not very efficient in treating great amounts of soils and waters with small amounts of contaminants and does not destroy toxic metals.*** Thus, they may require further treatment prior to disposal (USEPA, 1998).

5.1.3. Physical Treatment Methods

Physical treatment methods use differences in physical properties (particle size, density, volatility etc.) to separate waste components without altering chemical structure. Usually the hazardous components of the waste are concentrated while the non-hazardous components are separated as a liquid or solid. ***Physical methods don't destroy wastes, they change them into forms that are easier to treat further or to dispose.*** Traditional physical methods include carbon adsorption, filtration, flocculation, distillation, reverse osmosis and ion exchange.

A common physical treatment method is encapsulation, where wastes are enclosed or trapped in stable, water-resistant material. Wastes may be in containers or mixed with material that will hold the wastes together while the covering is applied. Once the process is complete, the wastes need to be landfilled. As long as the covering is intact, leakage potential is low. Special safeguards and monitoring systems are needed to quickly detect leakage. The major disadvantage of encapsulation is that it requires a large amount of area for large volumes of waste. This type of option should only be used in the case of unknowns which cannot be analyzed and waste that has been segregated and minimized e.g. the toxic ash from incinerators.

5.1.4. Biological Treatment

The biological treatment process may use naturally occurring microorganisms, such as native bacteria, yeast or fungi, to break down hazardous wastes into less toxic or nontoxic substances. Certain microorganisms can digest organic contaminants and break them down into such harmless products as carbon dioxide and water. Biological treatment is not new but its application to hazardous wastes is relatively new and raises many questions. Factors such as temperature, strain of bacteria or bacterial consortia, amount of air and type and concentration of waste influence the effectiveness of naturally occurring organisms, but these factors can be controlled. In some cases, since degradation under natural conditions is often slow, it must be "enhanced" or speeded up. Microbial population and the types of contaminants determine whether substances must be added to stimulate bioremedial activity and, if so, which ones.

The treatment of obsolete pesticide stocks would require the construction of bioreactors. These bioreactors could comprise of aerobic or anaerobic microorganisms. In most cases it is likely that an integrated process would be most successful combining pre-treatment, aerobic reactors, anaerobic reactors and post treatment technologies. Microbes may use aerobic respiration to transform organic contaminants to carbon dioxide by transferring electrons from the contaminant to oxygen or anaerobic respiration, which uses a compound other than oxygen (nitrate, sulfate, carbon dioxide, or a metal) to transform organic compounds to carbon dioxide. Microbes may also use cometabolism, where enzymes produced by microbes during the degradation of certain compounds will help transform a contaminant that normally resists biodegradation (MacDonald and Rittman, 1994). Various studies have shown that a number of different microorganisms are capable of degrading a variety of pesticides (Table 5-1).

Biological treatment may use either naturally occurring or synthetic (genetically engineered) bacteria to break down chemicals. With genetically engineered bacteria many more factors influence effectiveness, many of which cannot be controlled. The following problems will need to be resolved before these systems could be used effectively:

- Bacteria developed in the laboratory may kill off natural bacteria or simply not survive when used in the real world.
- Results from laboratory tests cannot always be repeated in the real world because of the lack of control over the environmental factors.
- Toxic elements, soil acidity and temperature are factors that might reduce or eliminate a bacteria's ability to degrade a certain chemical. In addition, possible predators could be a critical factor in the effective use of laboratory-bred organisms (USEPA, 1996 ; USEPA, 1997).

Table 5-1 : Biodegradation of pesticides

Pesticides	Remarks	References
Aroclor 1221	Process : aerobic Inoculum: sewage *Pseudomonas* sp. 7509 capable of degradation	Liu , 1981
Alachlor 1242	Process: anaerobic Inoculum: sediment Anaerobic dechlorination but digestion incomplete	Rhee et.al., 1993
Alachlor	Process: aerobic and anaerobic Inoculum: subsoil and aquifer Aerobic degradation rates faster than anaerobic with a 126 d incubation	Pohuluri et.al., 1990
Atrazine	Process: aerobic Inoculum: soil 80 % removal in 100 d Degradation occurs with carbon supplementation but limited with nitrogen supplementation.	Ames and Hayle, 1999
	Process: Aerobic / anaerobic Inoculum: Wetland water Nitrogen found to hinder aerobic degradation but enhances anaerobic transformations. Atrazine disappeared within 21 d under aerobic conditions	Nair and Schnoor, 1992
	Process: Anoxic Used In situ microcosm – shallow sand and gravel No significant change in atrazine concentration.	Papiernik and Spalding, 1998
Acifluoren	Process: anaerobic Inoculum: soil and sludge Co-metabolism with acetate enhanced rates	Gennari et.al., 1994
Bendiocarb	Process: aerobic Inoculum: bendiocarb enrichment Degraded by *Anabaena azollae*, a nitrogen fixing alga.	Singh et.al., 1990
Bensulfuron-methyl	Process: anaerobic Inoculum: enrichment culture – methanobacteria Co-metabolism Activity lost with time in non-controlled system but systems with low organics and strong buffering capacity remain active and stable.	Brusa and Ferrari, 1997

