AGROCHEMICALS (PESTICIDES AND FERTILIZERS)

The term “agrochemicals” means pesticides and fertilizers. Pesticides are substances used to prevent, destroy, repel or otherwise control objectionable insects, weeds, rodents and other undesirable forms of life. On the other hand, fertilizers are used mostly in agriculture to enrich the soil. Thus it increases the soil fertility in order to increase the crop yield per acreage.

Pesticides are conveniently classified on basis of target-organism or nature of biological usefulness and on the basis of chemical structure.

1. Target-organism classification or nature of biological usefulness is as follows:
   1. Fungicides: These are fungi which cause diseases to crops.
   2. Insecticides: These are toxic to insects, pests that damage crops and vectors that

transmit zoonotic and human diseases.

* 1. Herbicides: They are made to destroy weeds, herbs and unwanted plants that compete with crops.
  2. Nematocides: These chemicals are toxic to plants, nematodes, especially those that destroy roots and aerial parts of crop plants.
  3. Molluscicides: These type of chemicals are toxic to snails and slugs (land molluses), most of which are intermediate vectors of bilharzias (schistosomiasis).
  4. Rodenticides: These substances are used to control rodents such as rats, mice and Squirrels. Rats and mice are known animal reservoirs for plague.

1. Classification of pesticides on the basis of their chemical structure or scientific name is as follows:
   1. ***Organochlorines*** (chlorinated hydrocarbon pesticides).
   2. ***Organophosphates*** (organophosphorous pesticides).
   3. ***Carbamate***s (carbamate or derivates of)
   4. ***Pyrethrins*** (botanical pesticides)
   5. ***Fumigants*** (fumigants pesticides)

Global and Kenya’s trend on use of pesticides has consistently increased over the years. In 1987 Kenya imported 740 million.

Figure 1 demonstrates the global and Kenya’s trend on use/importation of pesticides.

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There are several questions and answers to such a trend. However, there are two obvious reasons or factors to the increased use of pesticides. These factors are known as green revolution and industrial revolution.

1. What is Green Revolution?

It is a branch of science, which deals with development of new agricultural plants with an aim of achieving better yield. Thus genetic engineering results into genotypic crops and this of course requires use of more pesticides and fertilizers.

b) What is Industrial Revolution?

This deals with mass production of new synthetic toxic and non-toxic chemicals. Some of course are pesticides and fertilizers, which sustain “Green Revolution”. For instance, every year more than 3,000 new chemicals are synthesised world wide and of these 10% (i.e. 300) are indiscriminately introduced into the environment.

Besides sustaining Green Revolution, pesticides are known to play both positive and negative roles. The main positive role is maintenance of human health through suppression of insect disease vectors:

In public health, pesticides have made dramatic contributions. Between 1955 – 1970 use of DDT against malaria mosquito-vectors saved 15 million lives in the world.

A WHO 1962 report, indicates that large quantities of DDT and its isomers were used in spraying huts and living quarters, which were highly infested with mosquitoes. Thus 65 million Kg of DDT, 4 million Kg of dieldrin and 0.5 million Kg of lindane were used.

Obviously, pesticides have made places which were once labelled as ‘grave yards’ liveable. In Kenya such places include: Mwea Tebere, Lambwe Valley, Shimba Hills and Makueni.

Mortality and morbidity rates decreased significantly due to use of pesticides. The major disease vector whose population has been drastically reduced or controlled by use of pesticides are as demonstrated in Table 2.

Table 2: Disease Vectors and the Causative Organisms

|  |  |  |
| --- | --- | --- |
| Name of Vector | Disease | Disease Causative Organism |
| 1. Mosquito (Anopheline) | Malaria | Plasmodium(malaria parasite) |
| 1. Aedes aegypti (new name?) | Yellow Fever | Virus |
| 1. Anopheles and Culex | Filariasis (Elephantiasis) | Filaria worm |
| 1. Sandfly (Phalebatomus\_ | Kala-azar Visceral Leshimaniasis | Filaria worm |
| 1. Kissing bug | Chaga’s disease | Trypanosoma cruzi |
| 1. Simulium (Blackfly) | River blindness (onchocerciasis) | “Round worm” (onchocerca vovulus) |
| 1. Tse-tse fly (Glossina) | Sleeping sickness (Trypanosomiasis) | Trypanosomiasis |
| 1. Body louse pendiculus (human humanus) | Relapsing fever | Spirochaetes |

In agriculture, advent of pesticides use has witnessed a revolution in the achievement of high crop yields in this century.

