Towards sustainable pesticides

JEM

Focus

In the light of increasing concern over the environmental impact of pesticides, we look at the evolution of national and international policies for sustainable pesticide use, and the associated data requirements.

Few issues are as divisive as pesticides. Since the publication of *Silent Spring*, Rachel Carson's landmark work on chemicals in the environment, published in 1962, pesticides have become something of a touchstone in the environmental debate. For environmentalists, pesticides have come to symbolise our over-reliance on chemicals of which we know little and care less. For industrialists, they epitomise the increasing scrutiny being extended to chemical products in all areas of modern life.

Pesticides remain of central importance today, touching, as they do, many central issues in the sustainability agenda. In waste management, water quality, chemical hazards, product labelling, sustainable agriculture and third world development, pesticides retain a prominent role. What, then, are the prospects for a more sustainable approach to pesticide use, and how can environmental monitoring inform such policies?

Pervasive pollutants

Pesticides—the term is used here to include categories such as insecticides, herbicides and other agricultural chemicals—are pervasive in modern society. They are important to modern agriculture to control pests, weeds and diseases. They also have significant non-agricultural uses, such as the treatment of textiles, timber preservation, and the fouling protection of boats. Around 500 pesticides are in common use, many of them either known or thought to be hazardous.[1]

The main environmental impacts arise from the high potential to pollute water courses, through direct run-off, spray drift or shortcomings in storage, handling or disposal. They vary greatly in their chemical and physical characteristics, and thus in their solubility in water. However, pesticides are, by their nature, highly active in that they have a high potential to kill specific organisms.

Concerns over health effects focus around three issues:

(1) Persistence: many of the chemicals are known to be highly resilient and to accumulate within the environment. Even where they do degrade, their breakdown products may also be toxic to some animals and plants.

(2) Low doses: for some chemicals, there is increasing evidence of health impacts through long-term exposures at very low dose levels. These long-term effects are thought to include cancer, reproductive changes, neurotoxicity and endocrine disruption.

(3) Multiple interactions: while attention to date has focused mainly on single species, there is increasing evidence of detrimental effects from low-level exposures to mixtures of different chemicals—known as multiple chemical sensitivity (MCS).

Dangerous cocktail

Taken together these factors amount to a significant threat. So much so that Professor Nicholas Ashford of Massachusetts Institute of Technology, a leading environmental scientist and health adviser to the United Nations, warned recently that 'pesticides are the most serious problem we have today in the industrial countries'.[2]

Professor Ashford is particularly concerned about MCS. The huge rise in pesticide use over the last fifty years could be responsible for a variety of illnesses with common symptoms, such as skin rashes, breathing problems, cancers and birth defects. According to Professor Ashford, sensitised patients have been found to react to levels of chemicals so low that they are undetectable with existing testing methods. Unable to diagnose a classic cause-and-effect, the resulting symptoms baffle doctors, who frequently attribute the condition as a mental illness. In his latest book, he advocates that this sensitisation can be explained by a new theory called toxicant induced loss of tolerance (TILT).[3]

The MCS theory is still contentious, but according to Ashford there is now compelling evidence that this condition should be recognised as a separate illness. 'The last seven years of research has not furthered the case for psychosomatic origins at all', he says, 'but it has definitely furthered the case for physiological origins'.[2]

The shortcomings in current toxicological testing procedures have been underlined by recent research from the University of Wisconsin (see Box 1).[4] A five year study suggests that combinations of commonly used agricultural chemicals, in concentrations similar to those found in groundwater, can significantly influence immune and endocrine systems, as well as neurological health. Study leader Warren Porter said the single most important finding was that 'common mixtures, not the standard one-chemical-at-a-time experiments, can show biological effects at current concentrations in groundwater'. The study focused on three farm chemicals in common use: aldicarb, an insecticide, atrazine, a herbicide, and nitrate, a chemical fertiliser.

