WATER CONSERVATION TECHNICAL BRIEFS

TB 4 - Integrated Pest Management: A guide to protecting water quality

SAI Platform

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WATER CONSERVATION

TECHNICAL BRIEFS

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Pesticides are widely used to protect crops and to prevent diseases. If not properly managed, point and nonpoint sources of pollution can pose a threat to freshwater depending on a series of factors such as the characteristics and toxicity of the pesticide, the environmental conditions and the site characteristic. There exist several mitigation measures to prevent the contamination of water sources from pesticides such as Integrated Pest Management (IPM). The introduction and adaptation of IPM practices can reduce pesticide use which in turn can reduce the impact on surface and groundwater from pest management practices. The aim of this technical brief is to provide an overview of pesticides and IPM as a mitigation measure to protect water courses.

The structure of this technical brief is as follow. Section 1 provides an introduction of pesticides. Section 2 describes the pesticides properties, site characteristics, environmental and applications conditions that influence the fate and transport of pesticides in water. Section 3 set outs the movement of pesticides into surface and groundwater. Section 4 provides an introduction of IPM as a mitigation measure of pesticide water contamination and discusses the details and logic of IPM as a strategy to prevent water pollution. This section also explores that its advantages, limitations, the range of methods and recommends some steps to succeed on IPM adoption. Section 5 discusses pesticide management measures and risk assessment tools to prevent the risk of water contamination. Section 6 provides some case studies. Section 7 outlines an appendix on the different methods of IMP. Finally, Section 8 provides some recommended lectures and websites.

Contents

Section 1: What are pesticides?

Agricultural pesticides constitute chemicals that are used to protect crops against pests. Pests such as insects, fungi, and weeds can affect crop production by decreasing yields and crop quality or even in some cases destroy the crop. As a result, pesticides are used to reduce this damage.

Section 2: Pesticide fate and transport?

Pesticides or pesticide residue can move along several different pathways depending on properties of the pesticide, the application method, and conditions at the application site. This movement is a complex process and, combined with several other factors, influences a pesticide's fate and potential water quality impacts.

1. Pesticide Properties

Pesticide properties help determine a pesticide's fate after application. Those include physical and chemical characteristics such as persistence, solubility, adsorption, volatility, and the potential for degradation.

- Persistent pesticides can pose a greater threat to the environment since they remain active in the environment longer. Persistence is a function of the chemical and biological degradation processes, which break down the pesticide into less harmful compounds.
- Pesticide chemicals that dissolve readily in water are highly soluble and, thus, are generally carried with the water flow. Such pesticides have a tendency to leach from the soil to groundwater. However, many pesticides do not leach because they are adsorbed on the soil particles or organic matter even though they may have a relatively high solubility.
- Highly volatile chemicals are easily lost to the atmosphere and are less likely to leach to groundwater unless they are also highly soluble and, thus, collected in water systems.
- Degradation affects the potential for a pesticide to reach groundwater. The persistence of the pesticide influences the potential for contamination. The longer the compound lasts before it is broken down, the longer it is subject to the forces of leaching.

    - **Formulation**: Pesticides come in several physical forms or formulations that make them easy to store, transport and apply, and that help in controlling target pests. Common formulations include granules, powders, dusts, aerosols, solid or liquid baits, granules, emulsifying concentrates and solutions. There are other less common formulations designed to give special properties to the pesticide mixture or to take advantage of properties of active ingredients or protect the environment. These include microcapsules, plastic beads, plastic membranes, plastic ropes, controlled release dispensers and others.

While most environmental hazards come from the active ingredient in a pesticide, the way its formulation interacts with the environment determines the overall hazard of a pesticide. Spray formulations can drift with the wind or vaporize into the air. Other formulations can leach into ground water or be carried into surface water by rainfall or irrigation runoff. Even pesticides in formulations that bind them to soil particles can find their way into surface waters if soil is eroded by wind or water.[1]

- **Toxicity:** The active ingredient is the chemical compound in a pesticide that kills or otherwise affects the target pest. Other substances in a pesticide formulation are inert ingredients that act as carriers and preservatives for active ingredients, and also make mixing and application easier.[2]

  When determining the toxicity of a pesticide, there are some tools available. (See Section 5.3)
- **Dose and Effective Dose:** A dose is the amount of a substance used at one time. The effective dose is the amount of a substance needed to kill or otherwise affect a target pest. Amounts less than the effective dose will likely not kill the target pest. Amounts greater than the effective dose will not necessarily be more effective in killing the target pest. Instead, this larger dose may kill more non-target organisms, cost more, and pollute the environment. Common measures of a chemical's toxicity are the LD50 and LC50. These measures refer to doses that kill 50 percent of the animals in a test group. These toxicity terms can apply to target pests or non-target organisms, including humans. The toxicity of a substance determines its proper dosage.

2. Site Characteristics

Several site characteristics influence the behaviour and fate of pesticides after application:

- **Soil properties** (such as texture, permeability, and organic matter content) can affect pesticide movement. Soils rich in clay and organic matter tend to hold water and dissolved chemicals longer. These soils also have more surface area on which pesticides can be adsorbed. In sandy soils there are more chances of pesticides leaching.

- **Organic matter content** promotes pesticide sorption. Soil organic matter influences how much water a soil can hold and how well it is able to absorb pesticides. The organic matter content help determining the amount of pesticides that in course of time stays behind in the soil. This concentration in the soil, along with the toxicity, determines the risk of a pesticide for soil organisms. Organic matter content also determines the risk of leaching of pesticides to the groundwater as it can bind pesticides. When the organic matter content is high, the risk of leaching is lower.

- **The location of the farm** in relation to water courses influence the date of pesticides. Surface water near pesticide application sites is more susceptible to contamination when pesticides are applied to highly erodible soils or to over-irrigated or rain-soaked fields. Using the wrong pesticide or an incorrect application method in these situations increases the risk for contamination. The use of GIS tool in this case is helpful. (See risk assessment tools in Section 5.3)

3. Environmental Conditions

Weather conditions at the time of pesticide application can influence pesticide fate and transport:

- **Adverse weather** or irrigation conditions can reduce pesticide performance and have a negative impact on the environmental fate of a pesticide. Heavy rainfall or irrigation shortly after application can increase the risk of pesticide contamination from runoff or leaching. This often results in the need for additional applications to the crop, as well as the risk of environmental contamination.
- **Extremely high and low soil temperatures** can adversely affect the degradation rate of some pesticides, as well as interfere with other areas of pesticide performance. During very hot weather, it is important to safeguard against volatilization by using pesticides that have strong sorption and low vapour pressure.
- **Volatilization** can also be a problem in windy weather. Pesticides should not be applied in these conditions. Drift, which results when stray pesticide particles fall onto non-target species (including humans) can also be a problem. Many pesticides are incorporated, or applied directly into the soil, to decrease the potential for drift and volatilization.