Table 5-1 continued

Carbofuran	Process: aerobic Inoculum: carbofuran enrichment Degraded by *Anabaena azollae*, a nitrogen fixing alga. Completely removed in 5 – 10 d	Singh et.al., 1990
Carbosulfan	Process: aerobic Inoculum: *Anabaena azollae*, nitrogen fixing alga which is found on the fern Azolla.	Singh et.al., 1990
CPTH	Process: aerobic Inoculum: soil Only 13 % removal in 99 d	Spanggard et.al., 1996
2,4 D	Process: anaerobic Inoculum: sediments Degradation of 2,4-D produced 4-chlorophenoxyacetic acid by ortho-chlorine removal.	Bryant, 1992
DDT	Process: aerobic Inoculum: *Pseudomonas putida* 531 ; *Enterobacter* sp. Strain 535 and *Pseudomonas* strain 537. 24 to 55 % converted to other metabolites	Subba-Rao and Alexander, 1985
	Process: aerobic Inoculum: white rot fungi Co-metabolism Nutrient limitation required	Arisoy, 1998
	Process: aerobic Inoculum: *Alcaligenes eutrophus* A5 DDT oxidised by dioxygenase. Hydroxylations at the ortho- and meta- positions on the aromatic ring	Nadeau et.al., 1994
Diuron	Process: aerobic Inoculum: pond water and sediment 67 to 99 % diuron degraded	Ellis and Camper, 1982
4,6-dinitro-ortho-cresol	Process: aerobic Inoculum: contaminated soil and activated sludge Batch cultures removed 61 % of the compound	Gisi et.al., 1997

Table 5-1 continued

Fenac	Process: aerobic Inoculum: sewage and lake water Nutrient supplemented lake water degraded 25 % in 30 d Nutrient supplemented sewage sludge degraded 40 % after 21d. Nutrient supplementation essential.	Rosenberg, 1984
γ-HCH	Process: aerobic Inoculum: rice fields Accelerated biodegradation when re-applied to non-flooded and flooded rice fields Degradation is a stepwise dechlorination following by ring opening.	Bharati et.al., 1998
α-HCH	Process: anoxic Inoculum: *Cyanobacteria anabaena* sp. Strain PCC7120; and *Nostoc ellipsosporium*. Requires a functional nir operon that encodes for enzymes for nitrate utilization.	Kuritz et.al., 1997
α,γ-HCH	Process: anaerobic Inoculum: polluted sediment Complete removal in anaerobic flow through system	Middeldorp et.al., 1996
Mecoprop	Process: aerobic Inoculum: sewage sludge – *Sphingomonas herbicidovorans* MH	Zipper et.al., 1982
Malathion	Process: aerobic Inoculum: compost from municipal refuse 98% degradation in 7 d	Kelkar et.al., 1982
Methyl Parathion	Process: aerobic Inoculum: compost 98 % degraded within 7d	Kelkar et.al., 1982
Quinolphos	Process: aerobic Inoculum: compost 80 % degraded within 7 d	Kelkar et.al., 1982

5.2. Clean-up Options for Soil Contamination

Soil contamination can occur from the indiscriminate use of pesticides and from accidental spills during transport and storage. The contamination should be treated in order to reduce environmental and health impacts. This section deals with some of the technologies that can be used to reduce or clean-up the contamination. The clean-up of soil and groundwater can consist of relatively simple techniques or more sophisticated methods. The applicability of the clean-up options depends on the following:

- The risk to human health and the environment posed by the observed contaminant.

- The financial resources.
- The nature of the use or redevelopment of the site.
- The nature and extent of the contamination present.
- The range of remedial technologies available

One of the easiest and least expensive is the implementation of institutional controls. These are not clean-up options *per se* but are designed to limit contact with contaminated soil. The costs involved are low and the method probably favours soil contamination that occupies a small area on the site. This method is probably similar to natural attenuation since no remedial action is taken. Another commonly applied technique for dealing with contaminated soil is capping. Capping minimizes the amount of precipitation that infiltrates contaminated soil, thereby, protecting the water table, and prevents direct contact with the contaminated soil by humans and wildlife. The capping material may be as simple as gravel, clay, asphalt or concrete. The lifespan of a properly designed cap can range from 20 to 60 years. Another commonly applied technology is the physical excavation and removal of contaminated soil material for treatment on or off site. The more conventional options for the treatment of excavated soil include incineration and off-site disposal in a landfill. Another option is biological remediation which uses bacteria to degrade organic pollutants. The more advanced treatment options include: the lasagna process, *In situ* vitrification, thermal desorption, OHM infrared thermal destruction unit, soil washing, and solvent extraction systems. Many of these technologies are in the developmental stage and have not been widely applied to contaminated soils but they do have the potential to clean-up either sites contaminated with specific wastes or a mixture of wastes (Tillotson, 1993). Some of the treatment options are discussed below.

5.2.1. Bioremediation

In situ bioremediation can be used to treat contamination by providing aeration and by adding nutrients and water to stimulate bacterial growth. Another bioremediation technique is the bioreactor, which is used to mix contaminated soil or sludge with water, nutrients, and oxygen to create a slurry. Or, contaminated solids can be placed in a lined bed with nutrients, moisture, and oxygen to promote degradation. Bioremediation technologies can also be used in conjunction with wastewater treatment to increase contaminant removal. Bioventing is a technique where oxygen is forced or pulled through the soil, stimulating aerobic bacteria and enhancing the bioremedial activity of the microorganisms.

One advantage of bioremediation is that it is a natural process. Therefore the bacteria increase in numbers when a food source (the waste) is present and decreases when the contaminant has been broken down. Furthermore, bioremediation does not merely transfer the contaminants from one place to another but destroys the target contaminants or may render them less hazardous. Bioremediation is also less expensive than other technologies. The major disadvantage of bioremediation is that it is often a slower process than other treatment technologies. In some cases, some degradation products may be more harmful than the original chemicals if the biodegradation process is incomplete. Different bacteria and plants treat different types of contaminants, so it may be difficult to comprehensively treat waste with a mixture of contaminants without significant pretreatment studies to determine the site requirements and what microbes and plants are needed to treat the present contaminants (MacDonald and Rittman, 1994; USEPA, 1996). Little data are available for complex waste mixtures. In some cases genetically engineered microorganisms may be required to clean up the contamination. The major advantage of mutant bacterial strains is that once the contaminants have been cleaned up, the bacteria should die because the contaminants (food source) have been eliminated. Other problems may result if private companies try to market their products too soon i.e. before the bacteria have been thoroughly tested and the controls understood (USEPA, 1996; USEPA, 1997).

