UNIVERSIDADE FEDERAL DE SANTA CATARINA
CENTRO TECNOLÓGICO
DEPARTAMENTO DE ENGENHARIA SANITÁRIA E AMBIENTAL
ENS 5502 – Estágio Supervisionado

RELATÓRIO FINAL DE ATIVIDADES: FLORICULTURE WASTE MANAGEMENT: BEST MANAGEMENT PRACTICES TO ETHIOPIA

(GERENCIAMENTO DE RESÍDUOS SÓLIDOS NA FLORICULTURA: MELHORES PRÁTICAS DE GESTÃO PARA ETIÓPIA)

Por
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FLORIANÓPOLIS/SC
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1 INTRODUÇÃO

O uso ostensivo de pesticidas e fertilizantes, uma das principais causas de impactos ambientais na atualidade, contribui para o aumento significativo da produção agrícola, e, consequentemente, para a maior disponibilidade de alimentos a produtos de base vegetal. A floricultura é atividade chave para a economia na Etiópia, no entanto traz consigo contaminação do meio-ambiente e de pessoas por pesticidas.

Pesticidas degradam o meio-ambiente porque muitos são agentes recalcitrantes, não degradam facilmente, e, desta forma, bio acumulam através da cadeia alimentar, causando problemas gênicos em nível específico e também problemas ecológicos mais gerais por afetarem todo ecossistema. Por sua vez, fertilizantes são os principais responsáveis pela eutrofização dos ambientes aquáticos, processo que se caracteriza pelo grande crescimento de algas em ambientes que recebem excessiva quantidade de nutrientes, causando a posterior morte de outros organismos devido à diminuição das concentrações de oxigênio dissolvido na água quando as florações de algas degradam.

Contrariamente aos malefícios ambientais causados por pesticidas e fertilizantes, desde o início da utilização de pesticidas e fertilizantes sintéticos na agricultura, por volta dos anos 50-60, a produção vegetal no mundo expandiu consideravelmente. Considerando este fato, pesticidas e fertilizantes são importantes químicos para a garantia de produtos agrícolas no mundo, onde massivas quantidades de vegetais são necessários para suprir a população atual.

Neste cenário, onde pesticidas e fertilizantes precisam ser utilizados para a garantia de produtos agrícolas no mundo, o gerenciamento ambiental de resíduos contaminados com pesticidas e fertilizantes precisa ser adotado para a minimização dos impactos ambientais das atividades agrícolas. Melhores práticas para o tratamento de materiais contaminados com pesticidas e fertilizantes, como embalagens contaminadas, bem como para pesticidas e fertilizantes obsoletos, ainda são limitadas. Em muitos locais do mundo estes compostos são dispostos no meio-ambiente sem tratamento prévio, principalmente em países em desenvolvimento e subdesenvolvidos, devido a falta de recursos financeiros e capacidade técnica para adotar elaboradas técnicas, com altos custo. Considerando-se que pesticidas e fertilizantes são utilizados massivamente em países em desenvolvimento, nos quais é maior produção agrícola, soluções eficientes e econômicas para o tratamento destes químicos precisam ser desenvolvidas com urgência para contenção da degradação ambiental.

Este relatório objetiva apresentar os resultados das atividades desenvolvidas pelo aluno Abel Silva Vieira, do curso de graduação em *Engenharia Sanitária e Ambiental* da *Universidade Federal de Santa Catarina* durante seu *Estágio Final* de graduação na empresa holandesa *Waste – advisers on urban environment and development*, de 01/12/2008 a 28/02/2009. O tema do projeto foi estabelecido depois da convocação da empresa Waste para realização de consultoria ambiental que pesquisasse e sugerisse técnicas de tratamento para embalagens de pesticidas e fertilizantes, bem como fertilizantes e pesticidas fora da validade, aplicáveis à realidade econômica e geográfica da floricultura na Etiópia. Para este projeto as seguintes atividades foram desenvolvidas pelo aluno:

1. Análise de literatura sobre a produção de flores na Etiópia fornecida pela empresa WASTE;
2. Revisão bibliográfica sobre melhores práticas no gerenciamento de pesticidas e fertilizantes e suas embalagens com prazo expirado;
3. Proposição e recomendações no estabelecimento de um sistema de gerenciamento de lixo perigoso, incluindo coleta e tratamento eficiente e seguro de embalagens contaminadas e fertilizantes e pesticidas expirados;
4. Apoio a procura de técnicas e práticas para a redução da quantidade de lixo perigoso que deve ser descartado;
5. Apoio a procura de melhores soluções para o descarte de lixo perigoso;
6. Relatório final sobre o assunto fornecido à WASTE em 2 a 3 meses.

No ANEXO I consta a avaliação de desempenho do estagiário e no ANEXO II são relatados os resultados do trabalho desenvolvido.

2 AVALIAÇÃO DAS CONDIÇÕES DE TRABALHO

As condições de trabalho foram favoráveis durante todo o período. As principais fases deste trabalho foram: discussão do tema, recebimento de informações e pesquisa bibliográfica, e elaboração de relatório técnico sobre o tema. Em todas as fases a supervisora da empresa, Lilliana Abarca, esteve em contato, acompanhando as atividades e criticando o produto obtido ao longo do projeto. Da mesma forma, o estagiário esteve sempre presente para a discussão e o melhoramento do projeto. Assim sendo a cooperação mútua foi ponto chave para o desenvolvimento deste projeto. O clima de amizade e a troca de conhecimento foram muito apreciados também. Concluindo, em todos os momentos problemas estiveram ausentes. O estágio propiciou inestimável valor e aprendizado para o aprimoramento do aluno Abel Silva Vieira como graduando.

ANEXO I

AVALIAÇÃO DE DESEMPENHO DO ESTAGIÁRIO

Universidade Federal de Santa Catarina
Centro Tecnológico
Departamento de Engenharia Sanitária e Ambiental
Coordenadoria de Estágios

Internship Evaluation / Avaliação de Estágio

Student's Full Name: Abel Silva Vieira
Registration Number: 02240203
Company: Waste – advisers on urban environment and development.
Address: 201 Nieuwehaven, Gouda/CW - The Netherlands. Zip Code: 2801
Internship period: from 01/12/2008 to 28/02/2009
Project title: Floriculture Waste Management: Best Management Practices to Ethiopia

✓ **Evaluation 1 (Company Supervisor)**

General Knowledge	90
Specific Knowledge	N.A
Frequency	100
Creativity	90
Responsibility	100
Initiative	100
Discipline	100
Sociability	100
Oral expression	N.A
Written expression	85
Median Score	

Comments: Written expression English is not his mother tongue language & the topic neither.

Date: 15-06-09
Company Supervisor Signature and Stamp:

✓ **Evaluation 2 (ENS supervisor)**

Comments:

Date:
ENS Supervisor Signature and Stamp:

✓ **Final Score:**

Nome do aluno: Abel Silva Vieira
Matrícula: 02240203
Empresa: Waste – advisers on urban environment and development.
Endereço: 201 Nieuwehaven, Gouda/CW – The Netherlands. Zip Code: 2801
Período do estágio: de 01/12/2008 a 28/02/2009

Conhecimentos gerais	
Conhecimentos específicos	
Assiduidade	
Criatividade	
Responsabilidade	
Iniciativa	
Disciplina	
Sociabilidade	
Expressão oral	
Expressão escrita	
Média	

Título do trabalho: Gestão de Resíduos na Floricultura: Melhores Práticas para a Etiópia.

✓ **Avalição 1 (supervisor da empresa)**

Comentários:

Data:
Assinatura e carimbo do supervisor da empresa

✓ **Avalição 2 (supervisor ENS)**

Comentários:

Data:
Assinatura e carimbo do supervisor do ENS:

✓ **Média Final:**

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Coordenador de Estágios - ENS

ANEXO II

FLORICULTURE WASTE MANAGEMENT: BEST MANAGEMENT PRACTICES TO ETHIOPIA

Author: Abel Silva Vieira
Supervisor: Lilliana Abarca

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1 Introduction

All around the world hazardous waste is one of the most problematic by-products of most of production systems. Regarding the floriculture sector, it is not different, where the use of pesticides and fertilizers in its production is harmful to either human beings or nature. In an effort to achieve both environmental and economical sustainable development, manufactures ought to reduce and mitigate the environmental problems from their activities. Thus, specifically to the agriculture sectors, a reduction and treatment of their main hazardous waste (pesticides and their containers) as well as non-hazardous (fertilizers and other waste streams) could give rise to more profitable and environmental friendly businesses.

The treatment of hazardous waste encompasses a huge range of chemical, physical and biological processes. Such processes can destroy, convert or detoxify hazardous waste. However, prevention and waste minimization are generally greater options than treatment, as seldom there are cheap to run treatments.

In one hand, physical processes can be either macro processes, such as filtration, centrifugation, and floatation, or molecular-ionic processes, such as ion exchange, reverse osmosis, ultrafiltration, carbon adsorption, liquid absorption, and air stripping (Roberts, Teaf and Bean 1999). On the other hand, chemical processes encompass another breach of treatment, such as:"thermal processes (incineration, calcinations, volatilization, catalytic oxidation, etc), wet processes (chlorinolysis, hydrolysis, neutralization, electrolysis, chemical oxidation/reduction), and precipitation process" (such as coagulation). The biological process is the third array of treatment options, which covers: "activated sludge, soil vapour aeration and extraction, bioremediation, aerated lagoons, anaerobic digestion, composting, and others". Hardly ever will just one of these processes be sufficient to treat a hazardous waste, as pollutants suffer changes in their physical states.

According to Alterra, the floriculture sector in Ethiopia deals with their hazardous waste (pesticide packing material) burying or burning it. Both practices are extremely dangerous for human health and the environment, as burning (low temperature process) does not destroy pollutants, and burying does not guarantee that pollutants will be immobile for a long term. Thus, where these practices are developed, it increases the likelihood of environmental contamination with hazardous substances in air, water, ground water and soil. The floriculture sector in Ethiopia is concentrated in Ziway, Holleta, Sebeta, Debre Zeit, Koka and Addisalem, at the Rift Valley region in Ethiopia. The rift valley is a large area, which covers Ethiopia and other eastern African countries. This region has several large lakes without outlets and with a great biodiversity, where pollutants can concentrate and harm wildlife. Besides, Addis Ababa, with about 4 million people, is in the Rift Valley, and depends on this water resource. Therefore, to develop adequate treatment facilities for hazardous waste and wastewater treatment will protect human health and the environmental. Besides, hazardous waste reduction programmes will also help such improvements in the Rift Valley in Ethiopia.

The present project aims to guide Ethiopian floriculture sector towards a more sustainable development. Here we will appoint options of treatment and reduction of hazardous and non-hazardous waste (expired pesticides and fertilizers, used containers, contaminated materials, deteriorated or unusable chemicals and excess pesticide supplies) that can be applied in the floriculture sector in Ethiopia in order to overcome environmental and human health deterioration.

2 Pesticides

"All pesticides are toxic to some or all living organisms" (FAO 1999). Such toxic characteristic makes pesticides to be considered hazardous waste. Definitely, it is the most important chemical component of the agriculture waste stream. In one hand pesticides prevent, destroy or control pests. On the other hand, even in very small quantities they may threaten the health of farm animals, wildlife, and people (FAO 1999). As a consequence, most of the people in the globe have already been exposed to pesticides (Hirschhorn & Oldenburg 1991). All around the world pesticides lead to approximately 20.000 deaths and 3 million poisoning cases each year (FAO 1999). "Other estimates suggest that the annual figure for pesticide poisonings is as high as 25 million in developing countries alone" (FAO 1999).

Pesticides can bioaccumulate in animals and plants, and affect the whole food-web. They can have acute and chronic toxicity effects on mammals, birds, fish, invertebrates, and so on. To human beings, pesticides can cause: cancer, endocrine disruption, reproduction problems, development problems, acetyl cholinesterase inhabitation, neurotoxicity, respiratory tract irritation, skin irritation, eye irritation, malformations of an embryo or fetus, among other health issues.

2.1 Environmental fate

After the application, pesticides can spread out in the surrounding environments, reaching the air, waters (rivers, lakes, ground water, and sea). When it occurs, chemicals are wasted, target pests are not controlled so efficiently, environment can be damaged, and soil, water, and air can be polluted (Ministry of Agriculture and Land, British Columbia, Canada 2009).

There are several processes steering pesticides in the environment, such as: adsorption, transfer, breakdown and degradation. Transfer is a process in which pesticides move away from the target site, like: "volatilization, spray drift, runoff, leaching, absorption and crop removal" (Ministry of Agriculture and Land, British Columbia, Canada 2009). Decomposition is to breakdown the pesticides molecules. Such process leads to the total or partial degradation of them. Complete degradation of complex molecules is known as mineralization, what generates molecules of water, CO_2, and other small molecules depending on the pesticide chemical composition.

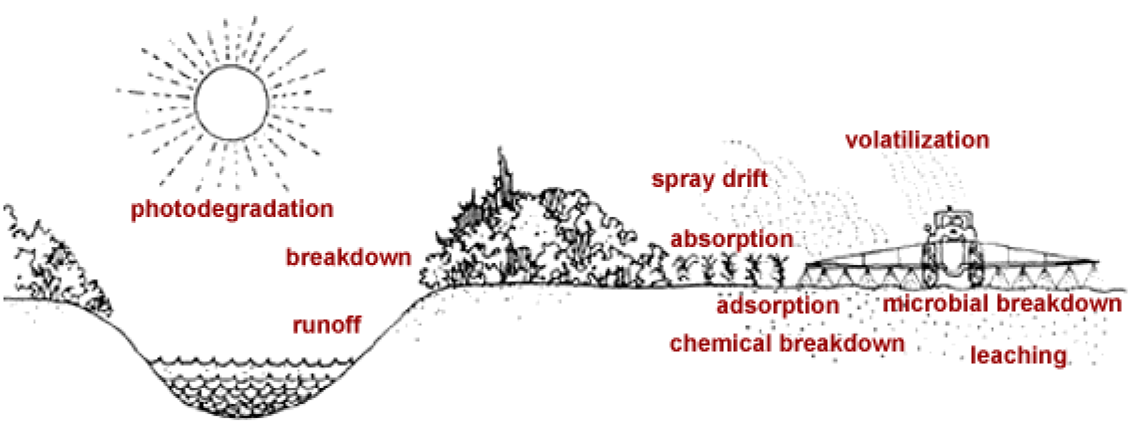


Figure 1: Environmental transfer and fate of pesticides. ***Resource: Ministry of Agriculture and Lands, British Columbia, Canada (2009).***

2.1.1 Transfer Processes

2.1.1.1 Adsorption

Adsorption is the accumulation of gases, liquids, or solutes on the surface of a solid or liquid, such as the binding of pesticides to soil particles. Regarding the adsorption of pesticides, this process depends on "the type of pesticide, soil, moisture, soil pH, and soil texture" (Ministry of Agriculture and Lands, British Columbia, Canada 2009). Almost always, pesticides bind strongly to soils with elevate content of either clay or organic matter. On the other hand, pesticides are usually slightly adsorbed to sandy soils. Adsorption capacity is indicated by the Adsorption Coefficient (Koc), an indicator of binding tendency of chemicals on organic matter of soil. The higher Koc, the greater is the tendency to bind on soil particles.

A key feature of the largest part of soil-bound pesticides is that hardly ever they are prone to volatilize and leachate. Furthermore, bound pesticides are not easily taken up by plants (Ministry of Agriculture and Lands, British Columbia, Canada 2009) as well as depredated by microbes.

Adsorption of pesticides can contaminate soil, what can be passed on throughout the food web when up taken by plants. It can also damage the microbial community of soil, what threats the ecosystems.

2.1.1.2 Volatilization

Liquids and solids can volatilize, converting themselves into gases. The volatilization cause the vapour drifting of pesticides from the initial application site to the environment, what can spoil nature and treat human health.

The volatilization of pesticides depends on their chemicals characteristics, and can be expressed by their vapour pressure. The higher vapour pressure, the greater is the tendency of solid and liquid chemicals becomes gas.

Physical factors have a great influence on pesticides volatilization as well. Pesticides are more suitable to volatilization in sandy soil, warm, dry, or windy weathers. Moreover, altitude also influence in volatilization. For instance, in Addis Ababa, where atmospheric pressure is approximately 570mmHg (0.076 MPa), the substances will volatilize at lower temperature than in regions in the sea level, as the sea level atmospheric pressure is 760mmHg (0.1 MPa). In Addis Ababa substance with vapour pressure greater than 0.076 will vaporize when exposed to atmosphere. The greater the substances vapour pressure, the more rapid will be its volatilization.

The volatilization of pesticides can transport pesticides for long distances. For instance pesticides have contaminated the arctic sea due to their transportation as vapours in the atmosphere (Bidleman et al. 1989 and Sua et al. 2008).

2.1.1.3 Spray Drift

Pesticides spray droplets can drift out from a treatment sites during application. This transport of pesticide is affected by: spray droplet size, wind speed, distance between nozzle and target. "The smaller the droplets, the more likely they will drift"; "the stronger the wind, the more pesticide spray will drift"; and "the greater the distance, the more the wind can affect the spray".

Drift can damage the surrounding environment, such as other crops, ponds, streams, forests, and so on. Moreover, spray drift can be hazardous to people, domestic animals, or pollinating insects. Excessive drift decreases the amount of pesticide applied onto the target plants and soil, causing a possible reduction in the effectiveness of a treatment.

2.1.1.4 Runoff

Runoff is when the liquid flow away, and occurs when water is not absorbed into the soil, and then flow in the soil surface. Such flowing of water can transport pesticides either because some pesticides are dissolved in the water flow or because other ones are bound on soil particles that are transported into the water flow. Therefore, pesticides move along with runoffs as they can be either soluble or adsorbed into soil particles.

"The amount of pesticide runoff depends on: the slope, the texture of the soil, the soil moisture content, the amount and timing of a rain-event (irrigation or rainfall), and the type of pesticide used" (Ministry of Agriculture and Lands, British Columbia, Canada 2009).

There are some measurements to reduce the pesticide cared into the runoff, such as: "using minimum tillage techniques to reduce soil erosion, grading surface to reduce slopes, damming to contain runoff, leaving border vegetation and plant cover to contain runoff", never spraying when it is forecasted heavy rains, and irrigating in accordance with the label instructions (Ministry of Agriculture and Lands, British Columbia, Canada 2009).

Pesticide contaminated runoff can pollute water bodies, groundwater, and sea. Hence, pesticide residues in surface water threat wild life and human health, as it may contaminate the water resources and the aquatic ecosystems.

2.1.1.5 Leaching

Leaching is the infiltration of water into the soil. Water soluble pesticide can be dissolved in water and leach into ground water too. The factors steering the leaching of pesticide into groundwater depend on the soil and pesticide types, and irrigation or rainfall. Then, leaching may be amplified when: "the pesticide is water soluble, the soil is sandy, a rain-event occurs shortly after spraying, and the pesticide is not strongly adsorbed to the soil (Ministry of Agriculture and Lands, British Columbia, Canada 2009).

Groundwater may be contaminated if pesticides leach from treated fields, mixing sites, washing sites, or waste disposal areas.

Table 1 - Summary of Groundwater Contamination Potential as Influenced by Water, Pesticide and Soil Characteristics

Risk of Groundwater Contamination	Factors	Low risk	High risk
Pesticide characteristics	Water solubility	low	high
	Soil adsorption	high	low
	Persistence	low	high
Soil characteristics	Texture	fine clay	coarse sand
	Organic matter	high	low
	Macropores	few, small	many, large
	Depth to groundwater	deep (100 ft or more)	shallow (20 ft or less)
Water volume	Rain/irrigation	small volumes at infrequent intervals	large volumes at frequent intervals

Pesticides in leachate waters can contaminate wells of drink water.

2.1.1.6 Adsorption

Absorption is the process by which chemicals enter the tissues of animals or plants. In this way pesticides can be up taken by plants or microorganisms. When pesticides are incorporated into plants, it is removed from the crop land by either decomposition into plants or harvesting of the pesticide contaminated plants.
Often pesticides breakdown when they are absorbed. Pesticide metabolites can be mineralized or accumulate in plants or animals, and, afterwards, be released into the environment when the animal and plants die and decay.
Persistent pesticides may accumulate into the soil for a long term, and, consequently, to be absorbed by plants grown in a field years later. Then, pesticides may damage or leave residues in future crops and pass on throughout the food chain. In this way pesticides can bioaccumulate, pass on through the food-web and affect human beings and wild life.

2.1.2 Breakdown Processes

Breakdown processes are the routes of degradation undergone by pesticides. Such degradation can be due to microbes, chemical reactions (hydrolysis, oxidation, and others), and photodegradation. As such processes depend on the chemical properties of the pesticides, like susceptibility to oxidation, reduction, hydrolysis, photolysis and substitution; these processes may have different timing, from hours or days to years. Besides, physical properties also influence pesticide breakdown, such as vapour pressure, solubility in water, dissociation constant, partition coefficient, sorption to soil, and volatility from water and soil (Greenhalgh *et al.* 1980). Different degradation rates occur in a diverse range of environmental conditions, as it also depends on climatic conditions, clay/silt/sand ratio in soil and sediments, water content, organic matter, pH, microbial biomass and temperature (Greenhalgh *et al.* 1980).