- **The time in the year of application** influences the rate of leaching – which is larger in spring. The expected lower temperatures and precipitation surplus in this period end in an slower pesticide degradation.
- **The wind speed**, wind direction, crop size, temperature and atmospheric humidity play a part in the amount of drift.

4. Pesticide Application Practices

The ways in which pesticides are stored and applied affect pesticide fate and transport in the environment:

- **Transportation, storage, disposal of containers and cleaning, and spill prevention** are basic concerns in handling pesticides safely and keeping them on-site. See Appendix B for a promotional poster in the Netherlands to improve pesticides handling practices at a farm level.
- **Location of sensitive areas,** like sinkholes, depressions, wells, surface water, public institutions and private buildings, relative to where pesticides are applied influence the chances of pesticides moving to undesired areas.
- **Existence of buffer zones** around such sites affects delivery of pesticides off-site.[a]
- **Selection of appropriate pesticides** for the pest, crop, and site will reduce the likelihood of pesticide losses.
- **Knowledge and practice of pesticide applicators** and their adherence to product labels help reduce the chances of undesirable pesticide transport.
- **Application technique** can have different effect on the environment. The table below depicts some calculated environmental exposure indices for different application methods.[3]

Table 1: Environmental and operator exposure rates for different pesticides application methods

Application method	Environmental Exposure	Operator Exposure (AMO)
Application of treated seeds	0.5	0.1
granular application	1	0.1
Fooging machine (greenhouse)	1	1
tractor-mounted/trailed band sprayer	1.5	1.5
tractor-mounted/trailed boom sprayer	3	3

[a] See Technical brief on Buffer zones

knapsack sprayer	15	5
tractor-mounted/trailed braccast air assisted sprayer	75	4.5

Source: Pesticide Risk Indicators at National Level and Farm Level– A Swedish Approach –Available at http://www.kemi.se/upload/Trycksaker/Pdf/PM/PM6_04.pdf

Section 3: Pesticide movement into surface and ground water

Pesticide persistence and toxicity can have damaging effects on the environment and most importantly, they can reach and contaminate surface and groundwater. Pesticides that enter water supplies can come either from point sources or from non-point sources. Point sources are small, easily identified objects or areas of high pesticide concentration such as tanks, containers or spills. Non-point sources are broad, undefined areas in which pesticide residues are present.[4]

Pesticides can reach ground and surface water sources in a number of ways. The extent of the contamination is often well defined, but the source(s) of contamination can be elusive. Figure 1 below illustrates the major environmental effects of pesticides.

a. Movement to surface water

As shown in the figure below, pesticides can reach surface water through drift, runoff, seepage, evaporation, precipitation and evaporation-dry deposition.

Contamination of surface water could arise from:

- spray drift from approved application of a pesticide to land
- accidental overspray of water during application
- long distance drift of volatile pesticides and of wet and dry aerosols during application
- atmospheric deposition and rainfall
- leaching from disposal sites
- leaching from soakaways e.g. used for the disposal of sheep dip or horticultural bulb washing
- surface runoff and subsurface drain flow after a rainfall

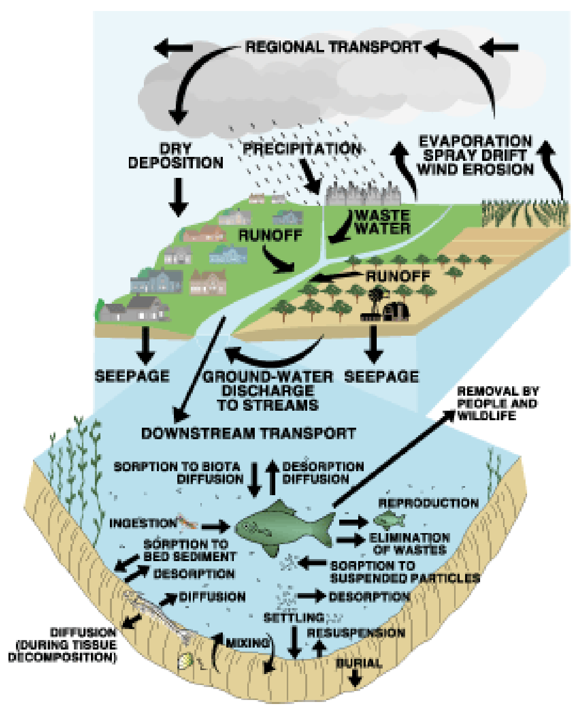

Figure1 : Pesticide movement in the hydrologic cycle including pesticide movement to and from sediment and aquatic biota within the stream Available at http://water.usgs.gov/nawqa/pnsp/pubs/fs09200/

event from either agricultural or non agricultural use

- inflow of contaminated groundwater

Most pesticide contamination of streams, lakes, and estuaries occurs as a result of runoff from agricultural and urban areas. Runoff carries with it a mix of suspended soil particles and any pesticides which were either attached to the particles or dissolved in surface moisture just before runoff began. Losses of pesticides to runoff generally range from <1 to 5% of applied amounts, depending on various factors. The amount of runoff is affected by rain, soil condition, slope and application rate as follow:

- High rain intensity results in minimal infiltration and maximum runoff.
- Soil condition can affect resistance to runoff. Maximum runoff potential occurs during the month after planting, since the soil is exposed and the crop has not grown large enough to intercept rain and reduce its ability to detach and transport soil particles.
- Reduced tillage practices that maintain residue on the surface will decrease runoff relative to conventional tillage practices that leave the soil bare and smooth at planting.
- Steeper and longer field slopes increase runoff energy, and the transport of soil and adsorbed pesticides.
- Pesticides tilled or injected into the soil are less likely to be lost in runoff, although the disturbance of the soil by tilling or injection may increase soil (and attached pesticides) losses. Large losses of pesticides in runoff can result if a heavy downpour occurs soon after application. Higher application rates will also generate higher pesticide concentrations in runoff.

A drawback of pesticides is that they can enter surface water from the atmosphere in the form of drift or rainfall. Drift into surface waters can be a serious issue if the pesticide is highly toxic to aquatic organisms, as in the case of many insecticides. Rain and fog have been shown to contain pesticide residues, particularly during the spring planting season.

b. Movement to groundwater

Groundwater contamination poses a serious risk due to the persistence of pesticides. When aquifers become contaminated via any mechanism, pollution is likely to be extremely persistent. This is because of the large residence times of groundwater systems, which are often of the order of decades, and because the process causing the breakdown of pesticides is likely to be far less active underground than in soil and surface watercourses. Unsatured zones and confining beds of aquifers afford a significant degree of natural protection against contamination by some pesticides.