If we take Kenya’s coffee which alone accounts for 2/3 of the pesticides imported, you find that if not for captafol (Difaloton) – which controls coffee berry disease (CBD) – most of plantations would probably be wiped out; moreover 1/3 of foreign exchange obtained from coffee is as a result of ultimate use of pesticides.

A. ORGANOCHLORINES(CHLORINATEDHYDROCARBONS)

They are characterised by a chemical structure consisting of carbon, chlorine and hydrogen. They are referred to as chlorinated hydrocarbons, chlorinated organics, chlorinated insecticides, chlorinated synthetics or Persistent Organic Pollutant (POP) pesticides. They exist in many varieties with dichlorodiphenyl trichloroethane (DDT) as the commonest of all. The other classical examples of this group include; endrin, dieldrin and aldrin.

Figures (i) and (ii) demonstrate the chemical structures of some chemical pesticides of this group.

1. DDT



1. Endrin and Deildrin (isomers)



***Dieldrin and Endrin*** are used as insecticides and control tse tse flies, locusts, rice, maize, cotton and sugar cane pests. On the other ***hand 2, 4-Dichlorophenoxyacetic acid and 2,4,5-Trichlorophenoxyacetic acid*** (figures iii and iv). These two herbicides are used to control algae in water bodies in lakes and ponds.

 

Most organochlorines are also known as organic pollutants (POPs). On the other hand improper formulation of 2,4, 5-T results in production of dioxin. Dioxin is a very well known toxic and carcinogenic chemical.

Due to their persistent and potential health effects, some of the pesticides POPs are in the process of being phased out/eliminated worldwide. This elimination is based on the Stockholm Convention of which many countries including Kenya are signatories. Table 1 summarises some of the POP pesticides being eliminated as per the Stockholm convention.

Table 1: Some of the POP Pesticides for Elimination as per Stockholm Convention, 2004

|  |  |  |
| --- | --- | --- |
| Chemical Name | Use | Potential Health Effects |
| 1. Chlordane | Ectoparasite/insecticide, termiticide additive in plywood adhesives | * Potential carcinogen inhibits cell-to-cell communication in culture. * Interferes with formation of red cells in bone marrow. |
| 1. Dieldrin | In agricultural operations insectides, termiticides, locusts, control of tse tse flies. Has been used in Lambwe Valley (Kenya) to control tse tse flies. | * Potential carcinogen. * An autoimmune like haemolytic anaemia. |
| 1. Endrin | Insecticide for cotton, rice, maize and sugar cane plantation pests. | * Dizziness, headache. |
| 1. Heptachlor | Termiticide, wood treatment. Used underground. | * Myochlonic jerking, psychological disorders including insomnia. |
| 1. Hexachlorbenzene | Used as a solvent in pesticides | * Immune alterations |
| 1. Mirex | Termiticide | * Ataxia incoordination, slurred, speech. |
| 1. Toxaphene |  | * Generalised convulsions. |

Major Characteristics of Organochlorines

1. They are ***highly lipophilic*** i.e. accumulate in adipose tissues (fatty tissues).
2. They are ***very persistent*** 2 – 30 years in environment during which they accumulate in food chains and webs. The persistence varies with climate. It takes 10 – 15 years for one half of the amount of DDT to breakdown in temperate climate, while in tropical climate the same amount takes 6 months or less to breakdown. This is due to the sunlight effect.
3. They are ***ubiquitous environmental*** contaminants.
4. Most of them are not well absorbed through the skin.
5. They have generally low toxicity.

Effects of Organochlorines at Cellular Level

The exact mechanism by which they cause toxicity is not yet known. It has however been demonstrated that they stimulate the nervous system and toxic doses are known to cause the following reaction:

Trigger – anxiety – hyperexcitability – convulsions – death

There is some conclusive evidence that DDT interferes with both sodium and potassium transport across the neural membranes (inhibits Na+ and KM±g++ AT pase mechanism in neural tissues once in the body some of the DDT is metabolised.

DDA (excreted in urine)

DDD

DDT

Metabolised DDE (intact in the body)

DDT, DDE and DDD cross the placental barrier and are excreted in human milk. DDT interferes with birds and fish reproductive abilities. In birds, it interferes with the calcium available during formation of the egg shell, thus the shell becomes very thin.

