Pesticides: chemicals for survival?

by D. A. Lindquist*

Pesticides are chemicals used to control pests such as insects, weeds, plant diseases, nematodes, and rodents. The increased use of pesticides since 1945 has greatly aided the increase in crop production, protected livestock from diseases such as trypanosomiasis, protected man from diseases such as malaria and filariasis, decreased losses of stored grain, and has generally improved man's welfare. The quantity of pesticides used throughout the world probably exceeds 2 million tonnes [1]. Most is manufactured in developed countries, and the annual production is worth more than US$ 10 billion [2]. The use of pesticides throughout the world is increasing, and will continue to increase for the remainder of this century as the race between food production and population continues. However, the use of pesticides is not without problems.

Need for pesticides

It has been estimated that the agricultural return in the mid-1960s was approximately $4 for every dollar spent on pesticides [3]. It is more difficult to calculate benefits to the public health, however they are undoubtedly very high.

It has been reported that field losses from pests average 35% for the world's main food crops [4]. In some places losses will far exceed this figure. Studies in the United Kingdom have indicated that if no pesticides were used on cereal crops losses would be 24% in the first year, but by the third year without the use of pesticides losses would be 45% [5]. Pesticides have accounted for 20% of the increase in farm output in the United States since 1945 [4].

No-till production practices (crop production with little or no ploughing and cultivation), which are becoming increasingly popular to prevent erosion and reduce energy requirements, require effective weed control. This and the availability of effective herbicides has resulted in a dramatic increase in the use of herbicide over the last few years and this increase will continue. Globally, more herbicides are used than insecticides; although in developing countries herbicides are not used as extensively as in developed countries. Competition from weeds for limited supplies of soil, moisture, and plant nutrients often results in enormous losses to the cultivated crop. Crop reductions of 50 to 70% resulting from competition by weeds are not uncommon [6, 7]. Thus weed control is of great importance to developing countries.

Control of vector-borne diseases of man and animals is based to a large extent on insect control, because there are very few vaccines [8]. Thus insecticides play a major role in the control of malaria, filariasis, dengue and many other vector-borne diseases.

Problems caused by pesticides

Despite the enormous benefits derived from pesticides, these chemicals are not problem-free. Many pesticides are toxic to living organisms and interfere with specific biochemical systems. Since all living organisms have some similar biochemical systems, it stands to reason that a chemical which kills a fly may also kill a dog. Thus the problem that a chemical may be toxic to non-target organisms must be taken into account not only in developing the pesticide, but in its use.

The widespread and sometimes improper use of pesticides has led to resistant strains of insects, plant diseases, weeds, and rodents which can no longer be controlled by certain pesticides. New pesticides must be developed to control these resistant pests. The increased cost of pesticide development (currently estimated at US$ 15 million to US$ 20 million per pesticide over a six to ten year period) has resulted in fewer new pesticides being developed in recent years [9].

Pesticide residues in food are a potential hazard which has received much attention during the past 20 years. Extensive regulatory agencies have been created in developed countries to deal with pesticide residues in food. In many developing countries acceptable quantities of pesticide residues in food (tolerances) have not been established, however the guidelines developed by FAO and the World Health Organization are generally followed. Because of the very small quantities of pesticide which are permitted in food, elaborate analytical procedures are required. With some pesticides the original chemical is modified by the plant into a more toxic one, and this must be taken into account when residue analyses are conducted. Some pesticides are relatively stable and, since a considerable amount of the applied pesticide frequently ends up in the soil, there is some chance that these pesticides will accumulate. These chemicals may then be leached into underground water-supplies or rivers and lakes, and in some cases bio-accumulation can occur to an extent which causes damage to fish or birds. Bio-accumulation will normally result only when the pesticide is stable in the environment; most newer types of insecticides are not sufficiently stable to result in this type of problem.