Different bioremediaton methods have been tested at treating volatile organic compounds, petroleum products, chlorinated compounds, hydrocarbons, polynuclear aromatic hydrocarbons, pesticides, and some metals. Studies on contaminated sites have shown removal efficiencies to be greater than 99% for many contaminants. Bioremediation has been used extensively in recent years to clean up waste sites (USEPA, 1996). Different methods of bioremediation can be used to treat different contaminated media including soil, sludge, wastewater, and groundwater. There is no "one best method" of bioremediation. Each particular situation needs to be assessed to properly match contaminants, medium and microorganisms.

5.2.2. Natural Attenuation

Intrinsic Remediation (IR) or Natural Attenuation (NA) is the process of letting *mother nature* clean up contaminated sites. More technically, IR/NA is defined as *the reliance on natural processes, including volatilization, sorption, dilution, reactions with naturally occurring chemicals, and, most commonly, biodegradation, to decrease contaminant concentrations without human intervention other than careful monitoring*. This process is often appropriately described by community activists as a *do nothing* approach and is generally rejected outright when raised at sites where communities are organized and active (Powers and Rubin, 1996). The fundamental problem is that while, in theory, natural microbes can degrade some chemical it is not clear that this approach does anything more than allow clean groundwater to slowly spread the contamination, resulting in little more than a carefully monitored dilution of the problem. This approach is problematic for many reasons: (i) there is no treatment or cleanup of the contamination, (ii) the source continues to contribute to the problem, (iii) the company is not held accountable for the contamination they created, and (iv) it would take many tens, if not hundreds of years to let nature take its course before it is known if this process has worked.

5.2.3. Phytoremediation

Another form of bioremediation uses plants to "treat" contaminants. This is called phytoremediation. Phytoremediation uses a plant's natural abilities to take in water and nutrients through roots, evaporate water through leaves, and act as a filter to capture and breakdown organic compounds, like oil and pesticides, or to absorb and concentrate toxic trace elements, like lead and selenium. Phytoremediation has two components: plants that can absorb metals, and plants that can attract microorganisms that can speed up degradation of organic compounds like oil. Plant-based methods for treating heavy metals include: phytostabilization, which prevent metals from migrating through soil; phytoextraction, which removes the contaminants from the soil; and rhizofiltration, which removes contaminants from water. Phytostabilization can significantly reduce the mobility and the solubility of contaminants.

The roots of metal-accumulating plants absorb any residual lead and can also reduce the potential for groundwater contamination by reducing the total amount of water flowing downward (Dutton, 1996).

The benefits of this system are that it can provide low-cost, low-impact, natural, and environmentally sound remediation. It can be used as a primary method or a secondary process to aid in cleanup. However, the problem is that once plants have cleaned a site, they often become a disposal problem themselves because of the metals they have accumulated. Also, phytoremediation is a slow process and would not be suitable in situations that pose an immediate health risk. Furthermore, roots usually are limited to depths of 1 to 10 m and would not be effective in removing contaminants below such depths (Dutton,1996).

5.2.4. The Lasagna Process

The Lasagna™ technology was developed by a consortium of industry (Monsanto, DuPont, and General Electric) and government (EPA and the Department of Energy). It is designed for removing toxic compounds from dense, clay-like soil on-site. The process involves three phases: First, zones are designated in the soil to create vertical and horizontal treatment zones. Second, appropriate treatment materials, such as sorbates, catalytic agents, or microbes are injected into the treatment zones to create sorption or degradation zones. The third stage involves applying continuous low-voltage direct current between buried electrodes on either side of the treatment zones to slowly draw contaminated water out of the silt and clay, forcing it to migrate toward the negative electrode. The electric polarity is then reversed, recirculating the water through the treatment zones (Ho et al., 1995; Shannon, 1995)

The process is suited for treating low-permeability soils contaminated with compounds like trichloroethylene and perchloroethylene. Conceptually, the technology could treat organic and inorganic contaminants, as well as mixed wastes. Results from this field test on soil contaminated with trichloroethylene showed that an average of 98 % removal of trichloroethylene with over 99 % removal in some places. Trichloroethylene soil levels were reduced from 100 ppm to an average concentration of less than 1 ppm after four months treatment. The advantages of this technology are that it can be used to treat contaminated soil on site and no known by-products have been found as a result of the process (Ho et al., 1995; Shannon, 1995).

5.2.5. Thermal Desorption

Thermal desorption is a low-temperature heating process designed to remove volatile organic contaminants from soils and sludge. The process begins by heating the soil to temperatures between 80 °C and 472 °C to vaporize the contaminants (low enough temperatures to avoid combustion) and separate them from the solid matrix. The vaporized contaminants are collected and removed for further treatment or are disposed off-site. The treated solids then exit the unit and can be returned to their original location and compacted in place (if regulatory standards have been met).

Thermal desorption is designed to separate out organic contaminants such as volatile organic compounds (VOCs) that vapourize at relatively low temperatures. Other contaminants that are less volatile, such as PCBs and some polynuclear aromatic hydrocarbons (PAHs) may also be treated by thermal desorption, but removal of these contaminants will be lower. Thermal desorption is commonly used to treat hazardous waste.

Thermal desorption is a transportable treatment process, that has the advantage of reducing hazardous by-products that normally would result from incineration or pyrolysis. The disadvantage is that it does not destroy the contaminants, but simply transfers primarily volatile substances from the soil to the air where they have to be captured by air pollution controls and disposed of (CHEJ, 1987).