NB: ***LD50 of DDT 250mg/Kg body weight***.

Other health problems associated with DDT and other organochlorines are:

1. Toxic hepatitis.
2. Cholestatic jaundice.
3. Potential in elevation of cholesterol and α-lipoproteins especially in occupationally exposed individuals.

B. ORGANO PHOSPHATES (ORGANIC PHOSPHOROUS)

Organophosphates are known by several names i.e. organic phosphates, phosphorous insecticides nerve gas relatives, phosphorous esters and phosphoric acid esters. The names are derived from phosphoric acid.

It is important to note that they are widely used to vary in toxicity to mammals and that some are extremely toxic.

The first organophosphate called TEPP (tetraethylprophosphate) was synthesised in 1854. By early 1930’s Germans had synthesised what in World War II was referred to as nerve gases or warfare agents i.e. Sarin and Soman and tabun.

16 years later Germans introduced the most widely used insecticide – Parathion. Like the rest of organophosphates, Parathion is an aromatic compound with sulphur, nitrogen as well as phosphrous in its structure.



O,O-Diethyl-O-P-nitrophnyl thiphosphate (Parathion). Parathion is effective against pests, particularly fruit fly and is very toxic to humans.

Parathion  Paraoxon  more toxic and is known for most case fatalities.

Parent compound) (daughter camp)

In the body it can be metabolised and is found in the urine as paranitrophenol.

It is readily absorbed by all routes of the body, skin absorption is low and dermal exposure does result in a prolonged period of absorption e.g. it has been found on the hands 2 months after exposure.

The LD50 for parathion is 13mg/kg body weight.

Malathion

This is another type of organophosphate



S-(1,2, Dicarbethoxylethyl)-0, 0 dimethyldithiophosphate

It is highly toxic to variety of pests but unlike parathion and many other organophosphates, it is less toxic to mammals. Because of that it is extensively employed in insects and pests control.

Other significant organophosphates include:

* + - Dipterx
    - Systox
    - Diazinon
    - Azodrin and Vapona, etc.

Their characteristics

1. They are absorbable via intact skin and eyes.
2. Unlike chlorinated hychocarbons, they are readily metabolised and do not persist in human tissues.
3. They are responsible for more deaths, particularly parathion.
4. For occupational workers, inhalation is not significantly worse than dermal exposure.

Activity at the cell level

Their *mode of action is very specific, and that they inhibit the enzyme cholinesterase* and this increases endogenous acetyl choline at synaptic sites.

Early muscarinic effects of toxic exposure include:

* + - papillary constriction
    - chest tightness and headache

More severe intoxications causes:

* + - coughing
    - wheezing due to bronchial constriction
    - increased bronchial secretions
    - salivation (sialorrhea)
    - nausea, vomiting and diarrhoea and abdominal pain
    - involuntary urination, defaecation and bradycardia

Early nicotinic effects include:

- weakness  fatigability  twitching and eventual respiratory paralysis.

Effects on central nervous system does result into:

(a) anxiety

(b) restless

(c) irritability and in severe exposure one is seen to be confused, to have ataxia  speech disturbance  coma  death.

EMERGENCY MEDICAL TREATMENT

1. Atropine (antidote), 1-2mg for every 15-30 minutes given until tachycardia, flushing and dry mouth occurs.

It works by blocking the effect of acetylcholine.

2. Pralidoxine protopam chloride (2-PAM)

If given early enough, will reverse the inhibiton of the enzyme. However, it should be used in conjunction with atropine.

Dose: 1g IV (intravenous) slowly and repeated in an hour if necessary.

Note: Blood for cholinesterase activity should be drawn before administering 2-PAM.

CARBAMATES

They are carbarnic acid derivates. The three commonly used in pest control are:

(a) Sevin (carbaryl) which is an insecticide

(b) Maneb (bis-dithiocarbarnates) - fungicides

(c) Thiocarbarmic acid derivatives - herbicides

(a) Sevin (Carbaryl) LD50 – 300mg/kg

It is the most and widely used of the carbarnates insecticides. Its low toxicity and rapid

reversibility in inhibition of cholinesterase, it gives it a good safety record. (Normal range in

urine is 150-400 ug/dl)

(b) Maneb (Bis-dithiocarbarnates) LD50 6750mg/kg

It is sometimes contaminated with (ETU) ethylene thiourea which is a proven animal carcinogenic. Baygon (Kenyan trade name) with a common name as Propoxur is a very well known fly bait. These compounds are widely employed in agriculture as fungicides. Some have been found in foods (before and after cooking). ETU compounds have also been found in foods. Metabolites of these compounds are carbon disulphides which are neurotoxic. Multiple exposure of this group causes irritation to skin.

