HUMAN EXPOSURE TO PESTICIDES

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ABSTRACT
Pesticides have become a major group of environmental contaminants because of their widespread use in agriculture and public health. Misuse/abuse of these agents may lead to high human exposure to the chemicals with potential health hazards. In this review, the various sources of human exposure to pesticides are examined, potential health hazards are highlighted and ways of assessing extent of human exposure are presented. Recommendations are made for reducing environmental load of pesticides and minimizing human exposure.

1. INTRODUCTION

Global concern is growing over the huge number of chemical toxicants being discharged daily into the environment. This is because of the fear that human health is potentially endangered by these agents. Pesticides have gained widespread use since the early 1940s[1]. As a result of their widespread use, pesticides have become a major contributor to present environmental contamination. Useful as they may be in agriculture and eradication of disease vectors, most pesticides are poisons. Once used, they enter into the environment and accumulate in the food chain. Some pesticides, notably the organochlorine compounds, are persistent in the environment by virtue of their high chemical stability and lipid solubility. Hence, they may remain in soil and the tissues of various organisms long after their use[2,3]. It is estimated that at least 1kg of pesticide is used per person per year in the developed countries of the world[4]. Exact figures are not available for third world countries like Nigeria but given the high human population and the huge population of domestic pests in addition to agricultural pests, usage may well be higher.

While recommended use of pesticides may not pose significant danger, misuse/abuse and the use of substandard or banned products may lead to high levels of residues in food and the environment, leading to high human exposure and associated danger to health. To minimize the risks while deriving the benefits, the use of pesticides is regulated by governments all over the world and safety levels have been established for most pesticides by the FAO/WHO technical committee on pesticide residues. The effectiveness or otherwise of regulatory control is a major determinant of the level of human exposure in a particular environment. In Nigeria, National Agency for Food and Drug Administration and Control (NAFDAC) regulates and controls the importation, distribution, sales and use of chemicals, including pesticides[5].

2. WHAT ARE PESTICIDES?

Pesticides are chemical agents capable of destroying unwanted forms of life called pests[6]. A pest may be defined as any living thing that successfully competes with humans for food, space or other essential needs. Pests which transmit diseases from one living thing to another are called vectors. The definition of pesticides has been extended to include pest control agents such as growth regulators, defoliants, desiccants, repellents, attractants and chemosterilants[7]. Pesticides used mainly in agriculture are often referred to as agrochemicals.

3. CLASSIFICATION OF PESTICIDES

Pesticides may be classified in several ways based on:

i. **Chemical structure** - Main classes under this grouping are:

- **Organochlorines:** These are polychlorinated hydrocarbons used mainly as insecticides. They are more persistent in the environment than any other group of pesticides. Examples are dichlorodiphenyltrichloroethane (DDT), Hexachlorocyclohexane (HCH, Lindane), heptachlor, aldrin, etc.

- **Organophosphates:** Members of this class are phosphoric acid esters and therefore all possess the organic phosphate radical in their structure. E.g. malathion, parathion, dichlorvos, diazinon, etc. They are less persistent but more toxic than the organochlorines.

- **Carbamates:** These are carbamic acid derivatives. They are less toxic than the organophosphates and more readily degradable in the environment. They are used as insecticides, fungicides, herbicides and nematocides. Examples include carbaryl, propoxur and carbofuran.

- **Organosulphur Compounds:** These have sulphur as their central atom and are used as ascaricides and fungicides. e.g. ▶

the thiocarbamates and dithiocarbamates.

- **Dinitrophenols:** These are phenolic compounds which are effective as herbicides, fungicides, ascaricides and insecticides. Their use is limited by their high toxicity. Examples are Dinocap and Dinitrocresol.

- **Thiocyanates:** These compounds are insecticides which are highly toxic to flying insects but relatively safe for man and other animals. e.g. Thanite and Lethane 60.

- **Pyrethroids:** This is the main class of natural pesticides still in use. The compounds are derived from extracts of pyrethrum flowers, though synthetic analogs have been produced. They are broad-spectrum insecticides. E.g. cypermethrin, ellethrin. Permethrin, etc.

ii. Pest Classes Targetted

- Insecticides for use against all categories of insects.
- Herbicides for the control of weeds.
- Fungicides for the control of fungal diseases in plants, animals and stored products.
- Rodenticides for the eradication of rats and mice.
- Aviaricides for use against birds.
- Others such as ascaricides, nematocides, bactericides, molluscides, etc. for use against these various organisms.

