Occupational Pesticide Exposure in Vegetable Production

A literature and policy review with relevance to Indonesia

Edwin van der Maden, Melliza Wulansari and Irene Koomen
veglIMPACT is a program financed by The Netherlands’ Government promoting improved vegetable production and marketing for small farmers in Indonesia, contributing to the food security status and private sector development in Indonesia. The program builds on the results of previous joint Indonesian-Dutch horticultural development cooperation projects and aligns with recent developments in the horticultural private sector and retail in Indonesia. The program activities (2012 – 2016) include the Development of Product Market Combinations, Strengthening the Potato Sector, Development of permanent Vegetable Production Systems, Knowledge Transfer and Occupational Health.

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vegIMPACT Report 2. 54 pp.

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<th>Full Form</th>
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</thead>
<tbody>
<tr>
<td>CLP</td>
<td>Classification, labelling and packaging</td>
</tr>
<tr>
<td>CDI</td>
<td>Centre for Development Innovation, Wageningen UR</td>
</tr>
<tr>
<td>DAR</td>
<td>Draft scientific Risk Assessment report</td>
</tr>
<tr>
<td>EC</td>
<td>European Commission</td>
</tr>
<tr>
<td>EFSA</td>
<td>European Food Safety Authority</td>
</tr>
<tr>
<td>EU</td>
<td>European Union</td>
</tr>
<tr>
<td>FAO</td>
<td>Food and Agriculture Organization of the United Nations</td>
</tr>
<tr>
<td>FFPO</td>
<td>Fresh Food of Plant Origin</td>
</tr>
<tr>
<td>FFS</td>
<td>Farmer Field School</td>
</tr>
<tr>
<td>FGD</td>
<td>Focus Group Discussion</td>
</tr>
<tr>
<td>GHS</td>
<td>Globally Harmonized System of Classification and Labelling of Chemicals</td>
</tr>
<tr>
<td>HAIR</td>
<td>Harmonised Indicators for pesticide Risk</td>
</tr>
<tr>
<td>IARC</td>
<td>International Agency for Research on Cancer</td>
</tr>
<tr>
<td>ILO</td>
<td>International Labour Organisation</td>
</tr>
<tr>
<td>IPM</td>
<td>Integrated Pest Management</td>
</tr>
<tr>
<td>KAB</td>
<td>Knowledge, Attitude and Behaviour</td>
</tr>
<tr>
<td>LC</td>
<td>Lethal Concentration</td>
</tr>
<tr>
<td>LD</td>
<td>Lethal Dose</td>
</tr>
<tr>
<td>MoA</td>
<td>Ministry of Agriculture</td>
</tr>
<tr>
<td>MoH</td>
<td>Ministry of Health</td>
</tr>
<tr>
<td>MRL</td>
<td>Maximum Residue Level</td>
</tr>
<tr>
<td>OECD</td>
<td>Organisation for Economic Cooperation and Development</td>
</tr>
<tr>
<td>PIC</td>
<td>Prior Informed Consent</td>
</tr>
<tr>
<td>POP</td>
<td>Persistent Organic Pollutant</td>
</tr>
<tr>
<td>POPRC</td>
<td>Persistent Organic Pollutants Review Committee</td>
</tr>
<tr>
<td>PPE</td>
<td>Personal Protective Equipment</td>
</tr>
<tr>
<td>Acronym</td>
<td>Full Form</td>
</tr>
<tr>
<td>----------</td>
<td>-----------</td>
</tr>
<tr>
<td>RMS</td>
<td>Rapporteur Member State</td>
</tr>
<tr>
<td>UNEP</td>
<td>United Nations Environmental Program</td>
</tr>
<tr>
<td>US-EPA</td>
<td>Environmental Protection Agency of the United States of America</td>
</tr>
<tr>
<td>vegIMPACT</td>
<td>Vegetable production with IMPACT project</td>
</tr>
<tr>
<td>WHO</td>
<td>World Health Organisation</td>
</tr>
<tr>
<td>WP</td>
<td>Work Package</td>
</tr>
<tr>
<td>WUR</td>
<td>Wageningen University &amp; Research centre</td>
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</tbody>
</table>
Summary

Exposure to and inappropriate and unsafe use of pesticides is one of the most important occupational health risks among small-scale farmers in developing countries. This is also the case for Indonesia, where pesticide use is one of the most significant occupational health exposures for agricultural workers. Pesticides are used extensively based on the idea of preventive spraying to protect the crop to ensure good yields. Personnel protective equipment is not or rarely used and is of such quality that it does not provide sufficient protection. Furthermore, there is limited awareness about the chronic, negative, health effects of pesticides exposure. Major steps have to be taken regarding pesticide handling, application and control in order to reduce occupational health risk in Indonesian agriculture.

Different types of pesticides are used in agriculture, which can be divided into insecticides, herbicides and fungicides. Insecticides are the most harmful to humans, of which the most prominent classes are organochlorines, organophosphates, carbamates, and pyrethroids. There are still several pesticides in circulation, which belong to WHO Class Ia (extremely hazardous), Class Ib (highly hazardous) and Class II (Moderate hazardous), which are considered hazardous and should be banned from the market.