Mineralization is the entire breakdown of pesticides. Their products are simpler molecules, like: “carbon dioxide, water, and minerals containing elements which commonly include sulphur, phosphorus, nitrogen, and the halogens: chlorine, fluorine, and bromine” (EXTOXNET 1996). It is common that pesticides breakdown in different metabolites that will suffer successive breaks until their entire degradation. Hardly ever is it known both whether or not and when pesticides were mineralized (EXTOXNET 1996). Frequently the initial metabolites are considerably less toxic than the pesticide; however, at times metabolites can be as toxic as pesticides or present greater toxicity (EXTOXNET 1996). At a certain time, pesticide’s metabolites are no longer biologically active, it is: toxic for organisms (EXTOXNET 1996).

2.1.2.1 Microbial breakdown

Microbial breakdown are carried out by fungi and bacteria, which cause the degradation of chemicals. Throughout this route of degradation most of the organic matters are decomposed. It can be increased by: warm temperatures, favourable pH, adequate soil moisture and oxygen, and good nutrients ratio (Ministry of Agriculture and Lands, British Columbia, Canada 2009).

Microbial breaking dawn is one of the primarily processes that cause decomposition of pesticides in soil and sediments (EXTOXNET 1996).

Microbial bioremediation of chemical spoiled sites are based on such principal. To illustrate, landfarming, bioaugmentation and biostimulation are some of the techniques used to remediate contaminated soil, where the contaminants are decomposed by bacteria and fungi. Composting is another process that utilizes microbial breaking. Other organisms, such as plants and animals, are also responsible for the degradation of pesticides (EXPOX 1996).

2.1.2.2 Chemical breakdown

Chemical breakdown is when chemical reactions cause the degradation of pesticides. When in the soil its chemical reactions can be influenced by: "the binding of pesticides to the soil, soil temperatures, and pH levels. Many pesticides, especially the organophosphate insecticides, break down more rapidly in alkaline soils, and moisture (Ministry of Agriculture and Lands, British Columbia, Canada 2009). Chemical breakdown also occurs in water, such as by the hydrolysis process, an in the air by oxidation (EXPOXNET 1996). It is influenced by pH as well, for instance many pesticides, especially the organophosphate insecticides, are broken-down in water tanks with a high pH level.

2.1.2.3 Photodegradation

Photodegradation is when pesticides are broken down by sunlight. It occurs in all pesticides, but in different extents. The breakdown process is altered by factors such as: intensity and spectrum of sunlight, length of exposure, and the properties of the pesticide (Ministry of Agriculture and Lands, British Columbia, Canada 2009).

The exposure of pesticides to sunlight is the main factor steering photodegradation. Therefore, pesticides applied on foliage are broken down by photodegradation more rapidly than pesticide incorporated into the soil, as on foliage pesticides are more exposed to sunlight.

2.2 Pesticide Characteristics

Pesticide molecular characteristics are extremely important to define the degradation via in which pesticides will break down into the environment. The three major characteristics to be considered are: water solubility, soil adsorption, and persistence in the environment (half-life) (Ministry of Agriculture and Lands, British Columbia, Canada 2009).
Water solubility determines the degree of affinity between pesticides and water, and then the probability of pesticides be washed from crop, leach into the soil or move with surface runoff (Ministry of Agriculture and Lands, British Columbia, Canada 2009). It is measured in parts per million (ppm), which is equal to milligrams per litre (mg/L). Pesticides with solubility by up to 1 ppm are likely to continue on soil surface, as they are not prone to leachate. However, when soil erosion occurs, pesticide contaminated soils may carry insoluble pesticides into surface runoff. Pesticides with solubility greater than 30 ppm are expected to leachate.

Soil adsorption is the capacity of pesticides attach on soil, as explained in the item 2.1.1.. It is measured by Koc. Pesticides with Koc greater than 1000 are very strongly attached to soil. Hence, they are not expected to leachate, but when there is soil erosion. Values until 300-500 demonstrate that pesticides tend to move with water, being prone to move with surface runoff (Ministry of Agriculture and Lands, British Columbia, Canada 2009).

Pesticide persistence is the degree of stability of pesticides to be broken down in the environment. Such stability, that is the persistence of pesticides, is determined by a number of factors, including: "(1) how much pesticide is introduced and how it is distributed; (2) its reactivity in the environmental media; and (3) the conditions of the media". The pesticide persistence is measured in terms of the half-life of pesticides (DT 50) in soil. More simply, it is how many days 50% of an amount of pesticide takes to be broken down. Low persistent, moderate persistent and very persistent pesticides are the ones that remain in the soil for less than 30 days, between 30 and 100 days, and more than 100 days, respectively (Kamrin 1997, EXPOXNET 1996). For instance, DDT (Organochlorine pesticide) and Fenamirol (Pyrethroid pesticide) are persistent pesticides; whereas Chlorpyrifos (Oganophosphate pesticide) and Dicofol (Organochlorine pesticide) are moderately persistent. To illustrate, Spinosad (Biopesticide) and Dichlorvos (Organophosphate pesticide) are non-persistent pesticides. In the topic □, the persistent of the pesticides used by the Ethiopian Floriculture sector are described.

In one hand, pesticides that break down quickly generally do not persist in the environment or on the crop. On the other hand, pesticides that are hardly broken down persist for a long term in the environment. In general, the longer the half-life, the greater the potential for pesticide contaminate groundwater, superficial runoff, bioaccumulation, and so on. Moderately persistent pesticides are already likely to leach or move with surface runoff before they breakdown. Such persistent pesticide cause considerable threat to human health and nature as they have a prolonged effect, and then have more time to spread out and contaminate the environment. For example, nowadays DDT is found in the North Pole, where there are no crops.

All in all, these three factors (soil adsorption, water solubility and persistence) are applied to classify whether or not pesticides are like to leachate or move with surface runoff after application. For instance, "pesticides with high water solubility, low tendency to adsorb to soil particles and long persistence or half-life have the highest potential to move into water" (Ministry of Agriculture and Lands, British Columbia, Canada 2009). However, none of these factors can be used to predict accurately pesticide behaviour. Indeed, pesticide behaviour in the field will be determined by the interaction of these factors with the particular soil type and environmental conditions (Ministry of Agriculture and Lands, British Columbia, Canada 2009).

2.3 Main Pesticide Classes

2.3.1 Organochlorine

Organochorine, also known as Chlorinated hydrocarbons, were used extensively from the 1940s to the 1960s as so to tackle agricultural pests and malaria. In general, organochlorine are both powerful and low cost pesticides. From the 1960s on, such pesticides have been restricted due to their considerable persistence in the environment, and their, consequently, spoiling effects on human health and ecosystems. For instance, the main curtailment of pesticide worldwide was the elimination of DDT (dichlorodiphenyltrichloroethane), an organochlorine pesticide, in several countries.

Organochlorine pesticides do not have a common structure, but they all have one or more chlorine atoms positioned around one or more hydrocarbon rings. Such pesticides are divided in three groups: dichlorodiphenylethanes (DDT and similar compounds), cyclodienes, and the other related compounds (Kamrin 1997). Pesticides of each group have similar or identical composition, however their molecular structure may be quite different, what guarantees different effects and characteristics.
Organochlorines are very persistent and do bioaccumulate. They are tightly adsorbed on soil particles and are not soluble in water (Kamrin 1997). Their local transportation occurs by the erosion and the dust of soils. These compounds are not prone to leach into the groundwater.

2.3.2 Organophosphate

Organophosphates (OP) are derivatives of phosphoric acid, and they have become the most widely used insecticide since the exclusion of organochlorines (NPIC 1996), as most of them are nonpersistent (Ware and Whitacre 2004). This group encompasses all insecticides containing phosphorus and is the most toxic of all pesticides groups to vertebrates (Ware and Whitacre 2004). Pesticides of this type have similar high toxicological effects. Due to this characteristic, since the 1990s there has been an extensive reappraisal this class of pesticides in USA (Ware and Whitacre 2004), in EU (EC Directive 91/414), and other countries.
There are three main subgroups of organophosphates: aliphatic, phenyl, and heterocyclic. Aliphatic OPs are carbon chain-like structure and the first group to be applied in agriculture; some examples are: monocrotophos, dichlovos, dimethoate, and acephate. Phenyl OPs contain a phenyl ring; for instance: profenofos. Hetereocyclic have a ring structure composed by different atoms, such as: chlorpyrifos. Besides, OPs are divided in 6 subclasses: phosphates, phosphonates, phosphorothioates, phosphorodithioates, phosphorothiolates and phosphoramidates (Ware and Whitacre 2004). Likely, these different molecules structures are broken down in the environment by different means, what makes OPs have unlike half-life in soil, water and air. Concerning their microbial breakdown, most of the organophosphates are biodegradable (Krueger & Seiber 1984).

2.3.3 Carbamate

Carbamates are derivates from the carbamic acid. They are produced since 1950s. Nowadays, there are more than 25 different carbamate compounds (Kamrin 1997). This pesticide group has replaced chlorinated hydrocarbons pesticides in several applications. Their main application is against insects, controlling a wide variety of invertebrates, such as: mites, spiders and earthworms (Kamrin 1997). They are usually applied to the soil and absorbed by plants. Generally, carbamates are colourless and odourless, and crystalline at normal temperatures.
In most of the cases, carbamates are not persistent in the environment, do not bioaccumulate in organisms, and usually they breakdown before reaching groundwater. Seldom, they remain for several months in soils and crops, fating in few hours or few months, because of they are susceptible to microbial breakdown and chemical hydrolysis. Their degradation rate depends on moisture, pH, and organic content of the soil. In alkaline media and sunlight, carbamates are decomposed more rapidly (Kamrin 1997). Plants absorb and breakdown carbamates rapidly as well, with a total degradation of carbamate residues in proximately 1 to 2 weeks (Kamrin 1997). On the other hand, Acidic soils do not contribute to a rapid break down of carbamates. Besides,

they are also more stable in soil with high organic content, as they bind more strongly in such soil type.

2.3.4 Pyrethroid

Pyrethroids are semisynthetic derivatives of the Chrysanthemumic Acids. They are synthesized in laboratories to mimic natural substances. Their desirable features are providing a quick knockdown of insects at low rates, relatively low mammalian toxicity and improved stability in outdoor environments in relation to natural pesticides from chrysanthemum plant (pyrethins) (EXTOXNET 1996). This feature has which increased their marketability in agriculture. Hence, such pesticides have been marketed for agricultural purposes since the 1970s.

Pyrethroids are frequently moderately persistent pesticides (Kamrin 1997). They bind tightly on soil particles and quite insoluble, and then are unlike to leach into groundwater (Kamrin 1997). When in water, they adsorb rapidly to particles. With some exceptions, they are decomposed by photolysis few days after being exposed to sunlight (Kamrin 1997). However in areas with limited sunlight it can persist for months. Plants breakdown pyrethroids as well. In water pyrethroids go through hydrolysis process, breaking down to nontoxic products (EXTOXNET 1996). In mild acids or alkalis they are rapidly fated (EXTOXNET 1996).

Pyrethroids have been developed as time goes by, and as a result there are 4 generations. However just the third generation was used in agriculture due to this photo stability (lasting 4-7 days) and their powerful insecticidal activity (Ware and Whitacre 2004). The fourth generation is even more toxic. Another characteristic is their low volatility, which also guarantees an extended period, up to 10 days, in the soil after being applied (Ware and Whitacre 2004).

2.4 Policies

International conferences have been discussing how countries should implement laws and practices in regards to pesticide management. Most of these conferences approach hazardous waste as a whole or some stream of it, in which pesticide in some way are included. There are three main conferences that are the key elements of global policy for hazardous chemicals, which are: the 1989 Basel Convention; the 1998 Rotterdam Convention; and the 2001 Stockholm Convention on Persistent Organic Pollutants. In such conferences hazardous waste practices were deeply discussed, and, as a consequence, important regulations in relation to pesticides use and management were made.

The Basel convention regulates mainly the transboundary movements of hazardous and other wastes. It obligates Parties to ensure that hazardous and other wastes are managed and disposed of in an environmentally sound manner. The member countries are expected to reduce the quantities that are moved across borders by treating and disposing the wastes as close as possible to their place of generation and to preventing or decreasing the generation of wastes at source.

The main objective of the Rotterdam Convention is to promote share of responsibility in the trade of hazardous chemicals in order to protect human health and the environment. Also it aims to facilitate the environmental friendly use of such substances by having a strong share of information about chemicals features. This information sharing is implemented through the prior informed consent (PIC), in which member states are able to inform the other members about the hazard effects of chemicals and a consequent restriction of them. These hazardous chemicals are listed in the Annex III of the convention.

The Stockholm Convention objective is to protect human health and the environment against the hazard of Persistent Organic Pollutants (POPs). These compounds, from natural or anthropogenic origin, are highly stable (resist to photolytic, chemical and microbial degradation), bioaccumulate in fatty tissues of living organisms, and are transported by fresh and marine waters even at low concentrations. As some pesticides have these characteristics, the Stockholm Convention is important to regulate pesticides as well. The list of chemicals pointed by the Stockholm Convention to be eliminated is available in the annex 1.
Along with the Stockholm convention, the UNECE Protocol on POPs, 1998, adopted by the Executive Body to the UNECE Convention on Long-Range Trans-boundary Air Pollution (CLRTAP), also aims to tackle POPs. Up to date, there are 16 substances listed in this Protocol, in which 11 are pesticides. The objective of this Protocol is to eliminate any discharges, emissions and losses of these POP substances. Among the pesticides listed by the UNECE Protocol (1988) are: aldrin, chlordane, chlordecone, DDT, dieldrin, endrin, heptachlor, hexachlorobenzene (HCB), mirex, toxaphene, hexachlorocyclohexane (HCH) (incl. lindane).
The conferences have suggested that governments can strengthen global chemicals governance by increasing ratification and participation, establishing improved coordination among relevant treaties and institutions, providing more effective and targeted financial and technical assistance to developing countries for monitoring and reporting, and focusing more attention on life cycle approaches to chemical controls.
Stockholm, Basel and Rotterdam Conventions can be found in the websites: http://chm.pops.int/, http://www.basel.int/, and http://www.pic.int/, respectively.

2.4.1 European Union

The European Union has established legislation on the marketing and use of plant protection products (pesticides are included among these products) and their residues in food. One of the main council directives on this regards in Europe is the CD 91/414/EEC. Such directive requires to parties the use of plant protection product listed in its Annex I. Other pesticides are not allowed. It is also defined that the substance used to protect plants: has to be effective, does not cause bad effects on plant or plant products, causes no unnecessary suffering and pain to vertebrates to be controlled, brings no directly or indirectly (drinking water, food or feed) harmful effects on human and animal health, does not spoil the environment (mainly on drink water and groundwater), has no unacceptable influence on the environment regarding mostly its fate and distribution in the environment and impact on non-target species; among other determinations.
The European Community has ratified the Rotterdam Convention in 2002. Besides, the European Parliament and the Council has applied European Regulation No 304/2003 in 2003, in which regulations to the trade of hazardous chemicals are undertaken. Such legislation is meant to implement a homogeneous notification and information system about trade of hazardous chemicals with developing countries. It also aims to apply the international notification procedure of prior informed consent (PIC). The appendix to the Regulation contains more compounds than the convention. Moreover, there is also the Directive 67/548/EEC that covers the classification, packaging and labelling (when on the market in the member states) of substances that are hazardous to humans or to the environment, that is complemented by the European Regulation No 304/2003, as its principles are expanded for chemicals exported to developing countries by the last European Regulation.

The Stockholm Convention obligations are reinforced in the Article 8 of Regulation (EC) No 850/2004 on Persistent Organic Pollutants in the European Community. There is a Community Implementation Plan on POPs (POPCIP) in the EC, which also covers the substances that fall under the UNECE Protocol on POPs. The main objectives of the POPCIP is both to undertake the legal obligations, and to improve strategies as well as action plans in order to expand the Community measures regarding POPs included in the Stockholm Convention and/or in the UNECE Protocol on POPs.

2.4.2 Ethiopia

Ethiopia ratified the three main conventions about Persistent Organic Pollutants: Stockholm Convention and Rotterdam Convention in 2002, and Basel Convention in 2000. Besides, in 2002, Ethiopia also acceded the Bamako Convention, on the Ban of the Import into Africa and the Control of Trans-boundary Movement and Management of Hazardous Wastes within Africa. In 2003, it agreed to participate in tow more piece of legislation, the Basel Ban Amendment and the Protocol on Liability and Compensation for Damage Resulting from the Trans-boundary Movement of Hazardous Waster and their Disposal.

Despite all ratifications made by Ethiopia in the internal conferences on POPs, there is no legislation that directly and wholly dedicate to the management of POPs chemicals. However, into the national legislations, POPs are covered at some extent (Ethiopian Government 2006). Two of the most important Ethiopian legislations about POPs are the Pesticide Registration and Control Council of State Special Decree No. 20/1990 and the Environmental Pollution Control Proclamation No. 300/2002 (Ethiopian Government 2006).

The Decree No. 20/1990 establishes that: “the manufacture, import, sale or use of an unregistered pesticide is prohibited; a pesticide, which is not duly packed or labelled, cannot be imported, stored, transported or offered for sale; a package shall be designed and made in such a way that it contains the pesticide safely during transportation, storage, marketing, distribution and use including reuse where applicable; accidents in connection with the transportation, storage, marketing, use or treatment otherwise of pesticides shall forthwith be reported; directives shall determine the storage and manner of disposal of pesticides and their packages; and contravention of the decree as enumerated shall be met with the cancellation of registration while other violations shall be punished according to the Penal Code” (Ethiopian Government 2006).

All in all, there is a serious lack of legislation and subsidiary laws in Ethiopia (RC 2007). Besides, no comprehensive system was established to timely decide on future imports of chemicals listed under the Annex III of the Rotterdam Convention (RC 2007). The Environmental Information System is operating at a very low capacity as well, putting even more obstacle to improve the management of hazardous substances and contaminated sites. Probably such problems arise from the political deficiencies in the management of chemical. In Ethiopia there are different ministries, agencies and other governmental institutions that take charge of various aspects of the management of chemicals. However, they “lack effective coordination among institutions, overlap in mandates, lack of clarity as to the role of regional states and insufficient linkage with federal institutions, lack of awareness among decision makers, merger and creation of new institutions from time to time and weak implementing capacity of institutions” (RC 2007).

2.5 Quantification and Qualification

The first step to manage waste is defining the quantity of material that is generated (Dawson & Mercer 1986). Due to the different management methods required for small and bulk quantities of obsolete and unwanted pesticides should be clearly differentiated from large or bulk quantities (FAO 1999). In order to decide whether or not a quantity of pesticides is large or small both the amount and the toxicity of the chemical have to be considered (FAO 2008). The risk of pesticides (hazardous rating) is classified by the World Health Organization (WHO) according to their "acute risk to health" (that is, the risk of single or multiple exposures over a relatively short period of time).

Regarding the hazardous rating of pesticides, it has to be indicated in the label of the chemical. Such rate has 5 different classifications: Products unlikely to present a hazard in normal use, Slightly hazardous, Moderately hazardous, Highly hazardous, and Extremely hazardous. This classification and the hazard power of each class are illustrated in Table 2. The label also illustrates the hazard statement, band colour, hazard symbol, and symbols and words in order to indicate the classification of the pesticide (Table 2). Pesticides without labels should be classified as extremely hazardous (FAO 1999).

Table 2 - Pesticide product label information to indicate the WHO hazard classification

WHO hazard class	**Information to appear on label**	**Hazard statement**	**Band colour**	**Hazard symbol**	**Words**
Ia	Extremely hazardous	Very toxic	Red	N	Very toxic
Ib	Highly hazardous	Toxic	Red	N	Toxic
II	Moderately hazardous	Harmful	Yellow	r	Harmful
III	Slightly hazardous	Caution	Blue		Caution
Products unlikely to present a hazard in normal use			Green		

Resource: FAO (1999)

Based on the hazardous rate of the pesticide, the volumes of pesticide will be defined as small or bulk (**Table 3**). Pesticide and Pesticide waste (pesticide contaminated soils, clothing or other materials and empty containers) should be classified in the same way (FAO 1999).

Table 3 - Definition of small quantities of pesticides, based on the WHO hazard classification of pesticides

WHO hazard class	Small quantity	Large quantity
Extremely hazardous (Ia)	< 2.5 kg/litre	> 2.5 kg/litre
Highly hazardous (Ib)	< 2.5 kg/litre	> 2.5 kg/litre
Moderately hazardous (II)	< 10 kg/litre	> 10 kg/litre
Slightly hazardous (III)	< 10 kg/litre	> 10 kg/litre
Less hazardous than Class III	< 25 kg/litre	> 25 kg/litre

Resource: FAO (1999)

Dissipation of chemicals at elevated concentrations is rather slower than at lower concentrations (FELSOT, RACKE & HAMILTON 2003). It is because high concentrations of pesticides are more toxic for microbes that breakdown them. Besides, high concentrations of pesticides can have a faster leaching into the soil, especially when pore water becomes saturated with a pesticide. The disposal of high pesticide quantities is rather difficult, and probably they will require more sophisticated techniques. If disposed locally such high quantities can contaminate groundwater and surface water (FELSOT, RACKE & HAMILTON 2003). Small quantities of pesticides are easier to handle locally (FELSOT, RACKE & HAMILTON 2003).
Regarding the volume of pesticide generated there is another classification that varies from small to large generator of effluents. According to Nesheim & Fishel (2005) when the monthly generation of effluents from a facility lays under 100kg (about half of a drum) it is a "Conditionally Exempt Small Quantity Generator" (CESQG), from 100 to 1000kg (approximately 5 drums) it is a "Small Quantity Generator" (SQG), and over 1000kg (greater than 5 drums) it is referred as a "Large Quantity Generator" (LQG).