Pollution from indirect sources depends on the type of surface to which the pesticide is applied, the crop and soil type, the weather, the nature of application, the application rate, the equipment used to apply and contain the pesticide and the physical and chemical characteristics of the pesticide or its formulation. Indirect groundwater contamination could arise from:

- Leaching from inappropriate use of agricultural soakaways
- Leaching of pesticides through the soil and subsoil following approved application of pesticides to land => This is affected by pesticide characteristics & soil type:
  - Soil organic matter content determines the amount of pesticide that in course of time stays behind in the soil. Higher levels of organic matter reduce the amount of leaching.[5]
  - Pesticide characteristics such as its degradation rate and mobility in the soil determine the amount that leaches. [6]
- Recharge of aquifers by river water contaminated with pesticides
- Overspray around wells and boreholes

SECTION 4: INTEGRATED PEST MANAGEMENT (IMP) AS A MEASURE TO REDUCE THREAT TO WATER POLLUTION

IPM represents a balanced approach to optimising pesticide use, generally reducing the frequency of pesticide application and, therefore, reducing water contamination.

a. What is IPM?

Most pest species are naturally regulated by a variety of ecological processes, such as competition for food or by predation and parasitism by natural enemies. The logic behind IPM is to understand these ecological processes and apply them in order to minimise pesticide use.

IPM is the integrated use of a range of pest (insect, weed or disease) control strategies in a way that not only reduces pesticide use but is sustainable and minimises pollution through use of chemical pesticides. However, IPM is a complex process and requires levels of analytical skills and certain basic training in crop monitoring and ecological principles.

According to the UN's Food and Agriculture Organisation (FAO) IPM "means the careful consideration of all available pest control techniques and subsequent integration of appropriate measures that discourage the development of pest populations and keep pesticides and other interventions to levels that are economically justified and reduce or minimise risks to human health and the environment. IPM emphasises the growth of a healthy crop with the least possible disruption to agroecosystems and encourages natural pest control mechanisms."

IMP includes preventative methods as well as corrective measures, and manages the population of a pest so that it is below damaging levels. It also integrates appropriate tactics including cultural practices, natural enemies, resistant host varieties, physical methods, and pesticides to suppress a pest population to a tolerable level, based on economic or aesthetic considerations.

b. What are the advantages?

The advantages of using IPM are that:

- It reduces the amount of pesticides used thereby contributing to food safety, reducing occupational hazards, reducing environmental risks of pesticide use, reducing development of resistance and reducing pollution of water sources including drink water.

- It reduces water contamination risk
- It optimises the use of pesticides and reduce pest management costs
- It is a sustainable way of producing crops and maintains biodiversity

c. What are the limitations on IPM application?

While IPM has demonstrated the successful use of host plant resistance, natural biological control as well as reduced pesticide application to protect crops from pests it has not been widely adopted. The limitation of its application can be explained because of the knowledge-intensive management that is required by IPM but also subsidized pesticide costs do not promote uptake of IPM.

d. What are the methods for IPM[7]?

There are many methods of pest management available, some of which concentrate on producing a healthy crop or on producing an environment that is unfavourable to pest populations. The figure below depicts the different suitable techniques that help keep pests below levels that cause unacceptable crop loss.

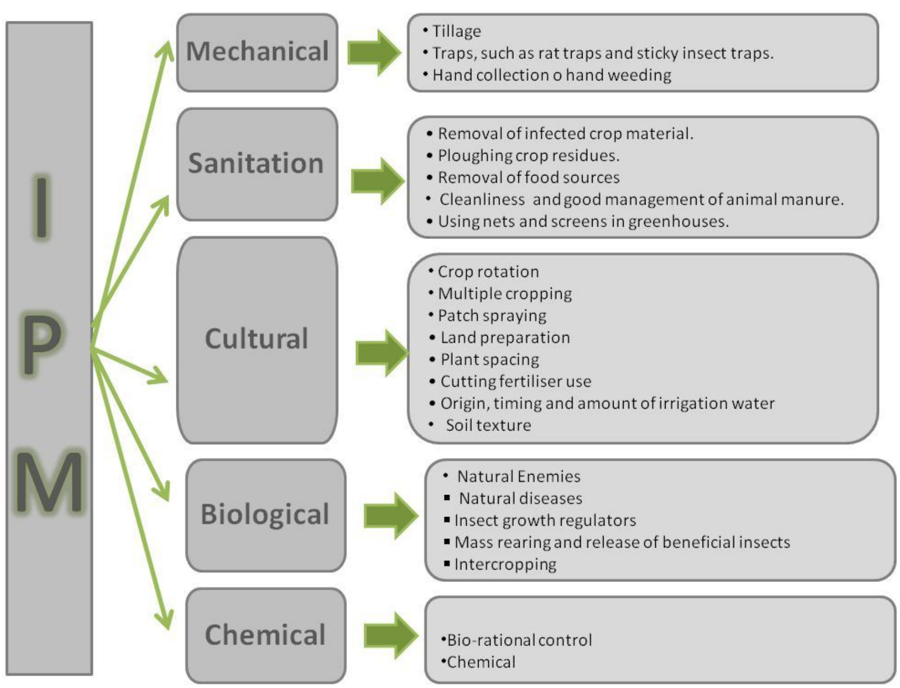

Figure 2: Different methods for IPM. Source: Modified from Croplife. Available at http://www.croplife.org/files/documentspublished/1/en-us/PUB-MAN/5081_PUB-MAN_2008_10_01_Introduction_to_IPM__Facilitator's_Manual_-_Text.pdf

For specific information on each method is available in Appendix A. among the different methods of IPM, the chemical methods should be as a last resort.[8]

e. What is the key to IPM success?

IPM relies heavily on natural mortality factors, such as natural enemies and weather, and that seeks out control tactics to disrupt these factors as little as possible. To understand the dynamic interactions among the environment, the pest and the host it is important to assess the pest biology and life cycle, and to conduct monitoring programmes on a regular basis.

As shown in Figure 3, IPM requires evaluating the pest problem, the previous pest control measures, and cropping history and assessing the physical characteristics of the soil. To reduce water contamination it is recommended to evaluate the water contamination potential for each pesticide, identify and map mixing, loading, and storage areas to evaluate leaching and/or runoff potential and select the most environmentally benign pesticide products.