Different groups can be identified that are directly or indirectly exposed to pesticides, like occupational pesticide users (farmers, sprayers and field workers), but also families of occupational pesticide users, bystanders and residents. Pesticide exposure to the human body occurs through ingestion, inhalation, skin contact and skin absorptions and can result in either acute or chronic effects on health. Skin absorption is the primary and most important route of exposure to pesticides for workers directly handling pesticides.

Pesticide exposure can cause a range of health effects ranging from acute health problems like e.g. dizziness, headaches, nausea and skin problems to chronic health effects like e.g. asthma, allergies, hypersensitivity, cancers, hormone disruption, neurological disturbance and respiratory diseases. Women are especially vulnerable to some of the negative side effects, as they have little influence on the use and application of pesticides, often work in fields while pesticides are being sprayed and are often not the beneficiaries of knowledge and information on the risks pesticides might pose. Several studies found evidence for problems with reproduction, foetal development and development of the child in later life.

For quantifying the level of potential danger of direct or indirect exposure to pesticides, risk indicators can be used. In general pesticide risk is a function of exposure and toxicity (Risk = Exposure x Toxicity). Risk indicator models make use of extensive formulas and comprehensive sets of parameters to come to good estimates of exposure and toxicity and therefore require a large amount of specific input data. In developing countries good qualitative data is often lacking and therefore risk indicator models are difficult to apply in developing countries. However, it might be less important to accurately quantify the exposure of farmers in developing countries to pesticides than to understand the determinants of exposure, both in terms of risk factors and risky behaviour. Alternatively biomarkers can be used for assessing exposure to pesticides and evaluation of potential health risks, which includes detection of the chemical substance itself or its metabolites in human tissues or body.

The legislative framework for use of pesticides is often weak or absent in developing countries. In Indonesia, there is still room for improvement in pesticide legislation. European legislation is already well developed and good compliance takes place. The European pesticide legislation system can be used to further develop, improve and strengthen the legislation in Indonesia.
The literature on occupational pesticide exposure and correlated health effects due to inappropriate and unsafe use of pesticides is numerous. However, despite the fact that almost all researchers agree that clearly something has to be done to reduce the occupational pesticide health risk in developing countries, hardly anyone has the ultimate solution to the problem or has proof for success stories. The first and foremost solution that is being offered is education and training. However, education should not be the only way. Awareness is an important other route. Furthermore it seems that changing human behaviour related to pesticide use is not as simple and goes far beyond solely awareness raising and training programmes. It should be understood more clearly why farmers continue to use pesticides and take the negative effects for granted.

The article “why farmers continue to use pesticides despite environmental, health and sustainability costs” by Wilson & Tisdell gives a good summary in eight reasons: 1) negative impact of pollution on production, 2) non-adopters need to adopt, 3) ignorance about unsustainability, 4) high yielding varieties, 5) damage is not immediately visible, 6) long term health effects are not visible and difficult to prove, 7) farmers become locked in to unsustainable agriculture, and 8) to be the only one to practice biological control is not possible.

In his dissertation ‘Learning from Carchi – Agricultural Modernisation and the Production of Decline’ Sherwood concludes that too many people benefit from the pesticide business and therefore do not want to recognise or take responsibility for the problems. According to Sherwood, farmers will only stop using highly toxic pesticides if the government imposes restrictions on their use. However, the government will only do this if it is forced to, possibly by international regulations and control measures.
1. Introduction

Exposure to and inappropriate and unsafe use of pesticides is one of the most important occupational health risks among small-scale farmers in developing countries (Wesseling, et al. 2001, Konradsen, et al. 2003). Misuse of potentially toxic pesticides, coupled with a weak or absent legislative framework in the use of pesticides, is one of the major reasons for incidents of pesticide poisoning in these countries (Konradsen, et al. 2003). Erroneous beliefs of farmers about pesticide toxicity, lack of attention to safety precautions and lack of information have been identified as elements of unsafe use of pesticides in developing countries (El-Wakeil, et al. 2013).

The World Health Organisation (WHO) and the United Nations Environment Programme (UNEP) estimate that each year 3 million workers in agriculture in the developing world experience severe poisoning from pesticides (Miller 2004). Another estimate is that pesticides cause 14 per cent of all known occupational injuries in agriculture and 10 per cent of all fatal injuries (ILO 1996). Incidents in developing countries are even expected to be much higher due to poor regulation, lack of surveillance systems, poor enforcement, lack of training, inadequate access to information systems, poorly maintained or non-available personal protective equipment, and large agriculturally-based populations (Thundiyil, et al. 2008).

Exact numbers of acute and chronic pesticide poisoning are difficult to measure. A clear estimate of the chronic effects is lacking, as this cannot always be traced back to the use of pesticides and the effects only become visible after a long period of time. Therefore chronic victims will most likely also form a most likely an additional, not reported substantial part of the total victims of pesticide poisoning.