2.6 Pesticide Management

Dispose pesticide waste, using environmental safe means, is one of the most important aspect about handling pesticides. However, many farmers do take wrong management practices, such as: "reusing pesticide containers to store food and water" (FAO 1999), burning in open fires or dumping by the field empty containers, releasing the leftover spray solution and the equipment rinse washings near or into irrigation canals and streams (Damalas, Telidis & Thanos 2007), and so on. Then, a considerable amount of deaths and health problems due to pesticides arise from mismanagement of pesticide waste. Several Developing Countries have been dumping pesticides, some of them Persistent Organic Pollutants (POPs), in the environment (Zinovyev *et al.* 2004).
The careless use of pesticides has spoiled vast areas worldwide (Zinovyev *et al.* 2004). The inadequate disposal of containers and effluents in the environment pose threat on air, water and land, poisoning people, livestock, fish and wildlife as well (FAO 1999). Besides, contamination also comes from: "obsolete, banned and unwanted pesticides, any POPs pesticides (including materials which are contaminated with POP pesticides, such as soils and equipment), grossly contaminated soils saturated with pesticides, contaminated building fabric, heavily contaminated equipment used during the execution of repackaging activities" (UNIDO 2004).
Such pesticide waste usually requires "collection, transportation, storage and final treatment and or disposal in an environmentally sound manner" (UNIDO 2004). The disposal options ought to have "Best Available Techniques" (BAT) and "Best Environmental Practices" (BEO) (Articles 5 and 6 and Annex C of the Stockholm Convention on Persistent Organic Pollutants and as outlined in the Basel Convention).
In this context, environmental sound management of hazards substances and remediation of territories are urgent issues. Such measures are mainly important in developing countries (Zinovyev *et al.* 2004). Thus, both containers and effluents of pesticides as well as expired pesticides have to be disposed safely. These actions will help to prevent human health problems and environmental deterioration.
As a whole, there are five types of pesticide wastes:

- Empty containers

- Excess mixture
- Excess product
- Rinse water from containers and application equipment
- Material generated from cleanup of spills and leaks

In some cases it is added other two elements to this branch of hazardous waste: expired and obsolete pesticides. Such pesticide hazardous waste and wastewater have to be treated and disposed safely (Nesheim and Fishel 2005).

2.6.1 Simple treatment technologies

Not all pesticide waste streams will require high technology solutions (UNIDO 2004). Some pesticide waste stream can be disposed in-situ, such as non Persistent Organic Pollutants with very low toxicity, obsolete pesticides with no trace of active ingredient that do not threat human health and the environment. Such characteristics have to be defined in laboratories. In any case, no single technology is suitable to all the wide-range of pesticide waste streams. Appropriate in-situ technologies are Local landfill of non-toxic materials, long term remediation process such as bioremediation techniques, among others technologies (UNIDO 2004). "By applying the principles of Best Available Technique (BAT) and Best Environmental Option (BEO) it can prove possible and preferable to treat many of the waste streams locally, in the country of origin with no measurable impact on the local or global environment" (UNIDO 2004).

2.6.1.1 Triple- and pressure-rinse

Empty containers of pesticide have to be cleaned out as completely as possible (FAO 1999). The triple-rinse or pressure-rinse is one of the best solutions to clean up pesticide containers. Such procedure is adequate to: empty drums, bottles, or cans (Nesheim and Fishel 2005) made of glass, metals, plastic (PEAD, PET and COEX) (Agostini 2002). "Properly rinsed pesticide containers are classified non-hazardous and are plastic packaging, according to the European Waste Catalogue" (OECD 2004) and CroLife (2004). In several countries, correctly rinsed containers are considered non-hazardous material (CropLife 2004).

In order to triple-rinse containers, pesticide container has to be kept up-side-down for 30 seconds after putting pesticides into the spray tank. Containers have to be refilled with water until 1/4-1/5 of the total volume, and shaken vigorously in all direction for 30 seconds or more. After this, the container has to be drained for few seconds. Such triple-rinse procedure ought to be done 2 more times, washing the container with water 3 times in the total. Pressure Rinsing can also be used to clean up containers. Such system is done by using water under pressure to rinse the inside of containers. Special pressure-rinsing device have to be used to this purpose.

Triple- or pressure-rinsing have to be done immediately after the empting of containers, as pesticide leftovers cannot dry up inside the bottles. When the containers are not rinsed, the pesticide leftovers bind on containers. On the other hand, when containers are rinsed under rigorous procedures, the reduction of pesticide on containers after the triple- or pressure-rinsing is up to 99.99 % (Agostini 2002 and CropLife 2004).

When a pesticide container is emptied into the spray tank, it has to be triple-rinsed at this instant. In case of pesticides that require dilution, the rinse water from the triple-rinsing can be used to dilute such pesticide. This procedure avoids the generation of effluents and the later treatment of hazardous effluents by reusing contaminated water. Then, when preparing pesticides that need dilution, like emulsifiable concentrate or wettable powder pesticide formulations, it is greater to use rinse water to dilute them (FAO 1999), and later to add more water into the spray tank to bring it up to the required dilution (Nesheim and Fishel 2005). If pesticides are not to be diluted, the rinse water should be emptied in a special selected tank to be treated afterwards. This procedure is aimed to avoid the generation of wastewater from rinse water and to use all pesticide content of the containers. Containers for dry application products should be emptied as completely as possible.

After being triple- or pressure-rinsed, holes have to be punctured in the bottom of the containers in order to prevent reuse. Even apparently empty containers contain some extent of pesticide residues. The triple-rinsing is done to guarantee that containers have adequate levels of pesticide to handling, transportation and disposal (Agostini 2002). Thus, the containers can never be used for any purpose other than storage of the pesticides that they originally contained. The puncture container procedure in rather important as in many countries, as empty pesticide containers are highly valued and often sold or exchanged as storage containers for other materials such as fuel, chemicals and even food or water. For example, 1 large drum costs USD 50 in Mozambique, which is the salary per month for farm workers (OECD 2004).

Properly rinsed and punctured containers may be final disposed as non-hazardous waste. Pesticide bags that cannot be cleaned up by triple rinsed, such as plastic bags, have to be shaken clean. This procedure is applied in Florida, US (Nesheim and Fishel 2005). However, pesticide bags can be considered as hazardous waste, and require technologies like incineration or chemical treatment to be disposed.

All around the world rinsed containers have been disposed in different ways, such as recycling (INPEV 2009), burning or burying (Nesheim and Fishel 2005), and landfilling (Nesheim and Fishel 2005). CropLife (2004) considers container management as a priority subject for both users and environmental protection.

2.6.1.2 Local engineered burying

Hazardous waste should not be buried (FAO). Not only burying takes areas that could be used for greater endings, but mainly it can pollute severely water table and adjacent environments.

On the other hand, it is advice to bury rinsed containers in distant farms where access to collect pesticide containers can be complicated and expensive (Agostini 2002). However these practices require a great extent of knowledge and technical advice. It is needed knowledge about local hydrology as well as of the environmental behaviour of pesticides. Besides, the rinsed containers should be disposed in engineered encapsulation cells. FAO (1999) do not advice burying and burning pesticide in-situ, as hazardous wastes that were unsafely buried can be a continuous source of pollution to groundwater.

Agostin (2002) explains how waste cells have to be constructed:

- The area in which waste cells are build up has to be: distant of houses, nearby the agricultural site, away from water sources and water pipes, out of the dislocation routes of people and animals, a non-agricultural area in the short and long run, easily accessible.
- Consideration about wind direction have to be done to prevent vapour gases to reach houses;
- The place cannot be either flood-prone or accumulate water;
- The soil layer has to be deep and non-permeable such as clay or a clay layer have to be done;
- Sandy soils are not advice to have such waste cells;
- The water table has to be at least 1,5 metres distant from the lowest part of the waste cell;
- Waste cells have to be from 1 to 2 meters deep, and up to 3 meters wide and long depending on the quantity of solid waste;
- It has to be made on the bottom of the cell either an irregular median-sized gravel layer, or a simple filter with 6 layers of 15 cm each (large-sized gravel, fine-sized gravel, coarse sand, lime-stone, coal, fine-sized gravel)
- As so to minimize percolation of water into the soil, it has to be built all around the cell either a drainage stormwater system or a concrete wall;
- Barbed-wire has to be settled all around the area to prevent passage of people and animals (a great number of barbed-wires have to be put nearby the ground to prevent small animal to go into the area);
- The area ought to have toxic hazard signs ;
- An fine layer of limestone should be made both before disposing the waste in the waste cell and when waste layers reach 15 cm high;
- When the waste cell is completely filled, it has to be covered with a first earth layer 50 cm high (such layer has to be well compacted), and a final earth layer 30 cm high (this layer has to be above soil level).

Regarding the leachate water, instead of letting it leach into the soil, the cell can be insulated with a compact clay layer (30 cm high) and drained with a leachate water collection system. This leachate water can be treated in a local wastewater plant by either microbial or sun light breakdown as these process do not occur into the deep layers of the soil.

2.6.1.3 Local burning

In its turn, local burning of hazardous pesticides will pollute the air with toxic gases and vapours. It is because open burning does not develop high temperatures and, then, does not breakdown pesticides. Hence, pesticides are transferred from the liquid and solid states to the air. Besides, burning hazardous waste in open fires can both release dioxins, toxic substance restricted by the Stockholm Convention, and other harmful compounds, such as: hexachlorobenzene, volatile organic compounds, particulate matter, hydrocarbons, carbon monoxide, and nitrogen oxides. FAO (1999) does not advise open burning.

2.6.1.4 Biological Techniques

Simple bio-treatment technologies are one of the most economical technical solutions to treat pesticides. Such methods will be applicable to chemicals in which toxicity is low. Such methods are intended to be economical and simple to design. However, they have restriction to deal with high volumes and elevate toxicity. Chemical and physical techniques can also be used along with biological; but they can increase expenses in the process.

Bioremediation technologies use micro-organisms to mineralize organic contaminants (UNEP 2003). It can be used indigenous or non-indigenous fungi, bacteria and other microbes (UNEP 2003). Under aerobic condition the microbes will convert the pesticides in biomass, carbon dioxide and water, while under anaerobic condition they will produce from pesticides methane, limited amounts of carbon dioxide, and trace amounts of hydrogen gas.

Some examples of bioremediation are: bioreactors, biofilters, land farming (UNEP 2003). This type of treatment is slower than incineration; however, it can be implemented locally and is cheaper as well. The degradation of the pesticides during bioremediation depends on: temperature, concentration, microbes, among other factors. Additionally, the mixing equipment and duration of mixing steps are fundamental for the effectiveness of such technology.

One of the limitations of bioremediation of pesticides is that such chemicals are highly resistant to biodegradation (UNEP 2003). Hence, a small amount of organisms can be utilized in this process. However, organisms can be selected naturally to mineralize certain type of pesticides, as it can occur in activated sludge and composting plants. Besides, microorganisms can be inoculated as so to decompose pesticides. For instance, field studies in Florida applying composting to treat DDT, dieldrin and toxaphene have had 90% of efficiency as an average (UNEP 2003).

Phytoremediation appears as a new technique to treat pesticides using plants to “remove, transfer, stabilize or render harmless contaminants” (UNEP 2003). However, the up-take is not equal to all types of pesticides in the plants. Besides, plants can accumulate hazardous substance, instead of mineralizing them. Due to the bioresistance of pesticides, the number of known species that bioremediate pesticide is undersized (UNEP 2003). All in all, along with Phyto-degradation, that is mainly the degradation of contaminants in plants tissues, plants can also extract contaminants from the soil or ground water (phyto-extraction), volatilize contaminates, immobilize contaminants in the interface of their roots and soil (phyto-stabilisation), have hydraulic control of ground water (plume control), and control of runoff, erosion, and infiltration (UNEP 2003).

As basic agricultural practices are required to implement Phytoremediation, it is an economical treatment method (UNEP 2003). On the other hand, Phytoremediation is a time consuming process, along with the risk of residual concentrations of contaminants (UNEP 2003). Besides, such technique is developed with plants that are site specific. It demands expensive monitoring and analyses to assure the efficiency of the treatment. Up to date, Phytoremediation cannot be classified as environmentally sound method for disposal of wastes containing POPs (UNEP 2003).

The triple rinse water effluent can undergo remediation by processes such as bioremediation. Depending on the pesticide characteristics it can also be treated by methods like bio-reactors.

2.6.2 Sophisticated treatment technologies

Great volumes and high toxic wastes will definitely “require expensive, high technology solutions to meet required standards in terms of health, safety and environment” (CPC 2004).

2.6.2.1 Recycling

Recycling of plastic is one of the most defused practices used in several management programmemes of pesticide containers. It can be made by ‘energy recovery,’ in which the plastic is used as a fuel source for incineration. This method is mainly used in Europe. Besides, the plastic can be recycled as other products. Such recycling methods are mainly applied in the Americas, for instance it has been largely used in Brazil (INPEV 2009). The recycling as other products are meant to produce alternative products that are handled to a minimum extent, such as electrical conduit, fence posts or void filling in concrete structures (CropLife 2004). Additional recycling options are hardly used, like as re-use of containers for crop protection products.

Recycling is the best option (Nesheim and Fishel 2005). This procedure conserves the energy value of the plastic of containers, lost when they are open burned and also removed pesticide containers from user's property, a problem when local burying is undertaken.

Plastic recycling plants can have rather simple technology, like extruder to produce pellets. Recycling plastics can be profitable, because it is both a final disposing to solid waste and can also be a new source of profits by producing pellets. However, the raw-material (pesticides plastic containers) delivered at recycling plants only can be recycled if thoroughly cleaned from pesticide leftovers. For that reason triple rinsing containers immediately after pesticide use is rather important. This procedure will avoid both uncontaminated products from recycling and health safety for employees at recycling plants. Employees have to use individual protection equipments to avoid contact with container without previous treatment. Such contaminated containers have to be separated from the process and be followed to different treatment procedures than cleaned containers.

So as to proceed recycling of pesticide plastic container it is necessary to implement a collection containers programme in order to gather containers in the recycling central units. Besides it is necessary to implement the proper recycling unit. Both the collection and recycling systems, not only contribute to solve environmental problems, but also bust employment generation (ADEC 2006).

2.6.2.2 High-temperature incineration

High temperature incineration, in a dedicated hazardous waste incinerator, is the most secure method to dispose pesticides. It can be considered as a recycling method because of its energy recovery. The European Council Directive 2000/76/EC on the Incineration of Waste requires that hazardous wastes have to be incinerated at 1100°C for at least two seconds when substances have more than 1% of halogenated matter (Council Directive, 2000). The US Environmental Protection Agency (US EPA), by the Toxic Substances Control Act (TSCA), defines that incineration have to be done for hazardous waste in kilns at 1,200°C with 3% of oxygen surplus for the combustion process, and with a residence time superior to 2 seconds (Federal Register, 1999). Incineration facilities have complex operation, which requires expert knowledge and high-tech equipment. The current cost of incineration rang from US$3,000 to 4,000 per tonne of waste (PAN-UK 1998). Apart from some newly industrialised countries, developing countries do not have safe and environmentally sound hazardous waste incineration facilities (Wodageneh & Wulp 1996). The utilization of mobile incinerators seems to be cost ineffectual for most of the cases.

On the other hand, cement kiln might also be feasible to use in order to incinerate limited quantities of pesticides and their contaminated containers in some specific situations. With some adaptations, pesticides can be co-fired with fuel in the cement kilns, what promotes their efficiently destruction. Such method depends on the type of cement kiln and the type of pesticides, and, consequently, the majority of cement kilns in developing countries are unlike to incinerate pesticide safely (Wodageneh & Wulp 1996). Besides, undersized incinerators are usually inappropriate for the destruction of bulk quantities of pesticides. Even with limited use of cement kilns to promote the thermal treatment of pesticides in developing countries, some experts consider this technique a great solution to treat pesticides in the future.

One of the major concerns with incineration is the emission of toxic vapours. In general, when using waste as fuel in cement kilns, gas emission has to be at least as low as gas emission of non-waste fuels. Although, there are some waste fuels which can overcome gas emission of normal fuels in cement kilns, such as polyethylene and polypropylene from agricultural packing waste. Measurements of atmospheric emissions have to be undertaken in start-ups of either new waste incineration plants or new schemes for burning hazardous waste in cement kilns. Annually, such measurements have to be redone. In case of success to comply over 50% with emission standards, measurements will be carried out each 3 years. These measurements have to be reported.

2.6.2.3 Chemical treatment

Chemical treatments break down pesticides by oxidizing them in reactions with other chemicals. Chemical treatments are highly specific to each type of pesticide. It provides limited or no solution for contaminated materials and containers, and the by-products have generally significant hazardous potential (UNIDO 2005). Such type of treatment to pesticides requires high levels of expertise and supporting infrastructure.

2.6.2.4 Engineered landfill

Landfills are facilities that are meant to dispose solid residues in a safe way into the soil. Engineered landfill guarantees human and environmental security. It has similar procedure than the one described in the topic 2.6.1.2, however in large scale and can be applied either to municipal solid waste or hazardous waste. Thus, in this technique, waste is confined into the soil avoiding the percolation of leachate water into groundwater. Some of the modern landfills include treatment of toxic vapours as well. Solid waste is always covered in insulated cells as so to avoiding the spread of waste into the environment. All in all, such system buries solid waste in daily waste cells, in which waste will be: compacted , covered, insulated from contact with

groundwater and surface waters, and their future gas emissions and leachate water will be collected and treated.
This system is quite complex, and can be applied just after a thorough site investigation, encompassing geological studies, distance of water bodies, elevation of the water table, sorrowing environment, among other factors. Besides, great investments in infrastructure have to be done to implement landfills as so to guarantee environmental safety, such as drainage and treatment systems of wastewaters and gases, insulation of soil, administrative centre, roads, and so forth. Long-term management and maintenance is required, because the waste has to be buried in an environmental safe way as long as leachate and gases have to be monitored and treated.
Some experts do not consider landfill a final disposal, but rather a containment of waste (UNIDO 2005). Thus, landfill cannot be considered as a permanent solution to waste. Generally, landfill of hazardous waste is not allowed in EU and the United States (UNIDO 2005).

2.6.2.5 Gas phase hydrogenation

Gas phase hydrogenation is a system that uses reaction with hydrogen at high temperatures as so to decompose chemicals. Theses chemicals are firstly breakdown to methane and hydrogen chloride. As the system is closed, there are no emissions. Up to date, there are one commercial plant in Australia and one experimental plant in Canada (UNIDO 2005). The Australian gas phase hydrogenation plant is destroying DDT and PCB successfully. This technology is being developed to treat contaminated soils.

2.6.2.6 Molten metal

Molten metal is a system in which organic materials are breakdown at high temperatures in a vat of molten metal. Such technology is to be implemented at commercial level in the US. Molten metal appear to be one of the greatest technologies to breakdown organo-metallic pesticides, as such type of pesticide cannot be incinerated (UNIDO 2005).

2.6.2.7 Plasma arc

In Plasma arc system, waste is decomposed at extremely high temperatures ranging from 5000 to 15000^{o}C. Such degradation occurs into a plasma arc field at which compounds are decomposed into their constituent atoms. Currently, there is only one Plasma arc plant in Australia. Such method generally will have higher costs than incineration, and pollutant breakdown efficiencies vary. Besides, Dioxins can be generated at high extents.

2.6.3 Implemented practices

2.6.3.1 General view

Pesticides management has been receiving more attention worldwide. Although, in spite of their toxic effects, hazard waste and wastewater are generally the last ones to be regulated and managed in of most the countries (Hirschhorn & Oldenburg 1991). The main focus of pesticide management is on safe use of pesticides, whereas hardly ever waste material management practices are approached (FAO 1999).
The situation is aggravated as not only there is lack of management practices, but also mismanagement practices are undertaken to treat unwanted pesticides and containers. (FAO

1999). For instance, non-engineered burying or burning in open fires of waste pesticides and empty containers are advised in several countries by pesticide suppliers and national authorities (FAO 1999).

In developing countries, seldom there are regulations to meet requirements of an environmental friendly economical improvement, which are essential to produce without degrading nature. Hazardous waste generation increases much quicker in emergent economies (Hirschhorn & Oldenburg 1991). Although developing countries represent 25% of global pesticide use, they account for 50% of pesticide poisoning, and over 70% of pesticide related fatalities (OECD 2004). Pesticides applied in developing countries are generally more toxic and contaminated than those in OECD countries. Besides, developing countries, which are improving their economies but still have a lack of technology and regulations to protect nature, commonly do not undertake adequate management practices of their hazardous waste (Hirschhorn & Oldenburg 1991), as in India (Kumar *et al.* 2008) and other developing countries (Nnrom & Osibanjo 2008).

