Ecosystem Health and Sustainable Agriculture

Sustainable Agriculture

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Pesticides are found in the environment in all parts of the World, both in areas where pesticides are used and in areas where they never have been used, e.g. in the Arctic areas. Use of pesticides on a large scale started during the 1950s and 1960s and the use was rather careless during that time. The authorities and the users were then not aware of the dangers of using pesticides as regards to dispersal and side-effects in the environment. Since then, we have learned much about the mechanisms influencing the appearance of pesticides. Many countries have begun educational programmes for farmers to teach them about safe handling of pesticides.

**Occurrence of Pesticides**

Pesticides can of course be found within the areas where they are used and a minor part also in the harvested crops. A great problem is the undesired distribution of pesticides in nature causing pollution of the air, surrounding land and water areas as well as the groundwater (see also Figure 23.1).

**Dispersal of Pesticides**

The dispersal of pesticides in the environment depends to a large extent on the chemical and physical properties of the compounds, such as molecular structure, water pressure, solubility in water, stability and adsorption properties. A second important factor for dispersal of pesticides is the properties of the environment in which they are appearing, for example:

- Air – wind, UV-radiation, moisture, particles.
- Soil, surface – UV-radiation, adsorption capacity, precipitation, wind and water erosion.
- Soil, ground – texture and structure, pH, adsorption capacity, biological activity, oxygen content, temperature, moisture.
- Water – pH, biological activity, oxygen content.
- Sediment – pH, adsorption capacity, biological activity, oxygen content.

A third factor is how the pesticides are handled, for example:

- Normal use for crop protection recommended by advisors and safe handling of the pesticides.
- Normal use for crop protection recommended by advisors but without safe handling of the pesticides, e.g. at filling up and cleaning of the spraying equipment.
- Misuse of pesticides, e.g. mixing of pesticides where there may be a risk of contamination of the farm well or other waters, use of overdoses, use of inappropriate spraying equipment, dumping of remaining pesticides (concentrated or mixed) on unsuitable places, washing of used spraying equipment in open waters (creeks, rivers or lakes).
- Accidents may occur during transport and storage of pesticides, spills into surface and groundwater bodies.
Reducing the Risks Associated with the Use of Plant Protection Products

Information on Pesticides
For about 30 years, the Pesticide Manual published by the British Crop Protection Council (BCPC) has served as a standard reference work on the active ingredients in products for the control of crop pests and diseases, weeds, animal coverage to include plant growth regulators, repellents, synergists, herbicide safeners and, latterly, beneficial microbial and invertebrate agents and pheromones. The manual contains information on pesticide nomenclature, e.g. its commercialisation, applications, physical chemistry, mammalian toxicology, ecotoxicology and environmental fate.


Degradation of Pesticides
The rate and route of pesticide degradation depends on a number of factors (see Figure 23.2). There are three main mechanisms for degradation of pesticides:

- UV-radiation (occurrence in rays of sunshine). The energy in UV-radiation can break the bonds in many chemical molecules if they are directly hit:
  - in the atmosphere
  - on surfaces of leaves and soil.
- Chemical reactions
  - mainly pH-dependent reactions in water.
- Biological reactions in:
  - animals
  - plants
  - micro-organisms, bacteria or fungi (most important mechanism for degradation of chemicals in the environment), microbial reactions in water, soil and sediment.
  + Metabolic degradation: The pesticides serve as an energy source to supply growth of the decomposers (see Figure 23.3a and b). e.g. the phenoxyacetic acids.
  + Cometabolic degradation: The rate of decomposition is largely governed by the size and general activity of the soil microbial biomass (includes the capability of free soil enzymes to catalyse decomposition of pesticides) (see Figure 23.4a and b). All pesticides can be degraded by this mechanism.
Properties of the environment in which the pesticides are appearing that affect degradation of the chemicals include:

- Air – wind, UV-radiation, moisture, particles
- Soil, surfaces – UV-radiation, adsorption capacity, precipitation, wind and water erosion
- Soil, ground – texture and structure, pH, adsorption capacity, biological activity, oxygen content, temperature, moisture
- Water – pH, biological activity, oxygen content
- Sediment – pH, adsorption capacity, biological activity, oxygen content

Important factors regulating microbial degradation of pesticides are:

- Microbial biomass and activity
- Bioavailability of the pesticide
- Aerobic or anaerobic conditions.

Accelerated degradation of pesticides has been observed for herbicides known to be metabolically degraded, e.g. 2,4-D, MCPA, TCA, dalapon and chloridazon. The mechanism behind this is utilisation of the substances as energy substrates for growth of the degrading microorganisms and, because of this, an increase in their number.

The number of actively pesticide-degrading microorganisms increases between the first and subsequent applications, since the pesticide is a source of carbon and energy for their growth. This is the main rate-regulating factor for degradation of the pesticide (see Figure 23.3b). The increased capability to degrade the above-mentioned herbicides can persist for several years.

Accelerated degradation of the soil-applied herbicides TCA and dalapon results in unsatisfactory weed control. Accelerated degradation in general means shorter persistence time which, from an environmental point of view, is desirable. The time for transport in the soil of the pesticides becomes shorter, which reduces the risk of groundwater contamination.