In Indonesia, pesticide use is one of the most significant occupational health exposures for agricultural workers. Pesticides are used extensively based on the idea of preventive spraying to protect the crop to ensure good yields. Personnel protective equipment are not or rarely used and are of such quality that they do not provide sufficient protection. Furthermore, there is limited awareness about the chronic, negative, health effects of pesticides exposure. Pesticide companies really promote the use of pesticides with giving rewards to farmers such as t-shirts, caps and radios. Major steps have to be taken regarding pesticide handling, application and control in order to reduce occupational health risk in Indonesian agriculture.

Therefore, within the vegIMPACT project and specifically in Work package (WP) Occupational Health the focus regarding occupational health will be on pesticide use in agriculture. Special attention will be given to women, as this is the most vulnerable group being exposed to pesticides. This literature review serves to understand occupational health risks as a result of pesticide use, determine indicators to assess the effects of interventions to reduce pesticide health risks and draw lessons from earlier attempts to reduce these risks.
2. Pesticides

2.1. Introduction
Pesticides are defined as chemical compounds used to: 1) kill, repel or control pests to protect crops before and after harvest; 2) influence the life processes of plants; 3) destroy weeds or prevent their growth and 4) preserve plant products. The three largest classes of synthetic pesticides, and which are of interest to agriculture, are insecticides, designed to kill insects, herbicides, designed to kill plants, and fungicides, to control fungi and moulds.

Pesticides work by interfering with an essential biological mechanism in the pests, but because all living organisms share many biological mechanisms, pesticides are never specific to just one species. While pesticides may kill pests, they may also kill or harm other organisms that are beneficial or at least not undesirable. They may also harm people who are exposed to pesticides through occupational or home use, through eating foods or liquids containing pesticide residue, or through inhaling or contacting pesticide-contaminated air (Gilbert 2011).

2.2. Pesticide classes and their effects on human health
The most prominent classes of insecticides are organochlorines, organophosphates, carbamates, and pyrethroids (Gilbert 2011). Here we will only discuss these main classes. In addition we will discuss several characteristics of herbicides and fungicides. In table 1 a more detailed classification of pesticides is given, which is used in the WHO Recommended Classification of Pesticides by Hazard report (WHO, The WHO Recommended Classification of Pesticides by Hazard and Guidelines to Classification 2009).

**Organochlorines**
Organochlorines belong to a group of insecticides with a highly toxic effect and the characteristic of being resistant to environmental degradation. Organochlorines are therefore a persistent organic pollutant (POP) (see section 3.5). The chemical structure of organochlorines is diverse, but they all contain chlorine, which places them in a larger class of compounds called chlorinated hydrocarbons. While organochlorines have the advantage of being cheap to manufacture and are effective against target species, they have serious unintended consequences. Organochlorines disrupt the movement of ions such as calcium, chloride, sodium, and potassium into and out of nerve cells. Depending on the specific structure of the organochlorine chemical, it may also affect the nervous system in other ways. They tend to accumulate in fatty tissue, therefore pass up the food chain, and remain in the human body for a long time. Organochlorines contribute to many acute and chronic illnesses. Symptoms of acute poisoning can include tremors, headache, dermal irritation, respiratory problems, dizziness, nausea, and seizures. Organochlorines are also associated with many chronic diseases. Correlations have been found between organochlorines and various types of cancers, neurological damage, Parkinson's disease, birth defects, respiratory illness, immune system suppression and hormone disruptions (endocrine disruption). The best-known organochlorine is DDT. Organochlorines are now largely banned in industrialized countries but they are still manufactured and used in developing countries. For instance, DDT is still recommended for indoor residual spraying to combat malaria (WHO, The Use of DDT in Malaria Vector Control - WHO Position Statement 2011).

**Organophosphates & Carbamates**
Organophosphates and carbamates are widely used as insecticides. These compounds have very different chemical structures, but share a similar mechanism of action. Organophosphate pesticides have increased in use, because they are less damaging to the environment (i.e. degrade relative rapidly) and they are less persistent than organochlorine pesticides. However, they are also...
associated with acute health problems and most common causes of severe acute pesticide poisonings, some of which have resulted in deaths. Symptoms of acute poisoning can include anxiety, headache, nausea, muscle weakness, fatigue, muscle cramps, fasciculation, paralysis, depression of respiration, ataxia, convulsion, tremor and general weakness.

Organophosphates and carbamates are cholinesterase-inhibiting pesticides, many which belong to WHO Classes Ia (extremely hazardous) and Ib (highly hazardous). Cholinesterase is one of many important enzymes needed for the proper functioning of the nervous systems of humans, animals, and insects. Organophosphates and carbamates block the enzyme and disrupt the proper functioning of the nerve cells. Structural differences between the various organophosphates and carbamates affect the efficiency and degree to which the cholinesterase is blocked. The toxicity of these pesticides presents significant health hazards. Several studies have shown persistent deficits in cognitive function in workers chronically exposed to low levels of organophosphates and therefore are neurotoxic (Jamal, Hansen and Julu 2002).