On the other hand, a number of programmes for pesticide container recycling are in operation in several countries across the world. Most of them are established in a partnership between industry, national and local governments and farmers (OECD 2004). The most successful ones are voluntary rather than mandatory (CropLife 2006). In 2005 there were 28 established container management programmes in which most of them practiced the recycling of plastic containers. In that year, about 17.3% of the 190,000 tonnes of crop protection products containers were recycled worldwide (CropLife 2006). A majority of these programmes are in OECD countries and in Latin America. Such countries can offer support to the implementation good models for container management (reuse, recycling and disposal) in developing countries (OECD 2004).

For instance, North and South America, Australia and most of Western Europe have launched dedicated recycling programmes. CropLife International in its worldwide survey demonstrate that out of 56 respondent courtiers, 49 have established management programmes for pesticide containers that goes beyond ‘triple rinsing’, including schemes mandated by national legislation (OECD 2004). Some of these schemes are described in the topics below.

In most of the countries that have established collection schemes of empty container of pesticide, the disposal technology of such material was mainly: reconditioned for reuse, recycled into new material/products, or incinerated with thermal recovery. In the recent past, pilot recycling programmes has been established in Africa and Asia (CropLife 2006). Incineration was also the most used method to dispose of obsolete pesticides along with containers.

However, in many regions recycling is not applied due to lack of funds, requiring appropriate disposal. The disposal of pesticide containers in these areas have to be done by simple but effective techniques (CropLife 2006), such as triple rinsing and burying. In Africa and Asia, either bury or burning in line with local law and recommended practice are commonly used as final disposal options for pesticide containers (OECD 2004).

Management programmes for obsolete pesticides have been also establishes in Australia, Africa, Brazil, European Union, among other locations. But it is still rather often mismanagement practices worldwide, such as: “incorrect storage of pesticide products (inside the home next to a sleeping baby, under the house where children and livestock have easy access), use of empty containers for water and food storage (e.g. an empty pesticide container being used to draw water from a well), and inappropriate disposal (e.g. burning or burying obsolete pesticides and containers in open field or a shallow pit)” (OECD 2004).

2.6.3.2 Australia

2.6.3.2.1 Obsolete Pesticides

The first action to tackle obsolete pesticides in Australia was the ChemCollect in 2000. It was invested by the State and Federal Governments about US$18 million at once to collect unused, unwanted and deregistered crop protection and veterinary products. More than 1,600 tons of pesticides were collected from 2000 to 2002. Organochlorines account for 150 tonnes of the total collected.
Afterwards, it was established the ChemClear, an industry-funded programme for on-going collection and disposal of unwanted registered chemicals, started in 2004. It is supported by AVCARE, the National Association of Crop Protection and Animal Health, a member association of CropLife International. The pesticides are final disposed in cement kilns.

2.6.3.2.2 Pesticide Empty Containers

Australia's national container management scheme (drum MUSTER) was establishes in 1999. It is a full stewardship, which encompass several stakeholders, such as: the industry (Avcare Ltd., the National Association for Crop Production and Animal Health and the Veterinary Manufacturers and Distributors Association), farmers (the National Farmers' Federation) and local governments (the Australian Local Government Association). DrumMUSTER is administered by an independent non-profit organisation, Agsafe Ltd., a fully-owned subsidiary of Avcare Ltd. Local governments undertake the collections in their jurisdictions, while the industry make the final disposal.
The drumMUSTER is co-regulation by industry and government pesticide containers management programme. It is included in the Australian waste management policy, which extends producer responsibilities and waste reduction at source to minimise the amount of packaging materials going to landfills. The programme is financed by a levy of AUD 0.04 (EUR 0.024) per litre or per kilogram on most products sold in non-returnable containers. Hence, the programme is ultimately paid for by final users. It is in line with the polluter-pays principle (OECD 2004).
DrumMUSTER collected approximately 35% of total containers sold (chiefly 20L containers) in Australia in 2003. From 1990 to 2004, about 4.85 million containers (2/3 were recyclable plastic, rest was steel drums) were removed from farms, corresponding to more than 7,300 tons of waste diverted from landfills. The major part of the recovered material is recycled as alternative products, and a minor share reconditioned for reuse as chemical containers.

2.6.3.3 Brazil

2.6.3.3.1 Obsolete Pesticides

The Brazilian state of Paraná, different stakeholders and the local crop protection industry association (ANDEF), a member of CropLife, decided in 1998, that the best way to dispose pesticides was incineration. Hence, incineration at a local industry plant was undertaken for obsolete pesticides. It was finalized in 2000, and funded by participating ANDEF member companies and the State of Paraná government.

2.6.3.3.2 Pesticide Empty Containers

Brazil uses pesticides in the agriculture sector since the 70´s. The consumption of agrochemical in Brazil, was approximately 210 tons in 2004, increased 9% a year from 1995 to 2005 (InterfacEHS 2008). It is estimated that 128 million pesticide containers are sold in Brazil annually (InterfacEHS 2008).
Brazil is one of the first countries in the world to regulate the fate of pesticide containers (Gazeta Mercatil 2003), through the implementation of the regulations. The Brazilian National Law No. 9.974/2000 and the Decree 4.074/2002, establish that whole pesticide containers have to be collected as so to be either incinerated or recycled in a safe manner (INPEV 2009). This law regulates the final disposal of pesticide containers by defining duties to: farmers, distributors, manufactures, and governmental agencies.
For the time being since the implementation of the Brazilian National Law Number 9.974/2000, in 2000, farmers have to triple rinse pesticide containers, to perforate their bottom in order to make them useless, to keep their cork, to keep them until delivering in receiving central units (it has to be done at least one year after buying the pesticides), and to keep the devolution receipt during one year. In their turn, distributors have to offer and to manage receiving central units and to inform farmers about the location of such units, to explain about triple rinsing procedures right when selling the agrochemicals, to issue receipts for returns delivered by farmers, and to inform farmers about pesticide risks. The manufactures have to collect the pesticide containers in the receiving central units and treat them in a safe manner (either recycling or incinerating). Moreover, along with the governmental agencies, manufactures have to implement educational campaigns to stimulate farmers to triple rinse and return the pesticide containers. Finally, the government have to inspect how is operating the delivering system, and to issue licenses for collecting and recycling plants under the requirements of the environmental agencies of the province.
The representatives of the manufactures (factors of pesticides) have created the National Processing Empty Containers Institute (InPEV), in 2001, in an effort to achieve the requirements established by the Brazilian law. In other words, the InPEV was created to assure that empty containers will be both collected and treated as so to guarantee that agrochemical industries are undertaken their environmental and social responsibility in accordance to the Brazilian National Law.
The InPev is a non-profiting organization supported by manufactures in order to implement a take-back programme for pesticide containers. They had been investing about US$ 25 million from 2003 to 2006 as so to create Receiving Units Plants and Distribution Units in Brazil (GAZETA MERACANTIL 2003). By contacting directly the company they have informed that until 2008 they have invested approximately US$ 132 million, and that they will probably achieve economical sustainability by 2015, in which recycling revenues will fund the programme. In other words, the container management scheme in Brazil will be inexpensive after 2015.
The Brazilian take-back programme has been boosting the recycling sector in that country (GAZETA MERCANTIL 2003). Up until now, InPev has collected approximately 108 tons of empty pesticide containers, in which 95% of such material can be recycled (InPev 2009). Inpev has been registering recycling companies as partners in this programme, which take charge of recovering rinsed and returned containers. “Today the collection and recycling rate is about 80% in this segment” (Business News Americas 2008), and up to 16 different articles are produced from the recycled material, such as: corrugated tube, bag for incineration, plastic wood, concrete saver, cardboard barrel, motor oil packages, PET rope, HSPW rope, and so on (InPev 2009).

Dinoplast Ind Com de Platicos, one of the companies registered in the InPev recycling programme, in 2003, had 30 employees, processed 200 tons/month of PEAD, manufactured 80 tons/month of corrugated tube, and sold recycled raw-matter to other plastic industries (GAZETA MERCANTIL 2003). The capital invested to build up Dinoplast under the requirement of the Environmental Agency of São Paulo (Cetesb), Brazil, was about R$ 700,000 (US$ 320,000) within 7 years. The company was profiting approximately R$ 200,000 (US$ 91,000) per month in 2003 (GAZETA MERCANTIL 2003).

In spite of all the accomplishments of the Brazilian Take-back programme for Pesticide Containers, it is still incipient regarding the collection of containers in small properties (Veiga 2009). Cantos *et al.* (2006) portray that it is important to improve the awareness among farmers about returning containers and triple rinsing procedures, as well as about the risks of pesticide, in order to improve the take-back programme. It is equal important that governmental agencies improve monitoring in both agriculture properties and receiving central units as so to guarantee that the programme is working as well as the laws determine, and to guide farmers in their difficulties (Veiga 2009 and Castro 2003).

2.6.3.4 Costa Rica

2.6.3.4.1 Pesticide Empty Containers

In Costa Rica, a programme was established in partnership with the German aid organisation (GTZ - Deutsche Gesellschaft fur Technische Zusammenarbeit). Such scheme collects about 12.5% of plastic containers and 45% of metal containers used in the country. The containers need to be triple-rinsed prior being delivered by farmers. Thermal recovery is the main recycling route.

2.6.3.5 Canada

2.6.3.5.1 Obsolete Pesticides

In Canada unwanted and unused stocks of crop protection products have been collected from final users and disposed of since 1998. This programme is funded by CropLife Canada and the Federal and State governments. Over 650 tons of obsolete pesticides were collected and disposed in an environmentally sound manner. Collection centres were established as so to farmers dispose of their unused and obsolete crop protection products free of charge. It is a multi-stakeholder scheme between government, industry, retailers and grower groups.

2.6.3.5.2 Pesticide Empty Containers

A voluntary collection and recycling scheme, called Stewardshipfirst from the CropLife Canada (dustry association representing manufacturers and Distributors), was developed in Canada for Empty Pesticide Containers. It is funded by federal and state funds, along with levy to all pesticide manufacturers at USD 0.36 per container put on the market. Annually, the programme cost roughly US$ 2.9 million. Approximately 70% of the plastic containers entering the market in Canada were collected in 2003. They all require triple-rinsing before to be taken to the collection points (over 1,250 across Canada) by users. The plastics are recycled into other products, such as: fence posts, highway guardrail posts or used for energy.

2.6.3.6 Ethiopia

2.6.3.6.1 Obsolete Pesticides

In 1995 it was conduced the first pesticide inventory of Ethiopia by FAO in partnership with the government of Ethiopia. This first action identified approximately 426 tonnes of obsolete pesticides, mainly located in agricultural farms and in the Ministry of Health stocks. In a more detailed inventory in 1999, over 1500 tonnes of 200 different types of pesticides were found. The obsolete pesticide were constituted by: organochlorines (258.3 tonnes), organophosphates (155.4 tonnes), carbamates (58.5 tonnes), coumarines (14.9 tonnes), inorganics (30.2 tonnes), others (257.2 tonnes), mixed pesticides (70.4 tonnes) and unknown pesticides (307.1 tonnes) (Haylamicheala & Dalvieb 2008).
In 1998 it was established a project under the leadership of FAO to dispose of such obsolete pesticides. The first phase (2000-2003), with the disposal of 1,500 tons of obsolete pesticides identified. The pesticides were shipped to Ekokem OY AB, incinerator in Finland. The cost for this operation was about US$ 4.44 million. This first phase was funded by The Netherlands Embassy, USAID, and the Swedish government, and Ethiopian authorities.
Phase 2 of the project has started in 2006. It was meant to dispose of approximately 1000 tones of the remaining obsolete stocks in Ethiopia, along with a great extent of heavily contaminated soil at a cost of about US$ 8 millions. The finance support to develop the second Phase of the project is being provided by the Governments of Belgium, Ethiopia, Finland and Japan, CropLife participating companies, and the ASP.
An ample programme of measures to avoid future stockpile accumulation of obsolete pesticides is also being launched in Ethiopia. Such programme encompasses activities such as: the "development and enforcement of pesticide policy, the implementation of Integrated Pest Management (IPM) and Integrated Vector Management (IVM), capacity building in terms of providing professional trainings, creating awareness among stakeholders on the environmental and human health hazard posed by obsolete pesticides as well as other actions to prevent pesticide accumulation and enforcement of national legislations and policies related to pesticides use" (Haylamicheala & Dalvieb 2008).

2.6.3.7 Germany

2.6.3.7.1 Pesticide Empty Containers

PAMIRA (Packmittelrücknahme Agro) was the pesticide empty container scheme developed by the German industry in 1996. The industry funds the costs of PAMIRA based on the amount of primary packaging material put on the market in Gemany. It is a voluntary scheme, and in this programme the containers are required to be triple-rinsed before famers bring them in the collection points. Up to date, there are over 230 collection sites at retailers, where during a limited period (1-4 days) each year they receive containers. Containers are inspected to guarantee that only well rinsed containers enter the waste stream. A levy is charged to receive uncleaned containers or the farmer can rinse it properly in order to deliver the container. Afterwards, generally containers are forwarded to cement kilns to thermal recovery. A minor part is disposed by conversion to methanol. This schemes collects about 52% of the plastic containers in

Germany in 2003, approximately 1,547 tons. The coast involved to procedure this scheme is about EUR 1,075/ton (OECD 2004).

2.6.3.8 Kenya

2.6.3.8.1 Obsolete Pesticides

There is a limited technology to dispose of hazardous and obsolete chemical in an environmental safe manner at Kenya. In spite of the incineration plants in Africa do not meet the requirement of FAO to incinerate hazardous wastes, incineration was undertaken in Kenya to dispose of POP pesticides (aldrin and dieldrin) (Saoke 2005). It was carried out by the Institute of Waste Management contracted by the Agro-chemical Association of Kenya. I has been suggested that the POP pesticide could be disposed in incinerators from cement factories since they develop temperatures over 1200ºC that breakdown the molecules of POP pesticides (Saoke 2005). However, if such facilities are not well developed to incinerate POPs they can release toxic gases such as: dioxins and furans. Another option, suggested by The Africa Stockpiles Programme (ASP), is to ship the obsolete pesticides from African member states for incineration in developed incineration facilities, most of them in Europe.

- *Pesticide Empty Containers*

Empty Containers management schemes were not adopted in Kenya. NEMA (the Kenya's National Environment Management Agency) were already in 2005 developing regulations and guideline standards to effectively control pesticides empty containers (Saoke 2005).

- *South Africa*

- *Obsolete Pesticides*

South African Government and the local industry association CropLife South Africa established in 1998 a collecting programme for obsolete pesticides. About 1,040 tons of obsolete products across South Africa, Swaziland, and Namibia were collected. The disposing was funded by by the South African and German governments and managed by CropLife South Africa. The German government financed the transportation of the BHC to the UK in order to be incinerated there. A total of 740 tonnes of obsolete stocks from this project were effectively incinerated by Shanks in 2000. The Danish Government launched a project in 2002 to treat the remaining stocks in Southern Africa. Afterwards, CropLife South Africa has acted to safeguard some of these stocks to prevent inappropriate disposal by farmers.
The disposal of the remaining obsolete products from South Africa is being developed to also achieve the ASP programme. Besides measures to prevent the accumulation of obsolete stocks in the future are being undertaken. Such programme will also be expanded to the other countries of Southern Africa (CropLife 2006).

- *Pesticide Empty Containers*

The industry has beginning pilot schemes for managing pesticide containers by either recycling as industrial pallets, or and use thermal recovery energy in cement kilns.

- *United States*

- *Pesticide Empty Containers*

Ag Container Recycling Council (ACRC) undertakes a voluntary pesticide container collection programme and recycling scheme in the United States since 1992. It is a non-profit organisation funded by CropLife America companies and seven other affiliate members. In such management system, famers take rinsed empty plastic containers to collection centrals. There, the containers are inspected and accepted free of charge. However, ACRC accepts only containers for agricultural use that are non-refillable and high-density polyethylene (HDPE). The collected plastic containers are grinded into flakes, which recycled as non-consumer products, like: field drain pipe, marine piling, etc. The ACRC recycling scheme is funded by members, which pay a levy related with the weight of plastic pesticide containers put on the US market.
Federal pesticide regulations obligate the use of labels to provide instructions on container management and disposal. In some cases, the recycling and disposal of used pesticide containers are pressured by federal and state regulations, which define some pesticide containers as hazardous waste. Besides, some state government also regulates open burning and landfilling of wastes, what impact disposal options such as recycling.
The US container recycling scheme collects approximately 3,175 tons (10 million containers) annually, what counts for about 28 % of plastic pesticide containers used by US farmers each year. More than 29,484 tons of pesticide containers had been recycled from 1993 to 2004. The programme cost till 2004 was roughly USD 3.9 million, of which more than 80% was spend on container collections.

2.6.4 Environmentally sound management

2.6.4.1 General view: FAO

According to FAO (1999), a majority of farmers cannot dispose of pesticide in an Environmentally Sound manner as they lack equipments and technology. Therefore, they should not be responsible for disposing of pesticides and pesticides contaminated material. The FAO international code says that manufactures and distributors of pesticides have to provide centre in which farmers can deliver empty containers and pesticide-related waste materials safely. Along with the industry (manufactures and distributors), local and national governments also play an important role in establishing pesticide management schemes. Such collection schemes for unwanted pesticides and empty pesticides containers are already developed in some countries, as foregoing mentioned.
However, there are limited resources from governments in several developing countries as so to develop appropriate toxic waste collection schemes. Therefore, the pesticide industries and distributors have to take the responsibility of collecting and disposing such toxic waste in an environmentally sound manner (FAO 1999).
FAO (1999) finds essential that unwanted and obsolete pesticide as well as pesticide related waste have not to be disposed of by farmers, but rather in collection schemes in which they will be disposed in high temperature incineration in a dedicated hazardous waste incinerator. If there is no incinerator locally, FAO advises to "ship the waste to an incinerator in an industrialised

country that is willing to accept it for destruction". Almost always, the costs of these operations are beyond the financial capacities of developing countries.
"Local disposal options should only be implemented on the advice and with the agreement and supervision of independent experts and national authorities" (PAN-UK 1998). New technologies have been developed, such as bioremediation (PAN-UK 1998).

2.6.4.2 Container Management: OECD (Organisation for Economic Co-operation and Development) and CropLife (global federation representing the plant science industry)

OECD (2004) says that programmes of pesticide empty containers management should not only focus on collection schemes and recycling, but rather in the entire product life-cycle with the participation of all stakeholders, encompassing: "product formulation and container design (manufactures and distributors handle it); distribution (manufactures and distributors handle it); use, handling and cleaning (e.g. triple-rinsing of containers, application equipment)(farmers handle it); collection; and re-use, recycling or disposal (operators of container collection and recycling schemes handle it).
Concerning the handling and cleaning of pesticide containers, triple-rinsing by farmers and other users is essential (OECD 2004). Besides, it is rather important adequate storage, product preparation and application, in order to avoid pesticide spill and excessive leftovers. Other important aspects are about choosing sprayer design (to avoid wasting of material) and encouraging safe handling and proper cleaning. In general the container management schemes concentrate great energy in awareness and training campaigns about safe handling and proper cleaning/triple-rinsing of pesticide and pesticide containers for users and retailers/dealers (OECD 2004).
Recycling appears as one of the best techniques available to deal with pesticide containers. Such method includes "energy/thermal recovery through incineration (e.g. France, Germany) and new material/products (e.g. Australia, Brazil, Canada)", such as: fence posts, construction material, aggregate in concrete, corrugated pipes to electricity, guardrails, among others (OECD 2004). The recycling method depends on technical and economic feasibility of each region, considering material prices (virgin vs. secondary/recycled) as well as the cost of technology (OECD 2004).
"Used pesticide container management need to be put it in the policy context of general waste management, i.e. minimising waste (source reduction) while maximising re-use and recycling/"valorisation" before disposal/destruction" (OECD 2004).
Because of quantities of used containers may be rather small to give reason for great investment in major recycling schemes in developing countries, which may not have existing usable facilities, then used container recovery and recycling schemes have to account for the value of empty containers in developing countries (OECD 2004).
Governments, industries and OECD countries can support the development of management schemes for pesticide containers. In its turns, governments need to legislate for recycling, since voluntary initiatives may not be sufficient, and provide support to the development of means for recycling. Whether one country cannot achieve economies of scale by itself, regional solutions may be one of the best strategies to tackle the pesticide containers mismanagement.

For instance, in Mozambique, PAN UK initiated negotiations with pesticide retailers as so to distributors collect the obsolete product and containers back from retail outlets when they are providing new stock. Such system could gather obsolete and unwanted pesticides as well as pesticide containers. Then this material could be disposed safely, likely possibly at an appropriate facility in South Africa if a local alternative is unavailable (OECD 2004).
Governments and industry need to strengthen education campaigns in order to improve awareness among final users and retailers. One of the most important topics to be approached is the triple-rinsing procedure (OECD 2004). Moreover, the final disposing should not be undertaken by final users. In spite of this, industry should provide recyclable containers and recycling schemes. OECD countries can also help and support developing countries by providing well developed models for container management (reuse, recycling and disposal).
Without a doubt, either recycling or recovery of containers are the most desirable final disposal option. Nevertheless, as such technologies are not available in all countries, practical solutions for the disposal of containers must be applied in accordance to the local reality (CropLife 2004). Although in less ideal conditions, in regions where it is necessary rinsed containers (non-hazardous waste) should be final disposed of at licensed disposal sites (CropLife 2004). Hazardous material such as pesticide contaminated paper, which cannot be triple-rinsed, should be disposed of at a site licensed to accept hazardous waste (CropLife 2004). If none of these options are available, the last options to be undertaken are local burning and burying; however, to do so, local burning and burying have to be permitted by local laws.