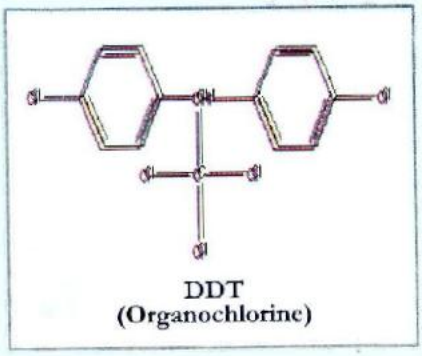
CLASS OF PESTICIDES	PERCENTAGE USE
Herbicides	46
Insecticides	31
Fungicides	18
Others	5

iii. Route of Entry into the Pest - Here the chemicals are grouped into:

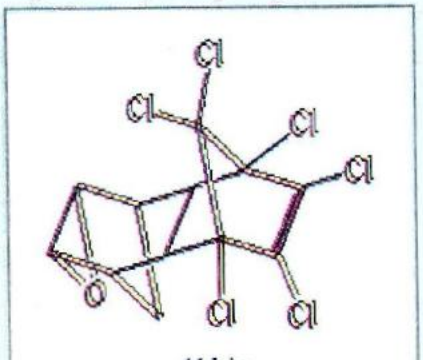
- **Contact Pesticides** - which penetrate the skin or cuticle of the pest.
- **Stomach Pesticides** - which are effective only on consumption by the pest.
- **Respiratory Pesticides** - taken in by the pest through inhalation for pesticidal action to occur.
- **Systemic Pesticides** - which penetrate all tissues of the pest and produce effects in parts other than the point of application.

iv. Degree of Toxicity (FAO/WHO Hazard Classification) In this mode of classification, LD50 in mg/kg is used to group the chemicals into:

- Class I: 5-40 - Extremely hazardous
- Class II: 40-4000 - Moderately hazardous
- Class III: >4000 - Slightly hazardous.



DDT
(Organochlorine)



Aldrin
(Organochlorine)

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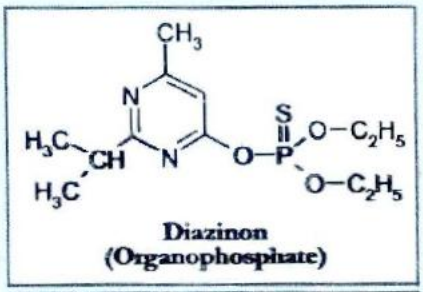
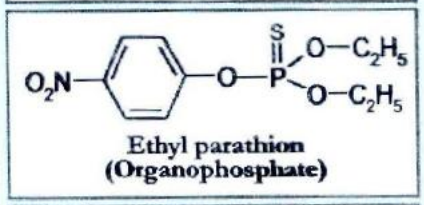
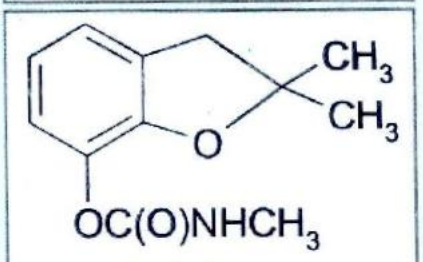


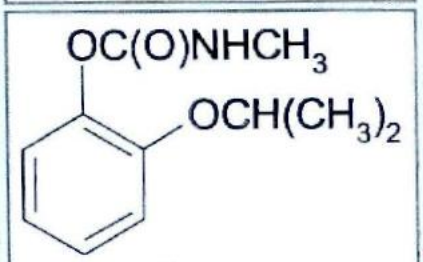
Diazinon
(Organophosphate)



Ethyl parathion
(Organophosphate)



Carbofuran
(Carbamate)



Propoxur
(Carbamate)

Figure 1: Structures of Some Common Pesticides

4. USES OF PESTICIDES

Pesticides are used in a variety of ways to improve human welfare. Areas in which they have been found useful include:

- **Agriculture** - Pesticides are widely used in agriculture to improve the quality and quantity of crop production by protecting crops against destructive pests both in the fields and during storage, transportation and handling[4,8]. In fields, they are sprayed on crops or applied to soil in the fight against weeds, insects and other pests. During storage, pesticides are applied to seeds and grains to prevent infestation by insects and fungi. Fruits and vegetables are often washed with fungicides to preserve their quality during ▶

transportation and handling, that is, reduce perishability[7].