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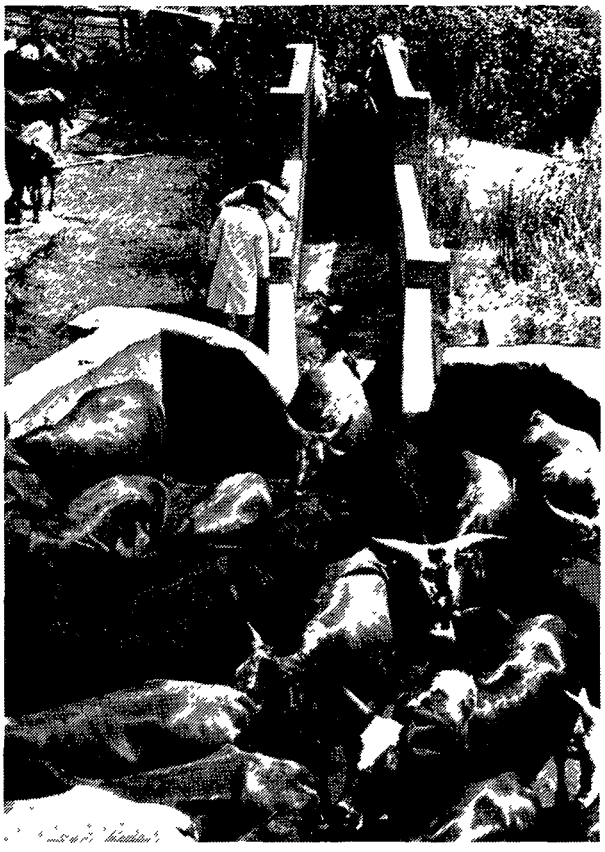

Cattle being dipped in an insecticide solution for tick control.

The ability to measure minute quantities of a chemical is essential in conducting research on the metabolism, fate, and residues of a pesticide in a food commodity Pesticide residues are usually reported in parts per million (ppm), which means the amount of pesticide in a million parts of the food commodity. One ppm can be visualized as one centimetre in one million centimetres or one centimetre in ten kilometres, one minute in two years, or one gram of butter in one thousand kilograms of bread. To measure these very small quantities of a pesticide radiolabelled chemicals are frequently essential, particularly to measure changes in the chemical structure of the pesticide, movement of the pesticide in soil, plants, or animals, amounts of the pesticide going through various steps in food processing, etc.

Methods of application and formulations of pesticides are currently receiving much attention. The objective of this research is to apply the pesticide as precisely as possible to the target and reduce the quantity of pesticide which misses the target and ends up in the soil, water, or non-target crops. Formulations of pesticides applied in or on the soil offer the potential of increasing the length of time over which they are effective, reducing the quantity of pesticide required, and reducing potential residues in the crops being protected.

Plant and animal food-stuffs exported from developing countries must meet the standards of the importing country. These standards include acceptable quantities of pesticide residues. Thus, developing countries must establish and maintain research and regulatory organizations to ensure acceptable pesticide residues in exported commodities. The research frequently requires the use of radiolabelled chemicals to solve pesticide problems.

Radioisotopes and pesticides

During the development of a new pesticide and before its commercialization, the synthesis of the radiolabelled product is a normal part of the r. and d. expenditure. The radiolabelled material is then used for a number of studies, including metabolism of the pesticide in each crop species for which it is intended, metabolism in a ruminant, in chickens and eggs, in soil (both aerobic and anaerobic), and possibly leaching and sorption in soil, hydrolysis, bio-concentration, and photodegradation. After the metabolism studies have been completed, the toxicity of any major metabolite is determined. Based upon these results, an analytical procedure is developed which can be used on all the crops for which the pesticide is intended, as well as in meat, milk, and eggs. In some cases the metabolism studies give clues pointing the way to other experimental pesticides. Nearly all this research is done on temperate-zone crops by scientists in developed countries. Solutions to some of the specific pesticide problems in developing countries are being sought with the aid of the Agrochemicals and Residues Section of the Joint FAO/IAEA Division.