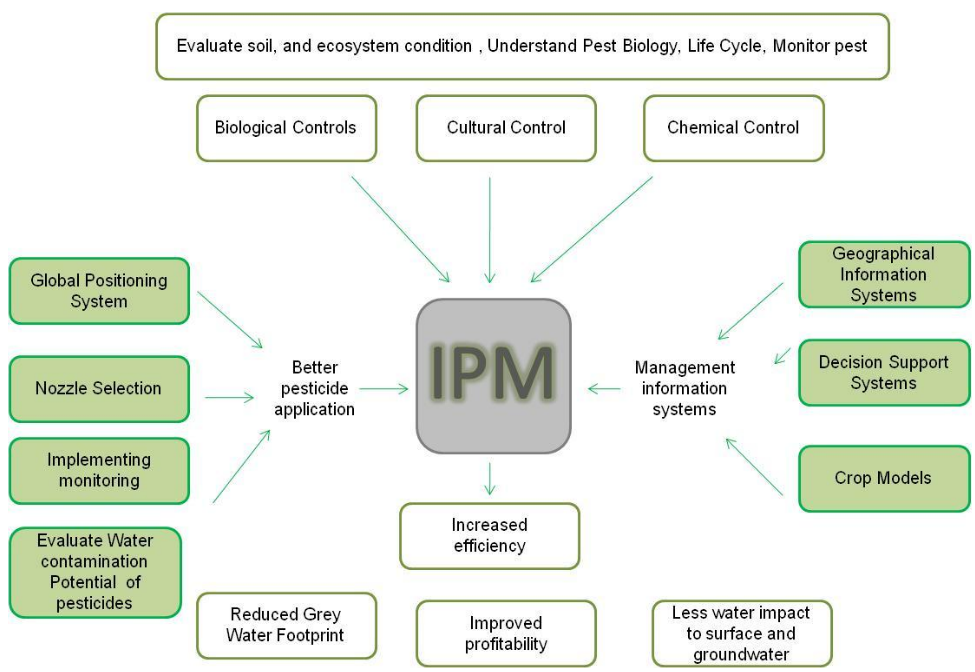

Figure 3: A framework that aims at increasing pesticide efficiency and better water quality.
Source: Adapted from Matthews, G. A. 2006, Pesticides : health, safety and the environment Oxford : Blackwell, 2006.

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- **Pest Biology and Life Cycle**

To effectively manage a pest, it is crucial to understand the pest biology and seasonal development or life cycle. The first step is proper identification of the pest, which is often overlooked, and to determine its stage of development. Most pests are more vulnerable to control at a certain stage. It is important to try to time control efforts within the susceptible stage, to understand the local environment and the role of the pests in the ecosystem and what conditions favour their development. Knowing the interactions amongst pests, hosts, and the environment can reveal a multitude of strategies for managing the pests.

- **Conducting Monitoring on a regular basis**

Regular systematic monitoring, often referred to as "field scouting" in agriculture, is the most important component of IPM. Monitoring provides the field specific information needed to make appropriate pest management decisions. It requires time and specific knowledge and if possible should be conducted by a pest management specialist.
A common method for monitoring insects is to sample and trap pest randomly. This ensures counting of pest numbers, damage, and natural enemy populations at random spots within a field. Ideally the monitoring should be conducted in different areas of the field and include at least four spots distributed throughout a field and record results for each spot. The field scout also observes any unusual conditions while walking between spots.
There exist different types of traps to detect the first appearance of mobile insects. Pheromone traps are very useful for predicting activity peaks for certain insects and predict the best timing of control actions. The information obtained during the monitoring is the basis for treatment and future monitoring decisions.

- **Monitoring Techniques**

Direct counting from plant foliage is one of the most common techniques in agriculture. Specialists can use a hand lens in the field, or collect leaves for later examination in the laboratory depending on the type of pest and desired accuracy. **Sweepnets** are also used to dislodge and collect insects from foliage. Regular monitoring of actual insect damage, for example, defoliation estimates or fruit entries, can help relate population estimates to damage ratings and need for treatment. Presence of faecal matter or exuviae (shedskins) indicates insect activity, which in some cases (e.g., powderpost beetles) is very important.

Due to the microscopic nature of plant diseases, field monitoring is often impractical. Environmental monitoring can be very important in disease management because treatments may be necessary before infection begins.

Recording climate and site parameters is an important step on monitoring. Use a weather station placed in a field to continuously monitor. Measuring parameters such as soil and air temperature, soil moisture, relative humidity, and leaf wetness and correlating them to disease development can be the basis for mathematical models. The models can be used to make accurate fungicidal applications based on environmental conditions. For example, disease predictors (or forecasting programmes) are available for managing late blight in potatoes and apple scab

- **Monitoring Program**

The monitoring program should aim at reflecting the biology and seasonality of the pest. Some pests are continuously monitored throughout the season. Others are evaluated perhaps only once or twice a year. Intensity of monitoring is driven primarily by economic considerations and required accuracy.

SECTION 5: PESTICIDE MANAGEMENT

The aim of pesticide management is to reduce the contamination of freshwater from pesticides. The basic concept of the pesticide management measure is to foster effective and safe use of pesticides without causing degradation to the environment.
The most effective approach to reducing pesticide pollution of waters is, first, to release a lesser quantity of and/or less toxic pesticides into the environment and, second, to use practices that minimise the movement of pesticides to ground and surface water.

a. Management Measure for Pesticides[9]

The pesticide management measure identifies a series of steps or thought processes that producers should use to reduce contamination of ground and surface water from pesticides:

1. Inventory pest problems, previous pest control measures, and cropping history.
2. Evaluate the soil and physical characteristics of the site including mixing, loading, and storage areas for potential leaching or runoff of pesticides. If leaching or runoff is found to occur, steps should be taken to prevent further contamination.
3. Integrated pest management (IPM) strategies should be used to minimise the amount of pesticides applied. Use integrated pest management (IPM) strategies that apply pesticides only when an economic benefit to the producer will be achieved (i.e., applications based on economic thresholds) and apply pesticides efficiently and at times when runoff losses are least likely.
4. When pesticide applications are necessary and a choice of registered materials exists, consider the persistence, toxicity, runoff potential, and leaching potential of products in making a selection.
5. Periodically calibrate pesticide application equipment.
6. Use anti-backflow devices on the water supply hose, and other safe mixing and loading practices such as a solid pad for mixing and loading, and various new technologies for reducing mixing and loading risks.

b. Risk assessment procedure

Some risk assessment for supporting a significant number of decisions in the field of pesticides are listed below:

- Classification and labelling
- Quality criteria (water, soil and air)
- Ranking and classification of pesticides

- Registration of new pesticides
- Review of existing active ingredients
- Correct management of the territory

