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Pesticides as Environmental Pollutants: A review of health and environmental impacts pose by continuous use of cyclodienes in developing countries

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ABSTRACT

Pesticides have been very effective in controlling disease-causing organisms, insects, weeds, and other pests. Characterised by a high toxicity to target species, pesticides may also be toxic, to a various degree, to non-target species, including human beings. Of major concern around the world are the organochlorine (such as cyclodienes) pesticides due to their severe toxicity, persistence and bioaccumulation. Thus their production, usage and disposal have been controlled or banned in most developed countries. However, they are still used in many developing countries. This paper examined why farmers and general public in developing countries continue to use these toxic organochlorine pesticides despite the resulting adverse effects associated with such practice. This research discovered that lack of strict regulations, poverty, ignorance, political instability and lack of economic and political commitments are among the factors responsible for this trend. The research further recommends that governments in the affected countries should adopt strict regulatory measures, educate farmers and the general public and restrict the availability of toxic cyclodienes.

Keywords: pesticides, organochlorine (OC), cyclodines, dieldrin, environment, exposure.

INTRODUCTION

Pesticide is described as any constituent or group of constituents that is used to prevent, destroy, repel or mitigate any unwanted organism [1]. Some major groups of pesticides are: insecticides, herbicides, fungicides, acaricides, larvacides, miticides, molluscides, pediculicides, rodenticides, pheromones, defoliants, desiccants, etc. [2].

Characterised by a high toxicity to target species, pesticides may also be toxic, to a various degree, to non-target species, including human beings. The health and environmental implications associated with pesticides usage, application, handling and exposures have been extensively studied ([3], [4], [5], [6], [7], [8], [9]).

According to [10], pesticides are classified based on hazards as class Ia, Ib, II, and III standing for extremely hazardous, highly hazardous, moderately hazardous, slightly hazardous respectively (Table 1.0). Of major concern to human health, wellbeing and environmental protection is the WHO class I and II pesticides. Of these, organochlorine insecticides (OC) are of major concern all over the globe because of their long-lasting toxicity, persistence and bio-accumulation [6].

Cyclodienes are among the toxic organochlorine insecticides (OC) that act on the central nervous system of target organism by interfering with Ca^{2+}-Mg^{2+} ATPase and $GABA_A$ receptor [2]. These substances have the potential of posing threats to ecosystem and human healthiness. Hence their manufacture, use and disposal have been delimited or even completely banned in most developed countries ([12], [10], [1]).

However, these banned toxic organochlorine insecticides (OC) are still used in developing countries ([6], [5]). The question remains why these toxic compounds are still used in developing countries despite the associated implications on human health and the environment and what measures could be taken to lessen the associated adverse effects.

Table 1.0: WHO-recommended classification of pesticides by Hazard [11]

		LD_{50} IN RAT (mg/kg body weight)			
		ORAL		DERMAL	
CLASS		SOLIDS	LIQUIDS	SOLIDS	LIQUIDS
Ia	Extremely hazardous	5 or less	20 or less	10 or less	40 or less
Ib	Highly hazardous	5–50	20–200	10–100	40–400
II	Moderately hazardous	50–500	200–2000	100–1000	400–4000
III	Slightly hazardous	Over 500	Over 2000	Over 1000	Over 4000
IV+	Unlikely to present hazard in normal use	Over 2000	Over 3000	Over 4000	Over 6000

This study discussed the toxicological impacts of cyclodienes insecticides on organisms and environment. The study further discussed why farmers in developing countries continue to use toxic organochlorines (OC) despite their adverse effects. The study also illustrates the measures that could be taken to lessen the adverse effects associated with the continuous use of these toxic pesticides.

These were discussed as follows:
1. Introduction
2. Worldwide usage and exposures to pesticides
3. Regulatory and risk assessment
4. Uses, site and mechanism of action of cyclodienes, their health and environmental implications.
5. Discussion and Conclusion

1. Worldwide Usage and Exposures to Pesticides:
Pesticides are used for decades to lessen the deleterious effects of a variety of pests. They are used worldwide to protect crops, food, and animals from unwanted contaminations, to control vector-borne diseases, to keep ponds, lakes, and water reservoir free of unwanted contamination, etc (Figure 1.0). It is estimated that about 1000 chemical substances, biological as well as physical agents sold under different brand names and formulations are used as pesticides in different parts of the globe [2].