2.6.4.3 Obsolete Pesticides

Many initiatives and programmes worldwide have been approaching the management of obsolete and unwanted pesticides as before mentioned. In Africa, The Africa Stockpiles Programme (ASP) is a multistakeholder scheme to remove obsolete stocks of crop protection products from all 53 countries in Africa and to take appropriate steps to prevent further accumulation. The first phase of the ASP is being funded mainly by the Global Environment Fund. Besides, donors and national governments aid the programme as well. Over the 15 year expected lifetime of the ASP programme, up to US$30 million in direct funding and as provision of expertise has been committed by the companies participating in the CropLife International obsolete stocks programme (CropLife 2006). To final dispose of pesticides obsolete and unwanted pesticides, the programme suggests either shipping the pesticides to European as so to be incinerated in an environmentally sound manner or incineration in local cement kilns, such as in the case of South Africa or Kenya (pilot project) (CropLife 2006).
By far incineration is the most advised and used method in well developed schemes for disposal of obsolete pesticides (OECD 2004). However, this sophisticated cleanup technique is not feasible to small-scale pesticide users that do not have support from their government, pesticide industry, and distributors, among other stakeholders. For instance, commonly either single farms or small application businesses do not have funds to treat and dispose of by sophisticated means contaminated soils, unused pesticides, obsolete pesticides and equipment rinsewater (Felsot; Racke & Hamilton 2003).
In many countries from Africa, lack of information gives rise to mismanagement and poor handling of pesticide containers by farmers and retailers. Commonly, problems encompass inappropriate disposal techniques, like: burning or burying obsolete pesticides in open field or a

shallow pit (OECD 2004). Besides there are problems from inability to properly handle spills, equipment loading and rinsewater generated after application as well as problems with wastewater handling.

Important points about pesticide management are waste avoidance, waste reduction, and waste recycling. In order to avoid and reduce pesticides wastes, pesticide stocks ought to have adequate stored, good inventory, regular turnover, and registered materials with either lowest recommended application rates or applied in the least volume of water (Felsot, Racke & Hamilton 2003). Wastewater from equipment and container rinsing can be both used to dilute pesticides that require dilution and recycled by spraying it onto cropland. Pesticides leftovers have to be avoided by a careful calculation of the volume to be applied on the crop.

Even with all cautious to avoid pesticide wastewaster, probably it will generated; and hence, a wastewater treatment have to be designed to treat the pesticide wastewater. It is important to stress that small quantities are much easier to handle than bulk quantities, than reduction and avoidance of pesticide are rather important. Regarding small pesticide waste generators, practical technology is still too experimental and not easily implemented on an individual farm (Felsot; Racke & Hamilton 2003).

STAP (Scientific and Technical Advisory Panel) suggested that only commercially demonstrated technologies ought to be considered appropriate by GEF (Global Environment Facility) for use in developing countries. Although, GEF-STAP has found that bioremediation technologies for soil decontamination can be applied without being commercially proved (Diky 2008). Nevertheless, researches have been quite active in application of advanced oxidation processes (UV/ozonation), chemical degradation, ball milling, among other treatment solutions for pesticides (Felsot, Racke & Hamilton 2003 and Dyky 2008). Biological treatment methods (composting, landfarming, and bioaugmentation/ biostimulation) are also expanding in order to tackle pesticides (Felsot, Racke & Hamilton 2003 and Dyky 2008).

Indeed, up until now bio- and phyto- remediation have been considered the only viable option to be applied for pesticide treatment locally in small properties (WWF 2008). Biological treatment solutions (bioremediation and phytoremediation) are promising technologies, as such methods can be applied in warm areas at low costs (Dyky 2008). Composting and landfarming, that can be developed with or without biostimulation, are among the easiest biological methods that can be directly applied for the treatment of pesticide waste of small-scale generators (Felsot, Racke & Hamilton 2003).

Bio- and phyto-remediation technologies can be more suitable and sustainable than conventional technologies in Africa (Dyky 2008 and WWF 2008). It is because of both the fact that bio- and phyto-remediation treatment facilities have low levels of investment and maintenance and the fact that the high temperatures developed there are favourable to such treatment option (WWF 2008). However, bioremediation and phytoremediation of pesticides are not yet proven or easily applicable in all cases. (Dyky 2008), as it depends on temperature, pH, biodegradability of pesticides, among other factors. Such technique needs to be evaluated on a site-specific and technology-specific basis given the wide range of bioremediation (UNEP 2003).

Fertilizers

- **Expired Fertilizers**

Fertilizers are essential nutrients for the growth of primary producer (plants and algae). Nitrogen and phosphorus are the two main nutrients. Trace elements, such as potassium and iron, are also required to primary producer growth.

Fertilizers improve tremendously agriculture production. However, apart from the benefits, fertilizers have also promoted huge impacts in the environment worldwide. It is the main factor that influenced an expansion of eutrophication worldwide, as fertilizer are dump in the natural environment and are up take by algae. Thus, algae have an excessive growth, with a consequent depletion of oxygen and death of fish and other organisms.

Besides, nitrogen fertilizers also pollute groundwater and threat human health. Nitrites, one of the nitrogen compounds, react directly with hemoglobin in the blood of people to produce methemoglobin which destroys the ability of blood cells to transport oxygen. Such disease is especially serious in babies under three months of age as it causes a condition known as methemoglobinemia or "blue baby" disease.

As nutrients are essential to the growth of primary producers and are also break down by microbial activity, fertilizers (nutrients) can be treated using bioremediation process. Hence, fertilizer related wastewaters and expired fertilizers can be treated by simple biological technologies, as described in the topic 2.6.1.4 .

Study of case: Ethiopia

Approximately 80% of the 67 million people that inhabits Ethiopia are employed in agriculture. Such activity accounts for 50% of the national economy. Though, agriculture is plagued by periodic "drought, land degradation caused by inappropriate agricultural practices and overgrazing, deforestation, population pressure, undeveloped water resources, and poor transport infrastructure (Ethiopian Government 2006). Environmental problem due to farming practices are common in Ethiopia, heading up to siltation, devegetation, chemical pollution, among others (Ethiopian Government 2006).For instance, the worst erosion problem in the world per hectare of farmland is in Ethiopia because of poor agricultural practices, overgrazing and deforestation (Devi *et al.* 2007).

In Ethiopia waste management also threats the environment and the health of people because of uncontrolled burning of waste in open fires, which pollute the air. Thus, one of the greatest sources of air pollution by polychlorinated dibenzodioxin and dibenzofuran (PCCD/F) is uncontrolled domestic waste burning (Ethiopian Government 2006). The National Implementation Plan for the Stockholm Convention says that "efforts should be intensified to reduce open burning" by using techniques such as "reuse, recycling, composting, modern sanitary land filling and incineration using best available techniques" (Ethiopian Government 2006).

What is more, Ethiopia has signed "the Cartagena Protocol on Bio-safety (CPB) of the UN Environment Programme (UNEP) and has embarked on a series of environmental initiatives including a National Conservation Action Plan" (Valkman & Bosch 2008). In 2002, they have stablished Environmental Protection Organs, Environmental Impact Assessment, and Environmental Pollution Control.

Along with such improvements, the water Resources Management Policy from Ethiopia establishes that sufficient water of acceptable quality is an essential requirement. They say that such management should base on rural cantered, decentralized management and participatory approaches. The Water Resources Management Policy, "focuses on promoting decentralized management, fosters the participation of user communities and support community self initiatives in water resources management" (Valkman & Bosch 2008). Such management system of water resources shall be social and environmental sustainable.

All these initiatives are meant ensure both the protection of the environments and human health. Therefore, the development of activities (industry, agriculture, etc) in the country will improve towards a more sustainable development, in which facilities will at least do not pollute the environment.

- ***Ethiopian Practices***

  - **Pesticides**

Since 1960 Ethiopia has been accumulating obsolete pesticide. Over 12 years of pesticides importation data (1996–2007) from the Ministry of Agriculture, demonstrate that approximately 2,973 tonnes of pesticides were purchased from 1996 to 1998, 3,670 tonnes from 1999 to 2001, 5,079 tonnes from 2002 to 2004, and 8,302 tonnes from 2005 to 2007. Besides, from 1996 to 2002 the Ministry of Health also imported a great amount of pesticide to fight malaria and other diseases; approximately 919 tonnes from 1996 to 1998, 812 tonnes from 1998 to 2000, and 970 tonnes from 2001to 2002 (Haylamicheala & Dalvieb 2008).

It is predicted that "the more Ethiopia develops, the more the use of pesticides will be" (RC 2007). The utilization of agricultural chemicals is increasing steadily (RC 2007). Although, Ethiopia lacks technical infrastructure to undertake chemical management in an environmental sound manner; for instance there is no laboratories working specifically for chemical management purposes (RC 2007). Records of chemicals used in the country are commonly missing or lacking key pieces of information. Besides, other problems are:prolonged storage of pesticides, inappropriate storage conditions because of poor storage facilities, the lack of trained staff and lack of national legislation for pesticide registration and monitoring system of pesticide use in the country(Haylamicheala & Dalvieb 2008).

The main environmental matter is related to huge amounts of stockpiles, wastes and contaminated sites in Ethiopia. If no management scheme be implemented, such problems will probably increase socio-economic and environmental deterioration (Ethiopian Government 2006). According to the study on human health and environmental effects of POPs chemicals conducted during the POPs inventory in Ethiopia, the health of people in Ethiopia has been affected by pesticides (RC 2007). First of all, people dwelling nearby pesticide store areas are affected by releases from stockpiles (RC 2007). Second, pesticide storekeepers and sprayers are the most affected group by health problems from pesticide exposure in Ethiopia (RC 2007). Among the areas in where there is likelihood to pesticide contamination water, air or food, people are developing "headache, nausea, asthma, vomiting, bronchitis, skin allergies and abdominal cramps (Ethiopian Government 2006). These symptoms are rather common among people that work directly with pesticides too. Besides, among storekeepers there are cases of abortion, infertility, nervous system disorders, kidney problems, chronic skin problems, and deaths (RC 2007). Additionally, it was found that mothers have significant residue level of DDT in their breast milk in Addis Ababa (Ethiopian Government 2006).

Along with health problems, there are environmental problems related with pesticides in Ethiopia too. For example, it was observed a decrease of some birds preying on fish from lakes with possible contamination of pesticides (RC 2007). Ayenew (2007) found agrochemical contamination in water bodies and soil from regions in Ethiopia. Such contamination of water goes directly against the national law FDRE,197/2000 Article 7sub-article 1, which establish that "domestic water use shall have priority over and above any other water uses", however, in this case, agriculture interests are above the safe use of domestic water.

The POP pesticides have not been treated locally in Ethiopia due to the lack of sophisticated facilities and information. On the contrary, the only treatment pesticides option being undertaken is to ship obsolete pesticides to developed countries as so to be safely destroyed. However, hazardous waste is commonly stored and dumped almost anywhere in Addis Ababa (UV&P 2004). It is rather important to establish hazardous waste treatment facilities in Addis Ababa as the local demand for hazardous waste destruction is about 8 tons per day (UV&P 2004).

- **Fertililzers**

The nutrient transportation from agriculture site is rather elevated in Ethiopia (Haregeweyn *et al.* 2007). There, leachate with fertilizers from farms has been correlated with algal growth (eutrophication process) (Devi *et al.* 2007 and Ayenew 2007). Besides, Devi *et al.* (2007) found used fertilizers spread out in catchment areas of their study area in Ethiopia, probably being one of the reasons of the high concentration of nutrients of their analysis. In this context, the utilization fertilizers are contaminating and changing the quality of water and soil in Ethiopia (Ayenew 2007). The excessive increase of nitrite in the fields is one of the effects from the use of fertilizers (Ayenew 2007).

Ethiopian rift-valley has been modified by farmers who change catchment areas of the lakes and contribute to an increase of nutrients and particulate run-off, "especially when the grasslands are overgrazed and the fields are tilled or fertilized" (Ayenew 2007). Now a days there is a considerable flux of nutrients from farms into the natural environment (Haregeweyn *et al.* 2007). Still, growers and government desire to use more fertilizers in the region, which will definitely enhance even more the nutrient load into lakes (Ayenew 2007). It is lacking studies to define the impacts of fertilizers and pesticides on the water bodies from Ethiopia, but it is clear that the ongoing pollution of the environment, owned to agriculture, leads to harmful long-term effects on the water bodies and wildlife (Ayenew 2007).

According to Haregeweyn *et al.* (2007), an integrated soil fertility management practices as well as public aware campaigns should be undertaken to reduce the losses of fertilizers from farm properties. Devi *et al.* (2007) say that it is important to implement efficient use of fertilizers for different agricultural activities, reparation of green belt, erosion control; and introduction of soil conservation activities besides creation of ecological awareness among the residents dwelling near of their area of study in Ethiopia.

- ***Ethiopian Floriculture***

The Floriculture sector produces, as by-products, non-hazardous and hazardous wastes due to the utilization of Pesticides and fertilizers. In accordance to WageningenUR (WUR), pesticide and Fertilizer contaminated effluents from Floriculture can offer major impacts on water bodies in which they are discharged (WUR). Thus, pesticides and fertilizers are the main risk that the Floriculture sector put on the environment in Ethiopia (WUR).

The utilization of pesticides in the Ethiopian floriculture sector can spoil hydrological system (WUR) as well as soil by causing toxicity for organisms of these ecosystems. Pesticide can also be generated atmospheric pollution and ground water contamination by the Ethiopian flower farms, as some farmers burn and bury waste in open fires and non-engineered cells, respectively. Pesticide contaminated waste (hazardous waste) can release pesticides into the atmosphere when burned or into the ground when buried. Fertilizers also cause environmental degradation as it can promote salinization of soils and eutrophication of surface water as well as contamination of ground water by nitrogen compounds.

- ***Pesticides in Flower Sector***

Up to date, the need of pesticide has been increasing in Ethiopia due to the booming of the floriculture industries (Michael & Abate 2007). In the studies conducted in parallel with this project, the Ethiopian floriculture farms visited use 66 varieties of pesticides. Such pesticides encompass 23 different classes (table 1), from the latest classes to the primer ones. The two main classes of pesticides used by the Floriculture sector are organophosphates and pyrethroids, with 10 and 9 pesticides types, respectively.

As explained before, agrochemicals have different toxic effects, environmental fate, environmental transportation, and so on, due to their different chemical composition. Thus, it is rather important to analyze each pesticide individually in order to define adequate treatment technologies to them. However, pesticides that have similar characteristics can be clustered as so to be treated in the same way.

Throughout this section, the environmental fate of the pesticides from each class will be described. Besides, some characteristics will be discussed as well.

Table 1. Pesticides utilized in the Ethiopian Floriculture Sector, their classes and environmental fate.

Common Chemical Name	Pesticide Class	Koc (Adsorption)	Soil breakdown (DC50/days)	Photolysis (DT50/days at pH7, water)	Hydrolysis (DT50/days at pH7 and 20°C)
Chorofenapyr	Arylpyrrole	-	2.4	6.2	600
Bromopropylate	Benzilate	-	59	-	118
Thiophanate-methyl	Benzimidazole	5	2.2	36	-
Benomyl	Benzimidazole	1900	67	250	0.8
Diafenthiurion (Diafenthiuron)	Benzoylurea	-	0.5	250	-
Lufenuron	Benzoylurea	-	16.3	0.75	1200
Teflubenzuron	Benzoylurea	26062	16.4	10	1200
Flufenoxuron	Benzoylurea	3200	42	11	267
Hexaflumuron	Benzoylurea	18257	170	6.3	-
Abamectin	Biopesticide – Antibiotics	5000	28	1.5	1200
Azadirachtin	Biopesticide - Botanical	7	26	250	13
Bacillus thuringiensis	Biopesticide – Microbial	5000	2.7	-	-
Spinosad (geg. Spinosyn A)	Biopesticide – Spinosyn	16420	0.4	0.9	1200
Primicarb	Carbamate	60	10	-	-
Benfuracarb	Carbamate	400	0.5	1.3	1.4
Methiocarb	Carbamate	300	2	11	24
Oxamyl	Carbamate	25	7	26	8
Methomyl	Carbamate	72	7	250	1200
Aldicarb	Carbamate	30	30	8	189
Hexythiazox	Carboxamide	6200	30	17	1200
Acetochlor	Chloroacetamide	150	14	250	1200
Iprodione	Dicarboximide	700	84	67	3
Amitraz	Formamidines	1000	1	250	1
Bifenazate	Hydrazine carboxylate	4600	4	0.7	0.8
Clofentezine	Miscellaneous Compound -	11000	39	7	1.5

	Tetrazine				
Thiocyclam	Nereistoxin analogue	20	1	1	5
Thiacloprid or acetamiprid	Nicotinoid	615	18	250	600
Thiamethoxam	Nicotinoid	70	39	2.7	600
Imidacloprid	Nicotinoid	440	127	0.2	1200
Dicofol	Organochlorine	180000	60	26	3.3
Endosulfan	Organochlorine	12400	62	-	20
Dienochlor	Organochlorine	1000	300	5	-
Chlorpyrifos	Organophosphate	6070	50	29.6	25.5
Dichlorvos	Organophosphate	30	2	-	4.7
Fenamiphos	Organophosphate	100	2	0.2	304
Acephate	Organophosphate	2	3	2	50
Monocrotophos	Organophosphate	1	7	26	134
Dimethoate	Organophosphate	20	7	175	68
Profenofos	Organophosphate	2000	7	-	1200
Diazinon	Organophosphate	1000	9	50	138
Omethoate	Organophosphate	-	14	250	17
Cadusafos	Organophosphate - Organothiophosphate	-	38	174	1
Propargite	Organosulfur	4000	24.2	13.2	64.8
Tetradifon	Organosulfur	100	112	-	1200
Azocyclotin	Organotin	4450	27	-	1
Cyhexatin	Organotin	4000	50	250	1200
Fentin Acetate (geg. fentin hydroxide)	Organotin	2300	140	-	0.07
Fenbutatin oxide	Organotin	3200	271	200	1
Tebufenpyrad	Pyrazole	4204	14	250	1200
Fenamirol (Acrinathrin) FENARIMOL	Pyrethroid	600	250	0.5	1200
Deltamethrin	Pyrethroid	186067	13	48	1200
Bifenthrin	Pyrethroid	240000	26	12	1200
Lambda-cyhalothrin	Pyrethroid	180000	30	40	1200
Fenpropathrin	Pyrethroid	5000	34	14	1130
Alpha-cypermethrin	Pyrethroid	57889	35	250	101
Cypermethrin	Pyrethroid	42367	60	13	179
Tau fluvalenate	pyrethroid (isomer mix)	1000000	30	4	22.5
Beta-cyflurthrin (Cyflurthrin	Pyrethroid, isomer mixture	64300	13	1	215

given)					
Fenazaquin	Quinazolines	26500	45	15	130
Spiromesifen	Tetronic acid		23	1.7	44.7
Cyromazine	Triazine	200	120	250	1200
Methyl-cyano / Methylacetamidine (geg. methyl isothiocyanate)	-	10	10	-	-
Oximatrin	-	-	-	-	-

- **Pesticide description and treatment**

In this section it will be described the feature of the pesticide used in the Ethiopian flower farms as well as the regulations to use them (mostly European regulations). Besides, a suggestion of simple treatment options will be done to each pesticide. It is no wonder that more sophisticated techniques can be used to treat these pesticides, depending on the economical and physical feasibility of the systems.