Risk reduction strategies

As well as health and environmental aspects, the social regulation of pesticide use is driven by other issues.[5] These include: a more general concern about agriculture's dependence on and heavy use of chemical inputs; and a new social mandate to incorporate environmental goals into agricultural policy and practice. The development of pesticide/herbicide resistance by some pests and crops, and the increased use of pesticides that has accompanied the intensification of agriculture, have been of particular concern.

Over recent years policy-makers have sought coherent frameworks for this highly complex agenda—so-called pesticide risk reduction strategies. These generally aim to balance the triple objectives of: promoting sustainable agriculture, achieving high levels of environmental and health protection, and maintaining free trade.

A wide variety of instruments are employed. A 1996 survey found that

Box 1: Shortcomings in pesticide testing

According to some commentators, current testing methods for the registration and use of pesticides are fundamentally flawed, in that they fail to address conditions under which mixtures of chemicals interact. Important deficiencies in current testing protocols include:

- *Unrepresentative formulations:* Tests tend to use pure forms of pesticidal active ingredients rather than commercial formulations. Most tests are missing three types of chemical additives: contaminants of manufacturing processes, toxic waste from reactor cleaning processes, and 'inert' ingredients.
- *Single exposure routes:* Standard toxicological tests only evaluate one route of exposure at a time, rather than all possible routes (oral, cutaneous and respiratory).
- *Non-carcinogenic effects:* Toxicological tests have typically focused on cancer and mutation end-points, at the expense of other critical concerns, such as endocrine and immune systems.
- *Pulse dose effects:* Current tests fail to evaluate low dose pulse exposure. Pulse doses of low levels of pesticides may damage a foetus at critical times in the development cycle. This is because the embryo has almost no defensive systems against chemicals and no feedback systems to modulate chemical concentrations in early development.
- *Multiple interactions:* Current testing requirements fail to evaluate exposure effects from chemical mixtures. While it is impossible to examine all possible mixtures, common combinations likely to arise from crop rotation and tillage practices could be examined.
- *Environmental conditions:* Laboratory animals generally live in a carefully controlled environment. Researchers know that different responses can occur under stress.

Adapted from '*Endocrine, immune and behavioural effects of aldicarb (carbamate), atrazine (triazine) and nitrate (fertilizer) mixtures at groundwater concentrations*', Warren Porter *et al.*, Toxicology and Industrial Health, 1999, vol. 15, pp. 133–150.

pesticide registration provided the foundation for pesticide risk reduction in all OECD countries.[5] Registration is the process by which pesticide producers submit data to governments on the potential health and environmental risks of specific products, and governments evaluate the data to determine whether or not to allow the products on the market. Such processes tend to be extremely slow and resource intensive, and have not been helped by the need for old pesticides to be re-registered.

Other measures commonly applied are:

- Reducing consumer risks, through setting and monitoring of residue levels;
- Reducing risks to workers, through occupational exposure levels, certification programmes, education and training, information campaigns, safety regulations *etc.*
- Reducing risk to the general environment, through emission limits, environmental quality standards, and special protection for sensitive species and habitats.

Additional measures are aimed at reducing pesticide use or patterns of use, often as part of national reduction programmes. These include:

- Increasing efficiency and effectiveness, through activities to help farmers adopt best pest control practices.
- Implementing integrated pest management (IPM), based on the use of biological pest control agents and/or pest-resistant varieties. IPM usually requires intensive guidance, information and demonstration actions.
- Economic instruments as a stimulus to reduce unnecessary use. Such instruments include subsidies for using IPM and organic methods; promotion of green labelling as a means of market differentiation; and introduction of taxes on pesticide sales.

Policy trends

Recognising that registration is a bottleneck, but also a key policy tool, an extensive international co-operation is being established, under the auspices of the OECD. Last year OECD countries agreed a set of common guidelines aimed at bringing their registration procedures closer together.[6] The guidelines establish two new formats—one for industry in making data submissions, the other for governments when writing their evaluations. The new formats do not require countries to make the same regulatory decisions. Rather they aim to minimise duplication of effort by industry and governments in pesticide registration and to improve the quality of evaluation reports. Further work is underway to improve the sharing of information between countries on pesticide risk assessments.

