WHAT'S YOUR POISON?

Health threats posed by pesticides in developing countries

A report by the Environmental Justice Foundation

Contents

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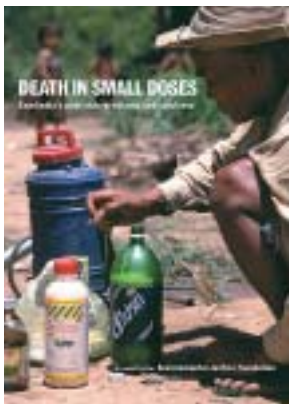


EJF. 2002. Death in Small Doses: Cambodia's Pesticide Problems and Solutions. Environmental Justice Foundation, London, UK.

EJF. 2002. End of the Road for Endosulfan: A Call for Action Against a Dangerous Pesticide. Environmental Justice Foundation, London, UK.

executive summary

- This report summarises health risks associated with pesticide exposure, particularly under conditions of use in the developing world. The information is drawn from over 50 nations and the findings are especially relevant to countries in Asia, Latin America, Africa and the Middle East where pesticide use poses serious health concerns.

- Every year, pesticides are estimated to cause tens of millions of cases of accidental poisoning, largely in the developing world.

- Developing world farmers are at special risk of harmful exposures due to the nature of the pesticides they use and the widespread lack of awareness of the risks they pose. Adequate safety measures are often not employed and pesticide poisoning is a frequent consequence.

- Acute symptoms of pesticide poisoning include: numbness, tingling sensations, lack of coordination, headache, dizziness, tremor, nausea, abdominal cramps, sweating, blurred vision, difficulty breathing or respiratory depression, or slow heartbeat.

- Very high doses can result in unconsciousness, convulsions, or death.

- Chronic effects of long-term pesticide exposure include: impaired memory and concentration, disorientation, severe depression, irritability, confusion, headache, speech difficulties, delayed reaction times, nightmares, sleepwalking, and drowsiness or insomnia.

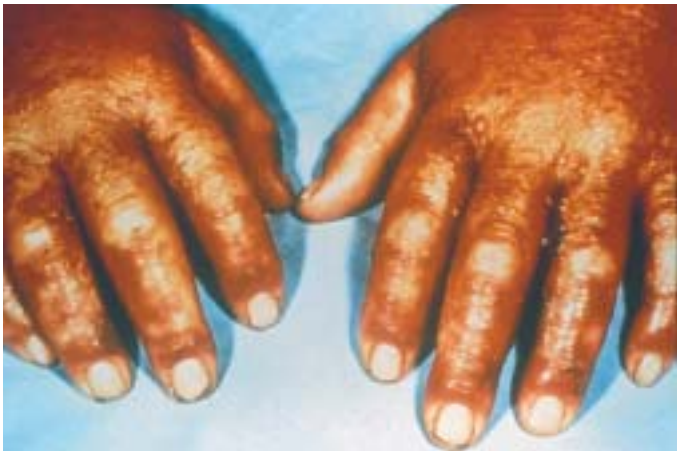
- Certain pesticides have been demonstrated to be cholinesterase inhibitors (disrupting nervous system function) or endocrine disruptors (interfering with hormone production and action).

- Evidence also exists linking pesticide exposure to respiratory and skin diseases, cancers, birth defects, and reproductive and neurological disorders.

- Children and unborn babies are particularly susceptible to pesticide poisoning. Their widespread exposure to pesticides in developing nations is of grave concern.

- Current regulatory frameworks do not adequately account for the patterns of pesticide use in developing countries (e.g. mixing of pesticides, lack of protective clothing, high exposure levels).

- Urgent action is required in order to reduce the health threats posed by pesticides. This report makes key recommendations to governments, the international donor community, and the agrochemical industry. Implementation of these recommendations will considerably reduce the health risks pesticides pose, but will require concerted efforts from all relevant players.



Safe hands? Farmers in developing countries routinely mix pesticides by hand (above). Skin complaints are a common symptom of such exposures (below).

A small price to pay for environmental justice

£5 / $6 per month could help kids get out of the cotton fields, end pirate fishing, protect farmers from deadly pesticide exposure, guarantee a place for climate refugees

This report has been researched, written and published by the Environmental Justice Foundation (EJF), a UK Registered charity working internationally to protect the natural environment and human rights.

Our campaigns include action to resolve abuses and create ethical practice and environmental sustainability in cotton production, shrimp farming & aquaculture. We work to stop the devastating impacts of pirate fishing operators, prevent the use of unnecessary and dangerous pesticides and to secure vital international support for climate refugees.

EJF have provided training to grassroots groups in Cambodia, Vietnam, Guatemala, Indonesia and Brazil to help them stop the exploitation of their natural environment. Through our work EJF has learnt that even a small amount of training can make a massive difference to the capacity and attitudes of local campaigners and thus the effectiveness of their campaigns for change.

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ENVIRONMENTAL JUSTICE FOUNDATION

Protecting People and Planet

introduction

IN THIS REPORT, we summarise pesticides' potential to harm human health, particularly under conditions of use in developing countries. We describe the mechanisms by which pesticides are suggested to cause ill health, and review published evidence of associations between specific human diseases and pesticide exposure. The data presented are drawn from over 50 nations and the findings are especially relevant to countries in Asia, Latin America, Africa, and the Middle East where pesticide misuse poses serious health concerns.

Many pesticides used in developing countries are banned or severely restricted in the industrialised world because of concerns about their safety. These concerns are generally not shared by pesticide users in the developing world, due to a widespread lack of awareness of the hazards of pesticide exposure. Pesticide labels leave much to be desired. They are commonly unclear, in a foreign language, lack clear health warnings, and are difficult or impossible for farmers – many of whom have poor literacy – to interpret. Recommended safety measures are often not employed. The use of protective masks, gloves and boots is often impractical or simply unaffordable. Pesticides are frequently mixed, stored or disposed of in a dangerous fashion and chemicals are often applied too frequently or at too high a concentration.

Country-specific details of pesticide problems in the developing world are beyond the scope of this report, but information of this nature is available in abundance. Readers seeking such information are urged to examine the 'Developing Country Hazards' reports in the quarterly journal *Pesticides News*[2], published by PAN-UK.

Reducing dangerous pesticide use without reducing food security is an achievable target. It is essential that pesticide users are educated about the hazards these chemicals pose, that laws restricting pesticide use are enforced, and that safe alternatives are promoted. Tackling the health problems posed by pesticides under patterns of use in developing countries is a challenge requiring the concerted efforts of governments, the pesticide industry, intergovernmental organisations, the international donor community and non-governmental organisations. This report recommends general and specific action for each of these groups. Implementation of these recommendations will help protect people, especially the poor and vulnerable of the developing world, from the health hazards posed by pesticides.

PESTICIDES ARE POISONOUS chemicals used to control species that have negative impacts on human activities. These pests include insect vectors of human disease (e.g. malarial mosquitoes), parasitic worms, and crop pests. Whilst such pest control plays an important role in modern medicine and agriculture, pesticide use is not without risk, as detailed in this report.

© Helen Murphy

LEFT: The risk of ill-health due to pesticide exposure is an everyday experience for many farmers in the developing world.

RIGHT: Endosulfan on sale in Cambodia, but labelled in Thai. The majority of pesticides sold in Cambodia are labelled in a foreign language[3].

© CEDAC

"Many pesticides that have been banned or whose use has been severely restricted in industrialised countries are still marketed and used in developing countries. These chemicals pose serious risks to the health of millions of farmers"

Dr. Jacques Diouf, Director-General

Food and Agriculture Organisation (FAO) of the United Nations[1]

how and why pesticides affect human health

PESTICIDES ARE TOXIC by design. Some of the most potent pesticides are insecticides, those targeting the nervous system of insects. Unfortunately, the basic neural mechanism is similar in insects and mammals, making humans susceptible to these potentially lethal chemicals as well. In both groups of organisms, messages are transmitted along nerve cells using electrical impulses. When these reach the end of a nerve, a chemical 'neurotransmitter' activates the next cell in the chain. Each new release of neurotransmitter can be detected by the recipient cell as enzymes exist which break down and remove any neurotransmitter left from previous signals.

One important neurotransmitter, acetylcholine, is broken down by the enzyme acetylcholinesterase. Two major classes of pesticides, the organophosphates and the carbamates, inhibit acetylcholinesterase (and are cholinesterase-inhibitors)[4]. Acetylcholine accumulates in the synapse and there is a 'jamming' of information preventing messages from being passed properly between nerve cells. Depending on the dose, effects may be minor or (at the extreme) fatal[4].

Cholinesterase-inhibitors prevent nerves from working correctly. This can affect the nerves in the brain, responsible for release of hormones or controlling hormones' actions. Since hormones are especially important in early stages of human development and in reproduction, such 'endocrine disruption' can be particularly damaging to human embryos or children (see pages 4 and 8).

Organochlorines and pyrethroids (two other major classes of pesticide) also attack the nervous system, but these chemicals are not cholinesterase-inhibitors. Their main effect is on individual nerve cells, interfering with the transmission of messages along their length.

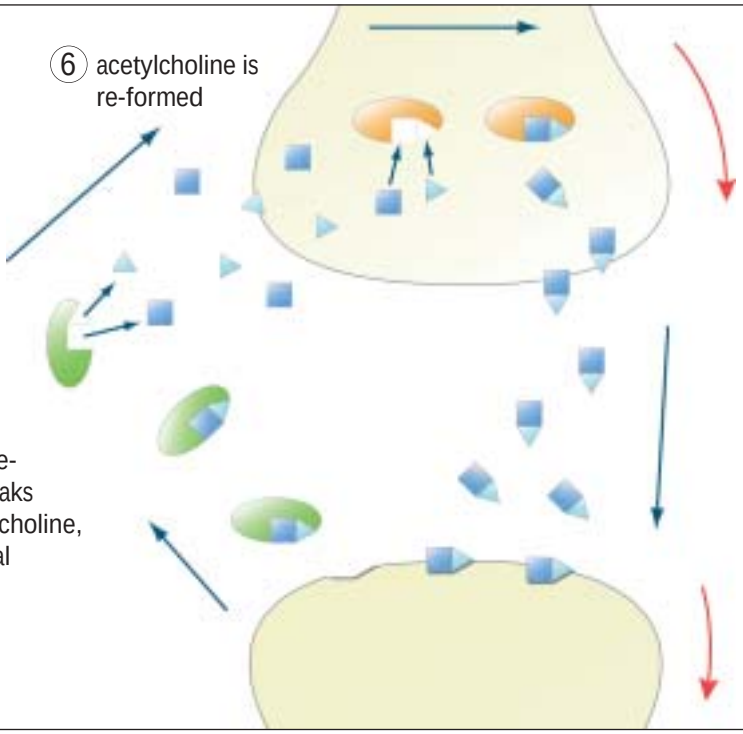
Organochlorine insecticides are often extremely resistant to degradation, making them persistent in the environment. They can accumulate in animals' fat tissue, concentrating further at each level up the food chain. Harmful effects are therefore most likely to be seen at the top of the food chain, in birds of prey, or humans, for example. This is the major reason that their use has been increasingly prohibited, especially in industrialised countries.

THE EXTENT OF THE PROBLEM

An estimated three million *reported* cases of pesticide-associated acute poisoning occur annually, resulting in 220,000 deaths. 99% of these occur in the developing world[5], in spite of these countries accounting for only 20% of global pesticide use[6]. The true number of cases is likely to be considerably higher. In 1990, the World Health Organisation Statistics Quarterly reported that an estimated 25 million agricultural workers are poisoned by pesticides every year[7]. Up to date global estimates are lacking, but today there are 1.3 billion agricultural workers[9] and it is likely that millions of pesticide poisoning cases still occur each year, for instance:

- In 2000, Brazil's Ministry of Health estimated the country had 300,000 poisonings a year and 5,000 deaths from agricultural pesticides[8].
- In an Indonesian study, 21% of spray operations resulted in three or more neurobehavioural, respiratory, and intestinal signs or symptoms[10].
- In a United Nations survey, 88% of pesticide-using Cambodian farmers had experienced symptoms of poisoning[11].