The global utilisation of pesticides has reached 2.6 million metric tons, of which more than 75% is on agriculture. Though pesticide is used mainly in advanced nations, its usage is witnessing rapid growth in less-developed nations. In addition, herbicides are the major pesticides used in advanced nations, the main pesticides used in less-developed nations are insecticides [3].

At this point, it is important to note that pesticides are designed and produced with intrinsic properties that make them toxic and lethal to the target organism and are deliberately released into the environment to execute this function. Thus, as long as pesticides continue to be used, human exposure is inevitable occurring mainly in occupational settings, households and as residues in food. This is because the mechanism of action that makes them efficient pesticides also makes them toxic to human [13]. This is because both the target and non-target species have closely related physiologic and biochemical organisation [2]. [13] recommends the understanding of related hazards associated with those pesticides and to minimise their use unless in necessary situations thereby minimising damage to human health and the environment.

The means of exposure to pesticides according to [2] are as follows (figure 2.0 and 3.0):
- Accidental and/or intentional poisoning
- Occupational exposure as a result of their direct contact with pesticides in their respective job designations (production, packaging, application, harvesting and handling of crops)
- Bystander exposure from spraying operations

• General public who take in pesticide residues as a result of illegal use or misuse in food items, water, fish and meat products.

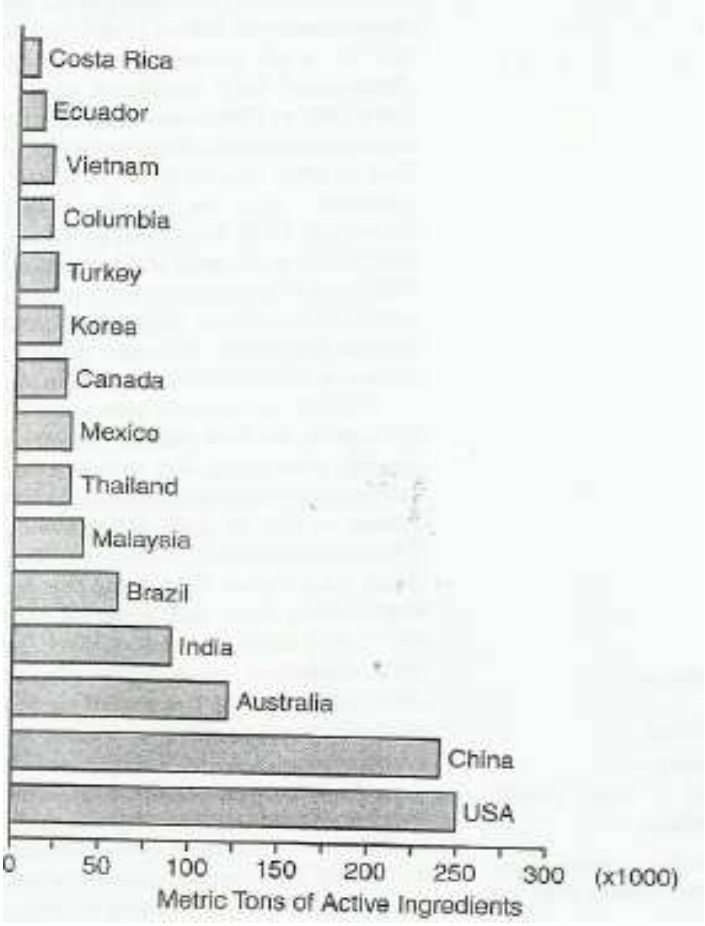


Figure 1.0: The global utilisation of pesticides in 1994 [2].

Human pesticides exposure is invariably associated with either acute or delayed toxicities. Globally, pesticides related toxicities have been valued as high as 3 million cases of severe, acute poisoning annually, with more unreported incidences and some 220,000 deaths [2]. The incidence of pesticides related toxicities are higher in developing countries than in developed countries due to lack of adequate regulations and extensive use of pesticides [4].