5.2.6. In Situ Vitrification

In situ vitrification (ISV) is a demonstrated technology used by Geosafe for remediation of contaminated soil, sediment, sludge, mill tailings, and other earthen materials containing hazardous and radioactive contaminants. The process works by melting soil in place using electricity applied between four graphite electrodes. Once the soil is molten, it becomes electrically conductive. Continued application of electricity results in heating within the molten soil between the electrodes. After the melt is fully established, the melt zone grows downward and outward through the contaminated soil. Once all of the contaminated area has melted, the current stops and the molten mass begins to cool. Inorganic contaminants in the soil are generally incorporated into the molten soil, which solidifies into a vitrified, glass-like mass. The organic contaminants are pyrolyzed and are reduced to simple gases. The gases move to the surface and are collected and then treated in an off-gas treatment system. The vitrified mass is hard and dense and reduces the possibility of leaching from the site (USEPA, 1995a).

The *in situ* vitrification system is designed to treat a wide range of volatile and semi-volatile organic chemicals, such as DDT, pentachlorophenol, and toluene, other organics including dioxins and polychlorinated biphenyls (PCBs), most metals and radionuclides, such as plutonium, uranium, lead, copper, mercury and arsenic. One concern with *in situ* vitrification is the production of contaminated vapours caused by the heating of volatile chemicals. These gases would have to be captured or they would escape into the surrounding community (USEPA, 1995a).

The *in situ* vitrification system has been shown to be effective in remediating soils and other earthen material, with total removal, destruction, or immobilization efficiencies (treatment mechanism depends on nature of the contaminant) running between 99.99 and 99.99999% for organics and inorganics alike. *In situ* vitrification has reached full-scale operation. The benefits of this treatment process are that waste is treated on site since the equipment is mobile and easy to set up. Furthermore, organic, inorganic, and radioactive contaminants are treated simultaneously. The disadvantages of this system are that it is best suited for treating material with a total organic content of less than 10 % by weight and the presence of large amounts of water in the treatment media may slow down the remediation process and increase costs. (USEPA, 1995a).

5.2.7. OHM Infrared Thermal Destruction Unit

The Thermal Destruction Unit developed by OHM uses high temperature incineration to destroy toxic waste. In this system, solids are fed into a combustion chamber on a conveyor belt where temperatures reach 976 °C. Organics are broken down into carbon dioxide, water, and hydrogen chloride. The thermal destruction unit is designed to destroy polychlorinated biphenyls and other organic contaminants. The system has been effective in treating PCB-contaminated soils with destruction removal efficiencies of over 99.9999% for polychlorinated biphenyls. An advantage of this unit is that it is mobile. The disadvantages of this system are that it won't handle liquids, and metals remain in the ash and need to be tested for toxicity before being disposed (Hay and McCartney, 1991).

5.2.8. Soil Washing

Soil washing uses liquids, usually water but sometimes combined with chemical additives, and a mechanical process to scrub soils in order to remove contaminants. The process begins by excavating the contaminated soil. The soil is screened and sifted to remove debris and large objects. The remaining material is placed in a soil scrubbing unit. The soil is then mixed with the washing solution and agitated. The solution removes a large portion of the contaminants. Soil washing can be used to treat both land-based soils as well as river and harbor sediments. Soil washing can separate both organic and inorganic constituents, including petroleum and fuel residues, radioactive contaminants, heavy metals, polychlorinated biphenyls, creosote, pesticides, and cyanides. Removal efficiencies depend on the type of waste present as well as the type of soil. The advantages of a soil washing system are that it can be cost-effective as a first step in a series of treatments because it reduces the amount of material that subsequent steps must process by as much as 90%. The equipment involved is mobile and can be moved to the site and it can convert the excavated soil into a more uniform consistency that can be more easily treated with other processes. The major disadvantage of soil washing is that additional treatment is usually needed to ensure safe disposal of the washed fine particles of clay, sludge and wash water (USEPA, 1996; USEPA, 1995g).

5.2.9. Solvent Extraction System

This system was designed to remove volatile and semi-volatile organic contaminants from soil and other solids. The process uses a solvent blend to separate hazardous constituents from soils, sediments, sludge, and debris. The soil is first excavated and loaded into the extraction tanks. The soil and solvent mixture is then held in the extraction tank long enough to solubilize organic contaminants into the solvent, separating them from the soil. The contaminant-laden solvent is then removed from the tanks and pumped into the sedimentation tanks. Suspended solids settle or aggregate in the tank, and are then removed. Any residual solvent in the soil is then removed using soil vapour extraction and biological treatment. The treated soils are then removed from the extraction tanks. The Terra-Kleen solvent extraction system is designed to remove polychlorinated biphenyls, chlorinated pesticides, polycyclic aromatic hydrocarbons, pentachlorophenol, creosote, polychlorinated dibenzo-p-dioxins, and polychlorinated dibenzofurans. Unfortunately, the system does not destroy the contaminants, but rather serves as a waste minimization process by removing and concentrating the contaminants so they can be collected and sent for treatment elsewhere (USEPA, 1996; USEPA, 1995j).

5.3. Clean-up of Contaminated Groundwater

As with the case of soil contamination, the clean-up of groundwater also depends on the risk, finances and nature and extent of the contamination. Many of the options that have been discussed for soil contamination have the effect of limiting contamination of groundwater through reduced infiltration, reduced mobility of contaminants, physical removal of source area, or treatment of the source area to remove contamination. However, none of these systems have the ability to remove dissolved contamination in groundwater (Tillotson, 1993).