- **Forestry/Horticulture** - Pesticides are used in forestry and horticulture for the control of weeds and for the protection of timber, forest and garden trees, ornamental plants, lawns, flowers and fruit trees.

- **Industry Pesticides** - are used in industries against weeds and other pests in industrial premises and drains.

- **Public Health** - Apart from their role in agriculture, pesticides are also used in homes and in public health programmes to control certain human and veterinary diseases by eradicating disease vectors such as mosquitoes, tsetse flies, black-flies, houseflies, cockroaches, etc. For example, the Rollback Malaria programme of the World Health Organization (WHO) advocates the use of insecticide-treated bed nets to prevent mosquito bites in the fight against malaria. Pesticides are also used in veterinary practice to rid pets and other animals of ectoparasites. Their main use, however, is in agriculture because of perpetual need to increase food supply.

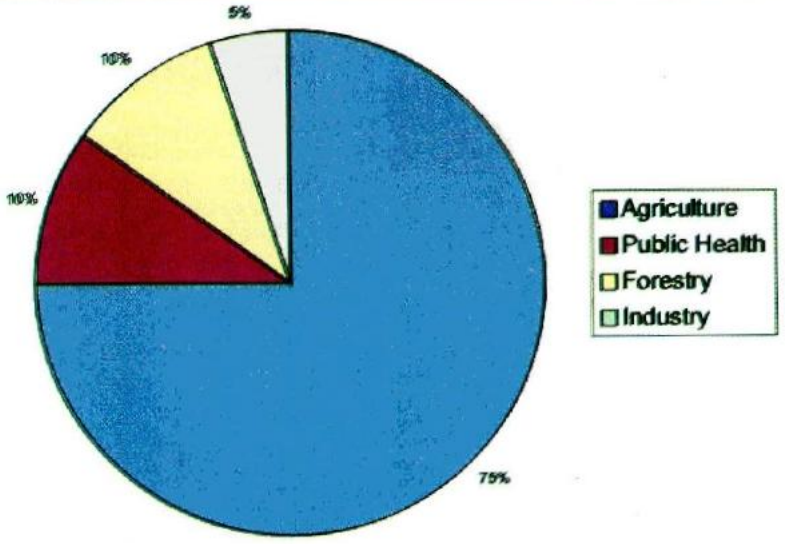


Figure 2: Estimated World Pesticide Usage[4]

5. MISUSE AND ABUSE OF PESTICIDES

Misuse and abuse occur wherever pesticides are in use but more commonly in developing countries[9]. Misuse and abuse of pesticides may lead to adverse consequences on health and the environment. Reasons for misuse and abuse of these agents are illiteracy, ignorance, poverty, fear of harvest failure, eagerness to protect crops, etc. Examples of pesticide misuse and abuse include:

- Use of high doses of pesticides and/or increased frequency of application in attempts to increase effectiveness.
- Use of highly toxic chemicals in preference to safer alternatives in the belief that the more toxic the chemical, the higher the level of pest control.
- Indiscriminate use of highly selective compounds against pest species which are not sensitive to them.
- Use of non-specific agents leading to destruction of target and non-target pests.
- Abnormal use of toxic chemicals such as gamma HCH (gammalin 20) in fishing[10], and for preservation of kolanuts.
- Use of DDT on dry fish to protect it against vermin infestation.
- Continued use of persistent compounds (because of their low price) in preference to newer, more environment-friendly alternatives.

6. TYPES, SOURCES AND ROUTES OF HUMAN EXPOSURE TO PESTICIDES

Pesticides are used in several areas of human endeavor and so people are exposed to these chemicals in several ways. The severity of damage to human health varies with the type, source and route of exposure. Three main types of exposure are: (1) Acute in which a person is exposed once to a large dose with immediate manifestation of toxic effects (usually within 24 hours). (2) Sub-acute which is due to frequent exposure to moderate doses and symptoms of toxicity are delayed for a week to one year. (3) Chronic in which a person is exposed to small doses over a long period of time and manifestation of symptoms is delayed for one year or longer[10].

