PESTICIDE POLLUTION OF OUR ENVIRONMENT

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The furor which has arisen in recent years over "pollution" of our environment by pesticides is rather difficult to comprehend. It developed largely as a result of a book called "Silent Spring" by Rachel Carson. This book served a purpose in that it stimulated an appraisal of the adequacy of information on pesticide residues and their persistence in the environment, but many of the statements in it were inaccurate and the conclusions based on emotion rather than true facts. Needless to say some segments of the pesticide industry responded with salvo after salvo in an attempt to refute Miss Carson. The end result has been that the book made a great deal of money; that industry has been hampered in the development of more effective, less persistent pesticides by restrictive and often ill-advised legislation; and that the public has become utterly confused as to the assets and liabilities of pesticide use. This confusion is best demonstrated by the fact that the urban dwellers, who on the one hand question the use of pesticides in agriculture, are on the other hand, responsible for the huge consumption of these same materials for home and garden use.

In 1945 a compound, now famous, by the name of DDT became available for general use. It was the first of a series of highly effective, broad-spectrum poisons, commonly known as the chlorinated hydrocarbons. Others in this category include aldrin, dieldrin, heptachlor, and endrin. These materials were fantastically effective against nearly all species of insect pests and naturally they were used extensively, often at excessive rates or by methods of application which were both wasteful and detrimental. We needlessly contaminated huge sections of our environment. More recently, two other major groups of compounds have become available for use - the organophosphorus and carbamate insecticides. These materials are generally less persistent, but also less effective than the organochlorines. Our major concern with regard to environmental pollution at present is with DDT, aldrin, dieldrin, and heptachlor.

In one way or another insecticide residues generally end up in the soil regardless of whether they are applied directly to the soil or to crops from which they are washed down into the soil by rainfall. The persistence of these materials in soil has been examined quite extensively. Both aldrin and heptachlor are relatively volatile and disappear quite rapidly from the soil. Unfortunately, soil microorganisms convert small amounts of aldrin and heptachlor to dieldrin and heptachlor epoxide, both of which are toxic, persistent compounds. DDT is also highly persistent in soil, but is slowly degraded by microorganisms to DDE. The persistence and degradation of all these insecticides is influenced by soil type, moisture, temperature, method of cultivation, and crop cover. From the available evidence, it would appear that residues of dieldrin and DDT will persist in soil for many years.

DDT, aldrin, and to a lesser extent, heptachlor have been used extensively in Ontario. Soils in many of our agricultural areas are contaminated with residues of these materials or their breakdown products. In most cases, the degree of contamination is not great, with total chlorinated hydrocarbon residues in the top six inches of soil being approximately 2 ppm or less. However, in tobacco and vegetable soils the residues average 3 and 10 ppm respectively while in orchard soils they average 62 ppm.

Although residues are present in our soils, this does not necessarily mean that they constitute a pollution problem. This will depend entirely on the side-effects which are occurring as a result of this residue buildup. Without going into great detail I would like to discuss some of these possible side-effects and the data which we have at present. Side-effects may be of two types - direct and indirect. The direct side-effects are primarily those relating to the soil organisms themselves. Indirect side-effects may result from movement of the insecticide from one sector of the environment to another.

What of the effects of insecticides on the soil organisms? The first to be considered must be the soil microorganisms which are of major importance in maintaining soil fertility. Extensive evidence obtained in our own laboratory and at numerous other laboratories throughout the world clearly indicates that the chlorinated hydrocarbon insecticides have little, if any, effect on soil microorganisms. As a matter of fact, the opposite appears to be the case, i.e. the soil microorganisms play a major role in the degradation of pesticides. In some cases the pesticides are degraded to even more toxic metabolites, as is the case with aldrin to dieldrin. In other cases, they are degraded to less toxic compounds.