The role of acetylcholine in transmission of information between nerve cells, a process interrupted by cholinesterase-inhibiting pesticides.



ENDOCRINE DISRUPTORS

Steroid hormones, such as oestrogens, androgens (e.g. testosterone) and progesterone, are crucial for primary sex determination, foetal development, and acquisition and maintenance of secondary sexual characteristics in adults. Their correct functioning is therefore essential for successful reproduction. Chemicals, including many pesticides, with similar structures to these hormones can interfere with their function and lead to a variety of developmental and reproductive anomalies. Effects of endocrine disruptors on wildlife include decreased fertility, abnormal thyroid function, demasculinisation of males, and defeminisation and masculinisation of females[16].

Mechanisms of action[17]:

1. Binding to and activating hormone receptors. For example, oestrogenic chemicals like DDT can create the same response in a cell as natural oestrogen. Although often weaker than natural equivalents, effects of different chemicals can be cumulative[18].
2. Binding to and deactivating hormone receptors thereby preventing natural hormones from binding.
3. Modifying rates at which hormones are metabolised, thereby affecting their abundance. Organochlorines, such as DDT and endosulfan, have been found to affect paths by which the female sex hormone oestradiol is broken down, creating higher levels of a metabolite linked to breast cancer[19].
4. Modifying hormone production rate.
5. Affecting cells' number of hormone receptors.

Exposure to endocrine disruptors is especially harmful to foetuses and young children, as the body's systems are particularly sensitive to hormones when they are developing. Effects produced in animals include abnormal sexual behaviour, structural deformities of the reproductive tract, including cross-gender type conditions and undescended testes, deficits in sperm counts, and distorted sex ratios. These effects have been observed both in laboratory animals and in wildlife and humans heavily exposed to endocrine disrupting pesticides[16,20].

As well as sex hormones, other endocrine systems can be affected by chemicals such as pesticides. For example, hormones produced by the thyroid gland, responsible for metabolism and normal brain development, have been shown to be affected by some pesticides[20].

ROUTES OF EXPOSURE

Pesticide-related health problems result from exposures, which occur chiefly via one or more of the following routes:

- oral ingestion
- inhalation
- dermal (through the skin)

Routes of exposure vary between chemicals. For example, dichlorvos (DDVP) is volatile and so more likely to be inhaled, endosulfan is more toxic dermally than by inhalation, and chlorpyrifos is less likely to be taken in across skin than by ingestion or inhalation[4].

Occupational exposure

Farm workers and people employed in the manufacture of pesticides are especially at risk of pesticide exposure. Such risks are particularly pronounced in developing nations, where hazards are commonly less well-understood and health and safety regulations are less stringent or are poorly-enforced[3].

Accidental oral contamination can occur when farmers eat, drink or smoke while spraying or do so shortly after spraying without first washing their hands. Inhalation of pesticides is promoted by spraying without protective masks, whilst absorption through the skin is made more likely when skin and clothes are wet during spraying[10] or when farmers mix pesticides with bare hands, or walk barefoot in fields while spraying.

Although ingesting pesticides is generally the most dangerous form of exposure, inhalation and absorption through the skin are probably the major causes of occupational poisoning cases among farmers in developing nations as they are often unaware of these particular risks.

Trouble afoot: Barefoot and without gloves, this Indonesian farmer risks a toxic exposure to the pesticides he is preparing.

A recent study has revealed organochlorine pesticide residues present in new-born humans 25 years after the use of the chemicals ceased[14], suggesting long-term public health problems.

These routes of contamination are very difficult to prevent as conditions in many countries make wearing of protective clothes and masks impractical. In such situations, a change of clothing after spraying can reduce risks. An Indonesian study showed that washing clothes immediately after use removes a significant amount (96-97%) of pesticide residues[10].

Environmental exposure

Most studies of pesticides' health impacts have considered only occupational exposure, and relatively little is known about health risks to the wider community exposed to pesticides. In rural El Salvador, detectable levels of organophosphate pesticide metabolites were found in the urine of 30% of subjects not involved in agricultural work[12]. Thus, exposure via environmental as well as occupational routes is a cause for concern although it is often harder to draw links between such exposure and illness.

There are a number of ways in which non-occupational pesticide exposure can occur, e.g. by aerial drift during spraying or via contact with contaminated food, water, soil, clothes or mother's milk. A recent study has revealed organochlorine pesticide residues present in new-born humans 25 years after use of the chemicals ceased[14], suggesting long-term public health problems.

© Bananalink

Something in the air: Aerial spraying of banana plantations in Costa Rica. Pesticide drift from such activities is implicated in environmental exposure to toxic chemicals.

Dietary risks

When pesticides are applied at excessively high concentrations and frequencies, or are used near the time of harvest, high levels of pesticide residues may remain on the crops. Consumers are therefore at risk of exposure. Drinking water may also be contaminated, either by direct pollution of water systems or through use of the same containers to mix pesticides and to transport drinking water. A major concern, especially in developing countries, is that low protein diets may increase people's sensitivity to the effects of certain pesticides[15].

© EJF / Williams

Poisoned produce: Vegetables in Cambodia are often sprayed with banned pesticides right up to the point of harvest[3].

POPS and the Stockholm Convention

POPs (Persistent Organic Pollutants) are a group of chlorinated chemicals whose structure and chemistry allow them to persist in the environment, thereby posing risks to human and environmental health. POPs can dissolve in fat (including human and animal fat), and thus bioaccumulate and biomagnify (increasing in concentration up the food chain). POPs are highly toxic and are implicated in neuro-toxicity, immunotoxicity, carcinogenesis, and reproductive and hormonal disorders. Reflecting these threats, the international community, under the auspices of the United Nations Environment Programme (UNEP) has initiated an instrument called the Stockholm Convention to address use, production and release of POPs. The twelve chemicals ("the dirty dozen") initially shortlisted by UNEP comprise nine pesticides (aldrin, chlordane, endrin, dieldrin, heptachlor, DDT, toxaphene, mirex and hexachloro-benzene), the industrial polychlorinated biphenyls (PCBs) and the industrial by-products, dioxin and furan. Most of the 12 chemicals are subject to an immediate ban. At the time of writing, the Convention had been signed by 151 countries, 25 of which had also ratified it. The Stockholm Convention will enter into force after the 50th ratification. (See http://www.pops.int)

The Food and Agriculture Organisation of the United Nations recommends that World Health Organisation Class Ia, Ib and, preferably, II pesticides should not be used in developing countries.

ACUTE VS. CHRONIC TOXICITY

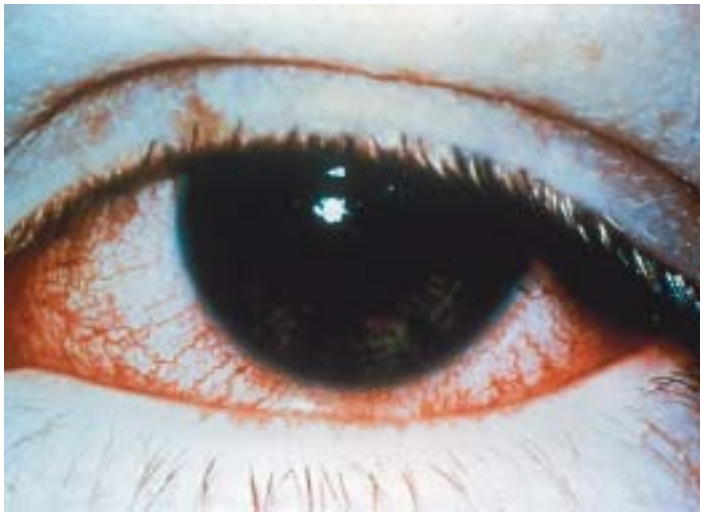
Pesticides can have both acute and chronic health impacts, depending on the extent of exposure.

Acute poisoning is caused by exposure to a high dose of the chemical, on one occasion, during a short time period. Symptoms of poisoning develop in close relation to the exposure and, in extreme cases, can result in death (see page 9). In contrast, in chronic poisoning the person is repeatedly exposed to toxic agents over a long period, but only a low dose enters the body each time. Normally, no symptoms develop in relation to each exposure (although that may happen). Instead, victims gradually become ill over a period of months or years. This occurs when the toxic substance either accumulates in body tissues or causes minor irreversible damage at each exposure. After a long time, enough poison has been accumulated in the body (or the damage has become significant enough) to cause clinical symptoms.

Acute poisoning symptoms depend both on the toxicity of the product and on the quantity absorbed. For example, effects of cholinesterase-inhibiting pesticides include: numbness, tingling sensations, lack of co-ordination, headache, dizziness, tremor, nausea, abdominal cramps, sweating, blurred vision, difficulty breathing or respiratory depression and/or slow heartbeat[4]. Very high doses may result in unconsciousness, convulsions and death[4]. Acute effects can be delayed by up to four weeks and can include cramping in the lower limbs that leads to lack of coordination and paralysis. Improvement may occur over months or years, but some residual impairment may remain[4].

Chronic effects of long-term pesticide exposure include: impaired memory and concentration, disorientation, severe depressions, irritability, confusion, headache, speech difficulties, delayed reaction times, nightmares, sleepwalking, drowsiness and/or insomnia[4]. An influenza-like condition with headache, nausea, weakness, loss of appetite, and malaise has also been reported[4]. Animal experiments indicate that exposure to cholinesterase-inhibiting chemicals can induce damage to the liver, kidneys and brain[4].

Whether affecting adults or children, consequences of chronic pesticide exposure may only appear later in life, or even in the next generation, and include learning difficulties, behavioural and reproductive defects (e.g. accelerated puberty, infertility), and increased susceptibility to cancer[20] (see page 12). Other long-term effects are teratogenic (inducing embryo malformation) and mutagenic (inducing genetic or chromosomal mutations)[4].



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The eyes have it: Red eyes, due to conjunctivitis, are a common acute symptom of pesticide exposure, as exhibited by this patient.

PESTICIDE TOXICITY CLASSIFICATION

The World Health Organisation classifies pesticides according to acute toxicity, using the LD50 (Lethal Dose 50%) benchmark. LD50 denotes the amount of a chemical required to kill 50% of an exposed population of laboratory rats. There are two measures for each product, oral LD50 (the product is given orally) and dermal LD50 (the product is given through the skin).

	Oral LD50		Dermal LD50	
	mg per kg body weight required to kill 50% of rat population			
WHO category	solids	liquids	solids	liquids
Ia Extremely hazardous	5 or below	20 or below	10 or below	40 or below
Ib Highly hazardous	5-50	20-200	10-100	40-400
II Moderately hazardous	50-500	200-2000	100-1000	400-4000
III Slightly hazardous	Over 500	Over 2000	Over 1000	Over 4000

N.B. The terms 'solids' and 'liquids' refer to the physical state of the active ingredient being classified

CHEMICAL COCKTAILS

When chemicals are mixed in an uncontrolled manner, effects can no longer be predicted and chemicals that act similarly (e.g. cholinesterase-inhibiting pesticides) can have additive toxicity even if, individually, they are below levels considered dangerous[21].

More dramatic interactions occur when two or more chemicals act in synergy, meaning combined effects are much greater than additive effects. A classic example of this is the interaction between tobacco smoke and asbestos. Smokers have a ten-times greater risk of dying from lung cancer than non-smokers. Also, people who are exposed to asbestos are five times more likely to die of lung cancer compared with those not exposed. However, someone exposed to both these factors has an increased risk that is 80 times greater than an unexposed control, rather than 15 times greater[22].