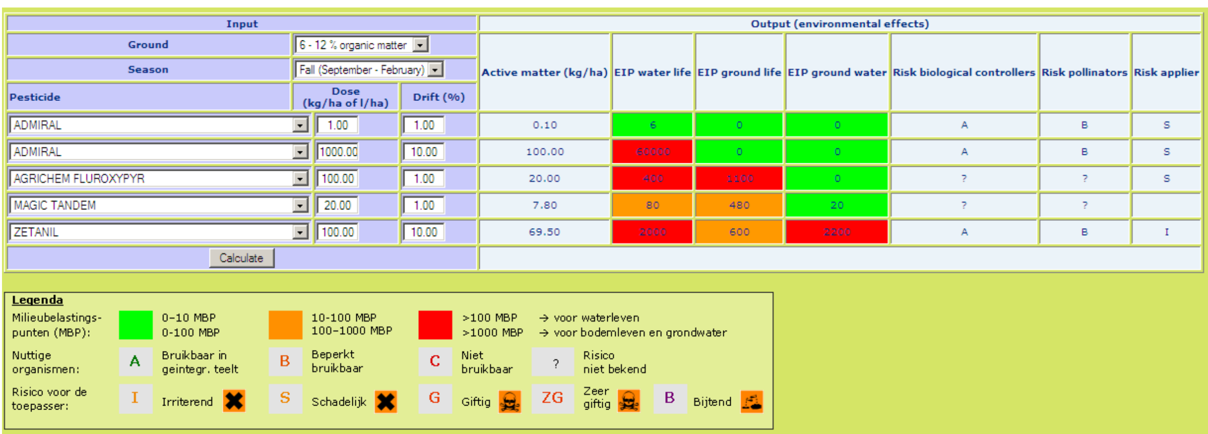
c. Tools for pesticide risk assessment

To assess the risk of pesticide effect on water resources some tools have been developed and are listed below. Please note that there is not an universal methodology applied and this list present some examples (It is not an exhaustive list).[b]

- ***Field crops indicator developed by the Centre for Agriculture and Environment (CLM)***

CLM developed a software for the assessment of the environmental risk and impact of some pesticides used in The Netherlands. The software provides with a quantified indicator of the environmental impact for surface water organisms and risks for infiltration to groundwater. This software provides with a comprehensive way of estimating the impact as it takes into account most of the environmental, social and climatic factors mention above.[10]

Figure 4: Display of the software for assessing pesticides risk in Water sources, The software allows to choose the pesticide, the dose and % of drifting and display the risk (green, orange, red) in surface and groundwater water life, groundwater.



Source: http://www.milieumeetlat.nl/

- ***Pesticide Risk Mitigation Engine***

PRiME (Pesticide Risk Mitigation Engine) is a US based tool that allows farmers and agronomist to evaluate the impact of pesticide on health and environment.

[b] For a comprehensive list of pesticide management tools see http://www.pfmodels.org/links.html

It consider application rate, method and timing, weather and soil site-specific data, the buffer strips and sensitive sites.[11]

Based on site-specific conditions, pesticide properties and empirical field impact data were available, the tool calculates risk to a comprehensive set of indices - low, moderate and high risk categories.

- ***The Groundwater Ubiquity Score***

The Groundwater Ubiquity Source (GUS) is another estimator model which, like trigger values, is useful for comparing the intrinsic leaching potential of pesticides. The GUS model is more sophisticated than trigger values because it uses a formula that combines pesticide mobility and persistence parameters. To calculate the GUS, average values for only two pesticide parameters are needed: the soil degradation halflife, and the soil Koc. Pesticides with a GUS greater than 2.8 are more likely to leach to ground water, while those with GUS values between 1.8 and 2.8 are somewhat less likely to leach. Pesticides with GUS values less than 1.8 are unlikely to leach to ground water.

- ***The Pesticide Root Zone Model***

The Pesticide Root Zone Model (PRZM) has been developed by EPA and provides site-specific leaching estimates. PRZM, like other pesticide soil fate and transport models, incorporates soil characteristics and hydrology, weather, irrigation, and crop management practices into complex mathematical formulas that estimate leaching potential. EPA uses PRZM (and similar models) to make multiple site comparisons of the leachability of a pesticide to older, reference pesticides with histories of use and extensive ground water monitoring. Models like PRZM also provide estimates of the concentration of a pesticide that will leach, but these estimates should be confirmed with actual field data.

- ***The Pesticide Assessment Tool for Rating Investigations of Transport***

The Pesticide Assessment Tool for Rating Investigations of Transport (PATRIOT) is a site-specific screening model. That is, PATRIOT provides a quick estimation of the relative leaching potential of a pesticide at representative sites. The PATRIOT user first must select crops, geographical areas, and soil types of interest. PATRIOT automatically simulates weather, using historical records from stations with soils that closely resemble those selected for modelling; and it automatically incorporates appropriate irrigation schemes. Pesticide characteristics needed for modelling are also provided by PATRIOT; however, for newer pesticides the user must input personal estimates of the required values. Finally, PATRIOT performs simulations of pesticide leaching and provides estimates

of pesticide leaching under varying conditions. Therefore, the leaching potential of a pesticide in
different cropping systems or in different soil types can be evaluated with PATRIOT.

- **PRI-Farm**

PRI-Farm generates a risk indicator for each treatment and is usually expressed as the indicator sum for all treatments on a farm, in a crop or in a field on a particular farm.[c]

- **GIS**[d]

Recently, several international institutions (such as OCSE, IOBC/WPRS, EU) are involved in implementing the risk assessment process in Geographic Information Systems (GIS). Such an implementation could be very useful for environmental-oriented monitoring, or for measuring the increased level of environmental quality.[12]

- **Local Environment Risk Assessment for Pesticides (LERAP)**

In the UK, certain pesticides have an aquatic buffer zone requirement when applied by horizontal boom or broadcast air-assisted sprayers. If you want to reduce this aquatic buffer zone, there is a legal obligation to carry out and record a Local Environment Risk Assessment for Pesticides (LERAP).[13]

[c] The result of the tests performed under the leadership of .Odling i Balans. on a number of Pilot Farms during 2003 and 2004 are available at www.odlingibalans.com

[d] For a list of tools based on GIS see http://www.ias.ac.in/currsci/oct252005/1362.pdf

Section 6: Case Studies

Protecting Water quality in India gherkins fields[14,15]

Unilever promotes the use of IPM as a way to protect water. In southern India, gherkin growers are using IPM to deal with three main crop pests: the gherkin fruit borer, melon fruit fly and downy mildew fungus.

Farmers were encouraged to grow pest-tolerant varieties, to introduce pheromones to disrupt mating and sticky traps to catch flying insects and to use crop rotations that avoid growing gherkins during the monsoon season, when pest outbreaks are most common and to irrigate using channels (instead of flood irrigation) that reduce humidity and the need for fungicides.

Farmers were supported by a local field officer with offer specific recommendations on site. Also some good practice demonstrations to make sure growers know how to apply and store pesticides safely, minimising the contamination were held.

Figure 5: Officer providing some recommendations on field

Not only farmers have ensured protection to water resources, but also they have doubled yields and reduce their fungicide use by 78%.