Groundwater that has been contaminated with organic or inorganic constituents present in the dissolved phase is most effectively cleaned up in the vicinity of the source area through installation of a multi-well pump and treat system. A series of recovery wells are installed at strategic locations within the groundwater contaminant plume. Groundwater is extracted continuously from the wells and directed to an above ground treatment system such as a bioreactor. The nature of the contaminants may require that a complex air stripper, bioremediation or other system be designed to treat groundwater. Combinations of pump and treat and vacuum extraction are common in the USA where dual purpose wells are constructed. The injection of air (sometimes heated) increases the volatilization of the compound which are then captured by the vapour extraction system. The timeframe for treating contaminated groundwater sources and returning them to near-pristine conditions is about 30 years. This method of treatment can be expensive and sometimes the cost of clean-up can be greater than the value of the land (Tillotson, 1993 ; Verheul et.al., 1993). Although cost for clean-up of contaminated sites can be expensive, the increasing public pressure on government and industry for a cleaner environment is playing a major role.

CHAPTER SIX

Discussion and Recommendations

6.1. Discussion

Firstly, this study was aimed at providing a comprehensive schedule of pesticide use. This report documents sales as being representative of pesticide use since the users of pesticides keep no annual records or there is no lead government department or chemical association documenting annual use. Thus, this report makes the assumption that the pesticides that are purchased are used immediately or during the short-term period. It also makes the assumption that since it is difficult to store pesticides, it will not be bought in bulk. In reality, however, it is likely that over-zealous sales may lead to buying of bulk stocks of pesticides.

The Food and Agriculture Organization (FAO) data for 1993 shows that the percentage of pesticides used by Africa is significantly lower that Western Europe and North America. However, South Africa is a leading user in Africa. This report documents pesticide sales in South Africa from 1994 to 1998. The information was obtained from the chemical industry umbrella association, AVCASA (Crop Protection and Animal Health Association), which represents majority of the 165 chemical companies in South Africa. The pesticide data includes sales to the agricultural, ornamental, and forestry sector. It does not include sales to industry, government, and the public. Most of the sales for 1997 to 1998 are for triazines, organometallic compounds, aniline and organochlorine pesticides. The quantity of biological control agents was not significant but this trend may change as global pressure forces integrated pest management and sustainability. The pesticide sales data also showed that herbicides sales were the highest. Since 1994 there has been an increase in the total sales of pesticides which suggests that there may be a potential increase in obsolete stocks in future if the correct management, training and education structures are not in place.

The second part of this study was to document the scope of the pesticide problem in South Africa and in Southern Africa. In this study, obsolete pesticide stocks include pesticides that have been banned or are unwanted. They also include pesticide stocks that are not in a usable form or products that have expired or are no longer registered. In South Africa, no databases have been or are being kept on the annual obsolete pesticide accumulation. In 1998, The South African government undertook to finance the collection and shipment of obsolete pesticides from South Africa and the National Department of Agriculture elected AVCASA to manage the drive. In 1999, after an extensive retrieval and disposal drive, the inventory volume was 1050 tons. These obsolete pesticides had accumulated over a 30-year period. The obsolete pesticides had been retrieved from 45 bulk collection sites around South Africa. In November 1999, 740 tons of highly toxic obsolete pesticides and unknowns were exported to Shanks, Wales for incineration. Enviroserv disposed the remaining 250 tons at the Holfontein landfill site. At this point, South Africa was considered to be technically clean. The South African government and donor organizations had contributed R13 million and R 300 000, respectively.

In 2000, however, reports from farmers suggested that South Africa still contained obsolete stocks because they had not been aware of the drive. This is not unexpected since the Department of Agriculture reported a low return from its postal survey. This suggests that further pesticides stocks may still be present on farms. In addition, obsolete pesticide stocks may be higher since the drive did not cover government facilities and industrial sites. These reports suggest that more funds will need to be made available for future disposal drives, which according to Kleynhans (2000) will have to be funded by the chemical industry. It is also likely that future transboundary disposal (i.e. incineration) from South Africa to another country will not be allowed. Thus, South Africa will need to look at ways of disposing highly toxic pesticides nationally.

The third objective of this project was to review some of the existing technologies for the disposal of obsolete pesticides. This section was expanded to cover soil and water contamination. Thermal, chemical, physical and biological treatment methods are reviewed. Incineration remains one of the common methods for the disposal of obsolete pesticides because it significantly reduces the wastewater volume. However, most thermal disposal methods are criticized because of the formation of dioxins and furans when treating chlorinated wastes. Some of the advanced treatment options tries to deal with chlorinated wastes by chemically removing it. The closed loop detoxification and Eco-logic systems are based on catalytic steam gasification and hydrogen-rich gas phase chemical reduction which hypothesizes no dioxin and furan formation. Existing incinerators deal with the latter by installing scrubbers and sorption systems to remove hydrochloric acid, inorganics and organics of incomplete combustion. However, the Eco-Logic system appears to be the most promising since it is already in operation in two countries and deals with the problem of chlorinated compounds prior to the burning process. The other new innovative technologies sound exciting and appear to solve some of the problems associated with incineration but it still requires more comprehensive field testing in order to be accepted as a disposal option for the destruction of hazardous wastes. It is important to bear in mind that these advanced thermal technologies can create similar problems experienced with incineration if not effectively maintained and operated by skilled staff.

The chemical and physical treatment options discussed are not stand-alone technologies and a secondary disposal option such as landfilling may be required. Biological treatment is definitely an option for contaminated land and groundwater since contamination sites can be bioaugmented with acclimated microorganisms or genetically engineered organisms. This is a long process of remediation. In the case of groundwater contamination microorganisms can be added to the water system with oxygen and nutrients or the groundwater can be pump and treated in a bioreactor above ground. The use of bioreactors to treat obsolete pesticide stocks will prove more challenging. The treatment of single pesticides will be possible but mixtures may prove more difficult to control and optimize. If bioreactors are to be used to treat obsolete pesticide stocks, it will have to be in high rate reactors operating at longer retention times and with acclimated biomass. No single technology can be applied for hazardous waste disposal due to the variations in chemical structures and concentrations. However, a provision of options within a framework policy may be useful in managing and expediting disposal of hazardous pesticides.