Characteristics of this group

1. Compared to organophosphates and cholorinated hydrocarbons they are less toxic.

2. Because of their low toxicity they have a remarkable safety record.

3. Though not so persistent and toxic like the other two, they have a higher immediate profound toxic effects on biosphere (exert target and non target effects).

Activity at Cell Level

They exert their toxic effects by the inhibition of cholinesterase i.e. their mode of action is similar to that of organophosphates.

Unlike phosphorylation by organophosphates, carbarnylation of the enzyme is readily and rapidly reversible. This is why it is less toxic than organophosphates.

Testing of cholinesterase activity in blood or plasma may not be useful because of rapid reversibility.

MEDICAL TREATMENT

The antidote for carbarmate poisoning is same as for organophosphate – ARTROPINE, however, (2-PAM) pralidoxime is not recommended because of its/or may be harmful.

FUMIGANTS

These are gaseous chemicals that kill insects and other pests by interfering with their respiratory system. They are usually applied in closed spaces.

Examples are:

(a) Hydrogen cyanide – released from calcium cyanide (cyanogas) by atmospheric moisture

(b) Methyl bromide – (CH3Br) in process of being phased out because it affects the ozone layer.

(c) Carbon disulphide (CS2)

(d) Carbon tetrachloride (Ccl4)

BOTANICAL PESTICIDES

These are extracted of synthesized from pyrethrum, hence are also called pyrethroids. “Doom” is an example of this group. They have very short half-life low toxicity.

Fig. 8: Types of Exposure to Pesticides

Chemical Manufacture Transport

Intermediate

Formulation Transport Warehouse or Retail

Wholesale

Crop

Air

User Application Water Breakdown

Soil

Human being

Fig 1: Types of Exposure to Pesticides

Unintentional exposure Intentional exposure

(dermal, oral, respiratory) (from water, air, food)

Occupational Non-Occupational Suicides Homicides

exposure exposure

(from water, air, food)

Short-term Long-term

Short-term Long-term

Suicides and mass Single and

Poisoning pesticide formulators, Short-term, very high

mixers, applicators and

pickers

pesticide manufacturers, Long-term, high level exposure

formulators, mixers,

applicators & pickers

All population Long-term, low level exposure

groups

EFFECTS OF PESTICIDES ON ENVIRONMENT AND BIODIVERSITY

1. Killing of Natural Enemies

Broad-spectrum pesticides kill both target and host species including predators. This makes farmers to continue to use more doses and more so frequently to keep them in control.

1. Creation of New Pests

Once some predators are killed off, parasites and insects especially mites can become new major pests.

1. Development of Genetic Resistance

Over usage of pesticides promotes mutation thereby emergence of a different generation of arid adaptation of pests. Such new pests are resistant to the pesticides.

1. Biological magnification of persistent pesticides.

DDT and other POPs are more soluble in fats than in water, their concentrations can be biologically magnified in food chains (tropic levels), posing high risk to humans’ health.

1. Global mobility of persistent pesticides.

Only 1% of the applied pesticide hit the target pest. The rest 99% enter environment (ecosystem). The persistent ones one transported by wind, rain, snow and moving water to other parts of the world. They are then magnified to higher levels. For instance 5 times in aquatic life than in water. Because of transport, Artic seals and Antarctic penguins located far away from agricultural areas have high concentrations.

1. Threats to wildlife

Marine life, some bees necessary for honey, pollination can be killed thereby threatening food security.

1. Threats to human health

Pesticides post health risk to:

1. General public (long-term, low level exposure group).
2. Pesticide manufacturers, formulators, mixers, applicators and pickers (long-term, high level exposure).
3. Suicides and mass poisoning; pesticide formulators, mixers, applicators and pickers (single and short-term, very high level exposure).
4. Summary on behaviour and effects of pesticides on environment and biodiversity.
5. Acute toxicity – toxic effects produced by short term exposure.
6. Chronic toxicity – toxic effects produced by cumulative exposure.
7. Metabolism – chemical absorption, distribution, excretion.

Metabolism within mammals.

