Insecticide Toxicology (Ent-714) Credit Hours 3(2-1)

Lecture # 4 Delivered by Dr.Hassan Yasoob

Topic- Introduction, General Concepts of Insecticide Toxicology

TOXICOLOGY

Toxicology is one of the oldest branches of pharmacology. Traditionally, it has been thought of as the science of poisons affecting human lives and, therefore, as a branch of medical science. DuBois and Geiling (1959) provided the following definition: "Toxicology is that branch of medical science that deals with the nature, properties, effects, and the detection of poisons. It is, therefore, the science of poisons." In this definition are included studies on the metabolism and excretion of poisons, on the action of poisons, and on the treatment of poisoning as well as systematic chemical and physical analyses and diagnoses (Stewart and Stolman, 1960). In recent years a branch of this subject, now known as environmental toxicology, has grown increasingly important. Its development has been fostered, even necessitated, by (1) the extensive use of industrial chemicals, pesticides, and natural resources, (2) more intense utilization of urban, agricultural, and recreational space and marine environments, and (3) heightened awareness of the hazards of chemicals to wildlife, domestic animals, and people. All this constitutes quite a departure from the traditional concerns of toxicology, since in the past the principal emphasis has been on human subjects and domestic animals. Until quite recently, for instance, the most important subfield of toxicology was industrial toxicology (DuBois and Geiling, 1959), which is concerned mainly with the safety of industrial workers and, to a much lesser extent, with that of other people who might accidentally be exposed to large doses of industrial poisons. Under the rubric of environmental toxicology, the domain of toxicologists has been enlarged to incorporate all forms of biological systems including wildlife, man, and domestic animals. Studies on metabolism, transport, translocation, physicochemical transformation, etc., have been expanded to include the entire spectrum of ecosystems, physical environments, the biosphere, and even the total environment on a global scale. Despite these roots, however, environmental toxicology is an entirely new discipline. Its history dates back to 1962, the year Silent Spring, the famous book by Rachel Carson, appeared. Its scope and principles are not yet clearly defined (see preface in Matsumura et al., 1972), although ultimately its natural evolution as a scientific discipline will resolve this problem. In the present chapter, I shall attempt to explain its background and my own view of the field today. The biocidal agricultural chemicals, collectively known as pesticides, are, without any question, the largest group of poisonous substances that are widely broadcast today. Pesticides include insecticides, acaricides, nematocides, rodenticides, herbicides, and fungicides. Insecticides (in the broad sense, acaricides and nematocides are included) are the most numerous and most valuable pesticides. As in the case of many other biologically active substances, insecticides have been developed mostly by empirical methods, notably by screening countless numbers of compounds that kill the pest organisms, and not by logical considerations of their properties and the consequences of their use. The necessity to use insecticides properly forced entomologists to study their properties, since far greater knowledge of the nature of insects as well as of the problems of insect pests in agriculture and public health was required. Insecticide toxicology differs from its parent discipline, medical toxicology, in that it does not include clinical diagnoses or treatment of human patients who are affected by insecticides; however, insecticide toxicology does include efforts to determine tolerance levels of pesticides in man and is concerned with establishing a logical basis for selective toxicity, in order to kill insects without affecting mammals. In this connection, there is an overlap between insecticide toxicology and veterinary toxicology, since the latter is often devoted to studies of the effects of various pesticides on domestic animals. Radeleff (1964) describes the field by saying, "A veterinary toxicologist, then, may be considered to be a veterinarian having a special knowledge of the poisons affecting the mammals and birds in which man is interested for his economic gain or personal pleasure, and of those substances which, when present in animal products, could be harmful to the people who may consume them." In other words, veterinary toxicologists are concerned with any toxic substance that may come in contact with domestic animals, just as medical toxicologists are concerned with the effects of poisons on humans, and these poisons include pesticides.

Insecticide resistance is a result of accelerated microevolution. Under selection pressure the fittest survive, multiply and spread. It results from the survival and spread of resistant insect genotypes that have the capability to endure insecticide selection pressures in the environment. Insect development of resistance to insecticides is an inevitable consequence of insecticide use for pest control. When the frequency of resistant phenotypes increases to a certain level infield populations, control efficacy with the concerned insecticide becomes economically unacceptable. But poor efficacy under field conditions is not always due to insecticide resistance. Amongst other factors, the quality of technical grade material used, the formulation, the application dose and the method of application can also play an important role in impairing field control. However, if resistance is the major factor, field control failure is inevitable, irrespective of quality, quantity or methods of application. Thus resistance eventually is the single most important phenomenon that threatens sustainable pest management. It is therefore important to detect resistance when it is at incipient levels and monitor its increase and geographical spread so that appropriate measures can be initiated to curtail its increase. The major objectives of resistance detection and monitoring must be to eventually ensure effective and sustainable pest management. Applications of resistance detection and monitoring are as follows:

1. Resistance monitoring methods help to document geographical and temporal variability in population responses to insecticide selection pressures. Monitoring helps to keep track of the precise changes in resistant phenotype frequencies occurring in field populations.