6.2. Recommendations

Pesticide use in all sectors should incorporate cleaner production techniques and sustainable strategies, which should result in a reduction in obsolete pesticide stocks. It is necessary to move from traditional pest management to Integrated Pest Management. The main aim should be to reduce pesticide use and achieve sustainability while catering for the food demand. This can be achieved by:

- Training / workshops in the field of pesticide application.
- Promotion of Integrated Pest Management.
- Training for the evaluation of exposure and risks
- Providing incentives to the farmer for using less pesticides
- Controlling pesticide quality and quantity
- Adoption of stringent monitoring programs
- Provision of disposal options to the user
- Creation of a hazard ranking system of contaminated sites.

South already has the legislation to control and regulate pesticides and with the National Environment Management Act (NEMA), there appears to be a strong desire to protect the environment for future generations. However, it is equally necessary that South Africa have the capability of enforcing its legislation in a controlled manner without placing undue costs on the manufacturer/supplier and the user. At present South Africa and most of its neighbours, except Mozambique, have relatively little or no obsolete pesticide stocks. However, if no disposal options are forthcoming, there is likely to be an accumulation of pesticide waste, illegal dumping and an abandoning of contaminated sites in future.

To this end, it is necessary the South Africa provide its users with all the tools necessary to use, store, transport and dispose pesticides in a responsible manner. Several technologies have been discussed under disposal options. No one technology will solve all of South Africa's past or future contamination woes. However, it is necessary that contingency plans be in place to deal with pesticide waste. It is possible that incineration may be the best available control technique for the destruction of hazardous waste if designed, built and operated specifically for hazardous waste. However, it is unlikely that the option of a high-tech waste incinerator would be feasible in South Africa. It is also necessary that treatment options like bioremediation are accessible for soil and groundwater contaminated sites. It is highly probable that an integrated hazardous waste disposal approach will be necessary to handle pesticide wastes.

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APPENDIX A

Public Perception of Pesticides: Newspaper Headlines.

Saturday Independent - 21/09/00

Herbicide debate crops up again

y CLAUDIA MPTTA

ESPITE being one of the components in he "Agent Orange" defoliant used by the nited States during the Vietnam War, a erbicide called 2,4-D is still being used by outh African farmers on food products.

According to the London Food ommission, 2,4-D can cause cancer and an cross the placental barrier and affect hildren in the womb. It has also been eported to cause damage to the nervous ystem.

2,4-D is being used by South African rmers on sugar cane, mielies, wheat, arley and rye produced in the country.

Controversy around the hormone herbicide first surfaced in KwaZulu-Natal in 1988 when farmers adjacent to fields where 2,4-D was used complained of crop damage. Hormone herbicides work by causing deformities in the growth cells of broad-leaf plants.

South Africa is currently participating in a United Nations-driven initiative that seeks to phase out and eliminate a "dirty dozen" list of identified toxic chemicals, including eight pesticides.

Dr Carl Albrecht, national research co-ordinator for the Cancer Association of South Africa, believes that pesticides could be a factor in causing cancer and says the use of pesticides should be decreased and controlled. But there are dissenting views, specifically about 2,4-D.

"It is a very simple molecular herbicide," says Professor Gerhard Verdoorn of the Endangered Wildlife Trust's Poison Working Group.

He said it was not toxic to humans or animals but, if it was used incorrectly, it could have a negative effect on plant life. However, he said "extremely large doses" would be required to have any negative effect on humans.

He said it was sold in accordance with legislation which says that no limitation needed to be placed on who could buy 2,4-D.

Poisonous containers pose threat

Business Day. Monday 21 August

Louise Cook

THE Poison Working Group, which is part of the Endangered Wildlife Trust, is concerned about the large number of empty pesticide and herbicide containers in SA.

These containers are highly poisonous, but are often used for drinking and cooking purposes or to carry paraffin.

This is despite past efforts to ship all remaining containers to Wales for incineration. The containers are mostly found on farms in the Eastern Cape, Gauteng, the Northern and North-west provinces, while the health and agriculture departments also are still storing "large quantities" of the empty containers.

The issue was raised in the wake of the illegal dumping of huge amounts of medical waste in Gauteng. Disposal problems also existed with banned agrochemical substances like DDT and Dieldrin. Other pesticides and herbicides, which did not contain DDT or Dieldrin, also remained a risk to the environment and health, Poison Working Group chairman Gerhard Verdoorn said.

He estimated that between 50 and 100 tons of containers had missed the boat to Wales and still posed a health risk.

40 MONITOR/NOTICE BOARD

Danida denies 'dirty-waste' trade

Thomas Schjerbeck
RIGHT TO REPLY

Matola stews over Danish plans to burn pesticides

Mercedes Sayagues

Activists are battling to stop a Danish funded project to burn pesticides in a dilapidated cement factory in Matola, near Maputo.

Burning toxic waste in cement kilns creates dangerous cancer-causing compounds known as dioxins and furans. Strict standards must be maintained for safety. It is doubtful whether the Portuguese-owned factory, which has a dismal worker-safety and pollution record, and Mozambique's lax and corruption-ridden administration can enforce them.

"This factory would not be open for one day in Denmark," scoffs António Reina, regional director of the Endangered Wildlife Trust.

Reina belongs to an informal coalition of environmental and community activists called Livaningo ("to shed light", in Shangaan) that has been fighting the proposal since mid-1998.

On paper, the project has a worthy goal: to help Mozambique dispose of 500 tons of obsolete pesticides — 42 tons containing products banned worldwide, ranked as class one, the most dangerous — while creating a national capacity to deal with toxic waste.

The Danida-funded project recommended that a Danish firm, Mohlberg & Thorsen, would set up a waste station in Matola. MGP, a Danish firm, did the environmental impact assessment. The total cost was $9,8 million.