This type of effect can occur when one chemical reduces the body's defences against another, e.g. by enabling it to pass through the blood-brain barrier, or by inhibiting the mechanism by which it is detoxified. Animal studies have shown that when two or more organophosphates are absorbed simultaneously, enzymes critical to the degradation of one can be inhibited by the other. For example, malathion has low mammalian toxicity as it is rapidly broken down by a carboxylesterase enzyme. However, EPN (ethyl p-nitrophenolbenzenethiophosphonate), another organophosphate, causes a massive increase in malathion toxicity by inhibiting this enzyme[23].

Research on cocktail effects is lacking as the number of possible mixtures and variables means that it is difficult to cover more than a tiny fraction of the total. It has been found that even the order of exposure to different pesticides can affect the outcome[24]. An Indonesian study showed a dose-effect relationship between the neurobehavioral signs and symptoms and the use of multiple organophosphates[10]. Recent research has shown that when pesticides are mixed together, they can be 10 times more toxic than individual chemicals[25].

© EJF / Trent

Mixed up: Cambodian farmers routinely mix up to ten pesticides before spraying their crops[26].

'Inert' Ingredients and Contaminants

'Inert ingredients' are chemicals used in pesticide products to make the pesticide more potent or easier to use, and include solvents, surfactants, propellants and carriers. More than a quarter of inert ingredients used in the USA have been identified as hazardous by state, federal or international agencies; these include chemicals that can cause cancer, reproductive effects, harm to the nervous system and damage to the environment[27]. For others, harmful effects may be unknown as the testing required is much less rigorous than that for pesticides' active ingredients. Also, inert ingredients are not required to be disclosed on product labels. One laboratory test found that the toxic effect of chlorpyrifos was enhanced in the presence of a solvent used in pesticides[28].

The most notorious pesticide contaminant is the dioxin TCDD, a by-product of manufacturing the herbicide 2,4,5-T (used in the Vietnam War as an ingredient of 'Agent Orange'). TCDD is recognised by the International Agency for Research on Cancer (IARC) as a 'known human carcinogen'. Short-term exposure to high levels may also result in skin lesions, such as chloracne and patchy darkening of the skin, and altered liver function. Long-term exposure is linked to impairment of the immune system, the developing nervous system, the endocrine system and reproductive functions[29].

Examples of Hazardous Inerts[27]

o-cresol	can cause genetic damage
ethoxylated p-nonylphenol	disrupts hormone systems
ethyl benzene	toxic to the nervous system
naphthalene	can cause anaemia and jaundice
o-phenylphenol, sodium salt	carcinogen
toluene	causes developmental toxicity
xylene	toxic to the nervous system

Currently Used Inerts 'of Toxicological Concern'

di-2-ethylhexyladipate (DEHA/DOA)	carcinogen
di-2-ethylhexylphthalate (DEHP/DOP)	carcinogen
hydroquinone	acute toxicity to aquatic organisms
isophorone	carcinogen
nonylphenol	acutely toxic to fish, bioaccumulates
phenol	neurotoxic, liver and kidney damage
rhodamine B	carcinogen

Researchers estimate that about 18% of all new Wilm's tumours, affecting the kidneys of Brazilian children, are attributable to pesticide exposure of their parents[44]

Early exposure: Children spraying pesticides in Ecuador.

RISKS TO CHILDREN

Developing organisms have increased susceptibility to the actions of endocrine-disrupting chemicals because differentiating tissues are more vulnerable to changes in hormone levels[30]. Thus, children are at greater risk of toxicant-related illnesses than adults.

Children also experience different exposure risks to pesticides generally[31]. For instance, there is a risk of pesticides affecting the offspring of exposed farmers through contamination of their sperm or eggs. Similarly, developing embryos can be exposed to pesticides in mothers' blood as it crosses the placenta, and infants may be exposed to contaminated breast milk, which may contain pesticides levels exceeding those recommended by the World Health Organisation[32,33,34]. Although exposure through breast milk is absolutely greater than that during development in the womb, *in utero* exposure is relatively more significant due to the greater vulnerability of the brain and central nervous system at the earlier stages of development.

Children have a higher surface area to weight ratio. Per kilogram of body weight, they drink more water, eat more food and breathe more air than adults. Playing close to the ground, children are exposed to pesticides in the soil. Also, some pesticide vapours form a low-lying layer in the air. Children have greater exploratory and 'hand-to-mouth' behaviour, and are therefore more likely to come into direct contact with and take in environmental pesticide residues and they are also vulnerable to accidents where pesticides are improperly stored (e.g. in food containers).

Farm children are at elevated risk of pesticide-related illnesses in many countries, not least because they are directly involved in agriculture, including mixing and application of agrochemicals. 48% of Cambodian farmers surveyed in 2000 said they allowed children to apply pesticides[11]. A study of Nicaraguan farm children revealed that 40% had reduced cholinesterase activity, a symptom characteristic of pesticide poisoning[35]. Similar decreased cholinesterase levels have been observed in children living on or near sprayed farms in Colombia, Honduras, Bolivia and Costa Rica[36].

In several cases of human poisoning by organophosphate insecticides, fatality rates were higher in children than in adults[37]. An important factor is the body's ability to detoxify and excrete pesticides, and infant metabolism can differ in important ways from that of adults. For example, considerable research on laboratory animals has demonstrated increased susceptibility to organophosphates in juveniles[38,39]. Also, kidneys of infants below one-year old are immature and cannot excrete toxic compounds as quickly[40].

In the Philippines, children were found to be the victims of nearly one in eight pesticide poisonings[41], and in a Pan-American Health Organisation study, occupational pesticide poisoning among children under 18 years of age accounted for 10-20% of all poisonings[42].

Exposure of the developing foetus to pesticides has been linked with birth defects and miscarriages (see pages 16-17), and there is evidence of associations between pre-natal or infant exposure to pesticides and childhood brain tumours, leukaemia, non-Hodgkin's lymphoma, soft-tissue sarcoma and Wilm's tumour[43]. Researchers estimate that about 18% of all new Wilm's tumours, affecting the kidneys of Brazilian children, are attributable to pesticide exposure of their parents[44]. Wilm's is a rare cancer, but the commonest form of childhood kidney cancer[45].

Dangerous game: Child playing with pesticide container in Laos.

48% of Cambodian farmers surveyed in 2000 said they allowed children to apply pesticides[11]

evidence of illness related to pesticide exposure

THE BULK OF THE information presented in this section is drawn from academic papers published in peer-reviewed scientific journals over the last decade (especially the last five years). These studies relate to hundreds of thousands of individuals and engaged rigorous controls for confounding factors such as age, sex, and cigarette smoking. They thus exhibit the scientific integrity required to weigh the evidence about putative relationships between pesticide exposure and disease.

Much of the published research hails from industrialised nations. The information remains relevant to developing countries, however, as many mortalities and illnesses studied were of individuals exposed to pesticides of the kind still widely used in such countries today.

Although there are many studies linking farming and other pesticide applications with disease, we have endeavoured to select, as illustrative examples, those that specifically draw relationships with pesticide use (as opposed to other agricultural risk factors such as solvents, fuels, and infectious micro-organisms).

Underestimating prevalence

Most pesticide-related diseases appear similar to common medical conditions[21] and there is a general failure by doctors to recognise pesticide poisoning[46]. In one review of medical records of 20 severely pesticide-poisoned infants and children transferred to a major medical centre in California from other hospitals, 16 were found to have been wrongly diagnosed at the time of transfer[47].

In developing countries, poisoning surveillance systems are usually maintained only at large urban hospitals and farmers typically discount or ignore symptoms[36]. Accurate diagnosis is even more difficult with less severe acute symptoms, if they are reported at all, and chronic symptoms may not develop until decades after exposure.

The extent of women's indirect exposure to pesticides is likely to be underestimated. Even if they do not spray the chemicals themselves, they tend to work in sprayed fields and be responsible for tasks such as washing work clothes and re-use of pesticide containers[48].

SUDDEN DEATH

In extreme cases of pesticide exposure, sudden death can result.

- In 1999, in Peru, 24 children died following ingestion of methyl-parathion, which had contaminated milk supplies[49].
- In Ireland in 1999, a man died after handling chlorpyrifos whilst gardening[50].
- In 2002, an 8-year old English girl died after swallowing a minute amount of lindane[51].
- In 1999, a boy in Benin died after eating corn sprayed with endosulfan[52].
- In Sudan, in 1988, three people died after drinking water from a canal in which endosulfan barrels had been washed[53].
- In 1991, also in Sudan, 31 people died after eating food containing seed sprayed with endosulfan[54].
- In South Africa, in 1989, 50 people were poisoned, and one girl died, after drinking water from a drum that had contained monocrotophos[46].
- In Senegal, in 2000, 16 farmers suddenly became ill and died. Government investigators identified the probable cause as two pesticides, Granox TBC and Spinox T (mixtures of fungicides and the insecticide carbofuran), which the farmers had been spraying on groundnut crops[55].

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Graves of Peruvian children who died after ingesting milk contaminated with Folidol (methyl-parathion).

In Ecuador, civil society groups have blamed the deaths of eight children living near the border with Colombia on the spraying of the herbicide glyphosate by Colombian authorities attempting to control cultivation of coca, the progenitor of cocaine. Communities in the areas are reportedly 17 times more likely to develop cancer and children are being born with deformities. Each time the crop spraying planes pass overhead, children develop symptoms of pesticide exposure including vomiting, head and stomach pain and diarrhoea. The Ecuadorian researchers claim that these health impacts are directly due to the aerial drifting of pesticides used by their neighbouring country.

Source: *Expreso de Guayaquil*. 22 October 2002, p.11.

'Pesticides are nerve poisons; they damage the brain and they are also known to be endocrine disruptors. Why isn't the research being done now to discover the true effects of pesticides on human health?'

Professor Nicholas Ashford, Massachusetts Institute of Technology[61]

RESPIRATORY DISEASE

In a study of over 20,000 American pesticide applicators, respiratory symptoms of wheezing were associated with paraquat, parathion, malathion and chlorpyrifos (all organophospates) and one thiocarbamate (EPTC)[56]. Excepting malathion, these all had significant dose-related trends. The herbicides atrazine and alachlor were also associated with wheezing[56]. Pesticides have also been associated with significantly-increased likelihood of phlegm, wheezy chest, and flu-like symptoms[57]. In a study of 1,939 farmers, asthma prevalence was significantly-associated with carbamate insecticide use[58], further suggesting that lung dysfunction in exposed farmers can be related to pesticide exposure.

In the United Arab Emirates, pesticide-using farm workers had a significantly-higher prevalence of cough, phlegm, breathlessness, sinusitis, throat discomfort, chronic bronchitis, asthma, and allergic rhinitis (inflammation of the nasal membrane), compared to non-farm workers[59]. Similarly-poor respiratory health was reported from Ethiopian pesticide-using farmers[60].

NEUROLOGICAL DISORDERS

A number of studies show strong associations between pesticide exposure and neurological symptoms, although mechanisms at work are not always clear[62].

Cholinesterase depletion

Some of the neurological effects associated with pesticides are due to their ability to inhibit neurotransmitters, like acetyl cholinesterase (AChE). AChE is a key enzyme functioning in transmission of neurological information across junctions between nerve cells (see page 3). AChE depletion has been positively associated with frequency of pesticide spraying, but negatively associated with use of gloves, overalls, nose and mouth protection, and implementation of health and safety procedures[63].

Neurological symptoms of cholinesterase depletion include many of the effects of acute toxicity (see page 6).

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Avinash, from Palepaddy, in India has cerebral palsy and cannot walk or talk. His village is in a 'hot-spot' where high incidence of neurological disorders has been linked to pesticide exposure[75].