The main routes of entry into the human body are oral (by mouth), dermal (through the skin) and respiratory (by inhalation)[11]. The type and route of exposure for any individual or group of persons depends on the means by which they come into contact with the chemicals. The main sources of exposure to pesticides are:

a. **Occupational Exposure:** This applies to workers in the industry who are involved in the manufacturing, formulation and packaging of pesticides. It also applies to agricultural workers responsible for pesticide application to crops especially if there is non-use of protective clothing during application and use of leaking or inappropriate application equipment. Public health workers directly involved in spraying these chemicals are also exposed. The route of exposure is usually via contact with the skin and by inhalation. This type of exposure may be acute, sub-acute or chronic.

b. **Non-Occupational Exposure:** This usually involves the general public who take in small doses of pesticides via consumption of agricultural products which have ▶

been treated with these chemicals. Sources of drinking water supply may be contaminated by run-offs from agricultural fields[12,13]. Packaged food and drinks are not spared as pesticides have recently been reported in soft drinks sold in a third world country[14]. The public may also be exposed through inhalation of contaminated air when pesticides are used in homes and public health programmes against disease vectors. The route of entry is mainly oral but sometimes respiratory and exposure is usually chronic as low doses are consumed over a long period of time.

c. **Unintentional Exposure:** This involves both occupational and non-occupational kinds of exposure and may be acute, sub-acute or chronic. It includes accidental exposure such as may occur when pesticides are stored in containers without labels or within reach of children and consequently consumed as medicines or food. Seeds dressed for planting may be erroneously released for consumption leading to unacceptable levels of exposure. Accidental exposure may also occur due to spillage of improperly packaged pesticide products. Exposure is unintentional when pesticide containers are ignorantly used for storing food or water meant for human consumption. The oral, respiratory and dermal routes of entry into the body are usually involved in this type of exposure to pesticides.

d. **Intentional Exposure:** Although most human exposure to pesticides is unintentional, intentional use occasionally occurs, mainly for the purpose of suicides or homicides. The route of entry is usually oral but sometimes dermal. This type of exposure results to acute poisoning or death.