However, a second, independent assessment demanded by Livaningo concluded that exporting the pesticides would be cheaper and safer. It would cost $3,2 million to return about 250 tons to the original producers, Bayer and Monsanto, and send the remainder to, for example, Holfontein in South Africa, 600km from Maputo.

Even more alarmingly, activists discovered that the Mozambican government had authorised in 1996 an obscure company called International Waste Group Mozambique (IWGM) to import hazardous waste from abroad for disposal in the country.

This would contravene three major international conventions to stop the dumping of toxic substances into poor countries willing to take them for a price: Bamako, Lomé IV and the Basel convention which Denmark championed. Livaningo wonders whether the incineration of pesticides would be a test for later burning of imported toxic waste.

Denmark hotly denies any link between the two projects, but as Greenpeace speculated: "Denmark appears willing to facilitate dirty-waste trade by giving away waste-attracting and polluting Danish technology to establish a waste station that could end receiving hazardous waste from Europe and North America."

Francisco Mabjaia, secretary general at the Ministry for the Environment, says the authorisation for IWG has since been revoked.

However, even without imported toxic waste, the incineration of pesticides in Matola is worrisome enough.

Clouds of dust frequently hang over the city, Mozambique's second largest. Two weeks ago, residents called Livaningo to report that the factory chimneys were spewing dense, black smoke. It turned out the electrofilters were down for 40 minutes. Residents complain of a high incidence of respiratory diseases. Asthma and bronchitis are chronic among children.

Another problem is the storage of 500 tons of obsolete pesticides at the waste station set up in the old warehouse of agricultural company Boror, in Matola, along a busy avenue, among factories, shops and homes, close to old, leaky water pipes that could easily be infiltrated with residual toxins.

The second environmental impact assessment says that choosing the Boror warehouse was "a mistake, given its physical risks and proximity to residential zones and eco systems".

> 'Matola is not Mozambique's rubbish bin and we want that rubbish out of here'

The site was already contaminated, as scientists have denounced since 1995, and was not decontaminated before storing this batch of old pesticides.

Last week, the Food and Agriculture Organisation warned about the danger posed by faulty storage of obsolete pesticides in developing countries, where metal drums are corroding and leaking and could contaminate irrigation and drinking water.

Reina says drums at Boror have been left uncovered and unlabelled, and some have exploded due to heat. Residents say that when pesticides leaked out during last season's heavy rains, surrounding grass yellowed and died. The liquid was hosed out to a nearby lagoon. Unconfirmed reports from neighbours say two people died after eating fish from the lagoon.

Danida official Peter Larsen declined to comment. "The decision is in the hands of the Mozambican government and we will abide by it, but we stand by our study," said Larsen.

As Livaningo informed residents, anger mounted. Neighbours wanted to march to Maputo to deliver a protest to Minister of the Environment Bernardo Ferraz.

"Matola is not Mozambique's rubbish bin and we want that rubbish out of here," said Eduardo Eugenio Mbalonga, a resident.

On May 15, about 40 community and church leaders met Livaningo to discuss the second assessment. They proposed to create neighbourhood committees, to meet the municipal council, "and if we need to go to the streets, we shall go", said one.

> 'Incinerating toxic waste is contested in Europe and Denmark is bringing its polluting technology here' -

A grassroots movement not linked to a political party is a new phenomenon in Mozambique. This is the first time that civil society has successfully mobilised over an environmental issue and challenged a state approved and donor funded project.

Environmental activists were alerted last year by an article in the daily Metical. Janice Lemos, an executive secretary at the Polana hotel with no green experience, contacted Greenpeace. In August, two toxic waste incineration specialists arrived in Maputo and met concerned NGOs.

Livaningo says Danida has been arrogant, not responding during months to its letters. Although invited, Danida did not attend its first press conference last August. Danida only agreed to meet Livaningo after it threatened a sit-in at the Polana while a Danida auditing team was visiting.

Livaningo sent Aurelio Gomes in October to explain its objections to the Danish Parliament and press.

"Incinerating toxic waste is contested in Europe and Denmark is bringing its polluting technology here," says Lemos. "This double standard is not fair."

The Ministry for the Environment agreed to a second, independent environmental impact assessment carried out earlier this year by consultant firm Impacto, with British firm Environmental Resources Management and the South African Council for Scientific and Industrial Research. Its results, critical of incineration, were discussed at public meetings in Matola and Maputo.

Mabjaia points out that the ministry has made concessions, agreeing to a new assessment, consulting residents and improving technical aspects, but Livaningo has made none.

"Livaningo is doing its job awakening civil society," he says, "but we must do ours, creating a national capacity to deal with toxic waste without depending on other countries."

The project is on hold, waiting for Ferraz to make up his mind.

APPENDIX B

Pesticide Sales in South Africa from 1994 to 1998

Appendix B shows the total sales (as volume active ingredient - kg or l) from 1994 to 1998. It includes the sales of pesticides for agriculture, forestry and ornamentals but excludes sales from the governmental and industrial sectors.

Table B1: Crop protection product sales (volume ai – kg or l) for herbicides

Herbicides	**1994**	**1995**	**1996**	**1997**	**1998**
Triazine	3,140,263	2,800,653	3,611,219	3,454,238	3,823,982
Aniline / Acetanilide	1,805,250	1,684,775	1,509,342	2,230,840	2,250,696
Organophosphorus	594,327	790,424	819,260	1,480,278	1,524,090
Fenolic	310,083	371,801	402,708	454,225	406,803
Urea / Thionylurea	316,246	282,626	263,711	312,330	374,221
Carbamate / Thiocarbamate	548,457	435,462	404,570	274,057	285,142
Pyridine derivative	246,865	279,009	269,713	412,721	236,187
Inorganic / Organometallic	84,755	105,764	53,680	190,343	227,943
Aliphatic acid	192,934	209,918	233,665	227,487	205,216
Hydroxybenzonitrile	144,680	190,075	231,994	192,811	133,942
Unclassified	89,773	97,69	78,802	97,260	67,791
Aliphatic amine / amide	89,590	80,068	20,952	48,113	64,603
Imidazole	9,325	10,410	8,734	17,152	24,183
Heterocyclic derivative	14,607	15,750	7,513	13,507	18,292
Benzoic acid derivative	24,542	31,159	4,666	22,826	11,476
Total	**7,611,697**	**7,277,484**	**7,920,529**	**9,428,188**	**9,654,567**