Pyrethroids
Pyrethroids are one of the newer classes of insecticides. They are a synthetic version of the naturally occurring pyrethrum, which is produced by chrysanthemum flowers. The chemical structure of pyrethroids is quite different from that of organochlorines, organophosphates, and carbamates but the primary site of action is also the nervous system. Pyrethroids affect the movement of sodium ions into and out of nerve cells, causing the nerve cells to become hypersensitive to neurotransmitters. Structural differences between various pyrethroids can change their toxic effects on specific insects and even mammals. They are seen as low-risk to people. However, pyrethroids can cause hyper-excitation, aggressiveness, incoordination, whole-body tremors, and seizures. Exposure at low levels may affect the respiratory system. Acute exposure in humans, usually resulting from skin exposure, can cause an allergic skin response, and some pyrethroids may cause cancer, reproductive or developmental effects, or endocrine system effects (Gilbert 2011). Synthetic pyrethroids are more persistent in the environment than natural pyrethrum, which is unstable in light and breaks down very quickly in sunlight.

Herbicides
Paraquat is one of the most widely used herbicides in the world. Paraquat is a non-selective contact herbicide that binds strongly to soil, where it is highly persistent. It is toxic to mammals and occupational or accidental exposure can occur by ingestion, skin exposure or inhalation, all of which can cause serious illness or death. Research has shown that it is linked to development of Parkinson’s disease (Tanner, et al. 2011, Kamel 2013). Paraquat is still widely used in developing countries (Gilbert 2011).

Atrazine is another widely used herbicide. It belongs to the triazine family, which is the group with the greatest concern regarding groundwater contamination. Atrazine does not break down readily after being applied to soils and it may be carried into the soil profile as far as the water table by soil water following rainfall. Studies suggest that it is an endocrine disruptor and has a possible carcinogenic effect.

Glyphosate is a systemic herbicide, meaning it is translocated through the plant. It is known by the trade name Roundup and was introduced to the market by Monsanto for non-selective weed control. It is one the most widely used herbicide. In addition, Monsanto introduced glyphosate-resistant crops, enabling farmers to kill weeds without killing their crops. Although the environmental and human health effects are considered to be relatively low, there is still a lot of controversy. In the review paper ‘Glyphosate: Destructor of human health and biodiversity’, Mason gives evidence for many negative impacts of glyphosate on the environment and human health (Manson 2013). Manson states that glyphosate is an endocrine-disruptor and it is a driver of mutations that lead to
cancer and has a significant correlation with e.g. obesity, diabetes, autism, thyroid cancer, liver cancer, deaths from Parkinson’s, Senile Dementia and Alzheimer’s, inflammatory bowel disease and acute kidney failure. A recent study carried out by Friends of the Earth (Friends of the Earth Europe 2013) found that over 40% of a test population had residues of glyphosate in their urine.

**Fungicides**

Fungicides were developed to control fungi and moulds that may grow on crops and stored foods and seeds. The control of plant pathogenic fungi in agriculture is important not only because fungi can damage crops, but also because some fungi produce toxic chemicals (mycotoxins) (Gilbert 2011). For instance *Aspergillus flavus* produces aflatoxin, a compound that can cause liver disease and liver cancer. Sulphur, copper sulphate, hexachlorobenzene and mercury-based compounds are examples of fungicides. Fungicides in general are harmful to human health.

### Table 1: Pesticide types used by WHO for classification

<table>
<thead>
<tr>
<th>Chemical type</th>
<th>Abbr.</th>
<th>Chemical type</th>
<th>Abbr.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Arsenic compound</td>
<td>AS</td>
<td>Organophosphorus compound</td>
<td>OP</td>
</tr>
<tr>
<td>Bipyridylium derivative</td>
<td>BP</td>
<td>Organotin compound</td>
<td>OT</td>
</tr>
<tr>
<td>Carbamate</td>
<td>C</td>
<td>Phenoxyacetic acid derivative</td>
<td>PAA</td>
</tr>
<tr>
<td>Coumarin derivative</td>
<td>CO</td>
<td>Pyrazole</td>
<td>PZ</td>
</tr>
<tr>
<td>Copper compound</td>
<td>CU</td>
<td>Pyrethroid</td>
<td>PY</td>
</tr>
<tr>
<td>Mercury compound</td>
<td>HG</td>
<td>Triazine derivative</td>
<td>T</td>
</tr>
<tr>
<td>Nitrophenol derivative</td>
<td>NP</td>
<td>Thiocarbamate</td>
<td>TC</td>
</tr>
<tr>
<td>Organochlorine compound</td>
<td>OC</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Source: (WHO, The WHO Recommended Classification of Pesticides by Hazard and Guidelines to Classification 2009)