There is no increase in number of co-metabolic pesticide-degrading micro-organisms. The rate of degradation depends then on the size and activity of the normal microbial biomass and the strength of the influencing factors (see also Figure 23.4b).

Environmental Risk Assessment
Pesticide residues may have an impact on the ecosystem depending on the properties of the active substance but also directly on humans through contamination of drinking water or indirectly by transport through crops and animals upwards in the food chain. Risk assessments should be carried out for (see Figure 23.5):
Reducing the Risks Associated with the Use of Plant Protection Products

- Landbased ecosystems – microorganisms, insects, animals (e.g. birds and mammals).
- Water and sediment ecosystems – microorganisms, algae, insects, plants, animals (lower forms e.g. earthworms and higher forms e.g. fish and mammals).
- Human beings – acute and long-term effects.

In work with pesticides it is often useful to make predictions of the risk of a certain pesticide polluting the environment. On comparing different pesticides with the same or similar fungicide/herbicide/insecticide effect, it may emerge that the risk of environmental pollution is different.

Information is needed on the chemical and physical properties of the pesticide and the chemical, physical and biological properties of the environment where the pesticide is expected to end up.

There are several possible ways to make predictions:

- With information on the chemical and physical properties of the pesticide, it is possible to predict its potential risk of polluting the environment compared with other pesticides. However, this is a method that can give many misleading predictions.
- With information on the properties of both the pesticide and the environment where it is expected to end up, it is possible to predict the risk of a certain pesticide polluting a certain environment compared with other pesticides. However, it must be borne in mind that most data available on a specific pesticide and an environment are themselves predictions, meaning that the prediction to be made is not highly probable to be exactly true, but is just a guess depending on the quality of the data available.
- In certain cases there are simulation methods that can help predict the risk of pesticide pollution. However, here too, high quality data on the pesticide and the environment are needed for use in the simulation model. It must always be borne in mind that simulation models only give guideline values with plenty of pluses and minuses.
Safe Handling of Pesticides

Pesticides can of course be found within the areas where they are used. A great problem is the undesired further distribution of pesticides in nature, causing pollution of water areas and the groundwater. It is now known that unsatisfactory management of pesticides at filling and cleaning of spraying equipment causes point sources of pollution of surface water and groundwater, as well as large areas of soils. Experiences from many countries have shown that point sources of pesticides are one of the most dominant reasons behind pesticide pollution of rivers, streams, lakes, groundwater and local water supplies.

However, the use of simple units (e.g. biobeds) can minimise the risks of pollution when filling spraying equipment. Many countries have started training programmes for farmers to teach them about safe handling of pesticides.

A biobed is a simple and cheap construction on the farm intended to collect and degrade spills of pesticides. Biobeds are facilities composed of a mixture of straw or other lignin-containing grass, mineral topsoil and peat or compost. They are covered with growing grass and, if the farm uses a sprayer carried or towed by a tractor, equipped with a ramp making it possible to drive the tractor and sprayer over the bed. The task of the grass layer is to regulate the moisture in the biobed as well as to serve as an indicator of pesticide spillage (See also Figure 23.6 and 22.7).

The composition of the biobeds is intended to absorb pesticides but sustain their bioavailability and support microbial activity, and thus degradation. Degradation of most pesticides is correlated with the amounts of straw present in the system, which indicates that straw supports an active microflora that provides a high degradation potential. Straw and its high lignin content favour the presence of microorganisms able to degrade this polymer. Fungi are important lignin degraders and it has been shown that the lignin-degrading system of these microorganisms is responsible for the degradation of a broad range of pesticides.

During recent years there has been increased interest in the use of biobeds for protection of the environment. Countries in Europe, Africa, South America and North America have started introducing the biobeds as a means of protection of surface waters and groundwater. The introduction of these systems requires prior studies about the type of material available and possible to use, the climatic conditions at which the biobeds are to be operated, the type of pesticides to be treated, the frequency of application, etc. Swedish experiences show that thorough knowledge of pesticide microbiology is of the greatest importance for a successful biobed.

Some points to bear in mind to get safe handling of pesticides are:

- **Remember**: The simplest and safest way to avoid pesticide pollution of the environment is that all advisors working within advisory services and all users of pesticides are educated in safe handling of pesticides.
• It is important to know the chemical, physical and toxicological properties of a pesticide in order to predict its environmental behaviour and toxicological effects.
• It is important that the pesticide is tested in the environment where it is expected to turn up after usage and under the conditions prevailing there.
• Environmental risks when filling and cleaning spraying equipments can be minimised if the filling is done on a biobed or other safe place.
• All handling of pesticides must be carried out by persons educated in ‘safe handling’ of pesticides.


**Chapter 22**


**Chapter 23**


References


Chapter 24


Chapter 25

Andersson, B. 2004. Output from the NEGFRY warning system for potato late blight with various types of weather input data. Workshop on Weather Information and Plant Protection, models, forecasting methods and information systems, Uppsala, Sweden 9-10 November.