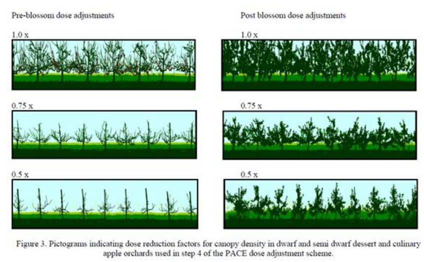
Farmers were taught the basics of IMP in their local language and containing explanatory photographs and graphics for those unable to read. In addition, the IPM guidance contained key messages in a user friendly way through a Bollywood-style film which is shown at village meetings.

Improving pesticide application in Europe[16]

Pesticide labels commonly express the dose rate as an amount of product to be applied per unit ground area occupied by the crop. However, adjusting the dose according to the canopy density can have reduced water contamination, reduce pesticides use and residues on fruit, reduced environmental and bystander contamination, reduced operational costs by more efficient use of pesticide and if applicable also reduce aquatic buffer zones.

The 'tree row volume' method of dose adjustment has been used to improve dose optimisation. This method considers the effects of different tree height, tree crown width and tree row width and ignores some important effects of foliar development and branching density at different growth stages. Pesticide Adjustment to the Crop Environment (PACE) is a dose adjustment system that additionally takes account of the increasing density of the canopy during the growing season.[17]

Figure 6: Example of PACE.

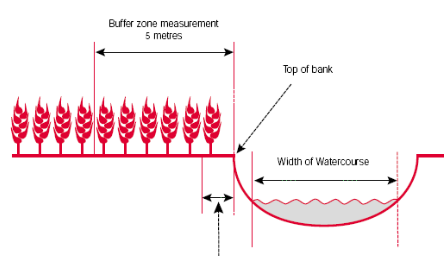


En England, research and grower trials have shown that there is the potential to apply pesticides from full-dose down to 1/4 full-dose during the pre-blossom growth stages depending on certain factors. Note that 1/4 full-dose applications reduce the risk of non-target contamination from drift by 75% and can be used to reduce the aquatic buffer zones. The figure above shows the dose adjustment taking into consideration the density of the canopy.

Buffer zones[18]

Buffer zones can play important roles in agricultural habitats, both in the protection of off-crop habitats from pesticide and fertiliser drift and run-off, and in providing important areas of non-crop habitats. Their role in the protection of aquatic habitats from pesticide drift is a significant feature of pesticide risk management. The size of the buffer zone reduction may depend on the width of the watercourse. Figure 7 shows a typical buffer zone to protect water courses.

Figure 7: Example of buffer zone



SECTION 7: APPENDIXES

Appendix A. Methods of IMP

A. Mechanical control involves the use of machines or other tools.

• Soil cultivation and tillage, which physically kills some pests, buries them, or exposes them to drying conditions on the soil surface or as food for birds or other predators. Soil cultivation also buries and kills weed seedlings, and buries potential food sources for insect pests.

• Traps, such as rat traps and sticky insect traps.

• Hand weeding or hand collection of insects, leaves/fruits that are diseased, with insect eggs, or infested with insect pests, etc.

B. Sanitation control helps to prevent and suppress pests by removing or preventing access to sources of infection or sources of food and shelter. Some practices include the removal of infected crop material, ploughing or burning of crop residues, the removal of food sources such as seed and grain (after both planting and harvesting), good management of animal manure, etc., nets and screens in greenhouses and rodent proof grain stores.

B. Cultural control includes practices that optimise plant growing conditions, and/or produce unfavourable conditions for pests. Some practices include assessing the quality of site and soil texture, crop rotation, land preparation, plant spacing, multiple cropping.

Crop rotation[19] The approach is to rotate non-host crops with susceptible crops in sequence. While the non-host crop is present, the pest population declines so it is very low or even absent when the susceptible crop is grown again.

Multiple cropping can control pests. Diverse crops can be grown row by row, or in alternative strips each consisting of several rows of the same crop, or they may be grown on a more complicated spatial patter or randomly.

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C. **Biological control**[20] involves the use of natural enemies of pests (predators and parasites). Pesticides can be dangerous to human health and damage natural resources but, more importantly to the farmer, pesticides are often inefficient at controlling pests. They can cause pest resurgences by killing the natural enemies of the target pest. They can produce new pests by killing off non-pest species. Pests and weeds can become resistant to pesticides. And also, pesticides provide no lasting control and have to be repeatedly applied.

Unsprayed crops contain a wide range of beneficial organisms (predators, parasites and disease causing organisms). These feed on the pests, providing a large measure of control. The beneficial organisms are present in the crop itself, and also in neighbouring fields and crops, and the vegetation between fields and along canal banks, waste ground, and roadsides. Some predators like ladybirds, spiders, lacewings and birds are the most commonly observed natural enemies, but parasites as parasitic wasps and flies often have the greater control effect. In many circumstances, natural enemies are extremely common in fields that have not been sprayed with a pesticide.

Figure 8: Multiple cropping as an IPM method

Biological pest control requires detailed information and knowledge about the population dynamics of pests and their natural enemies. In some cases where the growth dynamics of pest populations exceeds natural mortality, then biological control is physically impossible.

Figure 9: Biological pest management

Improving the habitat for natural enemies offers a good form of control measure. Natural enemy populations can be encouraged by **increasing the diversity of farms and their environments**. Many natural enemies need food sources of pollen or nectar, which can be provided by wild vegetation near or in the crops. Farmers in Sri Lanka encourage birds to come to their rice fields by putting food on unstable discs attached to the stakes so that when the birds attempt to perch, the food falls into the rice and in following they see the pests. In addition, biological control can be enhanced by the **mass rearing and release of beneficial insects.** Those commonly used include Trichogramma, Bracon, and Chrysopera.

In certain circumstances, the numbers of natural enemies can also be enhanced by intercropping, border planting, and relay cropping. **Intercropping** is the planting of strips of crops or plants, which are either habitats for natural enemies or which attract pests out of the main crop, between the main crop or next to it. **Border planting** is the establishment of refuge habitats of flowering plants around the edges of fields which attract natural enemies. Suitable plants are fennel, coriander, brassicas, crucifers, legumes and castor. **Relay cropping** is the planting of short duration crops early in the season, into which the main crop is planted shortly before the harvesting of the relay crop. The natural enemies which develop in these crops will then move into the main crop when they are harvested.

The use of **beetle banks, flowering strips and conservation headlands** are used in temperate agriculture to encourage predators. When the field habitat is manipulated to increase plan diversity then pesticide use can be reduced. Wild flowers also encourage predators. For example, hoverfly larvae are voracious predators of aphids. They thrive on farms rich in wild flowers to obtain pollen and nectar.

Pests also naturally suffer from diseases caused by viruses, bacteria, fungi, protozoa and nematodes, and which can reduce pest numbers. **Pesticides based on bacteria and viruses** can have good results in terms of selectivity and reduced potential for pollution. For example, the release of live coconut rhinoceros beetles infected with baculovirus in islands of the South Pacific results in a decline of beetle populations by 80% at some locations.