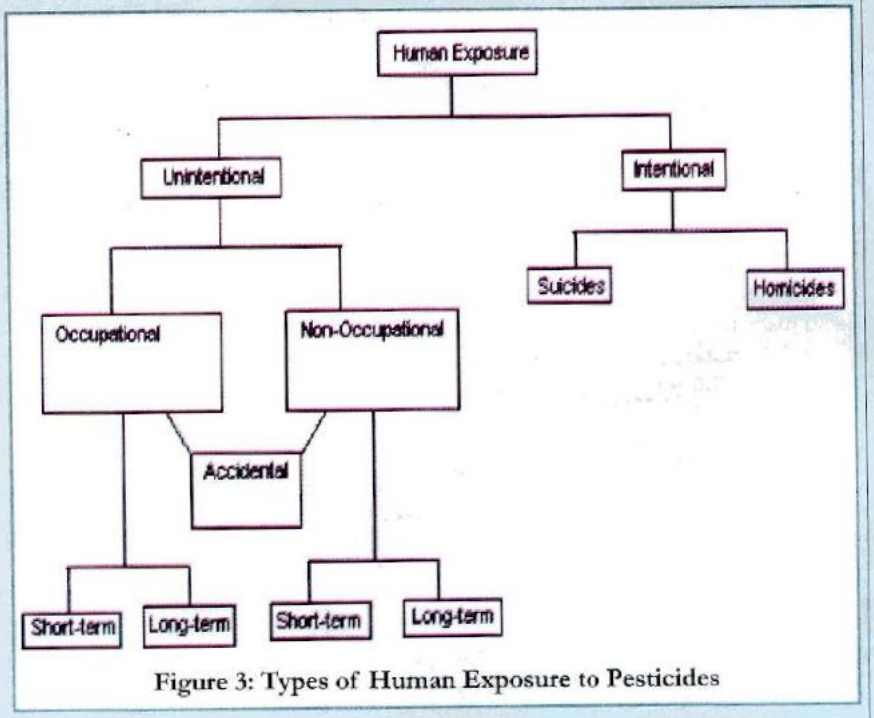


Figure 3: Types of Human Exposure to Pesticides

7. HEALTH HAZARDS DUE TO HUMAN EXPOSURE TO PESTICIDES

Pesticides are poisons and are known to be potentially hazardous to human health as well as the environment[15]. These hazards become manifest if the chemicals are carelessly handled. Observed toxic effects vary with the type of chemical and its mechanism of pesticidal action. For example, organophosphorus and carbamate compounds are known to inhibit the enzyme acetycholinesterase (AchE) leading to accumulation of acetylcholine (ACH) at neuromuscular junctions with consequent cholinergic effects such as muscle twitching and eventual paralysis[16]. Organochlorines are also known to be neurotoxic by disrupting the delicate balance of sodium and potassium within the neurons thereby preventing normal transmission of nerve impulses. Pesticides, being a class of xenobiotics, may affect liver mono- and mixed-function oxidases such as the cytochrome P-450 and the Ziegler enzyme[17]. This may lead to changes in the metabolism of compounds handled by these enzymes. Accumulation of pesticides in the body may also affect biochemical tests and interact with food and drugs. Potential health effects associated with pesticides include:

i. **Acute Poisoning:** This involves the immediate manifestation of adverse effects after exposure to high doses, usually resulting from occupational, accidental or intentional exposure. Acute poisoning may arise from the consumption of highly contaminated food such as grains treated directly with high doses of pesticides (the killer beans incident of 1996 in Lagos, Nigeria readily comes to mind) or animals that had fed on contaminated food. Also, acute poisoning may be due to excipients in the pesticide formulation e.g. solvents, carriers, emulsifiers, synergists; or due to metabolites or by-products of the manufacturing process.

   Acute poisoning may be fatal or non-fatal. An annual world estimate of one million cases and a fatality of 0.4-1.9% has been reported[18]. The effects of acute poisoning may be systemic or local and include dizziness, vomiting, cramps, coma, burns on the skin and eye, neurological effects, liver and kidney damage. The effects produced depend on the degree of toxicity of the pesticide, the mechanism of action and route of entry into the body. Fortunately, only a small proportion of the general population is exposed to pesticide levels high enough to cause severe acute effects.

ii. **Chronic Poisoning:** This occurs due to exposure of humans to low doses of pesticides over a long period of time, usually through residues in food, water and air. ▶

Pesticide residues have even been found in soft drinks which are usually consumed on a large scale. This means that no segment of the general population is completely protected against potential health effects due to chronic exposure to pesticides. As in the case of acute poisoning, additives in the pesticide preparations may be responsible for some chronic toxicity effects.

Chronic poisoning may affect the function of individual organs to produce cancers, congenital malformations, infertility, impotence, immunological disorders, blood dyscrasias, neurotoxic disorders, liver damage, kidney damage, skin alterations and worsening of existing health conditions. These effects may be produced even by compounds with low acute toxicity[19]. Examples of confirmed or suspected health hazards arising from chronic exposure to specific pesticides include the following:

- High rates of birth defects were recorded (in Vietnam, 1960) in areas where US Forces applied 2,4,5-trichlorophenoxyacetic acid (2,4,5-T) herbicide for defoliation of forests during the Vietnam war[20].

- Carbendazim used as fungicide on yam has been found to disrupt growth and affect sperm count in humans[21].

- DDT has been linked to cancer and male infertility as it blocks the action of male hormones[22].

- Lindane has been identified as an endocrine disruptor as it mimics the female hormone, oestrogen and is linked with fertility problems, breast and other cancers[19].

- Non-Hodgkins lymphoma (a rare type of cancer) was found six times as often in farmers who had been spraying herbicides (especially 2,4-Dichlorophenoxyacetic acid (2,4-D)) for more than twenty years than in non-farmers[20].