For example, in a case-controlled study in the United Arab Emirates, pesticide-using farmers had significantly higher prevalence than non-farmers of diarrhoea, nausea/vomiting, rash, red/irritated eyes, blurred vision, increased anxiety, dizziness, headache, muscular symptoms, memory loss, drowsiness, fatigue, breathlessness, and insomnia[59].

Symptoms usually occur within hours of exposure and typically decline within days or weeks as new cholinesterase is synthesised. In a study of cholinesterase-depleted termite control operators exposed to chlorpyrifos and other organophospate pesticides, sensory nerve conduction velocities were significantly reduced in nerves in both legs[65]. A study conducted by the Directorate of Hygiene and Sanitation in Indonesia showed that over 35% of 448 Balinese farmers had cholinesterase levels depressed by at least 25% [36].

Sensory threshold

A significant decrease in hand sensitivity among American pesticide applicators suggests previous organophosphate exposure was associated with a loss of peripheral nerve function[66]. A similar study showed a significant difference between subjects exposed to pesticides and control subjects in standard sensory tests – the minimum distance that subjects could discriminate two points on the back of the hand was 22mm for pesticide-exposed farmers compared with 8mm in non-exposed quarry workers[67]. These subtle differences are suggestive of an adverse neurological effect from exposure to organophosphates.

Neuro-psychological performance

In a comparison of 146 sheep farmers exposed to organophosphates with 143 non-exposed quarry workers (controls), the farmers performed significantly worse in tests assessing sustained attention and speed of information-processing; the farmers also showed greater vulnerability to psychiatric disorders[68].

Data from the Maastricht Ageing Study revealed that exposure to pesticides was associated with increased risks of mild cognitive dysfunction[69]. In a study of 917 French vineyard workers, subjects exposed to pesticides scored significantly lower in neuro-psychologic tests[70].

In a Mexican comparison of children exposed to pesticides and those from a nearby non-spraying area, the former demonstrated lower stamina, gross and fine eye-hand coordination, 30-minute memory, and the ability to draw a person[71] (see illustration on opposite page). Numerous other studies have linked pesticide exposure with poor performance in cognitive tests of memory, attention and abstraction[72,73,74].

In a study of Indian workers spraying DDT and malathion regularly, at least half had psychological symptoms, such as anxiety, sleep disturbance, and depression[46]. Twenty percent had impaired-memory and performed simple drawing tests clumsily. Some had retinal damage, blurred vision or saw flashes of light or black dots in front of their eyes[46].

Parkinson's disease

Parkinson's disease is a disorder in which damage to nerve cells in the area of the brain coordinating movement causes a loss of coordination that often appears as tremor, stiff muscles and joints, and/or difficulty moving. Current opinion holds that the disorder is caused by both genetic and environmental factors[76]. Evidence for pesticides being a causal factor comes from both laboratory and epidemiological studies of correlations between pesticide use and Parkinson's disease.

- A study of 2,273,872 Danish men and women revealed statistically-significantly high risks of Parkinson's disease for farmers and for all men in agriculture and horticulture[77].
- In an analysis of 22 previously published studies (11 North American, 5 European, 5 Asian and 1 Australian) there was found to be a significantly-increased Parkinson's disease risk associated with living in rural areas, farming and pesticide exposure[78].
- In a Canadian study of 130 Parkinson's disease patients and 260 control patients, previous occupational herbicide use was consistently the only significant predictor of Parkinson's disease, increasing risk about three-fold. In this study, most herbicide-exposed respondents were old enough to have used herbicides before personal protection became common[79].
- Another Canadian study found that working in orchards or involvement with chemical spraying programmes increased risk of Parkinson's disease[80].
- A Hong Kong survey of residents of homes for the elderly found that living in rural areas for over 40 years, or farming for over 20 years, increased the risk of Parkinson's disease, as did previous use of herbicides and pesticides[81].

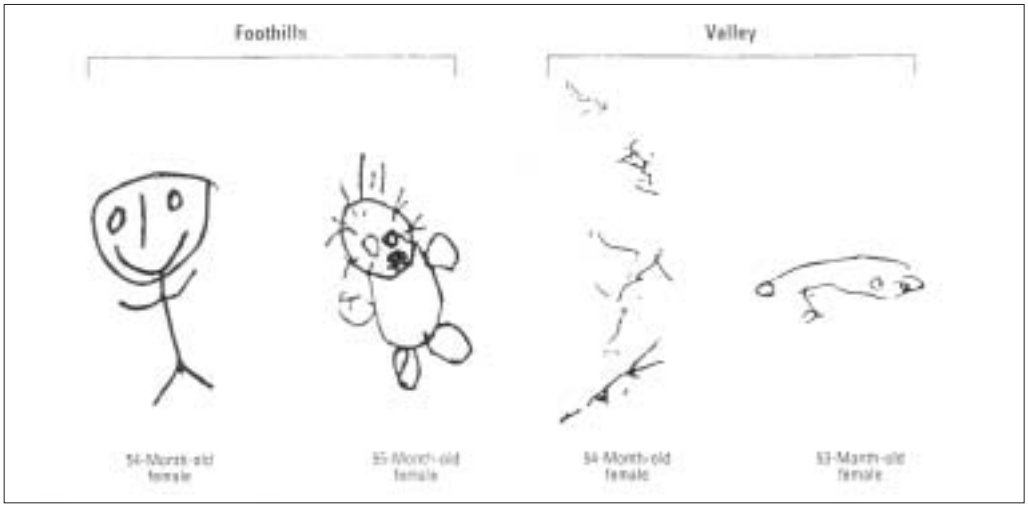
The first strong evidence linking toxins to Parkinson's disease was the appearance of irreversible Parkinson's-like symptoms in the early 1980s in people exposed to a substance called MPTP (a chemical, produced during attempts to synthesise a 'designer drug', which is structurally similar to the herbicide paraquat and other agricultural chemicals). There is direct evidence that paraquat and related chemicals may have similar effects, for example, several days after his hands were in contact with a solution of the herbicide diquat for ten minutes, a patient was reported to have developed a severe Parkinsonian syndrome[82].

Other classes of pesticide have also been identified as possible risk factors. Higher concentrations of the organochlorine insecticide dieldrin have been reported in the brains of Parkinson's disease patients compared to controls[83]. There is also evidence that polymorphism of the enzyme, serum paraoxonase, which is important in the detoxification of parathion, diazinon and chlorpyrifos, may be a factor in determining genetic susceptibility to Parkinson's disease[84]. Rotenone, a plant-derived pesticide, has been shown to cause the symptoms of Parkinson's disease in rats, as well as causing deposits in brain cells that resemble those found in Parkinson's patients[85].

Interactions between different chemicals may be important, as animal experiments have shown that chemicals (e.g. DDC, maneb, heptachlor) that do not themselves cause Parkinsonian symptoms may facilitate damage caused by other agents such as MPTP, for instance, by enhancing uptake[86]. The fact that age is the most important risk factor for Parkinson's disease is consistent with the theory that chronic exposure to low levels of toxins over time may drive a molecular chain of events, eventually leading to Parkinson's disease[87].

Stroke

Stroke is a potentially fatal interruption of the brain's blood supply, due to rupture of blood vessels in the brain. An American mortality study of nearly 10,000 aerial pesticide applicators and a similar number of controls showed that the former had significantly greater risk of stroke[88].



Source: Dr Elizabeth Guillette

Right: Four-year old Yaqui children from Mexico all born within two months of each other were asked to draw a person[71]. In the 'Valley', there is a long history of pesticide use and breast milk has been shown to contain excessive levels of persistent chemicals. Conversely, in the 'Foothills', pesticides have not been used. In all other respects, the two groups of children are similar. The illustrations are representative of those of other children in each location studied[89].

CANCER

Studies of farmers, mostly from industrialised countries, tend to show excesses of non-Hodgkin's lymphoma, melanoma, leukaemia, multiple myeloma and soft tissue sarcoma[90,91]. Cancers of the breast, ovary, lip, prostate, lung, bladder, cervix, brain, kidney, stomach, and sino-nasal cavities have also been frequently observed[90,91]. Cancers of the skin and lip are likely to be linked to increased exposure to UV light, but for the remainder there is evidence (varying in reliability for different cancers) linking them to pesticide exposure. One reason that associations are often difficult to confirm is that farmers use many chemicals, varying according to the crop, etc., and are exposed to other carcinogenic factors such as grain mould and diesel fumes[95]. Studies therefore rarely identify specific chemicals as being responsible.

Causal factors for cancers are in any case difficult to confirm. Onset can occur a long time after exposure to the causal agent. Even establishing the link between smoking and lung cancer took a decade of research, despite the fact that smoking has now been estimated to cause over 90% of lung cancers in the USA[92].

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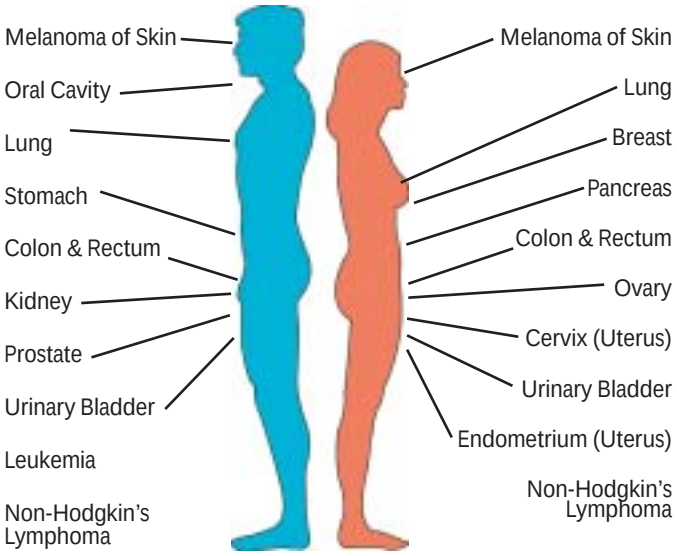
Young cancer victim: This boy from Kerala, India, is one of many in the area whose illnesses have been associated with long-term aerial spraying of the pesticide endosulfan[75].



Some of the cancers linked to pesticide use.

PESTICIDES AND CANCER

Carcinogenesis (cancer formation) involves irreversible alteration of a stem cell, its uncontrolled proliferation and, finally, invasion of other tissues. In this sequence there are various mechanisms by which pesticides may contribute to cancer development. The most obvious mechanism is genotoxicity, direct alteration of DNA turning harmless cells into cancer cells. Even levels of exposure to organophosphates too low to significantly decrease cholinesterase levels increased chromosomal aberrations found in blood samples from farmers[93]. Pesticides thought to cause cancer in this way include the fumigants ethylene oxide and ethylene dibromide[94].

Other pesticides (e.g. DDT) have tested negative for genotoxicity but are carcinogenic in tests on animals. These may be tumour promoters. Several pesticides, particularly the organochlorines, are able to cause fixation and proliferation of abnormal cells. One possible mechanism, suggested for DDT, is inhibition of intercellular communication[95].

Hormonal effects of some pesticides, as described on page 5, may also promote tumours in certain tissues by stimulating hormonally-sensitive cells to carcinogenesis. For example, the herbicide atrazine is generally non-genotoxic (does not directly affect DNA) but it is associated with increased incidence of cancers in sites such as uterus lining and mammary tissue in animal experiments[95]. Recent studies have shown that the incidence of hormone-related organ cancers, or hormonal cancers, is elevated among farmers[16], with exposure to endocrine-disrupting pesticides, particularly to DDT and phenoxy herbicides, suspected of involvement in some of these cancers.

Another way in which pesticides may promote cancer is through immunotoxic effects, disturbing the body's normal cancer surveillance mechanisms. Organophosphates, for example, can inhibit serine esterases, critical enzymes in the immune system's T-lymphocytes and natural killer cells[95].