### 2.3. GHS Acute Toxicity Hazard Categories

The Globally Harmonized System of Classification and Labelling of Chemicals or GHS is an internationally agreed-upon system, created by the United Nations. It is designed to replace the various classification and labelling standards of chemicals used in different countries by using consistent criteria for classification and labelling on a global level. The GHS Acute Toxicity Hazard Categories provides a classification of chemicals into health hazard categories for acute toxicity. Acute toxicity here refers to those adverse effects occurring following oral or dermal administration of a single dose of a substance, or multiple doses given within 24 hours. In Table 2 and 3 the GHS Acute Toxicity Hazard Categories are given for the different routes of exposure.
Acute toxicity experiments are required for the calculation of the median lethal dose ($LD_{50}$), which is the pesticide dose that is required to kill half of the tested animals when entering the body by a particular route. For example, if the substance is swallowed the figure is an oral $LD_{50}$, whereas if absorbed through the skin it is a dermal $LD_{50}$. In addition, the acute inhalation lethal concentration ($LC_{50}$), which is the pesticide concentration required to kill half of the exposed (for 4 hours) tested animals to a pesticide, is also calculated. The GHS also forms the basis for the WHO classification discussed in section 2.4. An earlier version of The WHO Classification scheme applied different criteria to liquids and solids, but the GHS does not make a similar distinction and applies the same criteria. Therefore the WHO classification has been aligned with the GHS Acute Toxicity Hazard Categories.
2.4. WHO pesticide classification

The WHO classification system (see Table 4) distinguishes between the more and the less hazardous forms of selected pesticides based on acute risk to human health (the risk of single or multiple exposures over a relatively short period of time). It takes into consideration the toxicity of the technical active substance and also describes methods for the classification of formulations (WHO, The WHO Recommended Classification of Pesticides by Hazard and Guidelines to Classification 2009). Especially class I and II pesticides are considered hazardous and should be banned from the market.

Table 4: WHO Classification (aligned with the GHS Acute Toxicity Hazard Categories)

<table>
<thead>
<tr>
<th>WHO Class</th>
<th>LD₅₀ (mg/kg body weight)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Oral</td>
</tr>
<tr>
<td>Ia</td>
<td>Extremely hazardous</td>
</tr>
<tr>
<td>Ib</td>
<td>Highly hazardous</td>
</tr>
<tr>
<td>II</td>
<td>Moderate hazardous</td>
</tr>
<tr>
<td>III</td>
<td>Slightly hazardous</td>
</tr>
<tr>
<td>U</td>
<td>Unlikely to present acute hazard</td>
</tr>
</tbody>
</table>

Source: (WHO, The WHO Recommended Classification of Pesticides by Hazard and Guidelines to Classification 2009)

2.5. Persistent Organic Pollutant (POPs)

Persistent Organic Pollutants (POPs) are chemical substances that persist in the environment, accumulate in the fatty tissue of living organisms and bio-accumulate through the food web, are toxic to humans and wildlife and pose a risk of causing adverse effects to human health and the environment. With the evidence of long-range transport of these substances to regions where they have never been used or produced and the consequent threats they pose to the environment of the whole globe, the international community has now, at several occasions, called for urgent global actions to reduce and eliminate releases of these chemicals, because they are in a nutshell:

- Highly toxic to humans and the environment
- Persistent in the environment, resisting bio-degradation
- Taken up and bio-accumulated in terrestrial and aquatic ecosystems
- Capable of long-range, transboundary atmospheric transport and deposition

In nature these substances affect plant and animal development and growth. They can cause reduced reproductive success, birth defects, behavioural changes and death. They are suspected human carcinogens and disrupt the immune and endocrine systems. Many POPs are currently or were in the past used as pesticides. Under the Stockholm Convention (see section 5.4) measurements are formulated to eliminate or reduce the release of POPs into the environment.

The list of POPs can be found on the Stockholm Convention website:
3. Occupational pesticide health risks and effects

3.1. Introduction

In developed countries, the use and application of hazardous pesticides are either banned or strictly controlled and agricultural workers who handle these pesticides are well trained in application and safety practices and are supposed to wear personal protective equipment (PPE; see Figure 1). Besides, workers are mostly well aware of the negative health effects of pesticides. This is in stark contrast to developing countries, where farmers use very hazardous pesticides with little or no personal protective equipment. Spraying is usually done using knapsack sprayers, which are poorly maintained and are often leaky, resulting in the skin and clothes being soaked with pesticides. Furthermore, agricultural workers in developing countries often spend long hours in the fields, mixing and spraying pesticides, or working in areas where spraying is taking place. In addition, washing facilities are rarely located near the agricultural fields, soap is rarely used and workers therefore wear contaminated clothing throughout the day, and eat, drink, and smoke with contaminated hands. Moreover, workers are likely to carry home pesticides on their clothes, skin, equipment and other things that they took to the field, and in this way and thus also indirectly expose family members to pesticides. The practices described above are all quite common in developing countries and have all been identified as risk factors of pesticide exposure with both acute and chronic health effects.