There is also increasing recognition that effective pesticide risk reduction policies need to go beyond safety assessments for individual chemicals prior to market authorisation. The European Commission last year presented the results of a six-year study into future options for a sustainable pesticides policy.[7] Among the project's findings, contained in a 3000 page consultancy report, were that, for a given crop, pesticide use varies widely between regions, for no apparent reason, and residues in drinking water sources sometimes exceed the EU limit of 0.1 $\mu g\, l^{-1}$. The project found no or very limited economic benefit in using pesticides beyond the level for integrated production, estimated to be 25–40% lower than current levels for the standard farm.

The report recommended potential EU involvement in monitoring the application and environmental impact of pesticides, inspecting spraying equipment and supporting farmer training. There is also broad agreement that the EU's programme for risk assessment, under the 1991 pesticide authorisation directive, is moving too slowly. A refocusing of resources is called for around a priority list of the most problematic chemicals. Sustainable pesticide use should also be integrated into agriculture and water policies. New initiatives, based on these proposals, will be set out in a policy paper from the Commission to be issued later in the year.

Europe weighs up taxes

As yet it is not clear whether the Commission will give its backing to EU-wide pesticide taxes. While the Commission has no powers to set taxation levels—a power reserved for the Member States—it could propose EU-wide frameworks on environmental charges to safeguard the Single Market.

Charges are already high on the agenda in several European countries. Belgium, Denmark and Sweden already have pesticide charging systems, while the Netherlands and the UK are considering them. Norway is set to introduce an environmental levy on pesticides later this year, under a four-year action plan.[8] The scheme involves a fixed levy of 13 Nkr (1.74US$) per hectare plus a differentiated levy based on health and environmental hazard. Products sold to farmers and other professional users will be divided into five hazard/risk classes, based on the weight of active ingredient. In March of this year, the UK government invited consultation on similar proposals for hazard-based tax rates.[9]

To date, the most rigorous regime against pesticides is that adopted in Denmark. The government has long advocated reduced spraying frequencies for agricultural use, and recently proposed a ban on the use of pesticides in private gardens (see *JEM*, 1999, **1**(2), 26N). Further measures were announced in March, following the publication of an advisory study into how to reduce environmental and health risks.[10] The Bichel report, named after its author, recommends a three-pronged strategy of cutting the application frequency; creating low or no-spray zones near drinking water catchment areas; and encouraging organic farming. In Denmark, as elsewhere, national targets used to be based solely on weight of pesticides used in each spray. Spray frequency is now seen as a more appropriate indicator, since it correlates better with environmental impacts as pesticide active ingredients become more concentrated.

Mind the gap

While even Denmark has stopped short of an outright ban, the writing is already on the wall for many common pesticides under legislation aimed at managing persistent organic pollutants (POPs). Under the auspices of the United Nations Environment Programme (UNEP), representatives of over 100 countries are negotiating an international treaty to reduce and/or eliminate releases of certain POPs (see *JEM*, 1999, **1**(1), 10N). Of the 12 specific POPs proposed under the first stage, eight are pesticides and many more could be added under the treaty's pollutant identification procedure. Participants will meet again in Geneva in September, and UNEP is optimistic of finalising the agreement by next year. Moreover, this is only one of many international fora involved in pesticide regulation. Mechanisms such as 'IRPTC', 'PRTR', 'GEENET', 'IPCS' all occupy particular roles: the whole field is a veritable alphabet soup.[11]

Despite this intensive international activity, what is striking is not how much we know about these chemicals, but how little. Take, for example, lindane, a persistent organochlorine insecticide in use since the 1940s. A recent (leaked) report from the European Commission, prepared by the Austrian government, points to potentially serious health effects.[12] Based on a review of the scientific literature, the report notes associations with cancer and birth defects, and toxic effects on blood and genes. However, the report's main conclusion is that despite fifty years of commercial use, there is a lack of basic scientific information about the impact of lindane on health and the environment. Multiply this by the many hundreds of pesticides in common use, and the scale of our knowledge gap becomes truly alarming.