Brain cancer

Pesticides have been shown to induce brain tumour formation in animals[96] and there is increasing evidence of a similar role in humans. Statistically-significant excesses of brain cancer mortality were observed among 2,310 Italian pesticide licence holders[97], and among French vineyard workers, for whom significant links with pesticide exposure were documented[98]. Brain tumour risks among Chinese women have also been linked to pesticide exposure[99]. A 1998 meta-analysis concluded that there were consistent significant positive findings suggesting an association between brain cancer and farming and that exposure to pesticides may contribute to increased brain cancer risks[100]. In a study of Swedish market gardeners and orchardists, tumours of the nervous system were in particular excess in the young and middle-aged horticulturists; the risk for brain tumours in the young and middle-aged subjects was increased about three-fold among gardeners, and about five-fold among orchardists; in particular, meningiomas (tumours of the tissue surrounding the brain and spinal cord) were in excess among the gardeners[101].

Cancer incidence was studied among Norwegian offspring of parents engaged in agricultural activities, and it was found that indicators of pesticide-use were associated with brain tumour risk[102]. When 17 studies were reviewed, nine found significantly-elevated risks of childhood brain cancer associated with pesticide use, and five showed elevated risks that were not statistically significant[43].

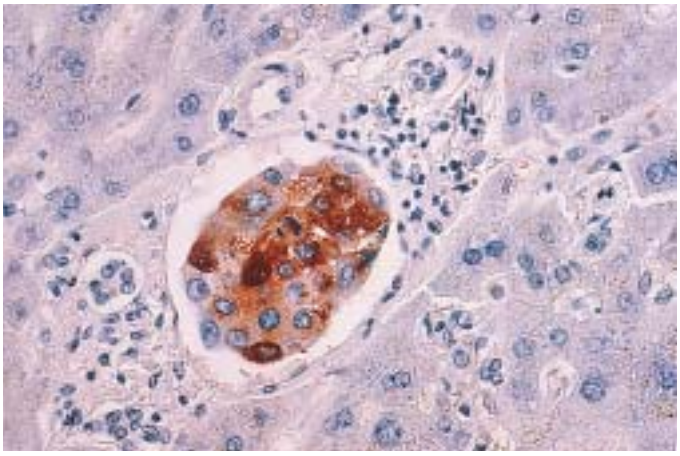
Breast cancer

Breast cancer has been estimated to have increased in incidence by 1% annually since the 1940s in the USA, and increased by 50% in Denmark from 1945 to 1980[103]. Excess breast cancer risks have been noted in a number of occupations and industries, notably those that entail exposure to solvents and pesticides, particularly crop farmers and the fruit/vegetable industry[104]. An American study showed that, among women farmers, breast cancer risks were elevated for women present in fields during or shortly after pesticide application, but not among those who reported using protective clothing[105].

A meta-analysis of data from eight industrial countries showed a weak association between breast cancer and farming.[16] DDT can support the growth of oestrogen-dependent tumours in rats[106]. However, most case-control studies since 1996 have failed to confirm earlier observations of a significant positive relationship between levels of DDT and DDE (a DDT breakdown product) to breast cancer risk[107]. Studies in Colombia[108] and Mexico City[109] have supported an association with breast cancer and there is a need, therefore, for more studies in countries where DDT is still widely used[107].

Liver cancer

In a study of 168 Italian pesticide applicators engaged in pest control for an average of 20 years, an increased risk of liver cancer was observed in those exposed to organochlorine pesticides between 1960 and 1965[110].



© National Cancer Institute

Space invader: breast cancer cells infiltrating the liver.

DDT is of interest as a possible cause as it has been shown to produce liver tumours in animal studies[111]. A study of 1975-1994 age-adjusted mortality rates from various cancers showed that liver cancer mortality increased significantly with adipose DDE levels in both sexes among white Americans, but not among African Americans[112].

Hepatic angiosarcoma is a very rare liver tumour, previously associated with the use of arsenic in vineyard spraying in Europe. Between 1980 and 1984, at the Ain Shams University Hospital in Egypt, 14 people were diagnosed as having hepatic angiosarcoma, a much higher incidence than expected. Ten of these had a definite history of direct and recurring exposure to agricultural pesticides[113].

Stomach cancer

In Italy, stomach cancer was elevated among farmers and licensed pesticide users with over 10 years' experience, significantly so in the case of the farmers; nitrosable pesticides and nitrate fertilisers were suggested as possible factors[114].

Bladder cancer

Fruit farming was found to be associated with an increased risk of colon and bladder cancer, which may be due to use of mildly-refined mineral oils as insecticides[115]. Bladder cancer is generally found to be slightly reduced among farmers, but some studies have shown that there may be a slight excess if the effect of smoking is removed[116]. A significant link between bladder cancer and exposure to pesticides was revealed in a study of French vineyard farmers[117].

Kidney cancer

In Italy, kidney cancer significantly increased among the farmers with over 10 years' experience, particularly in those associated with potato and olive farming[114]. Pesticide exposure has also been linked to renal cell carcinoma (a malignant kidney tumour) in Canada[118].

Skin cancer

Farmers exposed to arsenic pesticides are at risk of occupational skin cancer - mostly 'Morbus Bowen' (carcinoma *in situ*), multiple basal cell carcinomas and squamous cell carcinomas[119].

Prostate cancer

Prostate cancer appears to be elevated among farmers and evidence exists for relationships between use of pesticides and other agricultural chemicals and prostate cancer risk[120,121]. In Canada, a weak but statistically-significant association was found between the number of acres sprayed with herbicides in 1970 and risk of prostate cancer mortality[122]. A Swedish cohort study of 20,025 pesticide applicators found an increased risk of prostate cancer[123]. Another Swedish study reported an increased risk for men in agriculture-related industries[124].

Rectal cancer

In Italy, rectal cancer increased among licensed pesticide users with over 10 years' experience[101]. Rectal cancer was also associated with pesticide use by an Icelandic study.[125] In an Egyptian study, colo-rectal cancer patients had higher levels of serum organochlorines such as DDE and DDT than controls did[126].

Pancreatic cancer

Associations between pesticide exposure and pancreatic cancer have been revealed in studies from Spain[127], Italy[114], and the USA[88,128]. Increased prostate cancer risks related to pesticide exposure have been suggested in a number of other epidemiologic studies, including one which found excess risks for occupational exposure to fungicides or herbicides rather than insecticides[129]. Among chemical manufacturing workers, a significantly increased risk of prostate cancer was found with DDT exposure[130].

Lung cancer

Farmers tend to have lower risks of contracting lung cancer than the general population as they are less likely to smoke[95]. Studies on workers in other occupations exposed to pesticides, for example, pest control workers[131], and pesticide-production workers[132,133] have shown increased risks. Also, where studies on farmers have controlled for the effect of smoking, lung cancer excesses have been found[134,135]. Various chemicals have been implicated. A Uruguayan study showed exposure to DDT to be a factor increasing lung cancer risk[136]. A study of pest control workers in Florida (USA) found lung cancer to be associated with carbamates, organophosphates, and phenoxyacetic acids and more specifically with DDT, diazinon, carbaryl, and propoxur[131].

Ovarian cancer

There is some evidence linking pesticide exposure and ovarian cancer, but findings are inconsistent[16]. Italian research showed an association between exposure to triazine herbicides and ovarian cancer[137].

Testicular cancer

Developed countries have experienced dramatic increases in testicular cancer in the last 50 years[138]. Farming was found to significantly increase risk of embryonal testicular cancer in a study of occupational exposures[139], and (non-statistically significant) associations have also been found in other studies[16]. It has been hypothesised that testicular cancer is linked with urogenital malformations such as cryptorchidism and hypospadias (see page 16), along with deterioration in semen quality, and that hormone-disrupting chemicals may be the cause of the increase in these conditions[138].

Soft tissue sarcomas

These are cancers of soft tissues such as muscles, tendons, fat tissue, blood vessels and nerves. They have been widely associated with pesticide exposure, especially the phenoxy herbicides and their contaminant TCDD[140,141,142]. In Denmark, incidence was also found to be higher than normal among gardeners[143].

Multiple myeloma

Multiple myeloma is a cancer affecting white blood cells called plasma cells. In patients with multiple myeloma, cancerous cells occur in the bone marrow, the site of blood cell production. Here, tumours can develop that weaken the bones. Additionally, there is over-production of plasma cells, which normally produce antibodies to help fight disease but which, in the malignant form, harm the immune system.

Multiple myeloma prevalence has been shown to be elevated among farmers in France[144], Sweden[145], and the USA[146]. Indeed, a meta-analysis of 32 peer-reviewed studies of multiple myeloma published between 1981 and 1996 showed consistent, significant associations between farming and multiple myeloma, with pesticides considered to be one of the key contributory exposures[147]. In Norway, multiple myeloma was associated with pesticide indicators for both genders[148]. A study of herbicide applicators in the Netherlands found significantly elevated rates of multiple myeloma[149]. Phenoxyacetic acids and DDT-based pesticides were indicated as risk factors in Sweden[145], and chlorinated insecticides were implicated in Italy[150].

Leukaemia

Leukaemia is a cancer of bone marrow, where blood cells are formed, and results in production of abnormal white blood cells. There is evidence for leukaemia in both adults and children being linked to pesticide exposure. A 1995 review concluded that there was a weak association between farming and leukaemia, with pesticides a likely risk factor[151]. Incidence of chronic lymphatic leukaemia (the commonest form of leukaemia) was significantly increased among gardeners in Denmark[143]. A review of 18 studies found that the evidence supported a possible role of pesticides in childhood leukaemia[43]. Most studies reported increased risks among children whose parents were occupationally-exposed to pesticides or who used pesticides in the home or garden. Some studies were able to show increased risks with greater exposure, for example, in one study, children exposed to pesticides once a week, once to twice a week and on most days, had increased risks of 80%, 100% and 250%, respectively[152]. Statistically-significant associations between leukaemia mortality and pesticide exposure have been found among French farmers[144], and American aerial pesticide sprayers[88].

Hairy cell leukaemia is a very rare form of leukaemia. Studies have shown increased risk among farmers[153] and the disease has been linked specifically to pesticide exposure[154,155]. One study suggests a link with organophosphate rather than organochlorine insecticides[156].

Non-Hodgkin's lymphoma

Lymphomas are cancers originating in the lymphatic system. A lymphocyte (a type of white blood cell) becomes cancerous and tumours are formed, which enlarge the lymph nodes and other sites in the body. One type is known as Hodgkin's lymphoma, or Hodgkin's disease, while the remaining forms are grouped together as 'Non-Hodgkin's Lymphoma' (NHL). NHL incidence has been increasing rapidly. In the USA, age-adjusted incidence rose by 80% from 1973 to 1997, an annual percentage increase of nearly 3%, and is now the fifth most common cancer there[157]. Global incidence has also risen[158], even when adjusted for HIV, which is a causal factor.

A substantial body of evidence supports the hypothesis that there is an association between NHL and exposure to pesticides[159,160,121]. For example, use of organophosphate pesticides was associated with a statistically-significant 50% increased risk of NHL among American farmers[161]. A significant association was found for exposure to herbicides and pesticides with 1,469 NHL patients and 5,073 controls in Canada[162]. Incidence was increased among gardeners in Denmark[143]. In a study in Germany, residential use of insecticides was associated with childhood NHL[163].

While small increases in risk of NHL among farmers have been observed in general occupational surveys, considerably larger risks have been revealed in recent studies focusing on specific pesticides. For example, frequent use of phenoxyacetic acid herbicides (in particular, 2,4-D), has been associated with 2 to 8-fold increases of NHL in studies conducted in Sweden, USA, Canada, and elsewhere[164]. The US government committee responsible for assessing health consequences of Vietnam veterans' exposure to herbicides and their contaminants concluded that for non-Hodgkin's lymphoma, Hodgkin's disease and soft-tissue sarcoma there was sufficient evidence of an interaction[165].