- *Organophosphates*

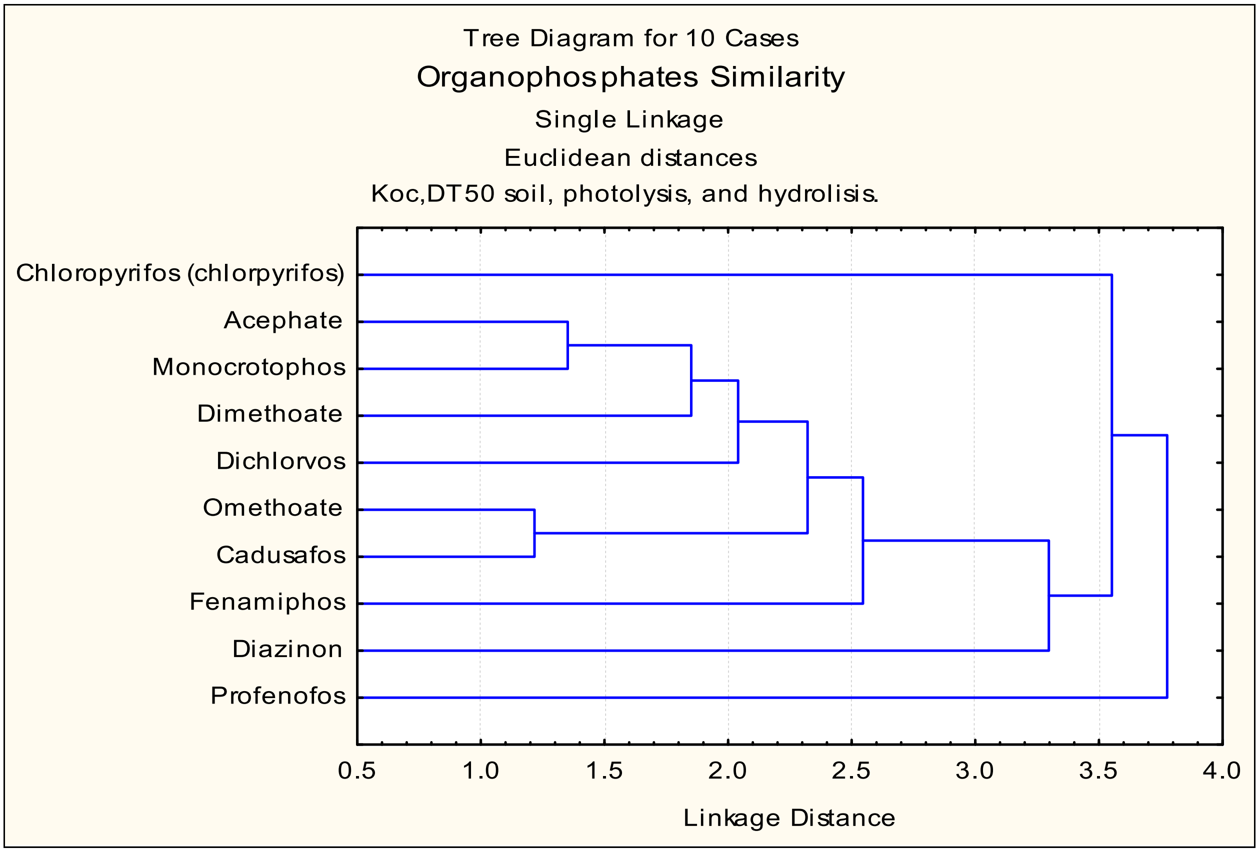
The Floriculture sector uses 10 different organophosphates: Chlorpyrifos, Dichlorvos, Fenamiphos, Acephate, Monocrotophos, Dimethoate, Profenofos, Diazinon, Omethoate, and Cadusafos.

- *Legislation*

Because of organophosphates is one of the most toxic pesticides classes to vertebrates they have been banned since 1990. For instance, the EU (EC Directive 91/414 Status) prohibit the use of Acephate, Diazinos, Dichlorvos, Monocrotophos, Omethoate, Profenosfos and Cadusofos. Thus, out of 10 organophosphates used by the Ethiopian Floriculture, 7 were forbidden. In the case of Monocrotophos, it is also banned from Brazil and in the list of very hazardous substance from the Rotterdam Convention (Annex III).

- *Environmental Fate*

Following the same trend of most organophosphate (OP) pesticides, the OPs used by the floriculture sector in Ethiopia are not persistent in soil. Among the applied organophosphates, Chlorpyrifos and Cadusofos are the only moderately persistent ones, with half life (DT50) of 50 and 38 days in soil (AERU 2008). Conversely to these two pesticides, the other organophosphates (Fenamiphos, Acephate, Monocrotophos, Dimethoate, Profenofos, Diazinon, and Omethoate) are non-persistent, with a degradation half life ranging from 2 to 14 days in soil (AERU 2008). Chlorpyrifos, Profenofos, and Diazinos are prone to absorb on soil particles, while the other organophosphates are likely to leach.
Regarding hydrolysis, both Chlorpyrifos and Cadusafos are non-persistent in water, breaking down in less than 1 day and 26 days, respectively (AERU 2008). Considering photolysis, it is the quickest pathway in which Fenamiphos and Acephate are breakdown, DT50 = 0.2 day and 2 days, respectively (AERU 2008).



EXTOXNET (1996) reported that Acephate, Montocrotophos, Dimethoate, and Dichlovos undergo greatly microbial breakdown in soil. The similarity test has demonstrated that these 4 OPs have a close relation in regards to their environmental fate. In the case of Acephate and Dimethoate, aerobic conditions and clay loam soil were pointed out as the greatest condition for degradation, respectively. These parameters, greatest soil type and air condition to biodegradation, were not informed to the other organophosphates. However, considering that organic soil, like loam soils, and aerobic conditions use to improve the microbial activity, it is probable that these conditions improve microbial breakdown to the other OPs. To Chloropyrifos and Dichlovos it was reported that in alkaline soil the degradation is improved as well. However, its breakdown also occurs in acidic conditions (EXTOXNET 1996). This information was not available to the other OPs.

EXTOXNET (1996) has written that in waters with a high content of microorganisms it has also occurred biodegradation of Dichlorvos, Dimethoate and Omethoate. Probably it also occurs to the other OPs, but studies have to be carried on. In water, degradation takes place both in acidic and alkaline media.

All organophosphates applied in flower farms in Ethiopia are volatile. Dichlovos and Cadusafos are very volatile (vapor pressures are around 2100 and 119 MPa, respectively), while Profenofo, Diazinon and Omethoate have moderate volatility, and the other OPs have low volatility.

- *Treatment*

As all of the organophosphates are, to some extent, biodegradable, a facultative lagoon appear to be a great treatment option, in which occurs process of photodegradation, microbial break down in water phase and sediment, and hydrolysis. Some of OPs are persistent to one of these

degradation pathways, but all of them breakdown by one of these degradation *vias*. As final treatment, it can be implemented a wetland system to uptake the more persistent water soluble OPs, since the other ones will be probably bond on sediment particles or broken down.
Special attention has to be paid to Monocrotophos and Acephate as they are extremely soluble in water and, are very prone to leach. Thus, they cannot have contact with soil should be treated in close biological system, with microbial breakdown followed by phytoremediation, that can uptake pesticides that are diluted in water. In the case of monocrotophos, such treatment can be still not efficient, and then a sophisticated disposal technology will be required.

- *Organochlorine*

The Ethiopian floriculture sector uses three organochlorine pesticides: Dicofol, Endosulfan, and Dienochlor.

- *Legislation*

The EU by the EC Directive 91/414, Excluded the use of Decofol, Dienochlor and Endosulfan.

- *Environmental Fate*

As expected, the organochlorine pesticides used are tightly adsorbed by soil, and then they are not likely to leachate into ground waters. Even though, Dienochlor presents a greater likelihood to leachate than the other two. Considering volatility, Dicofol and Endosulfan are low volatile and Dienochlor moderately volatile (Table 1).
Regarding the persistence in soil, that is the greatest worry about them, Dienochlor is persistent and the other two have moderately persistence. However, Dienochlor is rapidly breakdown by sun light degradation in water (DT50= 5 days) and on soil; whereas Dicofol and Endosulfan demonstrate a rapid degradation by hydrolysis (DT50= 3.3 and 20 days, respectively).
Dicofol breakdown improves both in soil by anaerobic microbial activity (DT50=16 days) and in water by more alkaline media (DT50=85 days at pH 5 and DT50=26 minutes at pH 9). Its degradation in the sediments is considered fast (AERU 2008), approximately DT50= 29days). Dicofol is persistent when adsorbed by plants. Equally important, Endosulfan undergo microbial breakdown (bacteria and fungi) in soil at relatively rapid timing (AERU 2008). Besides, alkaline soils also enhance its degradation. Endosulfan breakdown in 4 weeks in river waters, probably due to the microbial activity.

- *Treatment*

Dicofol and Endosulfan are prone to breakdown by microbial activity, whereas Dienochlor by solar light degradation. Anaerobic ponds could be a great treatment for Dicofol, and an activated sludge process could be great for Endosulfan. Shallow lakes, where with low concentrations of suspended soil, would be a great solution for effluents with Dienochlor.
On the other hand effluents with these three organochlorine pesticides can be treated by adsorption on suspended organic solids in the water column and subsequent decantation. Afterwards the sludge can be treated by landfarming.
The options pointed above are developed *in situ* and have low cost. Another options to the treatment of these pesticide can be the utilization of high tech process, such as incineration.

- *Carbamate*

Six Carbamates pesticides are used in the Ethiopian floriculture sector: Aldicarb, Benfuracarb, Methiocarb, Methomyl, Oxamyl, and Primicarb.

- *Legislation*

Among the carbamates used by flower growers in Ethiopia, only Methiocarb and Oxamyl are in the Annex 1 from EC Directive 91/414. Primicab is a new carbamate, since 2000, and it was not found information about its registration in EU. The other three carbamates, Aldicarb, Benfuracarb, and Methomyl were excluded from usage in EU. However the former is allowed to essential use only, and Benfuracarb and Methomyl were re-submitted to Annex 1 from EC Directive 91/414.

- *Environmental Fate*

All of carbamates have water affinity and are prone to leachate into ground water. In particular, the greatest water solubilities are from Oxamyl (148100 mg/L), Methomyl (55000 mg/L) and Aldicarb (4930 mg/L). Benfuracarb, Methicarb and Oxamyl are non-volatile, while Methomyl and Aldicarb are low volatile and moderately volatile, respectively (table 1).
With regards to degradation in soil, excluding Aldicarb (DT 50= 30 days), all of carbamates applied are rapidly breakdown (DT50 up to 10 days). Probably such rapid breakdown is due to microbial activity. To illustrate, fast biodegradation was repotted for both Methomyl and Oxamyl in soil and water (EXTOXNET 1996). Oxamyl breakdown rapidly under aerobic and anaerobic conditions on soil. Besides it was also demonstrated that Oxamyl breakdown more rapid in neutral and alkaline soils.
In water there is considerable biodegradation on carbamates as well. Oxamyl half-life in water ranges from 1 to 2 days (EXTOXNET 1996). Under aerobic conditions, Methomyl half-life is about 6 days in water (EXTOXNET 1996). What is more, Aldicarb is reasonably rapid broken down by microbial activity in water too (EXTOXNET 1996). Excluding Primicarb, that has not data available, AERU (2008) reports that all carbamates applied by flower growers in Ethiopia have a fast breakdown into sediments.
Plants also uptake Aldicarb, Methomyl and Oxamyl. Phytoremedation of Methomyl and Oxamyl were reported by EXTOXNET (1996). Methomyl has a half-life of 5 days in plants, while Oxamyl totally breakdown in plats varies from 1 to 2 weeks (EXTOXNET 1996).
Hydrolysis and photolysis are other pathways in which Benfuracarb, Methiocarb, and Oxamyl undergo degradation rapidly. Considering Aldicarb, although it is stable to hydrolysis, its breakdown by solar photodegradation is great (DT50= 8 days). On the other hand, Methomyl is persistent to both hydrolysis and photolysis.
It was not found data for Primicarb about these degradation pathways.

- *Treatment*

It is no wonder that biological treatments are highly indicated to treat the carbamates used in the Floriculture Sector from Ethiopia. It can be used to all carbamates a treatment which encompass microbial, sun light, and hydrolysis breakdown. Such treatment can be a combination of ponds with biological reactor.

Exclusively for Aldicarb, it could be used a lagoon system, with an adsorption on suspended organic soil system with decantation. This system includes degradation of the sediment by biological activity. This system can prevent volatilization as well. Although, such system probably will not encompass photodegradation, one of the most superior pathways to breakdown Aldicarb.

- *Pyrethroid*

The flower farmers in Ethiopia use 10 different Pyrethoids: Fenamirol, Deltamethrin, Bifenthrin, Lambda-cyhalothrin, Fenpropathrin, Alpha-cypermethrin, Cypermethrin, Tau fluvalenate, Beta-cyflurthrin.

- *Legislation*

Most of the pyrethroids used are in the Annex 1 from EC Directive 91/414, and, hence, are allowed in EU. However, Bifenthrin, Fenpropathrin, and Tau fluvalenate are prohibit in EU.

- *Environmental Fate*

As expected, 5 out of the 9 Pyrethroids are moderately persistent pesticides in soil. Deltamethrin, Bifenthin, and Beta-cyflurthrin are non-persistent. Only Fenamirol is persistent in soil among the pyrethroids used by flower farmers in Ethiopia. Not including Fenamorol, all of other pyrethroids bind tightly on soil particles, and then are unlike to leach into groundwater. Probably, when in water, they adsorb rapidly to particles, as described for Kamrin (1997). The majority of them are rapidly breakdown by sun light. Alpha-cypermethrin alone is stable against sun light degradation; while Deltamethin and Lambda-cyhalothrin are moderately persistent under sun light. The pyrethroids used are persistent against hydrolysis. Just Tau fluvalenate breakdown fast by hydrolysis (DT50 = 22.5 days). Besides, most of them are non-volatile, and only Fenpropathrin is moderately volatile.
Cypermethrin, that is moderately persistent, can breakdown quite rapidly by microbial activity (DT50 = 4days – 8weeks) in soil (EXTOXNET 1996). Lambda-cyhalothrin undergo microbial breakdown either in aerobic or in anaerobic in soil (EXTOXNET 1996). Alpha-cypermethrin has a relatively fast degradation (DT90 = 21 to 118 days) (EXTOXNET 1996). In general, alkaline media helps the degradation of pyrethroids, as observer for Alpha-cypermethrin, cypermethrin, Lambda-cyhalothrin, and Tau fluvalenate. Only Bifenthrin is degradated greatly in acidic media (EXTOXNET 1996).
As pyrethroids bind tightly to soil particles, its half-life in the water column is generally rapid. Among the pyrethroids used, only Deltamethrin has a long half-life in the water column (17 days), probably because of its low specific gravity (0.55 g/ml). The other pyrethroids' half-life varies from 8 days to 1 day, and the specific gravity varies from 1.15 to 1.40 m/ml. The denser is the pesticide, the greater is the likelihood of decantation. When in water sediments, most of them breakdown rapidly: Alpha-cypermethrin (DT50=21 days), cypermethrin (DT50=17 days), Fenpropathrin (DT50=28 days), Lambda-cyhalothrin (DT50=12 days), Tau fluvalenate (DT50=48 days), and Beta-cyflurthrin (DT50=3 days). Although, Fenamirol, Bifenthrin, and Deltamethrin are relatively stable in sediments (EXTOXNET 1996).
Plants also breakdown pyrethoids. In mild acids or alkalis they are rapidly fated(EXTOXNET 1996). For instance, Deltamethrin breakdown by phytoremedion is approximately 10 days

(EXTOXNET 1996). However, EXTOXNET (1996) reported that Bifenthrin is not absorbed by plants rapidly.

- *Treatment*

All of the Pyrethroids used are in the liquid form, so they have to be treated as effluents. To most of the pyrethroids it can be used a combination of systems, with an initial adsorption and/or decantation, bioderemediation, alkaline ponds, photodegradation, and a final wetland. It is a complex system, but with low operating costs.
However, there are some exceptions, such as: Fenamirol. This pyrethroid should be treated by bioremetion and photodegradation. Then a facultative aerated shallow pond could be a great solution to remediate this pesticide, with microbial a solar light activity. Anyway we have to consider the dangerous of volatilization, and, depending on the emission, try to minimize this by adsorption on soil particles. Such adsorption can minimize the microbial and photo degradation.
Besides, Bifenthrin cannot also be treated by the system described first. It should be treated in similar pathway of Fenamirol: bioremetion followed by or with photodegradation. An intermediate acid pond can also help to improve the breakdown of Bifenthin.
Deltamethrin should be treated by phytoremetion, such as wetland systems.
If it is not possible treat Deltamethrin and Bifenthrin by the mean pointed before, they can be adsorbed in soil particles and decantation. However, the sediment has to be treated in a landfarming process as these pyrethroids do not breakdown greately in the sediments, and do breakdown greatly in soil.

- *Pyrrole*

Chlorofenapyr is the Pyrrole used by the Ethiopian Floriculture sector. Pyrrole is a new goup of pesticides. Chlorofenapyr was introduced in 2001, and is used to control mites and insects, including the ones that are resistant to carbamates, organophosphates and pyrethroids.

- *Legislation*

Chlorfenapyr is not allowed by the EU directive (EC Directive 91/414 Status). Probably, it is due to the high toxicity of Chlorfenapyr to fishes, birds, and aquatic invertebrates. It is also classified by World Health Organization as moderately hazardous to human health.
In the US it is allowed to ornamental crops in commercial greenhouses, non-food use. However, the US EPA decided not to register outdoor use because of persistence and concerns regarding the reproduction of birds (US EPA 2001).

- *Environmental Fate*

Chlorfenapyr is not like to both leachate and vaporize. It is non-persistent in soil (DT50 = 1.4 days) and in water to photodegradation (DT50=6.2 days). However, Chlorfenapyr is persistent to hydrolysis.

- *Treatment*

Sun light and Biological treatment seem to be a great solution to treat Chlorfenapyr. Thus, aerated shallow ponds could be used.

- *Benzilate*

Only Bromopropylate is the pesticide from Benzilate group used in the Ethiopian flower farms.

- *Legislation*

In EU, Bromopropylate was excluded from the Annex 1 (EC Directive 91/414), and can be used only in essential applications. Probably, it is due to the moderate toxicity of Bromopropylate for: birds, fishes, aquatic invertebrates, and Earthworms. Bromopropylate has also a high potential to bioaccumulate.

- *Environmental Fate*

Bromopropylate is moderately persistent in soil (DT50=59days), and is stable to hydrolysis. It binds tightely in soil particles, and then is not prone to leachate into groundwater. It has more like to bind in soil particles than to leach. In water it has a rapid degradation, in which water phase and sediment half-life are 4 and 63 days (AERU 2008). Alkaline media improves its degradation. Besides, Bromopropylate is not volatile at 25ºC in Addis Ababa. However, it can volatilize at greater temperatures or higher altitudes.

- *Treatment*

Septic tanks could be a great solution to effluents with Bromopropylate, because of bromopropilate binds on solid particles and sediments quite rapidly from water column. Also it has a considerable rapid degradation into sediment. Ponds can be also used in this case, or even activated sludge.

- *Benzimidazole*

Benomyl and Thiophanatemethyl are the pesticides from Benzimidazole group used in the Ethiopian Floriculture sector. They are fungicides against diseases such as powdery mildew. They have been used since the 1970s.

- *Legislation*

Thiophanate-methyl is approved for use in several countries, while benomyl is restricted in some countries. For instance, Benomyl is not allowed in crops from the EU and Thiophanate-methyl is (EC Directive 91/414 Status).

- *Environmental Fate*

Both pesticides have conversely environmental fate. Benomyl is prone to bind in soil particles, whereas Thiophanate-methyl is more like to leachate. The former is moderately persistent, and the last is non-persistent. In one hand Benomyl is moderately photodegradable and does not vaporize; on the other hand, Benomyl is photo stable and volatile. The pathway in which Benomyl breakdown rapidely is hydrolysis. Moreover, it is greatly absorbed by plants. Thiophanate-methyl is moderately persistent against hydrolysis, but resides for a few period in water phase and breakdown rapidly into sediment.

- *Treatment*

Benomyl has to be treated by hydrolysis in ponds with a sequential Phytoremediation system; whereas Thiophanate-methyl should have a system that encompasses photodegradation, biological activity and decantation, such as a Partial-mix Aerated Lagoon.

- *Benzoylurea*

There are 5 different pesticides from Benzoylurea class used in the Ethiopian Floriculture Sector: Diafenthiuron, Flufenoxuron, Hexaflumuron, Lufenuron, Teflubenzuron, and Legislation. Benzoylureas are rather different from other insecticides classes, as they do not poison the the insects, but rather they interfere with chitin synthesis.

- *Legislation*

Firstly, Flufenoxuron and Hexaflumuron were excluded from usage in EU (EC Directive 91/414 - Annex 1). Secondly, Teflubenzuron is approved for use in EUropean Union. Lufenuron is also approved in EU, but is pending in relation to the Annex 1 - EC Directive 91/414. This last pesticide is registered in Australia as well. Finally, Diafenthiuron is not listed by EC Directive 91/414 Status, but it is registered in Australia, Asia Pacific, and Latin America.

- *Environmental Fate*

All of the Benzoylurea applied have the tendency to bind on soil particles. With expiation of Hexaflumuron, all the other ones are non-volatile. Hexafluram is also the only persistent in soil, while Flufenoxuron is moderately persistent and the rest are rapidly breakdown in soil. Diafenthiuron, that is the Benzoylurea with the fastest degradation in soil (DT50=0.5days), is the only one that is stable to sun light. All the other pesticides from this class are photodegradable. The 5 Benzoylurea pesticides used are not like to breakdown by hydrolysis.
It was reported by AERU (2008) that Lufenuron is moderately fast breakdown by microbial degradation in sandy loam soils (DT 50= 13d). However this pesticide is stable in water phase and sediments. Conversely, Teflubenzuron has demonstrated a fast residence in water phase and a rapid breakdown into sediments. In most of the cases alkaline media improves degradation of Benzoylurea pesticides.

- Treatment

All of the 5 Benzoylurea pesticides should be treated by either photodegradation or bioremediation, or even both systems. In special, Lufenuron has to be treated by microbial break down without sedimentation, as probably it needs aerobic condition to undergo mineralization. On the other hand, Teflubenzuron should be treat by system in which it is adsorbed on soil particles, sediments, and breakdown into sediments.