2. Regulation and Risk Assessment:

There are regulatory controls existing in many countries today regarding the distribution and use of pesticides which usually include a registration procedure. However, in assessing the possible risks associated with pesticides before approving their use, many countries depend almost entirely on internationally available hazard and risk assessments and have slight capacity to make locally based risk management decisions [13].

To minimise the hazards and risks associated with pesticides exposures, regulatory bodies at the international and local levels collaborate in establishing legislative and regulatory framework to minimise the adverse effects associated with the production, transport, handling, application and disposal of pesticides. They are also responsible for setting the guidelines necessary for testing, registration, effective management and licensing of any pesticides ([13], [10], [12], [1], [14]).

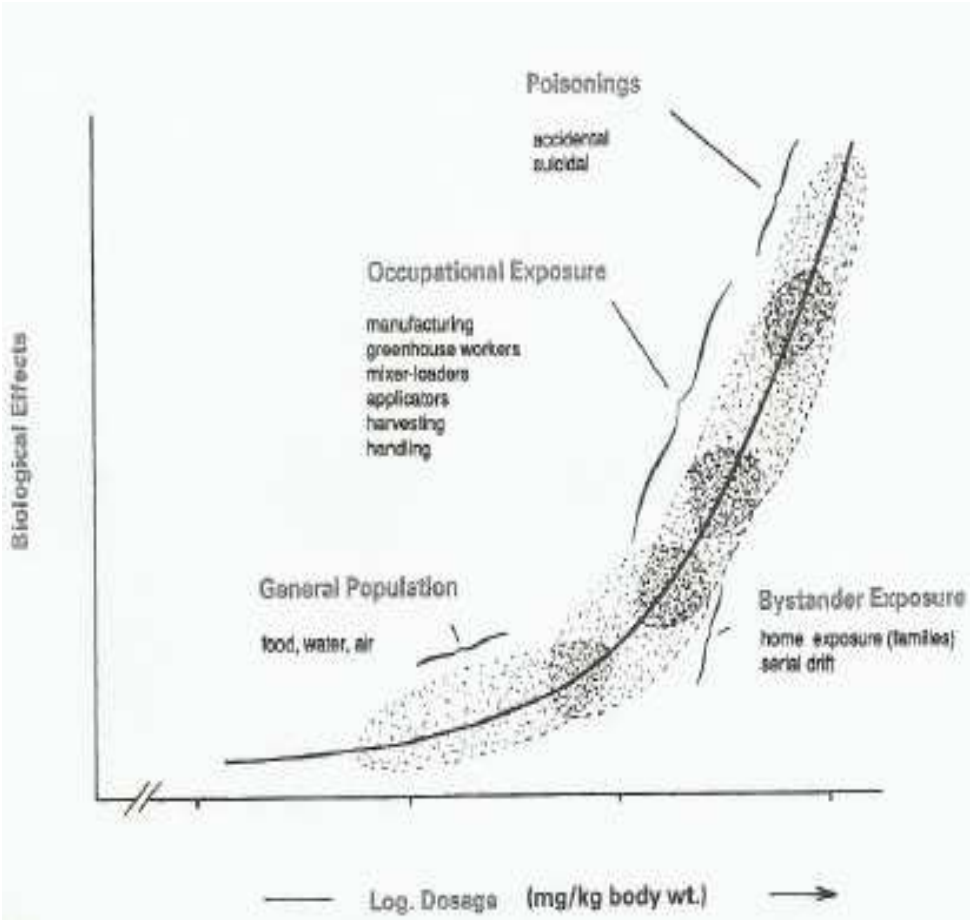


Figure 2.0: theoretical dose-effect relationship comparing occupation, level of exposure and possible biological effects [2].