Soil animals also comprise an extremely important part of the soil ecosystem. The major Phyla include the Protozoa, Annelida, and Arthropoda. Little is known about the soil Protozoa. However, there has been a considerable amount of work done on earthworms. The results clearly indicate that with one or two exceptions (heptachlor, chlordane), the chlorinated hydrocarbon insecticides have little effect on earthworm populations. Unfortunately, earthworms are capable of absorbing relatively large amounts of the chlorinated hydrocarbons from soil. When these contaminated worms are fed on by birds in sufficient quantities, it can result in serious side-effects.

As would be expected, the soil Arthropods are more seriously effected by the chlorinated hydrocarbons. In addition, to controlling pest species of insects, other beneficial species are also effected, including the parasites and predators of the pests. However, this broad-spectrum effect is not confined to the chlorinated hydrocarbons - the organophosphorus and carbamate

insecticides may be even more toxic to the beneficial soil animals. It has also been shown that in some cases, DDT can have a beneficial effect in so far as soil fertility is concerned, in that it will eliminate the predatory mites in soil which prey on beneficial Collembola. As a result, the beneficial Collembola will increase in soils contaminated with DDT. Aldrin and the other cyclodiene insecticides appear to have a greater detrimental effect on soil Arthropods than DDT. However, some interesting work in England has shown that the effect of aldrin on beneficial soil Arthropods is of less importance than normal soil cultivation.

One serious side-effect which has occurred as a result of the buildup of residues of the cyclodiene insecticides in soils has been the development of insecticidal resistance by soil insects. If insect populations were uniformly susceptible to insecticides, the residues in soil would result in complete elimination of the insect populations, and the ultimate in insect control would be attained. Unfortunately, this is not the case, since the individuals in any insect population will vary in their degree of susceptibility to an insecticide. In many cases, there are a few individuals in the population which are highly resistant to insecticides. As the insecticide concentration increases in soil to toxic levels, the susceptible individuals are eliminated for generation after generation. Finally the population becomes totally resistant. This is what has happened with many soil insects. In Canada the root maggots have become resistant to all the cyclodiene insecticides. Elsewhere, wireworms, corn rootworms, and grubs have also become resistant to the cyclodiene insecticides or DDT. In Canada, none of the soil insects have become resistant to DDT - indicating that residues of DDT in the soil have not yet reached a sufficient level to result in constant selection pressure on the soil insect populations. The search for alternative materials to control these cyclodiene-resistant soil insects has been both expensive and time-consuming, and in some instances, we still have not found satisfactory alternative control measures.

In any discussion on the effect of pesticide residues in soil on the soil organisms one cannot ignore the plants grown in the soil. Studies conducted in our own laboratory and elsewhere clearly indicate that residues of dieldrin and heptachlor epoxide, but not DDT, are absorbed from soils by some crops. Generally speaking root crops are the greatest "absorbers." Other vegetable crops also absorb dieldrin and heptachlor epoxide from the soil. However, the residues in these crops are not exceeding the tolerances for direct human consumption which have been established by the Food and Drug Directorate of the Department of National Health and Welfare.

A potentially more serious aspect of this problem, however, involves the absorption of residues of the cyclodiene insecticides by crops used for animal feed. Here we become involved with the problem of "magnification." When small amounts of dieldrin, for example, are absorbed by crops which are in turn fed in large quantities, continuously, to animals, the animals tend to store the insecticide in their fatty tissue. With continuous feeding of a contaminated crop, perhaps 10-25 x the concentration of dieldrin found in the plant may be found in milk or other animal products. Thus a residue of 20 ppb in feed may result in a residue of 0.2 ppm in milk - an unacceptable

level. We have found that crops such as alfalfa, oats, corn, sugar beets, potatoes, and turnips all absorb dieldrin and heptachlor epoxide from soil. Information from various areas in Canada indicates that we have fairly extensive low-level contamination of milk and to a lesser extent, other animal products with residues of dieldrin and other chlorinated hydrocarbons. However, residues of the chlorinated hydrocarbon insecticides in milk and animal products, are, in the vast majority of cases, well within the acceptable limits recognized by Federal Agencies. The evidence indicates that insecticide residues in our crops, milk, and other animal products do not constitute a hazard to human health.