3.2. Pesticide exposure

Different groups can be identified that are directly or indirectly exposed to pesticides. First of all the people that are occupational involved in handling and applying pesticides, (occupational pesticide users) like farmers, sprayers and field workers. Families of occupational pesticide users are directly and indirectly exposed through pesticides stored at home and residues that workers bring home. Other groups are bystanders, who are exposed to spray drift during pesticide application when being close to a field during spraying. Residents living close to regular sprayed areas may be exposed by means of drift spray, but also through residues being present in the environment (e.g. surface and groundwater). Pesticide exposure to the human body occurs in different ways: dermal, oral and inhalational routes (see Figure 2) and can result in either acute or chronic effects on health.
Dermal exposure
Dermal exposure, i.e. direct contact with the skin, is the most common route of poisoning from pesticides (Plianbangchang, Jetiyanon and Wittaya-areekul 2009). Absorption will continue as long as the pesticide remains in contact with the skin. Dermal exposure occurs through not washing hands after handling pesticides or their containers, splashing or spilling pesticides on skin, wearing pesticide contaminated clothing, exposure to spray drift and mixing of powder formulations. Exposure can also occur by rubbing skin with pesticides contaminated gloves or hands.

Oral exposure
Oral exposure mostly takes place when hands are not washed before eating, drinking, smoking or chewing. Pesticides can be accidental splashed into the mouth or can be accidental applied to food (e.g. when pesticides are stored in or near the kitchen). Spray drift could reach lip or mouth. Sometimes empty pesticide containers are re-used for water or food. Drinking water or food with pesticide residues can be consumed.

Inhalational exposure
Inhalation of pesticides occurs through pesticide fumes, spray drift, dusts, powders or other dry formulations. It can also occur through use of inadequate or poorly fitted respirators.

Work-to-home exposure
Work-to-home exposure has been identified as a key source of pesticide residues in the home and exposure to pesticides of children (Thompson, et al. 2003, Coronado, et al. 2006). Workers, who are exposed to pesticides on the job on a daily basis, whether as applicators or re-entry workers, are likely to carry home pesticides on their shoes, clothes, skin, equipment and other things that they took to the field. Adequate washing of changing facilities to remove residues and put on clean clothes before going home are usually not available at the worksite. Therefore they may transfer pesticide residues to the indoor environment of their home or directly to other household members.

Acute toxicity
Acute toxicity implies the occurring of adverse effects immediately or within 24 hours after exposure to the pesticide. Acute pesticide poisoning is often a serious health issue in developing countries, and is almost certainly under-reported.

Chronic or long term toxicity
Long term (or chronic) toxicity implies health problems that may arise from repeated or prolonged exposure to smaller doses of pesticide. Some pesticides are carcinogenic, and some have the potential to affect nervous, hormonal (endocrine disruptors) or immune systems. There are many studies showing that chronic exposure to pesticides may increase the risk of a wide range of serious health problems, including certain cancers, neurological problems such as Parkinson’s disease, diabetes, respiratory diseases, some birth defects such as hypospadias, and reproductive problems such as reduced sperm count. Although there is a lot of evidence linking pesticide exposure in general with a wide range of health problems, it is very difficult to demonstrate cause and effect with chronic health problems, and to identify which of the pesticide ingredients are responsible.
In Figure 3 below the distribution routes of pesticides into the environment and to receptor organisms are visualized.

![Figure 3: Distribution routes and receptor organisms for pesticides used in agriculture](http://www.who.int/ceh/capacity/Pesticides.pdf)

3.3. Symptoms of pesticide exposure

Pesticide exposure can cause a range of health effects. Acute health problems may occur with handling of pesticides, such as abdominal pain, dizziness, headaches, nausea, vomiting, as well as skin and eye problems. Other possible health effects include asthma, allergies, and hypersensitivity, and pesticide exposure is also linked with cancer, hormone disruption, Parkinson’s disease, diabetes, respiratory diseases and problems with reproduction and foetal development (Gilbert 2011).

Dermatological effects are one of the most common health effects of pesticides, as the skin is the primary and most important route of exposure to pesticides for workers directly handling pesticides. Inflamed skin or eczema through either irritant or allergic mechanisms are the most common effects (Sanborn, et al. 2007). Besides, as mentioned in section 4.2, skin absorption has been reported to be the most important route of poisoning (Plianbangchang, Jetiyanon and Wittaya-areekul 2009).

One of the most common investigated health effects of pesticide exposure is cancer. Many studies have examined the effect, however, as is in general the problem with chronic health effects related to pesticide exposure, identification of a causative mechanism for cancer is often problematic due to multiple exposures and long latency periods (Gilden, Huffling and Sattler 2010). Associations have been found with: leukaemia, lymphoma, brain, kidney, breast, prostate, pancreas, liver, lung, and skin cancers (Gilden, Huffling and Sattler 2010, Bassil, et al. 2007).