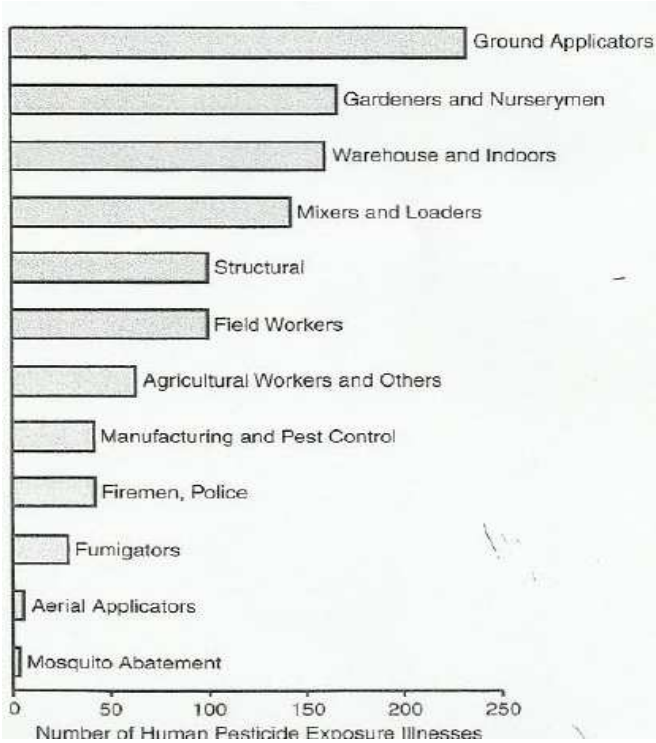


Figure 3.0: Pesticide poisoning related to occupation and potential for exposure [2].

Table 2.0 Basic requirements regarding Toxicity Data for New Pesticide Registrations [2].

Acute
Oral (rat)
Dermal (rabbit)
Inhalation (usually rat)
Irritation studies
Eye (rabbit)
Skin (rabbit, guinea pig)
Dermal sensitization (guinea pig)
Delayed neurotoxicity (hen)
Subchronic
90-Day feeding study
Rodent (rat, mouse)
Nonrodent (dog)
Dermal
Inhalation
Neurotoxicity
Chronic
One- or two-year oral study
Rodent (usually rat)
Nonrodent (dog)
Oncogenicity study (rat or mouse)
Reproductive
In vitro mutagenicity (microorganisms, etc.)
Fertility/reproduction (rat, mouse, rabbit)
Tetratogenicity (rat, mouse, rabbit)

Different regulatory agencies are empowered by certain regulatory act. For example, according to [1] United States Environmental Protection Agency (USEPA) is responsible for the regulation and control of any pesticide by registration or licensing prior to its marketing or application in United States. EPA receives its power to regulate pesticides from the Federal Insecticide, Fungicide, and Rodenticide Act (FIFRA). EPA ensures that a pesticide would cause little or no harm to human health and environment when used as directed prior to its registration. It also sets tolerance limits (acceptable daily intake (ADI), and maximum residue levels (MRLs) of pesticide residue that can be allowed if the pesticide is used on food or food crops [1]

The regulatory bodies are responsible for setting risk assessment framework with four crucial steps: identification of hazards, dose-response assessment, exposure assessment and risk characterisation. The information obtained is then used in risk management which involves the development of regulatory options such as the control, substitution, policy decision, banning, etc. [15].

3. Uses, site and mechanism of action of cyclodienes, their health and environmental implications

Cyclodienes – endrin, telodrin, isodrin, endosulfan, heptachlor, aldrin, dieldrin, chlordane, etc. – belong to a diverse group of chlorinated hydrocarbons referred to as the organochlorine (OC) insecticides. Cyclodienes are neurotoxicants and act by attacking the nervous systems of target species. Though no longer commonly use in developed countries, these compounds witness continued usage in less-developed, humid nations because of their effective, cheap and importance in crop protection and public health [1].

Organochlorine (OC) insecticides are posing major worries globally due to their severe toxicity, persistence and bio-accumulation potentially threatening human health and environment [6]. Their production, application and disposal is restricted or banned in many advanced countries ([12]; [10]; [1]) yet, they are still being used in many less-developed nations [5].

The site of action of cyclodiene insecticides is the organism's central nervous system (CNS). They act on two major processes: first, they interfere with the chloride ion influx via the inhibition of gamma-aminobutyric acid (GABA) action on $GABA_A$ receptor; second, they interfere with efflux of calcium by inhibition of Ca^{2+} – Mg^{2+} ATPase thereby elevating the intracellular calcium levels [2]. All these result in interferance with the depolarization and enhance sensitivity and activation of neurons.