1. Sensitization – allergic reaction due to chemical exposure.
2. Reproduction – changes in the ability to produce off spring, birth defects and toxicity to the unborn.
3. Mutagenesis – alteration of genetic material through chemical interaction.
4. Oncogenesis – formation of cancerous or non-cancerous tumors or lesions.
5. Ecological effects – adverse effects of the chemicals on the health and life cycles of aquatic life (fish, etc) and wildlife.
6. Environmental fate – movement and persistence of the chemical in soil, air, water and in plants. Breakdown by sun (URV), microbes or plants. Accumulation in plants.

CONTROL MEASURES

There are two control strategies: The first one is the policy/legislation of pesticides while the second one is based on scientific control measures.

1. Legislation

There exists Pest Control Product Act 1982. This act is implemented through the auspices of Pest Control Product Board. This Act deals with the following aspects among others:

1. Licensing of synthesis of pesticides.
2. Registration including labeling procedures.
3. Work safety regulations
4. Education
5. Implementation of new/current policy matter.

2. Scientific Measures

This implies the application of the Integrated Pest Management (IPM). This includes and not limited to the following:

1. Cultural control methods:

* Mixed cropping.
* Crop rotation
* Breeding pest resistant crops.
* Practice of organic farming

1. Biological control methods:

* Use of insect predators e.g. parasites – lady bird (beetle).
* Use of certain bacteria, e.g. Bacillus thuringiensis

1. Mechanical control methods:

* Burning of field contents prior to planting the cops.

1. Health education and use of protective clothing

* The purpose is to minimize the exposure to the workers. All the workers or individuals involved in handling of pesticides.

1. Disposal of leftovers, expired pesticides and empty containers.

* Leftovers, expired and empty containers ought to be disposed off in an environmentally sound manner. This minimizes environmental pollution, accumulation in the food chain/web and consequently exposure to humans.

Alternative Methods of Insect Control

The ultimate goal of insect control would be to:

1. Kill only the target pest.
2. Be non-persistent and breakdown into harmless (non-toxic) chemicals.
3. Not result in genetic resistance in the target organism.
4. Be cheap i.e. affordable.

Unfortunately none of the known pest/insect control methods meet these mentioned criteria. There are however, a number of methods which work singly or in a combination form.

They include the following methods among others:

1. Cultural control methods:

This is a time immemorial method. It practices crop rotation to change the crop available to pest by adjusting planting times or seasons. Burning of farm contents

1. Biological control methods:

Use of natural predators, parasites and viruses have reduced by 90% the variety of pests with potential to affect and destroy plants/crops.

There has been successful projects of this nature in countries like Soviet Union and China. The following are some of the examples:

* + Lady bug (beetle) and praying mantises have been successfully used to control aphids.
  + Purple martin birds do control mosquitoes.
  + A bacterial agent (Bacillus thuringiensis) is capable of controlling caterpillars.
  + Certain viruses control Douglas fir tussock moth, gypsy moth and the cotton bollworm.

1. Genetic control by sterilization

Male insects are reared/raised in a laboratory setting, sterilized by radiation or chemicals then released to mate unsuccessful with fertile females. If the sterile males out number fertile males by ten to one (10:1) pest species in a given area can be eradicated in about four generations.

This approach has been used to control the oriental fruit fly, screw worm fly (a major livestock pest).

1. Attractants:

Sound, light and sex attractant chemicals are used to lure pests into traps containing toxic chemical or to confuse male insects so that they can not find mates. Pheromones are such chemicals and are used to control pink bollworm, cotton boll weevil, cabbage looper, bark beetle and oriental fruit fly.

1. Hormones:

This method uses synthetic or extracted chemical insect hormones such as juvenile hormones (JH) and molting hormones to prevent specific pests form reaching maturity and reproducing. They must be applied at the right time in the insect’s life cycle.

1. Resistant crop varieties:

This requires development and promotion of new varieties of plants resistant to insects/pests and fungi.

1. Integrated Pest Management (IPM)

The overall aim of this method is not to eradicate pests but to keep the population just below the level of economic loss.

This IPM approach integrates a variety of other method such as biological, chemical and cultural/traditional methods.

1. Other Methods:

These are intended to protect the environmental/ecology and humans. They include and not limited to the following:

* Education to processors, handlers, community users, e.g. farmers.
* Protection/protective clothing for all involved in formulation, transportation, packaging, wholesale, retailing and applicators.
* All expired, left over pesticides and empty containers should be disposed off in an environmentally sound manner.