2. Resistance detection bioassays determine the relative efficacy of insecticides for a given field population. In immediate practical terms, resistance detection helps in avoiding ineffective molecules and assists in making a proper recommendation of alternative molecules that are less resisted and can effectively control insect pests. This prevents wastage of pesticide applications that would have otherwise harmed the environment without actually having served the designated purpose of pest management. Thus, resistance detection serves an early warning of the impending problem of uncertain levels of pest control under field conditions.

3. The bioassays diagnose and confirm the causes of pest control failure by specific insecticides under field conditions.

4. Resistance monitoring helps to evaluate the impact of resistance management strategies, which have been implemented.

Resistance detection methods

are based on the following assays:

1. Conventional bioassays: Diagnostic dose assays and log-dose probit (LDP) assays are the two most commonly used methods of detecting, monitoring and documenting resistance.

2. Biochemical assays: Resistant strains may be characterized by the presence of a unique or over-expressed defence mechanism, that is either absent or if present may be expressed at lower levels in the susceptible strains compared to that in the resistant strains. Such strains can be characterized by biochemical assays that can detect and monitor insecticide resistance.

3. Molecular assays: Molecular assays are specifically designed based on observed mutations in the resistant allele itself or based on DNA fragments closely linked to the resistant allele.

4. Immunological assays: Immunoassays are generally based on antibodies raised against a major biochemical molecule that confers insecticide resistance in insects. The assays either use ELISA or the dip-stick format to detect the frequency of resistant insects in field populations.

General Concepts of Insecticide Toxicology

EVALUATION OF TOXICITY

Toxic interactions of any chemical and any given biological system are dose related. At extremely high concentrations, most chemicals have toxic effects on biological systems. The toxicology of poisonous chemicals can be termed the "science of doses." The toxicity of insecticides (or of any toxicant, for that matter) to a particular organism is usually expressed in terms of the LD50 (for "lethal dose"). This value represents the amount of poison per unit weight which will ki1l5(}% of the particular population of the animal species employed for the tests. The LD50 is commonly expressed as milligrams per kilogram (mgj kg) or occasionally as milligrams per body (e.g., mgjfemale fly). In some cases, the exact dose initially given to the insect cannot be determined but the concentration of the insecticide in the external media can, so that the LC50 is used. For example, the toxicity of insecticides to mosquito larvae or fish is commonly assessed by the concentration of the toxic compound in water that will kill half the animals exposed for a specified period of time. The term LT 50 is also frequently used; it represents the time required to kill 50 % of the population at a certain dose or concentration. This method of assessing toxicity requires relatively few individuals and therefore is often employed for field tests where the possibility of collecting a sufficient number of individuals is limited (e.g., the World Health Organization's standard test for German cockroach colonies). In limited instances, the rate of knockdown of insects becomes a more important criterion for assessing the efficiency of insecticides than the rate of kill; in such cases, the median knockdown dose and knockdown time, KDso and KT 50' are used. There are cases where killing or knockdown does not constitute the desired criterion. For instance, in tests for chemosterilants the idea is not to kill the test insects but to sterilize them without reducing their vigor. The chemical in question is measured according to its effects on fertility and fecundity. The EDso and EC so (effective dose and effective concentration) are used to describe results of such tests. The method of obtaining these values and its mathematical implications will be discussed later.

Toxicity Tests against Insects and Other Invertebrates

There are several ways to administer insecticides to an animal. The most commonly employed method for insects is topical application, where the insecticide is dissolved in a relatively nontoxic and volatile solvent, such as acetone, and is then allowed to come in contact with a particular location on the body surface. Usually combinations of a constant amount of solvent with varied concentrations of the insecticide are used for this purpose in order to keep the area of contact, as well as the effect of solvent, constant. Although the results obtained with the topical application procedure can be a very reliable indication of the relative contact toxicity of any insecticide to a certain animal, the method is not sufficient by itselfto indicate the actual amount entering the animal's body. When knowledge of the exact amount of insecticide inside the body is required, the injection method is usually employed. The insecticide is commonly dissolved in carrier material, such as propylene glycol or peanut oil, and injected into the body cavity, e.g., intraperitoneally. For insects, injection is usually made at the abdominal sterna or the intersegmental regions, avoiding the longitudinal center line so as not to injure the abdominal nerve cord. The needle is held in position for a while and then pulled away gradually in order to avoid bleeding due to internal pressure. These standard methods cannot be used in certain cases where the insect's mode of life or its morphological arrangement conflicts with the testing method; for instance, dipterous larvae cannot withstand the skin injury caused by the injection method, and topical application cannot deliver a sufficient quantity of insecticide. A number of specially designed testing methods are available for many of these unorthodox cases (Busvine, 1971). For instance, the dipping method is used for dipterous larvae. The insects are simply picked up with a pair of forceps and dipped into the insecticide preparation, which is either a suspension in a solvent such as acetone or methyl ethyl ketone or an emulsion in an emulsifier such as Triton X-I 00.