- *Biopesticides*

Biopesticides are substances of natural origin that have been used as pesticides. In some cases they are called of biorational pesticides, as, in most of the cases, they have low hazardous effects on nature. There are 4 different biopesticides in use by the Ethiopian Floriculture Sector: Abamectin (Antibiotic), Azadirachtin (Botanical), *Bacillus thuringiensis* (Microbial), and Spinosad (Spinosyn).

- *Legislation*

All of 4 biopesticides used are permitted in EU (EC Directive 91/414 - Annex 1). Although, Azadirachtin status is pending in the Annex 1 (EC Directive 91/414).

- *Environmental Fate*

Abamectin has been isolated from the fermentation products of Streptomyces avermitilis, a member of the actinomycete family.
Botanical insecticides are natural insecticides from plants. As they are natural, they can give rise to environmental advantages. Some examples of this class are: tobacco, pyrethrum, derris, hellebore, quassia, camphor, and turpentine. Before synthetic pesticide production, some of them were one of the most important plant products.
Microbial insecticides are microorganisms used as pest control agents. There are few members of this group, 55 natural and16 bioengineered organisms for use on food and feed crops , where most of them are fungi and bacteria (Ware and Whitacre 2004).
Spinosyn is among of the newest classes of insecticides, first registration in 1997 (Ware and Whitacre 2004). It is represented by spinosad, a fermentation metabolite of the fungus actinomycete (Saccharopolyspora spinosa). This fungus is a soil-inhabiting microorganism.
All of the 4 pesticides have a fast degradation in soil, where Spinosab and Bacillus thruringiensis are broken down more rapidly (DT50=0.4 and 2.7 days, respectively), while Azadirachtin and Abamectin are broken down in a longer time (DT50=26 and 28 days, respectively). With exception of Azadirachtin, all the other 3 biopesticides are adsorbed on soil, and then, they are not like to leachate into groundwater. None of them appeared to be volatile. Considering degradation by sun light in water, Abamectin and Spinosad are broken down rapidly, while Azadirachtin is persistent. No data was available about Bacillus thuringiensis photodegradation in water.
In aerobic conditions Abamectin breakdown more rapidly. The Photodegradation of this pesticide on soil varies from 8 hours to 1 day, and on plants from 4 to 6 hours. Azadirachrin in water breakdown rapidly (DT90=100h). *Bacillus thuringiensis* suffers photodegradatio immediately on soil and plants (DT50 3.8 hours). It also breaks down fast into water. Such pesticide remains in the water phase for up to 2 days. Last but not least, Spinosyn has a fast breakdown in water due to sun light (DT50= 0.9 days). In alkaline media its degradation is enhanced.

- *Treatment*

Biological treatments are highly advised for biopesticides as they are biodegradable. Sun light can be also used as a treatment for Abamectin, *Bacillus thrringiensis,* and Spinosad. Ponds can be used to Azadirachtin as it breakdown rapidly in water.

- *Carboxamide*

Hexythiazox is a carboximide pesticide that has been used in the Floriculture Sector in Ethiopia.

- *Legislation*

Hexythiazox is excluded from EU (EC Directive 91/414). However it is approved for use in some countries of Europe and in Australia. Probably the restriction are because of Hexythiazox is highly toxic for fishes, and is moderately toxic for many other animals.

- *Environmental Fate*

Hexithiazox is prone to bind tightly on soil and is not volatile. It is moderately persistent in soil, and has rapid degradation in water due to photolysis. Hydrolysis does not occurs considerably. Hexithiazox stay for a short term in water phase (DT50=11.5 days), and its breakdown is speedy into sediments (DT50= 37days).

- *Treatment*

One of the treatment option for effluents with Hexythiazox is a Septic Tank followed by a shallow pond.

- *Chloroacetamide*

Acetochlor is a Chloroaceramide herbicide used in the Ethiopian Floriculture Sector.

- *Legislation*

Acetochlor was excluded from the annex 1 of the EC Directive 91/414 Status, and then is prohibited in EU. Certainly such exclusion is because of Acetochlor harmful effects on aquatic plants, algae, birds, fishes, and aquatic invertebrates. Although, this pesticide has been used in some countries from the EU.

- *Environmental Fate*

Acetochlor is not volatile and do not bind on soil particles immediately. It has non-persistence in soil, and is barely breakdown by sun light and hydrolysis. Acetochlor is biodegradable, with total degradation ranging from 8 days to 12 weeks in soil. It is undergo rapid microbial breakdown into sediments (DT50=19.7 days) as well, but has difficulty to sediment (water phase DT50 = 10.5 days). Acetochlor is also absorb quite suddenly by plants.

- *Treatment*

In order to treat Acetochlor it could be used a treatment system with an activated sludge followed by a wetland.

- *Dicarboximide*

Iprodione is a fungicide from the class Dicarboximide that has been used in the Ethiopian Floriculture Sector.

- *Legislation*

Iprodione is allowed in EUropean Union (EC Directive 91/414 - Annex 1).

- *Environmental Fate*

Iprodione has moderately water solubility, and can bind on soil or leach with water. It is moderately persistent in soil (DT50=84 days). Such pesticide is also moderately persistent to phodegradation in water. On the other hand, it breaks down rapidly by hydrolysis (DT50 3 days). Alkaline media improves its degradation. Iprodione has a fast degradation in sediment (DT50=30days) as well, but is stable in water phase (DT50=30days). Under aerobic conditions it breaks down more rapid. This pesticide is up take and breakdown rapidly by plants. Iprodione is not volatile.

- *Treatment*

Iprodione can be treated using a system with a facultative lagoon followed by a wetland.

- *Formamidines*

Amitraz is the pesticide from the small class Formamidine, and has been used in the Ethiopian Floriculture Sector.

- *Legislation*

Amitraz is only permitted for essential uses in EU, and has been excluded from the Annex 1 (EC Directive 91/414 Status). Naturally, it is because Amitraz has high bioaccumulation potential, high toxicity for aquatic invertebrates, moderate toxicity to several other animals, and neutotoxical effects on humans.

- *Environmental Fate*

Amiatraz adsorbs on soil particles, and then has low leachability. It does not volatilize, and is very rapidly breakdown by microbial activity (DT50=1day in soil) and hydrolysis (DT50=1day). On the contrary, it is stable to photodegradation. Amiatraz breakdown more rapidly in acid media.

- *Treatment*

Effluents with amitraz can be treated by facultative lagoons, in which such pesticide will break down both by microbial activity and hydrolysis.

- *Hydrazine carboxylate*

Bifenazate, from the class Hydrazine carboxylate, is a new pesticide (since 1999, US; and 2000, UK) against mites. It has been used in the Ethiopian Floriculture Sector.

- *Legislation*

Bifenazate is allowed in Europa, US, Australia, among other countries.

- *Environmental Fate*

Bifenazate binds tightly on soil particles, and then is not like to leach. It is not like to volatilize as well. Its break down is super rapid in all of the main pathways: soil (DT50=1-4 days, aerobic conditions), photodegradation in water (DT50=0.7 day), and hydrolysis (DT50=0.8 day). Neutral and alkaline pHs improve Bifenazate degradation. Its half-life is approximately 0.25 day in both water phase and sediment.

- *Treatment*

As Bifenazate breaks down rapidly in a diverse range of possibilities it can be used several types of treatment, such as: facultative lagoons, septic tanks, aerated ponds, activated sludge, shallow ponds, among other options.

- *Nereistoxin*

Thiocyclam is a insecticide from Nereistoxin group. It is currently used in the Ethiopian flower farms.

- *Legislation*

Thiocyclam is not used in EU, and has been excluded from the Annex 1, Directive 91/414. It is highly toxic for fishes, moderately toxic for aquatic invertebrates, algae, earthworms, and mammals.

- *Environmental Fate*

Thiocycla is very soluble in water and is prone to leachate into groundwater. It is also volatile. Its breakdown is quite fast in a diverse range of pathways: soil (DT50=1day), photodegradation (DT50=1day in water), and hydrolysis (DT50=5days).

- *Treatment*

Thiocyclam can be treated facultative lagoon system, and systems that encompass bio-, photo- and hydro- remediation. Probably, phytoremediaiton is also a great solution to deal with such pesticide.

- *Nicotinoids*

Nicotinoids are a newer class of pesticides. They have been previous named as: *nitro-quanidines*, *neonicotinyls, neonicotinoids, chloronicotines,* and more recently as the *chloronicotinyls* (Ware and Whitacre 2004). Nicotinoids were synthetic modeled based on the natural nicotine molecule. Imidacloprid, one of the nicotinoids, was introduced in Europe in 1990 and was first registered in 1992 in the U.S. Probably, in terms of volume, it is the most used insecticide throughout the world (Ware and Whitacre 2004). The Ethiopian floriculture sector used 3 pesticides from this class: Thiacloprid, Thiamethoxam, and Imidacloprid.

- *Legislation*

All of 3 nicotinoids are used in Europe. However decision to keep Imidacloprid in the Annex 1 from EC Directive 91/414 Status was postponed. The other two are included in the Annex 1.

- *Environmental Fate*

All of 3 Nicotinoids are non-volatile and soluble in water. Thus they are prone to leach into groundwater. Thiacloprid, Thiamethoxam, and Imidacloprid, are non-persistent (DT50=18days), moderately persistent (DT50=39days), and persistent (DT50=127days). The former is stable to photodegradation, but the two last ones breakdown rapidly under sun light non-persistent (DT50=2.7days and DT50=0.2day, respectively). All of them are persistent to hydrolysis.
Anhalt, Moorman, and Koskinen (2007) have demonstrated that Imidacloprid has had of 43% degradation in 21 days due to microbioal activity. Besides, it was also demonstrated thar Imidacloprid breakdown rapidly with plant activity (EXTOXNET 1996).
Thiacloprid is rapidly breakdown into sediments (DT50=50days), and has a moderately fast half-life in the water phase (DT50=8.5 days).
Thiamethoxam degradation is enhanced in alkaline media. It is stable in the water phase (DT50=30.6days), but in sediment it breakdown moderately rapidly (DT50=40days).

- *Treatment*

Imidacloprid should be treated in a system with photolysis, microbial degradation, and phytoremediaiton. Then a facultative lagoon followed by a wetland appear to be a good technical solution.
Thiacloprid should be treated in a system such as a septic tank or activated sludge.
Thiamethoxam can be also treated by activates sludge. After this first treatment it can be final treated in shallow ponds by solar light degradation.

- *Organosulfur*

Organosulfur is a small class of pesticides with very low toxicity to insects. They are used only as miticides (Ware and Whitacre 2004). Their structure resembles the DDT, with sulfur in place of carbon as the central atom. Such class includes tetradifon, propargite, and ovex (Ware and Whitacre 2004). The two formers are used in the floriculture sector in Ethiopia.

- *Legislation*

Both pesticides were excluded from the Annex 1 (EC Directive 91/414 Status). But Propargite is used in many country from EU and is registered in Australia. Tetradifon is allowed just to essential uses (Annex 1 - EC Directive 91/414 Status), and in used in Spain for instance, and is registered in Australia.

- *Environmental Fate*

Propargite and Tetradifon are quite different. The former is not soluble in water, and the last is not. Regarding degradation in soil, Propargite is rapidly breakdown (DT50=21.2 days) and Tetradifon is persistent (DT50=112 days). Considering hydrolysis, Propargite is moderately persistent (DT50=64.8 days), while Tetradifon is persistent. The only feature they share is the low vapor pressure, indicating that both are not volatile. Anyway the vapor pressure of Tetradifon is much higher than the one of Propargite. Propargite is breakdown by sun light (DT50=13.2 days).

- *Treatment*

Propargite can be treated using facultative lagoon, where it will undergo degradation in the sediments and in the water phase by photodegradation.
Tetradifon is persistent in soil and and to hydrolysis, and does not have data about its photdegradation. Thus, onsite treatement is not indicated in this case. Probably it will require more advanced treatment facilities, such as incineration.

- *Organotin*

The organotins are a group of acaricides. Some pesticides of this group are Cyhexatin and Fenbutatin-oxide, one of the most selective acaricides known and an extensively used pesticide against mites on deciduous fruits, citrus, greenhouse crops, and ornamentals (Ware and Whitacre 2004). From this group there are 4 pesticide in used by the Ethiopian Floriculture Sector: Azocyclotin, Cyhexatin, Fenbutation-oxide, and Fentin Acetate.

- *Legislation*

Azocyclotin, Cyhexatin, and Fentin Acetate were excluded from the Annex 1 (EC Directive 91/414 Status). However, Azocyclotin and Cyhexatin are still used in countries such as Italy, Portugal, France, among other EU countries. Fentin Acetate is not used. No data found to Fenbutation-oxide.

- *Environmental Fate*

All of 4 pesticides are tightly bind on soil. Fentin Acetate and Fenbutatin-oxide are moderately volatile; while Azocyclotin and Cyhexatin are non-volatile. These two last pesticides are persistent in soil. Fentin Acetate and Fenbutatin-oxide have a moderately fast residence time in water phase (D50 approximately to 7 days) and breakdown in sediment (DT50=30 and 90 days, respectively). Azocyclotin and Cyhexatin are non-persistent (DT50=27days) and moderately persistent (DT50=50days) in soil, respectively. Just Cyhexatin and Fenbutatin-oxide have had data for photodegradation in water, and both of them were persistent. Although, Cyhexatin is breakdown by solar light degradation (EXPOXNET 1996). Apart from Cyhexatin, all the other Organotin used are rapidely breakdown by hydrolysis.

- *Treatment*

Fentin Acetate, Cyhexatin, and Fenbutatin-oxide can be treated in facultative ponds.
Cyhexatin can be treated by adding suspended solids to trap such pesticide and after used decantation tanks to concentrate them. Afterwards the sludge from the system have to be treated by landfarming, for instance.

- *Pyrazole*

Pyrazole pesticides were designed primarily as non-systemic contact and stomach miticides (Ware and Whitacre 2004). Tebufenpyrad and fenpyroximate are original pyrazoles, and the first one was registered by US-EPA in 2002 (Ware and Whitacre 2004). Tebufenpyrad is used in the Floriculture Sector in Ethiopia.

- *Legislation*

Up to date, Tebufenpyrad status in the Annex 1 (EC Directive 91/414) is pending. However, several countries from the EU are using such pesticide. Australia and Japan also use Tebufenpyrad.

- *Environmental Fate*

Tebufenpyrad is not volatile and bind tightly on soil. It is rapidly breakdown in soil (DT50=14days), but is persistent to photodegradation and hydrolysis. Tebufenpyrad breakdown moderately fast in water phase (DT50=6.6 days) and sediment (90 days).

- *Treatment*

Tebufenpyrad can be treated using activated sludge, facultative ponds, or even septic tanks.

- *Quinazolines*

This class, with a total different chemical configuration, has just one insecticide: fenazaquin. It is miticide, with a ovicidal activity and rapid knochdown (Ware and Whitacre 2004). Fenazaquin is used in the floriculture by Ethiopian farmers.

- *Legislation*

In EU it is not allowed, and was excluded from the annex 1 (EC Directive 91/414).

- *Environmental Fate*

It has low solubility and moderately-low vapor pressure. Fenazaquin binds tightly on soil particles, and it is moderately persistent (AERU 2008). Besides it also has a slow photodegradation and is considered stable to hydrolysis process (AERU 2008). However, its breakdown is improved in acidic media (AERU 2008).

- *Treatment*

In order to treat Fenazaquin, acidic ponds could be used along with photodegradation. Another option is to use suspended soil in which Fenazaquin will bind and suffer decantation. Afterwards, the sludge of this system has to be collected and treated by process such as landfarming.

- *Miscellaneous Compounds*

Cofentezine is a pesticide from the Tetrazine group, that is considered from the Miscellaneous Compounds (Ware and Whitacre 2004). Such class is used as acaricide/ovicide. Confentezine is currently use in the Ethiopian Floriculture Sector.

- *Legislation*

Clofentizine is in the Annex 1 from the EC Directive 91/414, and is normally used in EU.

- *Environmental Fate*

Clofentezine binds tightly on soil particles, and is moderately persistent in soil (DT50=39days). Its half-life photodegradation in water takes approximately 7 days, while hydrolysis 1.5 day. Clofentezine is not volatile. Clofentezine half-life in water phase and sediments is also rapidly (DT50=2.1 and 4.5 days, respectively).

- *Treatment*

Clofentezine can be treated by facultative lagoon, in which it will undergo degradation in the sediments, and in the water phase by photodegradation and hydrolysis.

- *Tetronic acid*

Tetronic acid is also a new class of pesticides (since 2002), with two member: spirodiclofen and spiromesifen. The first acts specially against mites and is used in the Floriculture Sector in Ethiopia.

- *Legislation*

Spiromesifen is pending in the Annex 1 (EC Directive 91/414 Status). However it is used in the UK. It is highly toxic to fishes and aquatic invertebrates.

- *Environmental Fate*

Spiromesifen has low water solubility, and then is not like to leach. It is non-volatile, and is moderately persistent to hydrolysis process. On the other hand, it breaks down rapidly in soil (DT50=23 days). Photodegradation occurs rapidly as well (DT50=1.7day). Alkaline media improves its degradation. Spiromesifen is very rapidly breakdown in both water phase (DT50=0.15day) and sediment (DT50=5.95 days).

- *Treatment*

Spiromesifen can be treated by facultative lagoon.

- *Triazine*

Cyromazine form the Trizine class is used in Ethiopian Floriculture farms.

- *Legislation*

Cyromazine is pending in the Annex 1 (EC Directive 91/414). It is used in European countries, like: France, Spain, Italy, and so on. This pesticide is also registered in US and Australia. Certainly, such status in the Annex 1 is because of Cyromazine is known to cause either reproduction or development problems in humans. However it is classified by WHO as unlike to present acute hazard in normal use.

- *Environmental Fate*

Cyromazine is persistent to all commom degradation pathways: in soil, photodegradation in water, and hydrolysis. It is non-volatile and is soluble in water. Still, cyromazine is biodegradable, and aerobic conditions can improve its degradation in soil (DT50=3-4 months).

Such pesticide is also breakdown in a slow rate by photolysis and hydrolysis in soil. Its half-life in water phase as well as in sediments is long (DT50=15 days and 228 days, respectively).

- *Treatment*

Even degradation occurring in a slow pace, it occurs in soil. Thus, cyromazine can be treated using landfarming system, with biomagnifications. Effluents with cyromazine can be treated in decantation tanks, and the sludge from this process has to be treated by landfarming as well.
However, it must be considered that cyromazine is a persistent pesticide and then, if used in large quantities will need a more rapid and efficient treatment, such as incineration.

- ***Fertilizers***

The fertilizers used in the Ethiopian floriculture farms are the two main ones required to plants growth: Nitrogen and Phosphorus compounds. Potassium is also utilized. As discussed before, such pesticides can contaminate the environmental causing eutrophication of water bodies. In its turns, eutrophication causes the decrease of Dissolved Oxygen in the water and alterations in the pH. Besides groundwater can also be contaminated with nitrogen compounds, what causes health problem.
Many countries in the world have already established standards for nutrients and other parameters in the water. For instance, in Brazil, ammonium should be bellow 3.7 mg/L in fresh water nutrients when in pHs lower than 7.5. Phosphate has to be lower than 0.02 mg/L in Lakes and other lentic water systems. Another example in the Nitrate Directive in the EU to prevent contamination by diffuse source (agriculture is one of the main diffuse sources). They define that surface waters and groundwater are polluted when they have concentrations higher than 50 mg/l of nitrate.
Microbial treatment and phyto-remediation are enhanced solutions to deal with fertilizers. Such nutrients are almost always lacking for algae and plants development, and then are rapidly absorbed by these organisms.

- ***Management Strategies***

In this project it was mainly discussed different environmental sound management collection and disposal schemes for overwhelming problems related with pesticide and fertilize related waste and wastewater. We saw that there are two principal strategies to deal with waste and wastewater: by short and middle-term plan, or by a long-term plan. Both strategies have their advantages and limitations, but in average long-term strategies are more like to dispose of such waste streams in a environmentally sound manner.
As important as collecting and disposing of waste and wastewater from agriculture in a environmental safe way, minimization and avoidance of waste are two of the main important measures to be undertaken in a waste management scheme. Hence, we call attention to waste and wastewater reduction. In one hand in this paper we did not discuss in a broad way this topic, in the other most the advices regarding pesticide management discussion in a deep way about waste avoidance and minimization. FAO (1999) is one of the main reference approaching this issue.
Concerning waste and wastewater minimization of pesticide, pesticide stocks ought to have "adequate storage conditions, good inventory practices, and regular turnover of products" (FELSOT, RACKE & HAMILTON 2003). Such practices will improve the reduction of waste in

the long-term. Besides, registered pesticides with reduced application rates or reduced volumes are also welcomed to reduced waste and wastewater generation. What is more, rinse water can be recycled by spraying it onto cropland. These principles can be applied to fertilizers as well. Moreover, fertilizers can be substituted by organic compost.

- **Schemes**

The management schemes that will be proposed here will focus on the collection and disposal of obsolete and unwanted pesticides and fertilizers as well as their containers. Two different schemes will be done suggested: a short- and middle-term plan, and a long-term plan. It will be described the subsequent stage of each practical implementation, considering current and potentially future available resources. Possibilities within the flower sector in Ethiopia will be pointed as well, such as the implementation of management schemes along with government and industry. Regarding pesticide empty packages, it should be implement triple-rinsing for all of them both in short- and meddle-term schemes as well as in long-term schemes.