Table B2: Crop protection product sales (volume ai – kg or l) for insecticides

Insecticides	1994	1995	1996	1997	1998
Hydrocarbon	1,481,385	1,092,773	459,657	457,243	1,764,879
Organophosphate	1,066,880	1,200,882	1,341,846	1,367,792	1,537,874
Carbamate / Thiocarbamate	297,639	318,218	323,848	376,127	423,396
Organochlorine	211,758	203,276	202,342	214,872	220,156
Pyrethroid	66,303	62,518	81,760	84,720	87,583
Unclassified	113,545	94,447	79,381	12,639	48,956
Amine	15,436	17,637	22,287	20,601	27,209
Inorganic / Organometallic	60,267	78,867	129,436	65,257	20,531
Biological					19,455
Triazine / Tetrazine	7,297	8,867	6,806	5,486	4,722
Urea / Thiourea	5,195	11,254	3,513	5,643	4,007
Phenolic / Phenoxy	2,078	1,462	965	2,086	1,527
Total	**3,327,783**	**3,090,201**	**2,651,841**	**2,612,466**	**4,160,295**

Table B3: Crop protection product sales (volume ai – kg or l) for acaracides

Acaracides	1994	1995	1996	1997	1998
Inorganic / Organometallic	36,249	43,179	35,276	30,130	25,891
Unclassified	17,613	22,167	9,721	5,651	16,109
Phenyl derivatives	12,791	15,910	12,330	4,558	11,900
Organochlorine	1,770	1,712	4,005	5,599	6,709
Urea / Thiourea	65	1,262	1,082	882	946
Antibiotic	132	81	15	153	460
Triazine / Tetrazine	380	360	323	161	227
Oime / Oxime Ether	146	109	67	90	72
Pyrethroid	14	7	0	0	0
Total	**69,160**	**84,787**	**62,819**	**47,224**	**62,314**

Table B4: Crop protection product sales (volume ai – kg or l) for fungicides

Fungicides	1994	1995	1996	1997	1998
Inorganic / organometallic	1,898,671	3,109,300	3,143,195	3,503,251	3,371,273
Carbamate / Dithiocarbamate	975,432	1,513,408	1,669,435	2,651,093	2,488,899
Organochlorin	148,533	220,408	230,073	172,852	190,587
Unclassified	96,916	101,700	131,792	141,444	134,647
Benzimidazole	56,156	67,240	80,782	106,034	131,627
Triazine	84,338	89,341	120,851	150,359	100,577
Organophosphorus	30,296	33,166	42,580	101,793	62,181
Dicarboximide	20,841	27,210	12,263	27,738	27,443
Pyrimidine / Pyridine	11,854	13,694	18,948	29,453	19,386
Amine / Amide	12,974	18,579	32,870	17,911	17,685
Urea	3,552	5,404	8,396	9,335	16,877
Strobilurin					9,398
Phenolic	5,107	5,898	5,645	6,882	5,993
Triazole	4,426	4,194	8,949	4,560	4,007
Mineral oil		743	225	2,025	2,950
Acylalanine	2,602	1,589	2,765	3,909	771
Total	**3,351,698**	**5,211,874**	**5,508,769**	**6,928,639**	**6,584,301**

Table B5: Crop protection product sales (volume ai – kg or l) nematicides

Nematicides	1994	1995	1996	1997	1998
Organochlorine	660,613	798,220	1,497,246	539,920	1,711,549
Carbamate / Thiocarbamate	137,142	202,820	203,410	238,031	218,438
Organophosphate	77,440	89,769	104,561	100,149	110,426
Unclassified	2,619	6,286	11,809	25,816	25,530
Oxime / Oxime Ether	9,613	13,080	33,216	16,743	20,645
Total	**887,427**	**1,110,175**	**1,850,242**	**920,659**	**2,086,588**

Table B6: Crop protection product sales (volume ai – kg or l) for defoliants

Defoliants	1994	1995	1996	1997	1998
Inorganic / Organometallic	1,942	1,980	11,243	7,484	14,304
Urea / Thiourea	55	6	64	144	659
Unclassified	1,832	2,106	3,846	2,544	288
Benzoic acid derivative	47	218	0	192	0
Organophosphorus	1,356	74	89	0	0
Total	**5,232**	**4,384**	**15,242**	**10,364**	**15,251**

Table B7: Crop protection product sales (volume ai – kg or l) for PGR's

PGR's	1994	1995	1996	1997	1998
Hydrocarbon	1,058,940	1,071,630	1,283,328	1,298,736	1,211,891
Unclassified	31,389	24,289	15,504	36,855	105,930
Aliphatic amine / amide	23,261	29,590	20,171	42,784	85,153
Fenolic	39,710	40,186	48,125	48,703	43,069
Organophosphorus	5,932	11,782	15,714	12,463	21,733
Inorganic / Organometallic	791	11,350	11,115	8,935	10,198
Aliphatic acid	4,222	13,964	12,377	6,901	6,691
Heterocyclic derivative	578	2,965	3,362	3,356	5,911
Aniline / Acetanilide	2,522	1,159	2,292	1,464	4,525
Benzoic acid derivative	7,832	2,770	2,434	4,336	3,026
Total	**1,175,177**	**1,209,685**	**1,414,422**	**1,464,533**	**1,498,127**

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