From the discussion so far, it is apparent that the direct side-effects resulting from the accumulation of chlorinated hydrocarbon insecticide residues in soil are not sufficiently serious to merit major concern. Those problems which do exist, e.g. toxicity to earthworms, insecticide resistance, and absorption and translocation of residues by crops are limited to some cyclodiene insecticides. DDT has caused remarkably few direct side-effects when one considers the amount of material which has been used over the past 25 years, and the residue levels present in the soil.

But what of the indirect side effects? Are the organochlorine insecticide residues in soil being transferred by one method or another to other sectors of the environment? On preliminary examination it would appear that this is highly unlikely. The so-called "hard" insecticides, DDT, dieldrin, and heptachlor epoxide are virtually non-volatile and insoluble in water. They are strongly adsorbed by soil and do not move to any significant extent through the soil to the ground water. Yet, it is becoming apparent that relatively small amounts of these materials are indeed being transported from soil to water and air. Presumably this is occurring because of very limited volatilization, and because of erosion of topsoil by both wind and water. Because of its widespread use, the major offenders are DDT and its degradation product DDE. Although the extent of contamination of water or silt with these materials may only be at the ppb or even ppt level, these minute concentrations can, because of magnification, result in serious effects on the upper levels of the biological chains in the ecosystem. For example minute concentrations of DDT-DDE adsorbed on suspended colloids in water can be absorbed and concentrated by microorganisms. The microorganisms are consumed by plankton-eating fish, which are in turn consumed by larger predatory fish, which are then consumed in turn by predatory birds such as cormorants, mergansers, and ospreys. In one situation in Long Island Sound it is claimed that the concentration of DDT increased from 3 ppt in water to 25 ppm in the predatory birds - an astounding 8.3 million fold increase over the original amount. While such a concentration might not be toxic to the birds there is evidence that DDT interferes with calcium metabolism and hence the "thin-shell" phenomenon which is apparently common in predatory birds. More recently, the research results have indicated that it is not DDT which is so much responsible for the upset in calcium metabolism in birds or the toxicity to fish embryos, but rather its degradation product DDE, which for many years was considered a "harmless" residue.

While the evidence that DDT-DDE can result in serious side-effects in the ecosystem is generally accepted it is difficult at present to quantitatively estimate its importance relative to other pollutants. Unfortunately, much of the data on fish and wildlife is subject to question. Analyses by gas liquid chromatography which is the general method now in use is a difficult, exacting task. Interpretation of the data is extremely important and, unless one is careful, artifacts or contaminants can often be mistaken for DDT or DDE. However, because it seems like such a simple technique, virtually every biologist and conservationist has purchased a gas chromatograph and is busily injecting extracts of everything under the sun into his machine. Consequently, it is an almost impossible task to separate the good data from the bad, the fact from fiction, with regard to DDT and wildlife. Complicating the picture is a group of common industrial pollutants, related to DDT, which, it is now recognized, are in themselves highly toxic (more so than DDT-DDE) and produce similar physiological effects on fish and wildlife. These pollutants, known as PCB's (polychlorinated biphenyls) occur commonly in industrialized areas. The picture with regard to these materials is not yet clear, but it seems likely that future work will show that the PCB's are pollutants of equal or even greater importance than DDT-DDE.