- *Long-term plan*

Concerning pesticide containers, it should be recycled by energy recovery or by being raw-matter for other products. These alternatives are undertaken in Europe and Americas, respectively. This measure requires a good collection and disposal scheme, in which all stakeholders have to be involved. In the section foregoing mentioned chapter about "implement practice" there are some examples of on-going collection-recycle scheme for empty pesticide packages, such as the well developed scheme for container cycling undertaken in Brazil.
Definitely the pesticide containers should be triple-rinsed. As for registration of pesticides in Ethiopia it is already required that "any package has to be designed and made in such a way that it contains the pesticide safely during transportation, storage, marketing, distribution and use, including reuse where applicable, in accordance with relevant standards set by the Ethiopian Standards Authority", pesticide manufacturer or its agents could be required in the registration of pesticides to produce pesticide containers with an easier designed to be triple-rinsed.
Regarding pesticides, maintenance of books of records is important to manage stocks adequately. It will help farmers to buy adequate quantities of pesticides as well as to avoid pesticides to expire on shelves. It will help to avoid leftovers and the stockpiling of pesticides.
Unwanted and obsolete pesticides have to be collected by established central collection units, such as in Canada, Germany, Brazil, Australia, and so forth (see "implemented techniques" topic). The obsolete and unwanted pesticides are mostly disposed by incineration, that when well implemented account for 99.999% of pesticide destruction. In Africa, obsolete and unwanted pesticides have been shipped to Europe as so to be incinerated in dedicate kilns. However, it does not leave any capacity for African countries to deal with their pesticides, and is against the Basel Convention (Karstensen 2005). Besides, estimation cost to develop a dedicated incinerator for hazardous waste in Ethiopia is about 300 to 350 EUR per ton, while the cost to ship hazardous waste to Europe is about 2,100 EUR.
In developing countries to implement dedicated hazardous waste incineration plants is too expensive. Therefore, cement kilns appear as an option to incinerate hazardous waste in these countries (Karstensen 2005), as most of the countries have cement industry. In cement kilns, not only pesticide can be disposed in a safe way but also it can be used as a secondary fuel to

produce cement, in which pesticides and contaminated pesticide wastes can be energy recovered. Such method has been used to incinerate hazardous waste in many countries. Thus, a cement kiln can be adapted to suit the incineration of pesticides in Ethiopia. Michael & Abate (2007) say that the Mugher cement facility, in Addis Ababa, is one of the options to dispose obsolete pesticides in Ethiopia; however, there are problems affecting the viability of disposing obsolete pesticide in there.

It worth to consider that not only incineration of hazardous waste in cement kilns require improvements to suit pesticide incineration, but also such systems have to be well operated. In order to implement incineration in cement kilns in Ethiopia, it must to be performed Environmental Impact Assessment as it is predicted by the Environmental Impact Assessment Proclamation Nº 299/2002 (UV&P 2004).

In Ethiopia there is the need to implement treatment options to hazardous waste, and demand to dispose of 8 tons per day of hazardous waste (pesticides and other hazardous waste streams) (UV&P 2004).

Below it follows a scheme that illustrates one option to develop a waste management system to the Ethiopian flower farms. Such scheme covers whole floriculture production system, encompassing the management of hazardous and non-hazardous waste. It depends on agreements made among farmers, governmental, industry, and international aiding groups.

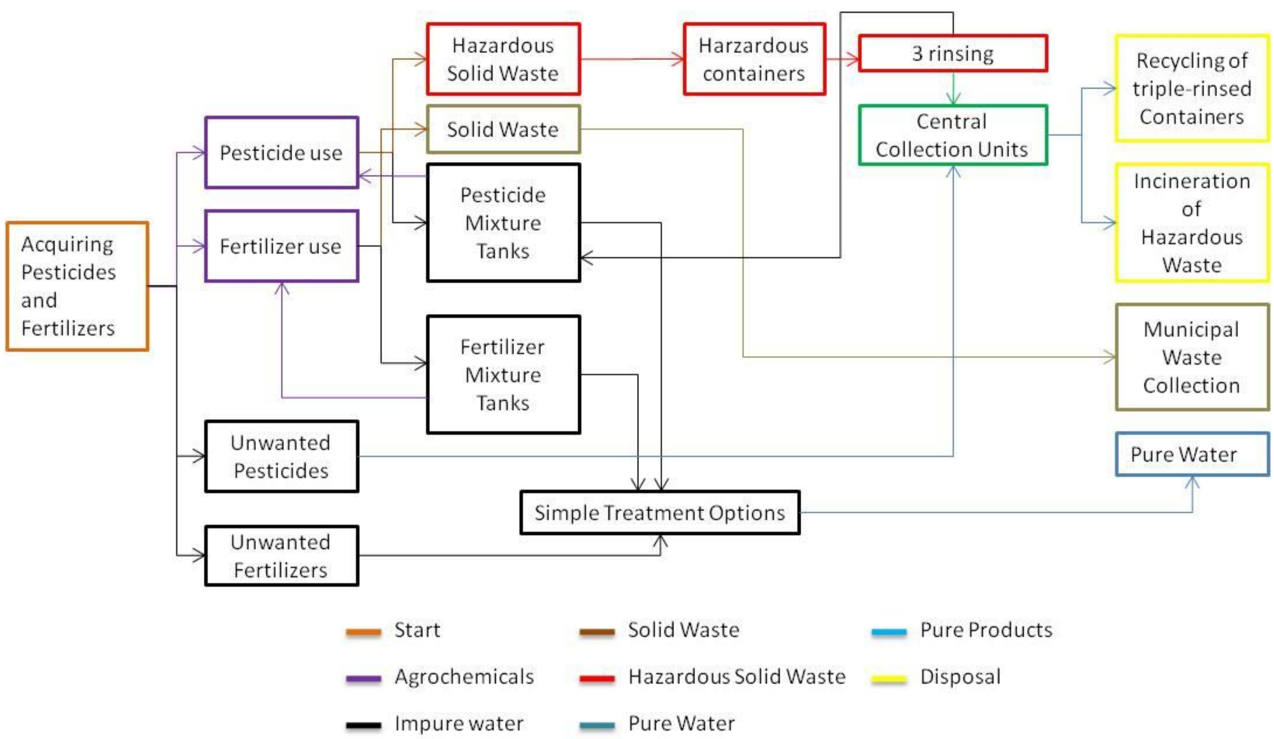


Figure 2 Suggested pestice waste management scheme to the Ethiopian Floriculture Sector (Long-term implementation). Obs: Such plain is suggested with basis on the supra cited chapters.

In summary, a long-term implementation of a well established scheme for disposing of wastes streams from the Ethiopian Floriculture Sector requires:

- Triple-rinsing of containers;

- Central Collection Units for collecting triple-rinsed containers and unwanted and obsolete pesticides;
- Recycling of triple-rinsed containers by energy recovery or production of alternative materials;
- Disposing of pesticides in either dedicated or cement kiln incinerators;
- Collection of non-hazardous waste in municipal solid waste collection schemes;
- Reutilization of pesticide and fertilizer rinsate by either fertirrigating such chemicals on the crop or using the rinsate to dilute chemical with similar characteristics that requires dilution;
- Pesticide and Fertilizer surplus have to be treated. Such effluent can be treated by simple treatment options like bioremediation, Phytoremediation, photodegradation, hydrolysis, among others.

- *Short- and mIddle-term plan*

In reference to immediate implementation of management scheme in the Ethiopian Floriculture Sector, the waste and wastewater management has to be done in a simple and efficient way, due to funds restriction to purchase cutting-edge technologies and a great demand for hazardous waste treatment, respectively.

Pesticide empty containers can be treated by triple-rinsing the containers. Triple-rinse procedure is available in the section 2.6.1.1. Afterwards triple-rinsing, containers can be considered as non-hazardous waste. Thus, triple-rinsed containers can be disposed as municipal waste. When not available municipal waste collection system, containers can be buried in local engineered cells (see section 2.6.1.2).

Unwanted pesticides and fertilizers as well as rinsate with such agrochemicals can be treated by biological treatment. It is important to say that such systems are not adequate for bulk quantities of pesticides. Bioremediation and phytoremediaton appear to be the most feasible technology to dispose of pesticides in a cheap way. Besides, treatment techniques such as photodegradation and hydrolysis appear to be cheap to implement. However such methods require a thorough investigation of the chemical characteristics to be treated. In accordance to section , the main degradation pathways of the pesticides from the Floriculture Sector, and their possible treatment option by non-expensive means. In the Annex 3 it will be described such treatment options.

Below it follows a scheme that illustrates one option to develop a waste management system to the Ethiopian flower farms. Such scheme covers whole floriculture production system, encompassing the management of hazardous and non-hazardous waste. It depends on mainly in the Floriculture Sector. But it should be kept in mind that pilot plants have to be implemented in order to define the efficiency of the treatment options, and that such options can be less efficient than incineration to dispose hazardous waste.

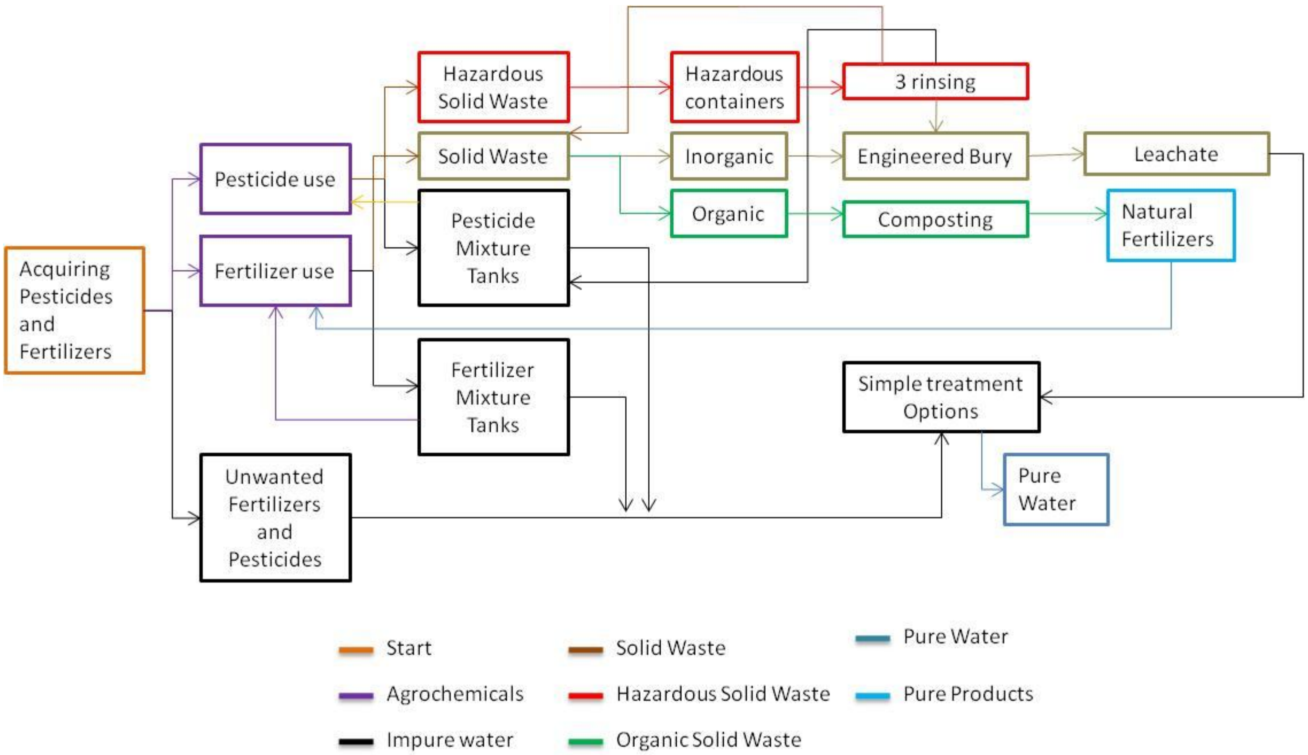


Figure 3. Suggested pestice waste management scheme to the Ethiopian Floriculture Sector (Short and meddle--term implementation). Obs: Such plain is suggested with basis on the supra cited chapters.

Summing up, a short and middle-term implementation of an urgent scheme for disposing of wastes streams from the Ethiopian Floriculture Sector requires:

- Triple-rinsing of containers;
- Disposing triple-rinsed container and solid waste by either burying it in engineered cells or delivering at municipal waste collection systems;
- Making composting treatment for organic waste;
- Reutilization of pesticide and fertilizer rinsate by either fertirrigating such chemicals on the crop or using the rinsate to dilute chemical with similar characteristics that requires dilution;
- Unwanted and Obsolete pesticides as well as Pesticide and Fertilizer surplus, and leachate from engineered cells have to be treated. Such effluents can be treated by simple treatment options like bioremediation, Phytoremediation, photodegradation, hydrolysis, among others.
- Composting product can be used as natural fertilizer.

Discussion and Conclusions

In this paper two treatment schemes for obsolete fertilizers and pesticides as well as the containers of them were demonstrated. The first one (section □) is a scheme in line with the FAO concepts for pesticide disposing (more sophisticated and complex schemes to treat hazardous waste); while, the second one (section □) is based on simple treatment options as so to tackle urgent needs for pesticide treatment in the Ethiopian Floriculture sector. Fertilizers were also approached as they are one of the main contributors to the widespread eutrophication phenomenon. As fertilizers are non-hazardous waste, they can be treated by microbial and plant uptake in simple treatment plants.

In order to implement more sophisticated treatment and collection schemes for unwanted and obsolete pesticides and their container, the Floriculture Sector as well as the other agriculture sector in Ethiopia will have to establish agreements with government, pesticide industry, aiding foundations, as well as other interested stakeholders. Such agreement is necessary because all stakeholders have to be involved when collection and treatment schemes are established. It is necessary that all interested parts take action and adhere to best environmental manners (such as triple-rinse, deliver of pesticide containers in central collection units, establishing collection centres, endorsing schemes, implementing regulations, etc). In general, voluntary agreements among stockholders are more successful than mandatory as all parties became more interested and aware about the benefits and importance of such programmes. Financial support has to be agreed among stakeholder as so to run schemes, because, for instance, schemes using a wide collection approach and incineration are expensive to be implemented and carried out. Moreover, policies are needed to enforce best management practices, and also to homogenize procedures. A surveillance programme has to be undertaken as well to guarantee adherence of the stakeholders. Hence, "a joint action plan is needed to tap the expertise of the different stakeholders in bringing a difference in managing obsolete pesticides and hazardous wastes in Ethiopia" (Michael & Abate, 2007).

Michael & Abate (2007) state that the African Stockpile-NGO network ought to help NGOs and government in Ethiopia to work together as so to tackle the pesticide problem. They also suggest that a workshop should be established in the country to bring all actors together as so to exchange experiences and broad their network. As advised by FAO (1999), farmers should lobby pesticide distributors, local authorities and agricultural advisers to establish schemes in regions in which no facilities exist for the return or safe disposal of empty pesticide container. The Ethiopian Floriculture farmers are already doing so by looking for pesticide advisers, but they should require action from the other stakeholders. If a collection scheme is not implemented, FAO (1999) states that empty pesticide containers and obsolete pesticides should be returned to distributor, removing these potentially hazardous waste from users and pass them on to competent authorities or industry who have the resources to deal with them safely (FAO 1999 and OECD 2004). For instance, PAN UK is attempting to implement an agreement between pesticide distributors and farmers in Mozambique in which farmers will deliver obsolete pesticide and containers in retail outlets when they are buying new stocks. Collected hazardous waste will be centralised and then disposed of in an appropriate facility in South Africa.

It is unlike that Ethiopia will implement a sophisticated technology to dispose of pesticide in the near future (Michael & Abate, 2007). The sophisticated scheme for pesticide disposing discussed here can take a while to be implemented as it depends on many factors, such as funds to put into operation this expensive solution. Although it is a great scheme, the implementation of such systems are usually expensive and risky, and then require high levels of training, sophisticated equipment, long term maintenance, and financial support. For this reason, such sophisticated technologies are inappropriate at some times to developing countries (PAN-UK 1998). While this is not employed, the lack of treatment facilities for hazardous waste in Ethiopia is probably causing human health problems. This situation leads to excessive expenses for medical treatment and loss of productivity due to poor health of workers. Persistent pesticides have to be treated to protect the health of Ethiopian citizens (Ethiopian Government 2006).

A great percentage of the obsolete pesticides from developing countries are repacked and transported to developed countries in order to be incinerated in high temperature toxic waste incinerators (PAN-UK 1998). Such practise requires "high costs, considerable environmental risks due to long transport distances and doe not provide the necessary capacity" to build on hazardous waste management schemes in the affected developing countries (Karstensen 2005). Thus, new technologies for local disposal of small quantities of pesticides have been implemented, like: plasma arc, molten metal and bioremediation (PAN-UK 1998). Such options almost always require expert guidance as well as agreements at government level and supervision of independent specialists and national authorities (PAN-UK 1998).

Up to date, bioremediation is one of the most common in situ technologies to treat hazardous substances, accounting for 27% of the treatment options (US EPA 2007). "In situ bioremediation and chemical treatment have increased significantly in recent years, with approximately 70 to 80 percent of these projects selected in the past six years" (US EPA 2007). Among the technologies for local disposal of small quantities of pesticide waste, one of the most economical is Biological treatment options, or the use of other natural breakdown process. Therefore, such options were pointed as a great solution for treat obsolete pesticides, pesticide wastes and wastewaters immediately (section □) in the Ethiopian flower farms as more sophisticated treatments are not to be implemented in the short run. Besides, biological treatment has a high efficiency to cleanup water from fertilizers. Definitely, it is the most rapid and non-expensive solution for treat the effluents and non-inert solid waste from the Ethiopian Floriculture Sector.

Seven Flower Farms in Ethiopia already have storage basins to stimulate transformation of the toxic compounds of pesticide effluents. Probably, such basins work like a facultative pond, in which agrochemicals may be breakdown or removed from water by biodegradation, hydrolysis, adsorption on suspended solids, photolysis, and decantation. Such type of basin is one of the options we are suggesting for pesticides treatment in Ethiopia.

In the short-term, biological systems as well as other systems using photodegradation and hydrolysis are being suggested for treating pesticide and fertilizers in the Ethiopian Floriculture Sector. Such systems are adequate to small quantities of pesticides. In the long run, well established long-term collection systems for both obsolete pesticides and their containers have to be implemented. Triple-rinsing of pesticide containers is suggested to clean up them in both long- and short-term schemes. In order to dispose triple-rinsed pesticide containers, recycling is the best option to do so, but while it is not implemented triple-rinsed containers can be disposed as municipal solid waste.

All in all, the Ethiopian flower farmers should enforce the implementation of collection and environmentally sound treatment facilities for the unwanted pesticides and their containers. This should be done by government, industry, distributor of pesticide, and so on. However, while it is not established, they have to take action by the utilizing the best environmental friendly technique to dispose this hazardous waste, instead of disposing carelessly obsolete pesticides and pesticide waste in the environment. Fertilizers have to be treated as well as so to prevent eutrophication in surface wasters and contamination of groundwater with nitrogen compounds. Besides, effort should be done to minimize the production of pesticide waste in Ethiopia by prevention and integrated pest management programmes (Michael & Abate, 2007).

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Annex 1.

Annex A from the Stockholm Conference (List of chemicals that have to be prohibited or eliminated by legal and administrative measures.

Chemical	Activity	Specific exemption
Aldrin CAS No: 309-00-2	Production	None
	Use	Local ectoparasiticide Insecticide
Chlordane CAS No: 57-74-9	Production	As allowed for the Parties listed in the Register
	Use	Local ectoparasiticide, Insecticide, Termiticide, Termiticide in buildings and dams, Termiticide in roads, and Additive in plywood adhesives
Dieldrin CAS No: 60-57-1	Production	None
	Use	In agricultural operations
Endrin CAS No: 72-20-8	Production	None
	Use	None
Heptachlor CAS No: 76-44-8	Production	None
	Use	Termiticide, Termiticide in structures of houses, Termiticide (subterranean), Wood treatment, and In use in underground cable boxes
Hexachlorobenzene CAS No: 118-74-1	Production	As allowed for the Parties listed in the Register
	Use	Intermediate, Solvent in pesticide, and Closed system site limited intermediate
Mirex CAS No: 2385-85-5	Production	As allowed for the Parties listed in the Register
	Use	Termiticide
Toxaphene CAS No: 8001-35-2	Production	None
	Use	None
Polychlorinated Biphenyls (PCB)	Production	None
	Use	Use Articles in use in accordance with the provisions of Part II of this Annex

Annex A from the Stockholm Conference (List of chemicals that have to be prohibited or eliminated by legal and administrative measures.

Chemical	Activity	Specific exemption
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Endrin CAS No: 72-20-8	Production	None
	Use	None
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	Use	Termiticide, Termiticide in structures of houses, Termiticide (subterranean), Wood treatment, and In use in underground cable boxes
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	Use	Termiticide
Toxaphene CAS No: 8001-35-2	Production	None
	Use	None
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	Use	Use Articles in use in accordance with the provisions of Part II of this Annex