Neurological health effects are memory loss, loss of coordination, reduced speed of response to stimuli, reduced visual ability, altered or uncontrollable mood and general behaviour, and reduced motor skills. These symptoms are often very subtle and may not be recognized by the medical community as a clinical effect (Gilbert 2011). Reports of women exposed to pesticides in developing countries suggest that, as a result of exposure to pesticides, acute neurological effects, chronic neurological effects and neurobehavioral changes have occurred (Naidoo 2011). Research on the effects of pesticide exposure in children and prenatal exposures indicates a link to social behavioural problems, neurodevelopmental delays and impaired gross and fine motor skills (Gilden, Huffling and Sattler 2010).
Zidenber-Cherr et al. Discusses that nutritional status can influence susceptibility to pesticides (Zidenberg-Cherr, et al. 2000). Animal experiments and human studies indicate that nutritional status can influence an individual’s susceptibility to environmental toxicant including air pollutants, food contaminants, heavy metals and pesticides. Dietary antioxidants are known to aid the metabolism of organophosphate pesticides. However low-income farmworkers and their children, who are at greater risk of pesticide exposure, often do not consume enough fruits and vegetables with these important nutrients. Conversely, good nutrition at all life stages can decrease susceptibility to adverse effects of toxicants.

In table 5 a list of possible signs and symptoms is given, which can indicate acute pesticide poisoning. Here the difference between a sign and a symptom is that a sign is something you can observe or that requires an examination, and a symptom is something a person feels but cannot be observed or examined.

Table 5: Signs & Symptoms of acute pesticide poisoning

<table>
<thead>
<tr>
<th>Signs</th>
<th>Symptoms</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tremor</td>
<td>Dry throat</td>
</tr>
<tr>
<td>Eyelid Twitching</td>
<td>Tired</td>
</tr>
<tr>
<td>Excessive sweating</td>
<td>Chest pain</td>
</tr>
<tr>
<td>Red eyes</td>
<td>Numbness</td>
</tr>
<tr>
<td>Runny nose</td>
<td>Eye stinging / itching / burning</td>
</tr>
<tr>
<td>Cough</td>
<td>Blurred vision</td>
</tr>
<tr>
<td>Staggering</td>
<td>Shortness of breath</td>
</tr>
<tr>
<td>Diarrhoea</td>
<td>Dizzy</td>
</tr>
<tr>
<td>White / scaling or red rash</td>
<td>Nausea</td>
</tr>
<tr>
<td>Loss of consciousness</td>
<td>Excessive salivation</td>
</tr>
<tr>
<td>Vomiting</td>
<td>Sore throat</td>
</tr>
<tr>
<td>Blisters</td>
<td>Burning nose</td>
</tr>
<tr>
<td>Abrasions</td>
<td>Muscle cramps</td>
</tr>
<tr>
<td></td>
<td>Headache</td>
</tr>
<tr>
<td></td>
<td>Stomach pain</td>
</tr>
<tr>
<td></td>
<td>Constipation</td>
</tr>
<tr>
<td></td>
<td>Itchy skin</td>
</tr>
</tbody>
</table>

Source: (Murphy, et al. 1999)

In addition, in Annex 1 a detailed table of chemical types and corresponding health effects can be found.

3.4. Women and children

Participation of women in agricultural production in developing countries like Indonesia is relatively high. Women typically perform low paid, low status and casual employment, with little opportunity for promotion or access to safety measurements. Therefore women in developing countries, especially in the agricultural sector, are increasingly exposed to pesticides. Since they are concentrated in the most marginal positions in the informal and formal workforces, and production is
organized in a gender-specific way, opportunities for women to control their exposure are limited (London, et al. 2002). Women’s greater dermal absorption and more body fat make them more vulnerable to adverse health effects and are subjected to risks related to reproductive effects, birth defects and miscarriages. Furthermore, as their literacy rates are generally lower, they have less access to advisory services and training men tend to take the decisions on what and how to spray.

Pesticide mixing and spraying activities are mostly carried out by males. Therefore, the majority of pesticide-related health and safety studies have been carried out among males. These studies report mainly on the absence of proper safety measures during mixing and spraying pesticides. Women are mostly indirectly exposed to pesticides and are especially vulnerable to some of the negative side effects. Women have little influence on the use and application of pesticides and are often not the beneficiaries of knowledge and information on the risks pesticides might pose. They often work in fields while pesticides are being sprayed or enter the fields too soon after spraying. In addition women can pass chemical hazards on to unborn and newly born children.

Atreya studied gender differences among Nepalese farmers with respect to pesticide use, knowledge and practices and found that women, due to lower levels of pesticide safety and awareness, were at greater risk for adverse effects as compared to their male counterparts (Atreya 2007). Women generally receive less education than men in the majority of developing countries, and are thus less likely to be sent for pesticide safety training courses. Research of Marinajati and co-workers in Chili and Shallot plantations in the sub district of Kersana, showed a relation between pesticides exposure and increased monocytes differential count, especially to women involved in agricultural activities (Marinajati, Endah and Suhartono 2012). Sari et al. studied pesticide exposure and pregnant women with low birth rate in Brebes (Sari, Yono and Hanani 2013). Sari found a correlation between low birth rates in Brebes and pesticide exposures, as a result of participation of pregnant women in agricultural, not using personal protective equipment and possible pesticide residues in the home.

Lu discusses that children living with parents who work with agricultural pesticides, or who live in proximity to pesticide-treated farmland, have higher exposures than other children living in the same community (Lu, et al. 2000). These children thus have additional exposure pathways beyond diet, drinking water, and residential pesticide use, the pathways considered common to all children.