A Canadian study revealed statistically significant increases in NHL risks with exposure to herbicides, carbamate and organophosphate insecticides, and amide fungicides[166] – specific chemicals associated with NHL were herbicides (2,4-D, mecoprop, and dicamba), insecticides (malathion, carbaryl, lindane, aldrin), and fungicides (captan and sulphur compounds).

In another US study, compared to non-farmers, farmers who had ever used carbamate pesticides had a 30-50% increased risk of NHL, whereas farmers without carbamate pesticide use showed no increased risk[167]. In an American study of NHL, elevated risks were found for personal handling, mixing, or application of several pesticide groups and for individual insecticides, including carbaryl, chlordane, dichlorodiphenyltrichloroethane, diazinon, dichlorvos, lindane, malathion, nicotine, and toxaphene[168]. Other chemicals implicated in other studies include dieldrin, atrazine and fungicides; organophosphates in general (and diazinon in particular), and organochlorines, including DDT, chlordane and dichlorvos[166,169,161].

IMPACTS ON FERTILITY

Evidence exists that exposure to pesticides can affect both male and female fertility and reproductive outcomes. The suggested mechanism of action is pesticides' ability to interact with steroid hormones' receptors, in particular those for oestrogens and androgens[170]. Many studies have shown declining sperm counts in the USA and Europe[171], and there has been concern in industrialised countries that this may be due to the effects of pesticides and other endocrine-disrupting chemicals in the environment. Recent research has shown that mouse sperm bathed in low levels of oestrogenic chemicals mature too rapidly, making them unable to fertilize the egg cell[172].

Dutch research showed that for partners of men highly exposed to pesticides, time to pregnancy may be longer; and female-biased sex ratios of babies can occur[173]. Another Dutch study showed that in couples in which the man had been exposed to pesticides, fertilisation rates were nearly four times lower than for non-exposed couples[174].

In a study of greenhouse workers, sperm concentrations and proportions of normal sperm were significantly lower in men with high pesticide exposures than those with low-level exposures[175]. Another study of male greenhouse workers with high exposure to pesticides revealed an increased risk of conception delay compared to controls[176], and male workers in cotton fields in India exposed to pesticides were at greater risk of infertility[177].

Half of the semen samples collected from 97 Ontario farmers who had recently used the phenoxy herbicides 2,4-D and/or MCPA had detectable levels of 2,4-D [178]. A study of agricultural workers found significant associations between organophosphate metabolite concentrations and increased frequency of sperm found to contain an abnormal number of chromosomes (thus, organophosphate exposure could interfere with sperm chromosome segregation and increase risks of genetic syndromes, such as Turner's syndrome)[179].

Sperm fertilising an egg. Pesticides are thought to impact both male and female fertility.

'In 1993, 44 children were born with congenital malformations in the Curicó Regional Hospital [Chile]. The same thing happened to a large proportion of children in 1994. Almost all the parents of these children had been exposed to pesticides, due to the fact that they worked in fruit orchards, packing plants, or lived close to them'

Dr Norman Merchak, Director, Curicó Regional Hospital, Chile[180]

DEVELOPMENTAL DISORDERS

Many pesticides are thought to be endocrine disrupters, capable of disturbing hormone function (see page 5). Growing evidence suggests that endocrine disrupters interfere with reproductive function at low exposure levels and can cause distinct effects at different concentrations within the same organ[30]. Interference with sex hormones can result in a variety of developmental and reproductive anomalies. For example, breast development occurs up to four years earlier among Yaqui girls exposed to pesticides in Mexico compared to those living nearby but without pesticide exposure[89].

There is also considerable evidence linking pesticide exposure to birth defects and to spontaneous abortions.[181] This is associated with foetal vulnerability to disruption of hormone levels, nervous system function, etc., especially during brief but critical periods in early development.[40] For example, new evidence suggests that acetylcholinesterase may have a direct role in nervous system differentiation, and therefore exposure to certain cholinesterase-inhibitors during brain development could have serious permanent effects.[182]

A review of epidemiological studies on paternal occupation and birth defects, showed that agriculture-related paternal occupations were repeatedly reported to be associated with birth defects. Possible mechanisms include mutagenic damage to sperm DNA and household contamination by substances brought home by fathers.[183]

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Shruti, a young Indian girl, whose severe congenital deformities have been linked to pesticide exposure[75].

Urogenital malformations

Pesticide exposure has been linked to cryptorchidism (failure of testicles to descend) and hypospadias (when the urethra opens on the underside of the penis)[184]. Significantly-higher levels of two organochlorine compounds, heptachloroepoxide (HCE) and hexachlorobenzene (HCB) were found in children with undescended testes[185], and an increased risk has also been found in sons of women in the gardening industry, which could suggest an association with pre-natal exposure to occupationally-related chemicals[186]. Cryptorchidism as well as carcinoma *in situ*-like testicular lesions have been seen in male rabbits treated during development with p,p'-DDT or p,p'-DDE, while in rats' foetal concentrations of p,p'-DDE have been found to be correlated with reproductive abnormalities in male offspring, including hypospadias and cryptorchidism[187].

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Indian baby, born with hydrocephaly in an area of Kerala heavily-sprayed with endosulfan. The use of this pesticide has been linked to high rates of birth defects in this area[75], and hydrocephaly has been specifically linked to pesticide exposure[184]. The child died shortly after this photo was taken.

Other birth defects

A study of offspring of Norwegian farmers found moderate risk increases for spina bifida and hydrocephaly, risks being strongest for exposure to pesticides in orchards or greenhouses[184]. Exposure to pesticides has also been associated with limb reduction defects[184]. In a study of 990 births in California, limb reduction defects occurred 3 to 14 times more frequently among the offspring of farm-workers than in the general population[188]. Two studies have shown limb reduction defects (when combined with other anomalies) to be associated with either agricultural work of parents, living in an agricultural area or occupational pesticide exposure[189,190].

Chlorpyrifos has been linked to births of children with deformed heads, faces, eyes and genitals[191]. Endosulfan has been linked to large numbers of serious birth defects in the Indian state, Kerala[192]. In a study of the risk of

congenital malformations in Spain, mothers involved in agricultural activities during the month before conception and first three months of pregnancy had an increased risk overall, mainly due to an increased risk for nervous system defects, oral clefts, and multiple anomalies[193].

The birth defect rate for all birth anomalies pooled was significantly increased in children born to private pesticide appliers in Minnesota[194]. For both appliers and the general population, the lowest rate occurred in non-crop regions and the highest in western Minnesota (a major wheat, sugar beet, and potato growing region) where birth defect rate was highest for babies conceived in the spring[194]. Specific birth defect categories, circulatory/respiratory, uro-genital, and musculo-skeletal/integumental, showed significant increases both for pesticide appliers overall, and for the general population in western Minnesota. In addition, there was a significant increase in central nervous system anomalies in the latter[194].

Miscarriage and stillbirth

In a Polish study, a significant increase of miscarriages associated with exposure to agricultural pesticides was observed[195]. In Canada, moderate increases in risk of early spontaneous abortions following pre-conception exposures to herbicides were reported, whilst late abortions were associated with pre-conception exposure to glyphosate, thiocarbamates, and a miscellaneous class of pesticides[196]. Pesticide exposure has been implicated in 22% of hospital stillbirths in Sudan[197], where a consistent, significant association between pesticide exposure and peri-natal mortality was found, risks being 50% greater for exposed women[198]. In another study, occupational exposure to pesticides during the first six months of pregnancy was found to increase risk of stillbirths and neonatal deaths five-fold[199].

Maternal residential proximity to pesticide applications in California was found to increase risk of late foetal death due to congenital anomalies[200]. In another Californian study, occupational exposure to pesticides during the first two months of gestation was positively associated with stillbirths due to congenital anomalies, and in the last six months with stillbirths due to all causes of death[201]. Home pesticide exposure was positively associated with stillbirths due to congenital anomalies[201].

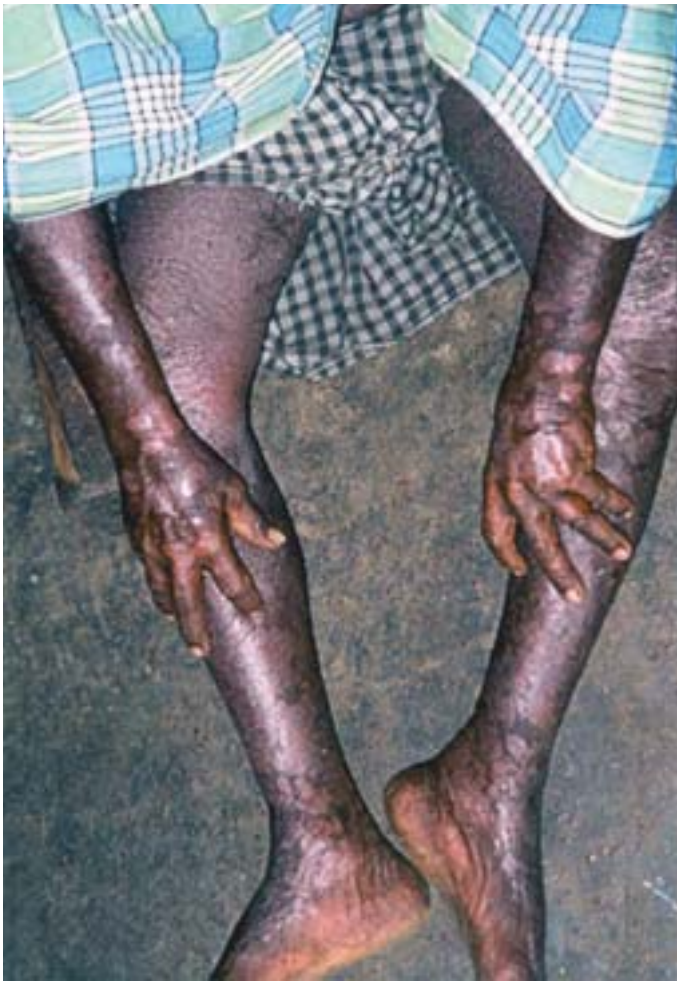
In a US study, maternal serum DDE concentrations were found to be higher for pre-term births and babies small for gestational age[202]. Serum DDE levels in female Chinese textile workers were found to be associated with spontaneous abortion, which is the most common adverse pregnancy outcome, affecting around 15% of clinically recognized pregnancies[203]. Other studies have also suggested that maternal and foetal tissue levels of DDT and its metabolites are higher in foetal deaths than normal pregnancies[204].

SKIN DISEASES

The majority of non-toxic diseases related to pesticide use are dermatoses, with most being contact dermatitis, both allergic or irritant[119]. For example, contact dermatitis related to pesticide exposure is a significant health problem for banana workers in Panama[205]. Rare clinical forms also occur, including: urticaria, erythema multiforme, ashy dermatosis, parakeratosis variegata, porphyria cutanea tarda, chloracne, skin hypopigmentation, and nail and hair disorders[119].

Of 122 Taiwanese pesticide-using farmers, c. 30% had hand dermatitis, and more than two-thirds had pigmentation and thickening on the hands. Fungal infection of the skin was noted in a quarter of subjects. Captafol, folpet, and captan were associated with dermatitis on hands[206].

In the United Arab Emirates, pesticide-using farm workers had a significantly higher prevalence of skin pruritus (tinea, contact dermatitis) and eczema, compared to non-farm workers[59]. Eczema was also common symptom recorded in cases of pesticide exposure in Finland's Register of Occupational Diseases[207].



This Indian farmer's skin betrays years of direct exposure to pesticides.