Persistence of pesticides in the environment. Data on persistence of pesticides in the environment now comes primarily from research conducted in developed countries in the temperate zone. Yet temperature, moisture, and other environmental factors which influence persistence are entirely different in most developing countries. Regulations regarding use of pesticides are greatly influenced by the persistence of the pesticide (for example DDT). Research on the persistence of pesticides in the tropics is being assisted through a co-ordinated research programme on the interaction of pesticides in soils. Data from these studies using radiolabelled pesticides will aid developing countries to determine regulations regarding the use of certain pesticides.

Bound residues: Following the application of a pesticide to soil or plants some of it or one of its degradation products may be so tightly bound to the soil or plant material that it cannot be extracted with organic solvents in the normal manner. Identification of these bound residues and the determination of whether they pose a possible residue hazard is being investigated by a co-ordinated research programme. Research with radiolabelled pesticides is the only feasible approach to answering the many questions regarding bound residues. The accumulation of bound residues in soil from repeated pesticide application could produce undesirable effects if the bound residues are toxic and are released at a later date, perhaps with a different crop or cropping

system. Identification of the specific chemical and physical nature of the binding may result in improved pesticide formulations.

The effects of pesticides on microbial action The primary mechanism degrading pesticides to non-toxic chemicals in the soil is microbial degradation. The rate and extent to which microbial degradation takes place not only influences residues but also influences the effectiveness of the pesticide. Knowledge about the microbial degradation of pesticides in tropical soils is seriously lacking throughout most developing countries. Research on this topic using radiolabelled pesticides is being supported by the Joint FAO/IAEA Division.

Information on microbial degradation of pesticides is necessary in designing control procedures and developing formulations to prevent rapid microbial degradation. On the other hand the effects of pesticides on soil microflora is important particularly under intensive cultivation where repeated pesticide applications are used. Radiolabelled substrate techniques are valuable in obtaining these data. Work in this area is being supported by the Joint FAO/IAEA Division.

Systemic activity. The absorption and movement of a pesticide within a plant is called systemic activity. The measurement of the rate of absorption and movement within the plant can best be accomplished using radiolabelled pesticides. Herbicides which are applied to the soil for weed-control depend primarily on systemic activity for their action. Movement of the herbicide in the soil, and absorption and translocation within the plant, can be accurately measured under various environmental, moisture, and plant nutrient conditions with the aid of radiolabelled herbicides.

Pesticide residues In developing countries many crops are grown which are uncommon in developed countries and for which residue data is lacking. However, the regulatory officials in developing countries must have data upon which to base residue tolerances for specific crops and specific pesticides. Some of the necessary data can be extrapolated from other research; however, it is often necessary to conduct research on the specific crops under the local climatic conditions using the specific pesticide. Examples include the efficiency of removal of chlorinated hydrocarbon pesticides during processing of oil seeds to obtain oil; the accumulation of a pesticide in fish grown in rice ponds which receive applications of a number of different pesticides; leaching of a soil-insecticide in tropical soils under high rainfall conditions; insecticide residues in meat and milk of goats and cows receiving insecticide treatments for tropical insect pests, and the fate of insecticides applied to vegetables which are consumed raw. All these topics have been, are, or will be, the subject of either co-ordinated research programmes or technical assistance projects of the Joint FAO/IAEA Division. Some of these problems can be solved, or partially solved, using non-radiolabelled pesticides. However, frequently more precise data are required and radiolabelled pesticides offer a means to obtaining the necessary information.

More food and a clean environment

Pesticides are essential to improve man's living conditions. The quantity of pesticides used throughout the world will continue to increase. To minimize the undesirable effects of pesticides while maximizing pesticide efficiency requires the use of radiolabelled pesticides to study pesticide metabolism, fate, residues, and formulations. Economical pest control with minimal effects on non-target organisms will result in efficient food production and a clean environment. Pesticide-related problems will continue to be identified, researched, and solved, partially with the aid of nuclear techniques with support from the Joint FAO/IAEA Division.

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