Informing policies

Against this background of pervasive use and a rapidly evolving policy agenda, there is an urgent need for reliable information. The analytical sciences have to provide a more comprehensive picture of the risks posed by pesticides—and find ways of communicating this beyond the scientific community.

Information programmes need to address three purposes:

(1) Product risk assessment: policy-makers need comprehensive reliable information to inform product registration and re-registration. The systematic assessment procedures and data-sharing exercises being promoted by OECD should go some way towards achieving this.

(2) Post-approval monitoring and surveillance: in most developed countries relatively little effort is devoted to the monitoring of pesticides' environmental impacts once in use, and where programmes do exist there is often a lack of transparency between the methodologies used. There is a need for more strategic approaches, similar to those being pursued for product registration. The EU is to explore new sources of funding for post-approval monitoring.

(3) User-friendly indicators: Securing the commitment of users and other stakeholders to pesticide reduction requires clear and meaningful indicators by which to measure progress. Given the complexity of the issues, this is a demanding requirement—but an essential one. Scientists should engage in this process and bring their own perspectives to it. The UK, for example, has already proposed potential indicators, while recognising that they are not always scientifically rigorous.[13] They include concentrations in rivers and groundwater, quantity of active ingredients used, total spray area, and number of wildlife incidents.

These data processes should, in turn, reflect and inform key policy themes. Four, in particular, stand out.

Firstly, there is the MCS debate. In the light of a growing body of evidence on the inadequacy of current testing protocols, new methods are required which take account of low dose exposures (including short, so-called 'pulse doses') and chemical mixtures.

Secondly, the implications of genetically modified crops for pesticide use is unclear. The agrochemicals industry claims that genetically modified herbicide tolerant (GMHT) crops will reduce herbicide use. However, there are indications that use of some herbicides, such as glyphosate, is increasing following the introduction of genetically engineered glyphosate-resistant crops (see Box 2).[14] With independently verified data hard to come by, there is a need for more rigorous scientific investigation of environmental impacts.

The level of pesticide residues in food is another major health issue.[15] A recent survey looking at seven pesticides in fruit and vegetables found much higher levels than expected (see *JEM*, 1999, **1**(1), 10N). In the US, maximum residue levels (MRLs) are regulated at federal level by the Environmental Protection Agency and the Food and Drug Administration, with information on the regulations and limits readily available on the EPA and FDA websites. This contrasts sharply with the EU where MRLs are still set by the Member States—in some cases under a great deal of secrecy. The levels need to be harmonised and the process made more transparent.

Finally, better information should help reinforce current trends towards cross-party stakeholder initiatives. In the UK, for example, indicators of pesticide

Box 2: Herbicide-tolerant crops in North America

In 1996, 2.8m ha of GM crops were grown in North America, of which 0.64m ha (23%) were herbicide-tolerant. By 1997 this increased to 0.7m ha, or 54% of all GM crops. In 1996, for example, only 2% of the North American soybean crop was glyphosate-tolerant. This increased to nearly 15% in 1997, 30% in 1998, and an estimated 60–70% in 1999.

Although both glyphosate and glufosinate are active against a wide range of weeds, there is evidence of varying effectiveness. In Iowa, weeds that emerge later were found to appear more often because they avoid the planned glyphosate applications. Moreover, glyphosate is not effective against all weeds at the application rates for which farmers are willing to pay. In practice, other herbicides are sometimes tank-mixed with glyphosate or are used in sequence. This is primarily to control the weeds that glyphosate does not control well, rather than to delay the onset of resistance. As prices fall, farmers may choose to use more glyphosate, either through a higher application rate or multiple applications.