D. **Chemical control** is the use of chemical pesticides which kill pests, control their activity or prevent them from causing damage. Pests can be biologically changed by the use of insect growth regulators, which prevent the pests from developing from one stage to another, and by pheromone mating disruption, which prevents the adult pests from finding one another to mate. Natural compounds should be subjected to a risk analysis the same as chemical pestcides. Take for instance derris or nicotine, very effective natural compounds but with great risks for various reasons

Pheromones for disrupting pest reproduction: Some pests can be controlled by disrupting their reproduction processes. Synthetic chemicals that mimic pheromones can reduce the chances of mating by confusing male insects. The release of larger numbers of pre-sterilized males will ensure that most mating males are sterile. For example, control of the pink bollworm (Pectinophora gossypiella) that affects cotton has been successful in Egypt, Pakistan and the USA. In Egypt, pheromone formulations are sold at the same price as pesticides but are more effective in the field.

Cutting pesticide use reduces the potential for water pollution. A more efficient and careful application of existing pesticides should be sought. However, the use of low dose mixtures is not appropriate for all farmers. It is primarily intended for those who can inspect crops regularly and make a timely application of the pesticide.[21] See case studies in section 10.

Patch spraying techniques are in used in some farms that have the appropriate information systems in place. Patch spraying requires modern technology; regular field monitoring and modified spray systems that allow application exactly where there are known problems. Aerial photography, image analysis and field walking are tools to map the location of weeds or pest. This information is recorded on a computer which controls the sprayer. In the field the operator enters the location of the tractor and the distance/speed monitor tracks its position as its moves. The position is compared with the pest map and pesticide is dispensed in the amount needed.[22]

Resistant crop varieties have resistance or tolerance to attack by certain pests. The degree of resistance can vary from slight to almost complete. A resistant variety is resistant to some pests, but not all pests. Resistance mechanisms work by preventing pests from completing their life cycle, introducing chemicals in the plant that repel the pest, and making the plant more tolerant and not susceptible to the pest.

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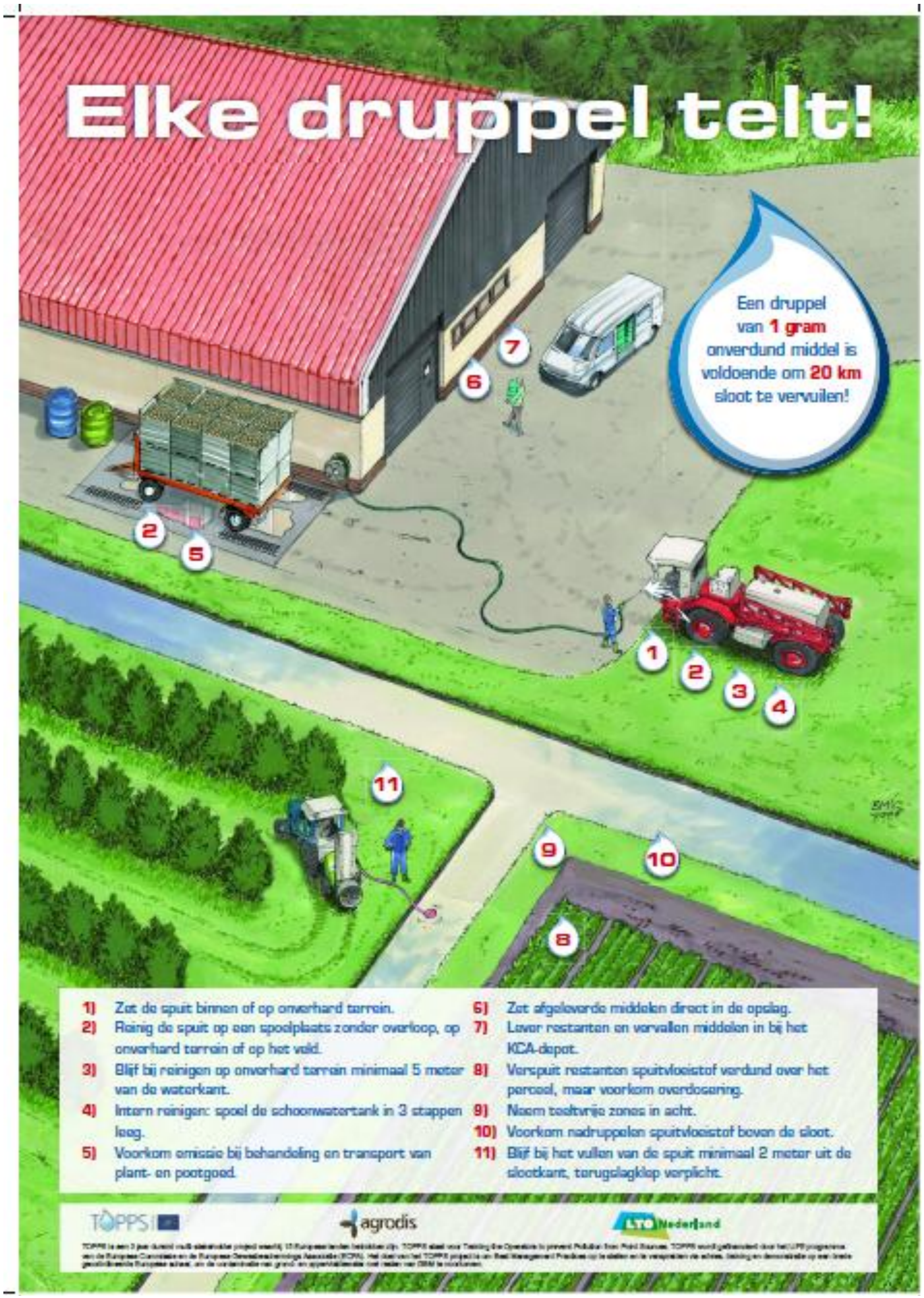
Alternative **Natural Pesticides** are used worldwide as a measure of helping control pests. There are locally available plants that have insecticidal or disease controlling properties which can repel, deter or poison pests. For example[23], the chili pepper (Capsicum frutescens) is used in Papa New Guinea is sprayed to repel aphids. Some of these natural pesticides are both selective in their action, killing pests and not predators, and degrade rapidly so that they do not contaminate the environment. However, some can be poisonous to humans, persistent in the environment or toxic to non-target organisms.

Figure 10: Chili pepper (Capsicum frutescens) is used in Kenya and turmeric's root (Curcuma domestica) used as a natural method for pest control

Non-plant products are also widely used, such as solutions of cattle manure and animal urine to repel insects and animals and sand or ash added to store grain to stop the movement of weevils. In Sri Lanka, turmeric root (Curcuma domestica) is mixed with cow urine and spread against insect pests.