DOUBLE TROUBLE: IMMUNOTOXICITY

Studies have shown that pesticides can alter the immune system, suppressing normal immune system responses, and reducing resistance to bacterial, viral and other infections[35]. Ten of the twelve persistent organic pollutants identified by the United Nations Environmental Programme as posing the greatest threat to humans and wildlife, are pesticides; all have been reported to alter immune function under laboratory conditions[208].

A recent review concluded 'Although a great deal of data are available from animal studies which show that pesticides are immunosuppressive, there is no good evidence *at this time* [italics in original] for immune suppression in the general population as a result of environmental exposure' [209]. One reason that effects of pesticide exposure are difficult to study is that there are so many variables affecting human immune function, including effects of illness itself.

Despite this, several persuasive studies show that immune system effects may be seriously underestimated consequences of pesticide exposure[36]. For example, among Indian factory workers chronically-exposed to pesticides, blood lymphocyte levels had decreased by as much as 66% – in a group asked to take time off from work experimentally, immune parameters returned to normal within three months[210]. Immune system abnormalities have been observed among farm workers in the former Soviet Union, where pesticides were used heavily[35]. A comparison of pesticide-exposed children with non-exposed controls revealed significantly higher rates of infectious disease in the exposed children[211].

An important link is that the cells of the immune system defend the body against cancer by destroying potentially cancerous cells. People whose immune systems are depressed (e.g. through taking immunosuppressive drugs after transplants) are at higher risk of certain cancers, including non-Hodgkin's lymphoma, leukaemia, stomach cancer, soft tissue sarcomas, melanomas and squamous carcinomas of the skin and lip[36]. This list shows striking similarity to the list of cancers often found in excess among farmers (see page 12), a group that has a *lower* cancer risk overall compared to the general population[95]. A possible mechanism suggested is that organophosphates may promote cancer by inhibition of serine esterases, critical proteins enabling destruction of cancerous cells[95].

Endocrine-disrupting chemicals are also linked to immuno-stimulation, resulting in hypersensitivity, which may present as auto-immune diseases, asthma, allergies and flu-like symptoms[211]. The most common of such reactions in humans are allergic reactions, especially acute dermatitis[209].

GENETIC HAZARDS

There is concern that pesticides can induce mutations in those exposed to them. Studies have shown that farmers exhibit greater numbers of sister-chromatid exchanges per chromosome (a sensitive test for damage to DNA)[212]. These variables were also high among farmers who prepared more than 70% of pesticides themselves, who conducted more that 7.4 sprays per year, or who had been exposed to pesticides for over 21 years. Another study showed that a one-day spraying period seems to be sufficient to significantly-modify DNA damage levels in mononuclear leukocytes (a type of blood cell), but the correlation of this change with pesticide-related exposure parameters depends on the pesticide concerned[213]. In a study of Costa Rican farmers exposed to pesticides, data showed that they had consistently higher frequencies of chromosome aberrations and significantly more abnormal DNA repair responses than control individuals[214].

OTHER DISEASES

A French study found relationships between pesticide exposure and myelodysplastic syndromes[215], a group of disorders in which the bone marrow overproduces cells that fail to mature normally. The only curative therapy is bone marrow transplantation.

Impaired thyroid gland function has been recorded in pesticide formulators exposed to liquid and dust formulations of endosulfan, quinalphos, chlorpyrifos, monocrotophos, lindane, parathion, phorate, and fenvalerate[216].

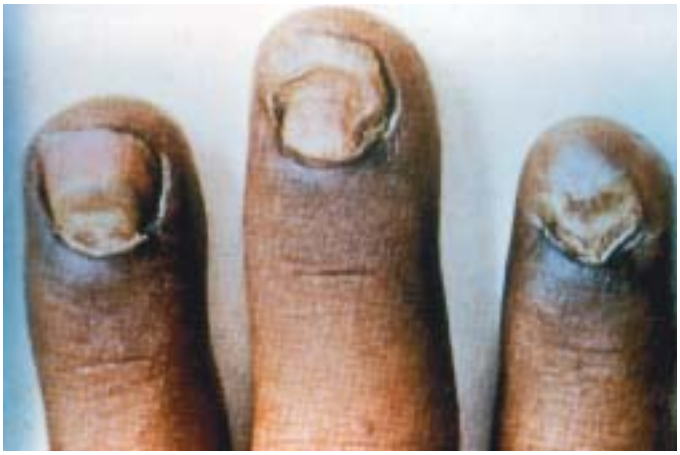
Aplastic anaemia is a rare, and often fatal, disease where bone marrow stops making enough blood cells. A review found 280 cases had been reported in the literature as being associated with pesticide exposure, with both organochlorines and organophosphates implicated[217]. In Thailand, a significantly increased risk was found for grain farmers and those exposed to pesticides[218].

Family business: Throughout the developing world, farmers' children are regularly exposed to dangerous pesticides.

IPM and Self-Surveillance of Farmer Health

When farmers assess their own health in relation to pesticide use, they rapidly become aware of the link between exposure and subsequent illness. In a recent Vietnamese study in which 50 farmers reported signs or symptoms of poisoning for a full year, 31% of spraying operations were followed by at least one clearly-defined sign or symptom of pesticide poisoning and 61% were associated with ill-defined effects[219].

Initiatives promoting self-surveillance have resulted in reductions in pesticide use and in reduced incidence of poisoning. Following self-reporting, the Vietnamese farmers in the above study reduced cases of moderate poisoning by limiting their use of WHO Class Ia / Ib products and the use of organophosphates in general[220].



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Skin deep: Fingernails damaged by pesticide exposure.

Such self-surveillance studies are now underway or planned in Cambodia, Thailand, Sri Lanka and India[220]. They are being implemented in association with Integrated Pest Management (IPM) programmes as a Health Component of the FAO Programme for Community IPM in Asia. IPM is a system of crop protection that encourages natural pest control through reduced use of chemical pesticides (for more information about IPM, see EJF's report on pesticide problems and solutions in Cambodia[3]).

School children and farmers also conduct one-time cross-sectional studies in their communities. Primary schools in Thailand that have IPM as part of their science curriculum have conducted studies in their farming communities. Through presentation of their results, they educate their parents on the hazards of pesticide use and encourage use of non-chemical alternatives. When Cambodian farmers enter IPM farmer field schools, they conduct a self-inventory health survey to assess their own risks and experience with acute pesticide poisoning. This serves as a strong motivation to learn IPM methods to raise crops without hazardous chemicals. Farmer field school graduates in Indonesia have conducted surveys among their fellow farmer colleagues as a means to recruit new farmers into IPM. Vietnamese farmers used the health surveys to evaluate the impact of IPM among 480 farmers in three provinces.

Putting health studies in the hands of farmers to directly raises awareness of health risks associated with pesticide exposure. Furthermore, it empowers farmers to develop their own personal pesticide policies.

See http://www.communityipm.org for more information on these initiatives.

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Food for thought: Folidol (methyl-parathion) is classed by the WHO as 'extremely hazardous to human health' and is banned in Cambodia but imported illegally from Thailand. Here it is seen on sale in a Cambodian shop (above), labelled in Thai, alongside chilli sauce and other foods. Ratifying the Rotterdam Convention would help Cambodia and other developing countries to eliminate this obvious health hazard.

PIC & The Rotterdam Convention

The Rotterdam Convention on the Prior Informed Consent (PIC) Procedure for Certain Hazardous Chemicals and Pesticides in International Trade was finalised in 1998. It allows importing countries to publish decisions to exclude chemicals they cannot manage safely. Currently, 31 chemicals are covered by the Convention (21 pesticides, 5 industrial chemicals and 5 severely hazardous pesticide formulations). It will enter into force after the 50th ratification (by January 2003 there were 73 signatories and 36 parties to the Convention).

The Rotterdam Convention is particularly relevant to developing countries, which are often unable to fully control patterns of pesticide use within their borders. By ratifying this Convention and completing decision documents about the chemicals it covers, such countries can signal to the international community resolutions not to receive certain chemicals considered to present danger to human health. More information on the Rotterdam Convention can be found at http://www.pic.int.

conclusions and recommendations

PESTICIDES ARE POISONS. In addition to the well-documented symptoms of acute over-exposure, there is a growing body of compelling evidence linking long-term effects of pesticide exposure to diseases of the nervous system, reproductive disorders, birth defects and elevated risks of cancer. The risk of such diseases is particularly high in developing countries where pesticide misuse is common and where basic safety precautions are not adopted.

The Food and Agriculture Organisation of the United Nations (FAO) recommends that World Health Organisation Class Ia, Ib and, preferably II, pesticides should not be used in developing countries. However, such chemicals remain widely available in these countries. The safe disposal of hazardous pesticides remains an immense challenge; Africa alone is thought to have 120,000 tons of obsolete pesticide stocks[219].

The FAO's Code of Conduct on the Distribution and Use of Pesticides, provides standards aimed at reducing the risks associated with pesticide use. However, the Code's standards are not always met, with shortcomings regarding pesticide labelling, advertising, and product stewardship in particular[220]. The Code of Conduct needs to be strengthened with regard to measures aimed at protecting human health and more effective monitoring of its implementation is required.

Not only are dangerous chemicals widely available in developing countries, but they are used under conditions which elevate the health risks documented in this report. Users remain largely uninformed of the dangers of pesticide exposure and poor practice is widespread. In light of this, we make the following recommendations to governments, the agrochemical industry, inter-governmental agencies, the international donor community and other interested parties.

© FAO

Obsolete pesticides poorly stored in rusting containers in Mozambique.

General Recommendations

In light of the information presented in this report, all relevant parties should:

- Explicitly acknowledge the health threats posed by current patterns of pesticide use, especially in developing countries.
- Call for a phase-out of World Health Organisation Class Ia and Ib pesticides.
- Raise awareness of these problems and how they can be avoided, through well-funded, extensive education programmes.
- Promote better agricultural practice based on reduced use of, reduced risk from, and reduced reliance on pesticides.
- Ensure that the 'farmer first' principle is applied by facilitating the availability of all relevant information on pesticide issues to agricultural workers.
- Acknowledge the threat posed by 'cocktail effects' of mixing pesticides.
- Press for stronger codes of conduct on pesticide use and for widespread adoption and surveillance of implementation.
- Conduct research to further document the extent of pesticide-related health problems.
- Lobby governments and the agrochemical industry to implement measures to reduce pesticide-related health risks.
- Promote organic agriculture.

The Health Sector

The health sector, including governments' health ministries, the World Health Organisation, and local and international non-governmental organisations should:

- Establish national poisoning surveillance centres to monitor the occurrence of pathological exposures to pesticides.
- Modify pesticide risk assessment procedures to take greater account of conditions of use in developing countries.
- Conduct coordinated research into the current extent of pesticide poisoning worldwide.

- Train health sector staff in symptom recognition.
- Engage in farmer, trader and consumer education about the health risks associated with pesticide misuse.

The Agrochemical Industry

Under present conditions in many developing world nations, safe use of pesticides cannot be guaranteed. Pesticide formulators have the financial power to reduce the health risks posed to the poor farmers using their products. The agrochemical industry should:

- Phase-out production of WHO Class Ia and Ib chemicals.
- Apply the same best practice standards in developing countries as are required in industrialised nations throughout pesticide products' entire lifespans.
- Include dyes in all powder formulations to discourage accidental consumption.
- To improve transparency, disclose *all* products and formulations they handle. Such information should be readily available to the public.
- Disclose comprehensive lists of the countries where each product they handle is manufactured, formulated, stored and sold.
- Fully disclose all 'inert' ingredients on pesticide packaging. Intellectual property arguments for non-disclosure are untenable when there is even a small risk that safety might be compromised by failure to provide full information about the exact contents of each product.
- Ensure that all pesticide packaging *and* advertising bears an explicit written health warning, of size and wording deemed appropriate by an independent third party, as is required for cigarette packaging in most countries.
- Pledge a significant percentage of annual profits towards funding efforts to inventory and dispose of obsolete pesticides in developing countries.
- Implement pesticide container 'buy-back' schemes in developing countries.