Adapted from *Scientific Review of the Impact of Herbicide Use on Genetically Modified Crops,* Pesticides Safety Directorate, Ministry of Agriculture, Fisheries and Food, UK. December 1998.

use for 'sustainable agriculture' are being actively supported by stakeholder groups which bring together manufacturers, farmers, NGOs, regulators and others.[16]

New approaches and techniques

As they contemplate these requirements, analysts have a variety of new approaches and techniques at their disposal. These include geographical information systems (GIS), fuzzy logic, artificial intelligence and statistical modelling (based on Bayesian and other methods).[17]

Over the last five years, GIS, in particular, has made significant contributions to the analysis of pesticide exposure. GIS techniques are now being extended to cover pesticide fate in the environment. Coupling of GIS with modelling enables the use of geographically based input data as well as spatial mapping and analysis of simulation results.

Notes

1 For general information on environmental and health effects of pesticides see sources such as: EPA Office of Pesticide Programs, www.epa.gov/pesticides/info.htm; Rachel Carson Council, members.aol.com/rccouncil/; and Pesticide Action Network, www.panna.org
2 Quoted in *Pesticides News*, No. 41, September 1998. Pesticides Trust, London. Available at: www.gn.apc.org/pesticidestrust
3 N. Ashford and C. S. Miller, *Chemical Exposures: low levels and high stakes*, 2nd edn. Wiley, New York, 1998.
4 W. Porter *et al.*, *Endocrine, immune and behavioural effects of aldicarb (carbamate), atrazine (triazine) and nitrate (fertilizer) mixtures at groundwater concentrations*, Toxicology and Industrial Health 1999, **15**, p. 133.
5 *Activities to Reduce Pesticide Risks in OECD and Selected FAO Countries I, Part 1: Summary Report*, OECD Environmental Health and Safety Publications, Series of Pesticides No. 4, OECD, Paris, 1996. Available at: www.oecd.org/ehs
6 The guidelines can be accessed at: www.oecd.org/ehs
7 *Proceedings of the Second Workshop on a Framework for the Sustainable Use of Plant Protection Products in the European Union*, European Commission, 1998. Available at URL: europa.eu.int/comm/dg11/ppps/home.htm
8 *Norway launches ambitious risk reduction plan* in *Pesticide Risk Reduction News*, (1), January 1999, OECD, Paris. Available at URL: www.oecd.org/ehs
9 *Design of Tax/Charge Scheme for Pesticides: Consultation Document*, Department of the Environment, Transport and the Regions, 1999. Available at: www.env.detr.gov.uk
10 *Denmark to further cut farm pesticides use,* in *ENDS Daily* 23rd March 1999. See www.ends.co.uk.
11 PRTR is the Pollutant Release and Transfer Register; GEENET is the Global Environment Epidemiology Network; IPCS is the International Programme on Chemical Safety.
12 *The end for lindane,* in *Pesticides News* (43), March 1999. Pesticides Trust, London. Available at: www.gn.apc.org/pesticidestrust/pn43.htm
13 *Development of a set of indicators for sustainable agriculture in the United Kingdom: A consultation document*, Ministry of Agriculture, Fisheries and Food, London. June 1998. Available at: www.maff.gov.uk
14 *Scientific Review of the Impact of Herbicide Use on Genetically Modified Crops*, December 1998, Pesticides Safety Directorate, Ministry of Agriculture, Fisheries and Food, London. See also, *Resistance to glyphosate* in *Pesticides News* (41), September 1998, Pesticides Trust, London. Available at: www.gn.apc.org/pesticidestrust
15 For a brief review of international experience see *Pesticide residues variability and acute dietary risk assessment*, Pesticide Safety Directorate, Ministry of Agriculture, Fisheries and Food, London. Available at: www.maff.gov.uk/aboutmaf/agency/psd/psdhome.htm
16 The UK Pesticides Forum. See: www.environment.detr.gov.uk/pesticidesforum/
17 For current status of analysis techniques see *Proceedings of the First International Conference on Predicting the Environmental Fate of Agrochemicals*, 26th–27th May, London, UK. Available from IBC Global Conferences, www.ibc-uk.com/IV140

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