8. ASSESSMENT OF HUMAN EXPOSURE TO PESTICIDES

Human exposure to pesticides may be potential or actual. Potential exposure may be estimated by environmental monitoring. This involves measurement of levels of pesticide residues in all environmental sources of human exposure, such as air, food, water and soil[11]. The values are then compared with guideline values established by FAO/WHO. How much of the pesticide residues found in the environment will eventually get into the human body depends on several factors such as:

- Chemical nature of the pesticide: Chemically stable pesticides are not easily degradable in the environment and are therefore more likely to be found in human tissues at higher levels than less stable compounds.

- Climatic Conditions: High temperatures and humidity may aid degradation of some pesticides and reduce their chances of getting into the human body.

- Level of education and awareness of users: This will help in the choice of safer pesticides and observance of good agricultural practice such as observing waiting periods between time of application of pesticides to crops/food and time of harvest or consumption. This will greatly reduce the concentration present in food at the time of consumption.

- Processing: Washing removes some surface residues especially the water-soluble pesticides while cooking could cause breakdown of thermally unstable pesticides. Thus processing could lead to lower residue levels in food at the point of consumption[21]. Some pesticides are however resistant to commonly used processing methods.
It is therefore important that environmental agents of exposure (especially food) be analyzed regularly to ensure that maximum residue limits (MRL) set by FAO/WHO are not exceeded. MRL is the maximum concentration of a pesticide residue expected on a crop or food commodity resulting from the use of the pesticide according to good agricultural practice and is expressed in milligrams of pesticide residue per kilogram of commodity[23]. In other words, MRL is the highest amount of residue to be found on a commodity after a pesticide has been used on it and is legally acceptable. The capacity for regular analyses is however lacking in most third-world countries[24].

Actual human exposure to pesticides, on the other hand, can only be measured by biological monitoring of human tissues and body fluids. This involves analyses of such samples as fat, serum, urine, blood, breast milk, skin or hair for pesticide residues or measurement of specific effects such as cholinesterase activity for organophosphorus and carbamate pesticides. Residue values are used to calculate daily intakes which are then compared with acceptable daily intakes (ADIs) established by FAO/WHO. ADI of a pesticide is the daily intake of the pesticide which during a life time appears to be without appreciable risk to the health of the consumer[23]. It is expressed in milligrams of pesticide per kilogram of body weight.

9. WAYS TO REDUCE EXPOSURE

Human exposure to pesticides can be minimized if attention is paid to the different sources of exposure and adequate precautions taken. Areas requiring such attention include:

a. **Packaging, storage and transportation of pesticides:-** Pesticides should be packaged in appropriate containers and adequately labeled for safe and effective use. Inappropriate packaging may lead to leakages and spillage while inadequate labeling or use of foreign languages would encourage misuse or abuse. Premature loss of labels may lead to accidental consumption. All these contribute to increased human exposure.

Pesticides should be stored out of reach of children and away from food stuffs and other items for ▶

human consumption. They should be transported in separate vehicles and handled with care during the process of transportation to avoid spillage and accidental contamination of consumable goods.

b. **Education of Users:-** The end-users must be adequately educated and trained on all aspects of pesticide use including:
   - Use of appropriate application methods and equipment to reduce overall exposure.
   - Use of protective clothing during mixing and application to avoid skin contact and excessive inhalation.
   - Disposal of pesticide containers and unused stock. For example, empty pesticide containers should not be used to transport or store drinking water or food.
   - Observance of good agricultural practice: This involves use of the right pesticide in appropriate concentrations to avoid high residues in crops/food.

   Farmers should also be trained to observe waiting periods between the time pesticides are applied to crops/food and the time the crops/food are harvested or released for consumption.

   Education and training is especially important in developing countries where end-users are mostly illiterate farmers who often lack awareness of the potential hazards of pesticides to human health and the environment.

c. **Use of alternative methods of pest control:-** This will also help to reduce the amount of pesticides in food and environment which will in turn lead to reduced human exposure to the chemicals. Such alternative methods include biological control of pests, use of natural predators and pheromones and cultivation of pest-resistant crops.

10. CONCLUSION

Pesticides are useful in the production of much needed food for the world's teeming population. They also help in controlling disease vectors. Their use, however, leads to residues in food and the environment, but human exposure and health risk can be minimized by selecting suitable, safe, non-persistent, high-quality compounds. Education, training and information for users and the general public is also of great importance in reducing human exposure to pesticides.

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