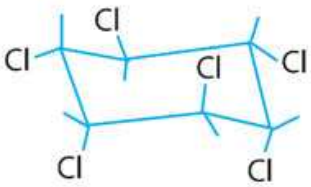
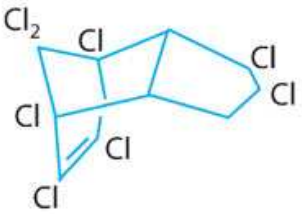
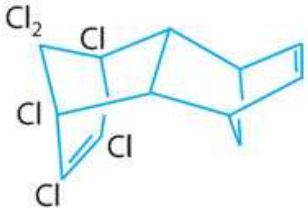
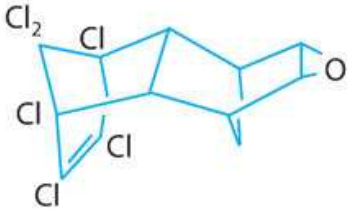
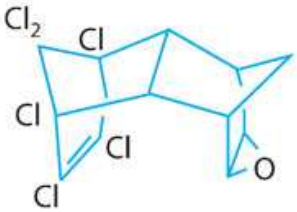
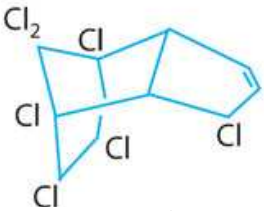
		Approx. LD_{50} (mg/kg)
Lindane (γ - BHC)		200
Chlordane		500
Aldrin		50
Dieldrin		50
Endrin		20
Heptachlor		150

Figure 4.0 Structure and acute toxicity (oral LD50 in rat) of selected organochlorine insecticides of different chemical classes [11].

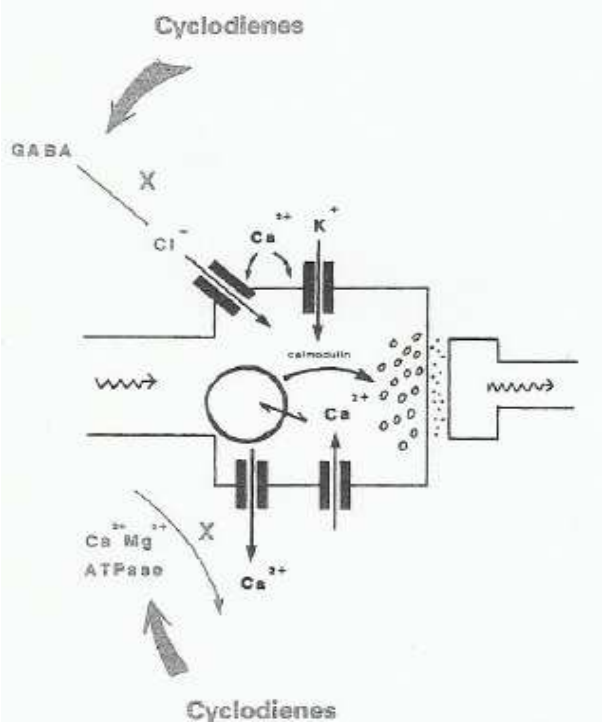


Figure 4.0 Proposed sites of action of cyclodiene insecticides on chloride ion transport through inhibition of the $GABA_A$ receptor channel as well as inhibition of calcium-magnesium ATPase [2].

Some signs and symptoms of poisoning associated with cyclodienes exposure in human and animals are dizziness, nausea, convulsion, tremor, seizures, vomiting, headache, motor hyperexcitability, psychological disorders, insomnia, anxiety, loss of cognisance, etc. [11].

The adverse effects of cyclodienes on health and environment are established. These effects are usually due to their toxicities; persistence, lipid solubility, and bioaccumulation. For example, [9] in a study on the effect of dieldrin on sparrow hawk growth in Britain maintained that direct effect of dieldrin resulted in an estimated 29% of sparrow hawks deaths in a region of high cyclodiene usage in comparison with just 6% deaths in region of low cyclodiene usage. Similarly, cyclodienes and other organochlorine compounds are also reported to have contaminated soil, land, surface water and fish in different parts of the globe ([5], [7], [8]).