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Balancing act: Reducing health risks associated with pesticide use in developing countries can be achieved without impacting food security

All concerned parties should encourage farmers to adopt the following measures to protect their health, if pesticide use cannot be avoided:

- Wash (preferably bathe fully) after using pesticides.
- Do not allow children to spray crops.
- Do not mix pesticides unless the products specifically recommend combination.
- Do not eat, drink or smoke during or immediately following the handling of pesticides.
- Change and wash clothes immediately after spraying crops.
- Store pesticides out of reach of children and away from food.
- Do not use containers for mixing pesticides for any other purpose.
- Wear gloves, shoes and a mask when mixing or applying pesticides.
- Avoid handling pesticides whilst pregnant or breast-feeding.

The International Donor Community and Governments of Industrialised Countries

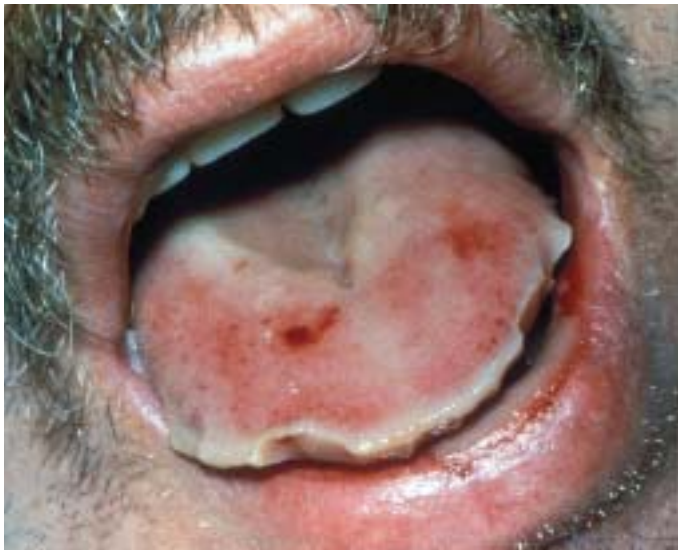
In order to tackle the health problems caused by pesticides, developing countries require considerable financial and technical assistance. The international donor community should:

- Assist efforts to inventory and dispose of obsolete pesticide stocks safely.
- Support mass education about the dangers of pesticide misuse, and of the alternatives.
- Promote organic agriculture wherever possible.
- Promote ratification and implementation of the Rotterdam and Stockholm Conventions, and provide funding to meet objectives.
- Provide assistance to allow countries to monitor pesticide residues on food and in the environment.
- Act immediately, in collaboration with the agrochemical industry to prevent the dumping of prohibited or obsolete stock, imposing far stronger penalties and dedicating substantially increased resources toward enforcement, and making details of such new initiatives fully available.
- Make available extra funds for the widespread inclusion of health components into IPM programmes.
- Undertake studies of health impacts and economic consequences of pesticide use, and support exchange of information for medical practitioners.

Developing Countries' Governments

Although pesticides are equally toxic world-wide, their availability and use is more stringently regulated in industrialised nations. The governments of developing countries, where most pesticide poisonings occur, should:

- Specifically seek donor assistance to tackle pesticide problems.
- Develop and enforce laws to control use and availability of dangerous chemicals.
- Prohibit the use of pesticides by children.
- Sign, ratify and implement international treaties aimed at reducing threats posed by pesticides (e.g. the Stockholm Convention and Rotterdam Convention).



This person accidently swallowed paraquat concentrate, severely damaging his tongue and mouth.

Strengthening Codes of Conduct

There exist a number of national and international codes of conduct or similar regulatory frameworks established in part in an attempt to reduce the health threats posed by pesticides. For example, the Food and Agriculture Organisation of the United Nations has a Code of Conduct on the Distribution and Use of Pesticides that establishes voluntary standards for governments, the agrochemical industry and other relevant parties.

In order to better protect human health from pesticides, such codes of conduct need to be strengthened. Incorporating some of the recommendations made in this report, particularly those directed toward the agrochemical industry, would help achieve this.

glossary

Acetylcholine: An important neurotransmitter (chemical which transfers signals between nerve cells)

Acute toxicity: Symptoms of poisoning develop in close relation to a single exposure to a high dose of the chemical during a short time period.

Androgens: A group of steroid hormones which develop and maintain male secondary sexual characteristics, e.g. testosterone.

Carbamates: A class of chemical compounds, among which are several insecticides which act as nerve poisons, inhibiting cholinesterase

Carcinogen: An agent which tends to cause cancers or tumours

Chloracne: An acne-like skin disorder caused by exposure to chlorinated chemicals

Cholinesterase inhibitors: These chemicals inhibit the enzyme cholinesterase, which is vital for the proper functioning of the nervous systems of both humans and insects. Chemical signals are rapidly passed between nerve cells by chemicals called neurotransmitters, one of which is acetylcholine. Cholinesterase ends each signal by breaking down acetylcholine, but cholinesterase inhibiters prevent this, and acetylcholine builds up causing a 'jam' in the nervous system. This can cause a wide range of symptoms, depending on the dose absorbed.

Chronic toxicity: Symptoms are produced after the person has been repeatedly exposed to low levels of toxic agents over a long period. Effects such as cancer may appear a long time after exposure to the agent has ceased

Congenital: Present at birth

Cryptorchidism: One or both testicles fail to descend into the scrotum during the infant period. This condition has been associated with testicular cancer

Dermal toxicity: The ability of a substance to poison people or animals by contact with the skin. Once absorbed by the skin they enter the blood stream and are carried throughout the body. Many pesticides are readily absorbed through the skin, and this form of exposure may be as dangerous as if they were swallowed.

Dermatitis: A common occupational skin disease which can lead to long-term skin problems. In allergic contact dermatitis, symptoms similar to those of eczema develop as a delayed allergic reaction to contact with a substance which may be at very low doses. Irritant dermatitis occurs on areas of the skin directly exposed to irritant substances.

Endocrine disruptor: A substance that affects endocrine function, causing adverse effects to the organism or its progeny

Endocrine system: The endocrine glands secrete chemicals called hormones, which regulate metabolism, reproduction, and other bodily functions

Enzyme: Molecules that act as catalysts, increasing the rate at which biological reactions proceed, they support almost all cell functions.

Hodgkin's lymphoma: A specialised form of lymphoma (about 8% of all lymphomas diagnosed each year)

Hormone: A biochemical substance that is produced by a specific cell or tissue and is secreted into the blood to regulate the growth or functioning of a specific tissue or organ elsewhere in the body.

Hydrocephaly: A birth defect where an increased quantity of cerebrospinal fluid inside the brain can result in damage through increased pressure on the brain.

Hypospadias: A birth defect in which the urethra opening is on the underside of the penis

Immune system: The cells and tissues which are responsible for recognizing and attacking foreign microbes and substances in the body

In utero: In the womb; before birth

LD50: Pesticides' acte toxicity is measured by the Lethal Dose 50 (LD50), the amount of the product (mg/kg body weight) that would result in the death of 50% of a population of animals tested, usually rats. Oral and dermal LD50 are both taken into account in classifying pesticides by toxicity.

Leukaemia: A cancer of the bone marrow, where blood cells are formed, it results in the production of abnormal white blood cells

Lymphocyte: A type of white blood cell that mainly stays in lymphatic tissue and is active in immune responses, including antibody production.

Meta analysis: The statistical analysis of a collection of results from individual studies for the purpose of integrating the findings

Multiple myeloma: A cancer that usually originates in the bone marrow, where blood cells are formed, and results in overproduction of plasma cells

Mutagen: An agent that causes alterations in the DNA of a cell. Mutations can usually be safely repaired by the cell, but occasionally the affected cell becomes cancerous. Mutations which occur in reproductive cells (sperm or eggs) can be passed on to the next generation and may cause abnormal development.

Natural killer cell: A type of lymphocyte (white blood cell) whose function is to kill infected and cancerous cells

Neonate: A newborn human or other mammal

Neurotransmitter: A chemical, such as acetylcholine, which is released from one nerve cell and binds to receptors on an adjacent nerve cell, triggering a nerve impulse

Non-Hodgkin lymphoma (NHL): Types of lymphoma other than Hodgkin lymphoma are grouped together as non-Hodgkin lymphoma, so this is a diverse group of cancers.

Oestrogen-dependent tumours: Cancers that are stimulated to grow by oestrogen

Oestrogens: A group of steroid hormones produced mainly by the ovary which are responsible for the development and maintenance of female secondary sexual characteristics and the regulation of certain female reproductive functions.

Organochlorines: A class of chemicals, mostly insecticides, which are typically very persistent in the environment, e.g. DDT. They are nerve poisons, but not cholinesterase inhibitors.

Organophosphates: The most widely used class of pesticides in the world, usually as insecticides, they are nerve poisons which act by inhibiting cholinesterase

Parkinson's disease: A disorder in which damage to nerve cells in the area of the brain coordinating movement causes a loss of control over a person's movement. This often appears as tremor, stiff muscles and joints, and/or difficulty moving.

Perinatal mortality: Stillbirths and deaths occurring in the first week after birth

Peripheral nerves: Nerves in any part of the nervous system apart from the brain and spinal cord

Pesticides: Any chemical substance used to kill organisms considered detrimental to human activities, including insecticides, herbicides and fungicides

Phenoxy herbicides: A class of herbicides that is widely used to remove broadleaved weeds from grass-type crops such as rice. Phenoxyacetic herbicides are a subclass which includes 2,4-D and 2,4,5-T.

Polymorphism: In genetics, the existence of two or more forms of a gene in a population

Pyrethroids: These are mostly synthetic chemicals modelled on natural insecticides produced by chrysanthemum plants. They are nerve poisons, but not cholinesterase inhibitors.

Receptor: A molecule on the surface of the cell that can bind with a specific hormone, neurotransmitter, drug, or other chemical, thereby initiating a change within the cell.

Rotterdam Convention: The 1998 convention making the Prior Informed Consent procedure legally binding to the governments that have ratified it. Under this, countries are informed of chemicals which have been banned or severely restricted in other countries (or of formulations that cause problems in developing countries because of their hazardous nature). Importing countries can then decide whether to allow import of that substance, and other countries must ensure their exporters comply with this.

Soft-tissue sarcomas: Cancers of soft tissues such as muscles, tendons, fat tissue, blood vessels and nerves

Spina bifida: A birth defect where part of the spinal cord is exposed through a gap in the backbone. Symptoms often include paralysis.

Steroid hormones: A group of biologically active compounds derived from cholesterol, including the sex hormones androgens and oestrogens.

Stockholm Convention: The 2001 convention that seeks the elimination or restriction of production and use of persistent organic pollutants (POPs). As of 15 July 2002, the Stockholm Convention had 151 signatories and 12 Parties. It will enter into force after the 50th ratification.

Synapse: A junction where a signal is transmitted between nerve cells, usually by a chemical called a neurotransmitter.

Synergistic: The situation in which the combined effect of two chemicals is much greater than the sum of the effect of each agent given alone.

Teratogen: A chemical that can cause birth defects by affecting the development of the embryo or foetus. The most notorious example is the drug thalidomide.

Thyroid: A gland found at the base of the neck that secretes many important hormones regulating aspects of metabolism and mineral balance.

Triazine herbicides: A class of herbicides which includes those such as atrazine that have been banned in some countries because of health concerns (including endocrine disruption), and are still widely used in others such as the USA.

Wilm's tumour: This form of kidney cancer is most common in children between the ages of one and five.

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