In recent months the opponents of pesticide use have mounted a tremendous campaign to have the chlorinated hydrocarbon insecticides banned in North America as well as other areas of the world. This group which comprises an unlikely combination of a) conservationists who are genuinely concerned about the environment; b) individuals out for personal gain; and c) out-and-out screwballs, has already succeeded in having DDT banned or restricted for use in several States in the U.S. and in Ontario. The common cyclodiene insecticides with the exception of endrin are also banned in Ontario. Unfortunately these "instant experts," do not have any concept of the new problems which they themselves are creating. As the persistent chlorinated hydrocarbons are discarded, organophosphorus and carbamate insecticides are being substituted, on the questionable assumption that these materials will have less serious side effects. I am willing to predict that in time we will be encountering far more serious problems with some of these substitutes than we have with the organochlorines at the present time. I say this for a number of reasons. First, there is a popular misconception that the newer materials are less persistent in soil than the so-called "hard" chlorinated hydrocarbons and this is not necessarily the case. Second, while most chlorinated hydrocarbons have limited solubility in water many of the newer materials are slightly to moderately soluble, and we run the risk of contaminating ground water as well as streams and lakes. Third, in many instances these newer materials are being applied at 5-6 x the rate that we applied the chlorinated hydrocarbons. Fourth, these materials are more toxic to handle, and can be as, or more toxic, to beneficial soil animals, fish, and wildlife. With some of these new materials we run a risk of sterilizing the environment!

The dismaying aspect of this problem of pesticide pollution is that, at present, it is only the radicals on each side who are being heard. The press and communications media, with their well-known weakness for shocking headlines such as "Zoologist claims DDT causes cancer" encourage such radical

approaches. The progress which the opponents of pesticide use have made in the past few months is terrifying. With each new blast from "Pollution Probe" the Provincial Government seems to react by banning another pesticide. In the midst of this controversy the voice of the moderate majority is seldom heard.

What can we as individuals, and as professional groups do, to bring some sanity to the situation? Obviously we must make our voices heard above the anguished screams of the radicals. In doing so it is necessary to recognize that both the Federal and Provincial governments are involved in the regulation of pesticide use, and we must be heard at both levels. What should we say? The following are just a few suggestions:

1) Research: We cannot do without pesticides; at the same time we do not want to use materials which will result in serious environmental pollution. There is a drastic requirement for expansion of our research programs on pesticide application, efficacy, and persistence and degradation in the environment. Research programs on integrated control should also be expanded. More research requires more funds both at federal and provincial levels.

2) Legislation: The requirements for registration of pesticides at the Federal level should be tightened. In addition to information on efficacy and hazard to human health, much more emphasis should be placed on the effects of pesticides on environmental quality. Once a material is registered it should be mandatory that in-depth reviews of the registered uses be conducted periodically. Sufficient qualified staff should be provided to enable the CDA to conduct these reviews. As a general principle, registrations (Federal) and recommendations (Provincial) should be in agreement. At the present time provincial recommendations are not worth the paper they are printed on since a material can be used if it is registered for use, regardless of whether it is recommended for use!

   At the Provincial level the Government should ensure that qualified staff are available to administer the Pest Control Act. At present the number of qualified pesticide specialists within the provincial civil service is shockingly small. The Provincial Government should consider appointment of a highly qualified pesticide coordinator responsible for coordination of pesticide work within the Provincial Government and for liaison with the Federal Government.

3) Control of Pesticide Use: At present, as long as a material is registered for use, there is little further control over its use. As a result, much of our problem of pesticide pollution arises from pesticide misuse. Drugs are sold by prescription; surely pesticides should be handled in a similar fashion.

Unless the moderates begin to make themselves heard in this pesticide controversy, the voice of the radicals will result in restrictions on pesticide use which will be a serious detriment to agriculture, and will at the same time result

in even more serious environmental pollution. Much of the uproar over pesticide use in the press today is resulting from hysterical accusations made by an ill-informed public, politicians, and other publicity seekers who have few facts and even less knowledge on which to base their obviously prejudiced comments. Hysterical accusations based on fiction rather than fact, have no place in science. Perhaps it would be wise to substitute caution in place of hysteria, prudence in place of politics, and sound research in place of press conferences to determine the best approaches to pest control.