DISCUSSION AND CONCLUSION

The fact is that unprecedented benefits have been obtained through the use of pesticides in controlling disease-causing organisms and insects, weeds, and other pests. However, pesticides cause harm to non-target organism due to physiologic and biochemical similarities between target and non-target species. The mechanism of action that makes them efficient also makes them hazardous to human, animals and environment. It is therefore important to understand associated risks and to limit use of pesticides to minimise possible damage to human health and environment.

Cyclodienes usage is associated with adverse effects on human health and environment due to their severe toxicities, persistence and bio-accumulation [6]. Thus, their manufacture, application and disposal have been control or completely banned in most developed nations, however, they are still used in many less-developed nations. The question is why these compounds are still being used in developing countries despite their adverse effects on human health and environment?

There are many explanations for this trend as follows:
One possibility is the lack of strict and stringent rules and regulations concerning the importation, licensing and sale of pesticides in developing countries. Governments in Africa have been very lax regarding the issue of legislation and control of pesticides; hence many internationally restricted and banned pesticides could be imported and used by farmers in these countries. [2] further indicates that most less-developed nations are yet to formulate strict 'regulations' regarding pesticide control and usage. Similarly, [13] argues that many countries have limited ability to formulate their own regulatory controls; hence they use internationally available pesticides regulations. In addition,

some of these countries are politically unstable, large stores of pesticides may be abandoned and leaked during uprising and civil war [16].

Poverty may be an important factor in the use of toxic pesticides in developing countries. Most of the banned, unpatented pesticides are very cheap and inexpensive making them simply available to farmers many of whom are relatively poor; so in their quest for the production of high yields, they resort to using the cheaper toxic pesticides. According to [2] some older, nonpatented, more poisonous, environmentally persistent and cheap pesticides are used widely in less-developed countries, leading to severe health problems and extensive environmental effects. Furthermore, [16] pointed out that donations of these older, nonpatented pesticides make them even more available to farmers in developing countries and further aggravating the problem.

Another important factor responsible for the continuous use of these toxic substances among farmers in the developing countries is ignorance and inexperience regarding the handling and use of those toxic pesticides. Consequently, farmers in these countries are under estimating the health effects arising from pesticide use and may even attribute the disease effect to other causes. This may be due to complication and time involved in the long-term relationship between dose and response. As pointed out by [3], lack of medical facilities and diagnosis related to pesticide exposure often ignores the dangers of pesticide use. In addition, farmers are ignorantly satisfied with the practicality and sustainable nature of pesticide use in crop protection practices in developing countries.

The urgent need of some developing countries to attack malaria by elimination of plasmodium-bearing mosquito may be important reason for the continuous use of toxic organochlorine insecticides. This practice may be explained based on the devastating, threatening and endemic nature of malaria among African communities. [5] noted out that this is understandable in African perspective considering the devastating nature of malaria killing one person in each 30 seconds.

Lastly, the economic and political commitment in switching from pesticides use to more sustainable organic agricultural practice make developing countries reluctant to stop the use of pesticides as the major means of crop protection. For example, in 1980s Indonesia spent as much as $1 million annually in trying to reduce the country's annual usage of pesticides [3].

CONCLUSION

The health and environmental impacts associated with cyclodienes exposure were discussed. The factors responsible for the continuous use of these banned substances in developing countries were also discussed and as long as these toxic substances continue to be used, health and environmental implications is certain.

To address this issue, governments need to adopt strict regulations and legislations (made available by International Organisations/Conventions) concerning the importation, licensing, storage, application and disposal of pesticides. In addition, toxic pesticides like cyclodienes should be banned and substituted with less hazardous ones. Also, government should enlighten and educate farmers and the general public regarding the safe use and handling of pesticides. Lastly, the general public should minimise the level of exposure to pesticide residues in food by food processing techniques such as washing, peeling, canning, cooking, etc.

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