Appendix B. Poster for increasing awareness on pesticide management at a farm level



Source: This poster has been used in a promotion campaign in the Netherlands making farmers more aware about protecting water sources. It discusses 11 points ranging from where to put your sprayer till what you do with cleaning empty containers. Available in Dutch.

SECTION 8: REFERENCES AND FURTHER READING

Crop Life
http://www.croplife.org/files/documentspublished/1/en-us/PUB-MAN/5081_PUB-MAN_2008_10_01_Introduction_to_IPM__Facilitator's_Manual_-_Text.pdf
This manual offers a introduction to IMP for a facilitator who runs a training.

Crop Life
http://www.croplife.org/files/documentspublished/1/en-us/PUB-MAN/5084_PUB-MAN_2008_10_01_Introduction_to_IPM__Trainee_Handbook_-_Text.pdf

EPA Integrated Pest Management (IPM) Principles Website
http://www.epa.gov/opp00001/factsheets/ipm.htm

FAO Pest and Pesticide Management
http://www.fao.org/agriculture/crops/core-themes/theme/pests/en/
Contains general information regarding pesticides and their use, residues, specifications, prevention and disposal.

FAO Global IPM Facility
http://www.fao.org/ag/AGP/AGPP/IPM/gipmf/index.htm

Aglearn.net (Asia)
http://www.aglearn.net
Specific information on IPM on cotton, rice and vegetables.

National Sustainable Agriculture Information Service (USA)
http://attra.ncat.org/attra-pub/biorationals/
Ecological Pest management Tool: This website provides an on-line pest management tool for farmers. This database highlights reduced risk materials that can be integrated with ecological pest management strategies.

Online Information Service for Non-Chemical Pest Management in the Tropics – PAN
http://www.oisat.org/
Germany: This site offers information on -Chemical Pest Management for a wide range of crops

Organic IPM Field Guide
This guide provides a pictorial guide about the concepts of organic IPM and important pests.

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http://attra.ncat.org/attra-pub/summaries/summary.php?pub=148

For insects pest management and predators life cycle see
http://attra.ncat.org/attra-pub/PDF/insects.pdf

Washington State University
http://whatcom.wsu.edu/ag/comhort/nooksack/eb1786.html
This website offers effective options integrated pest management for farmers

World Bank Pest Management Guidebook
http://web.worldbank.org/WBSITE/EXTERNAL/TOPICS/EXTARD/EXTPESTMGMT/0,,contentMDK:20631409~menuPK:586795~pagePK:64168445~piPK:64168309~theSitePK:584320,00.html
This guidebook contains information about policies and tools such as environmental assessment and pest management plan.

Case study on IPM in Europe
http://www.schonebronnen.nl/ (Dutch)

Pesticide and herbicide contamination
http://www.usgs.gov/science/science.php?term=879
Pollution resulting from chemical agents applied to crops, rights of way, lawns, or residences to control weeds, insects, fungi, nematodes, rodents or other pests (pesticides) or kill undesirable plants (herbicides).

PAN - Pesticide Action Network Pesticides Database
http://www.pesticideinfo.org/
Contains info on insecticides, herbicides and other pesticides.

Pesticide Fact sheets for framers
http://www.cals.ncsu.edu/wq/wqp/wqpollutants/pesticides/pestfactsheets.html

OECD Pesticide programme
http://www.oecd.org/env/pesticides
This programme helps OECD governments to cooperate in assessing and reducing the risks of agricultural pesticides.

Tools

Field crops indicator developed by the Centre for Agriculture and Environment (CLM)
http://www.milieumeetlat.nl/begin.en

Pesticide Risk Mitigation Engine
www.ipminstitute.org/prime

The Groundwater Ubiquity Score
http://ptrpest.com/pdf/groundwater_ubiquity.pdf

The Pesticide Root Zone Model
http://www.waterborne-env.com/model_przm.asp

The Pesticide Assessment Tool for Rating Investigations of Transport
http://www.epa.gov/nscep/

Local Environment Risk Assessment for Pesticides (LERAP)
http://www.pesticides.gov.uk
http://www.pesticides.gov.uk/uploadedfiles/Web_Assets/PSD/LERAP_Horizontal_boom_sprayers(1).pdf
http://www.pesticides.gov.uk/uploadedfiles/Web_Assets/PSD/LERAP_Orchard(1).pdf

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[1] http://insects.tamu.edu/extension/bulletins/b-6050.html
[2] http://insects.tamu.edu/extension/bulletins/b-6050.html
[3] http://www.kemi.se/upload/Trycksaker/Pdf/PM/PM6_04.pdf
[4] insects.tamu.edu/extension/bulletins/b-6050.html
[5] Koomen, Irene [Personal, Communication], WUR.
[6] Ibis.
[7] This section was obtained from: http://www.croplife.org/files/documentspublished/1/en-us/PUB-MAN/5084_PUB-MAN_2008_10_01_Introduction_to_IPM__Trainee_Handbook_-_Text.pdf
[8] Koomen, Irene [Personal, Communication], WUR.
[9] http://www.epa.gov/nps/agmm/chap4b.pdf
[10] http://www.milieumeetlat.nl/index.en
[11] www.ipminstitute.org/prime
[12] Environmental risk assessment for pesticides: A tool for decision making
Environmental Impact Assessment Review, Volume 22, Issue 3, May 2002, Pages 235-248
Antonio Finizio, Sara Villa
[13] http://www.pesticides.gov.uk/
[14]http://www.unilever.com/images/sd_Unilever_and_Sustainable_Agriculture%20-%20Water_tcm13-179363.pdf
[15] Picture taken from: http://www.unilever.com/images/sd_Unilever_and_Sustainable_Agriculture%20-%20Water_tcm13-179363.pdf
[16] Matthews, G. A. 2006, **Pesticides : health, safety and the environment** Oxford : Blackwell, 2006.

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[17] http://www.cigrjournal.org/index.php/Ejounral/article/viewFile/1240/1097

[18] Matthews, G. A. 2006, **Pesticides : health, safety and the environment** Oxford : Blackwell, 2006.

[19] Picture taken from http://www.hyparion.com/web/diccionari/dics/geografia/rotacion.htm

[20] Pictures taken from http://www.bugsforbugs.com.au/images/C_transversalis3.jpg and http://news.nationalgeographic.com/news/bigphotos/425079.html

[21] Pretty,Jules. **Regenerating agriculture: policies and practice for sustainability and self-reliance.** London: Earthscan, 1995.

[22] Idem

[23] Pictures taken from http://siamspices.com/images/Thai_peppers.jpg and http://sacredorigin.com/product_info.php?cPath=26&products_id=78