A mother's occupational exposure to pesticides prior to or during pregnancy is associated with an increased risk for the child of leukaemia, Wilms' tumour, and brain cancer (Gilden, Huffling and Sattler 2010). Other adverse reproductive health outcomes reported in pesticide-exposed communities include delays in fertility, time to pregnancy spontaneous miscarriages, birth defects altered foetal growth, foetal death and infant deaths (Naidoo 2011, Sanborn, et al. 2007).

A number of the studies on children found increased risk of cancer associated with critical periods of exposure, both prenatal and postnatal, and with parental exposure at work. It was recommended that everyone, especially children and pregnant women, reduce exposure to pesticides whenever possible, both at home and in the workplace (Bassil, et al. 2007).

Maternal occupational exposure to pesticides during pregnancy is an important risk factor for the neurobehavioral development of a child. Research by Grandjean et al. suggest that prenatal pesticide exposure may adversely affect brain development, that they may resemble those caused by malnutrition, and that they differ from postnatal toxicity (Granjean, et al. 2006). Sullivan discusses that for pregnant women who have a marginal iodine nutrition status, the disruption of the thyroid due to exposure to organochlorines could induce iodine deficiency and result in negative effects on the brain of the developing foetus (Sullivan 2008).
4. Pesticide risk indicators and parameters

4.1. Introduction

Pesticide risk indicators are important for quantifying the level of potential danger of direct or indirect exposure to pesticides as with regard to possible acute and chronic health effects. Furthermore, pesticide risk indicators can be used as a tool for evaluation and to measure if pesticide exposure has decreased due to a certain change in behaviour towards the use and application of pesticides or change in policies.

Risk assessment of pesticide impact on human health is not an easy and particularly accurate process because of differences in the periods and the levels of exposure, type of pesticides (regarding toxicity), mixtures or cocktails used in the field, and the environmental characteristics of the agricultural areas where pesticides are applied (Damalas and Eleftherohorinos 2011). Also, the number of the criteria used and the method of their implementation to assess the adverse effects of pesticides on human health could affect risk assessment.

Data of potential negative effects of the active substances on human health are usually obtained from several tests focused on e.g., metabolism patterns, acute toxicity, sub-chronic or sub-acute toxicity, chronic toxicity, carcinogenicity, genotoxicity, teratogenicity, generation study, and also irritancy trials using rats as a model mammal or in some cases dogs and rabbits (Damalas and Eleftherohorinos 2011). Because empirical research on this topic is difficult due to practical and ethical reasons, in many cases predictive models are used to estimate likely levels of risk.

In order to demonstrate the presence of pesticides in the human body and to link pesticide exposure to health effects mostly biomarkers are used as parameters. In the same way as with pesticide risk indicators, these parameters can be used for evaluation purposes and indication for reduction of pesticide exposure.

4.2. EU Harmonised Indicators for pesticide Risk (HAIR)

The HAIR model (Krujine, Deneer and Lahr 2011) is an instrument that calculates risk indicators related to the agricultural use of pesticides in Member States of the European Union. Besides aquatic, groundwater and terrestrial risk indicators, it also includes an occupational risk indicator. The HAIR occupational risk indicator distinguishes risk between operators, re-entry by workers, bystanders, residents and children. It includes both acute as well as chronic risk indicators and considers dermal and respiratory exposure. The calculation of the risk indicators is done according to the following simplified formula:

\[\text{RI} = \frac{\text{ED}}{\text{TRD}}\]

RI = Risk Indicator
ED = Estimation of Human Exposure Dose
TRD = Toxicological Reference Dose

In general pesticide risk is a function of exposure and toxicity: \(\text{RISK} = \text{EXPOSURE} \times \text{TOXICITY}\), meaning that the risk to human health from pesticide exposure depends on both the toxicity of the pesticide and the likelihood of coming into contact i.e. the exposure, with the substance. At least some exposure and some toxicity are required to result in a risk, i.e. if the pesticide is very toxic, but no people are exposed, there is no risk. Likewise, if there is abundant exposure but the chemical is non-toxic, there is no risk.

The exposure is related to the amount that enters the body (oral, dermal or respiratory), or the amount that is released into the environment. The toxicity of a pesticide is a measure of how
poisonous it is to people or the environment. The amount of a chemical a person is exposed to is as important as how toxic the chemical might be.

For the HAIR model, extensive formulas are used to come to a good estimate of exposure and toxicity. Therefore, in order to use the HAIR model, or any other type of pesticide risk model, a comprehensive set of parameters and corresponding input data are needed.

Developing countries are often characterized by particularly serious pesticide related incidences but also by a general lack of data and expertise dedicated to environmental and health protection and the promotion of sustainable agricultural production. In this context, the availability of a simple but reliable pesticide risk indicator would be particularly relevant (Feola, Rahn and Binder 2011). Furthermore, models are usually developed under European conditions, while it has been shown that in developing countries, pesticide application techniques and chemicals used might differ extensively from those conditions. In fact, it might be less important to accurately quantify the exposure of farmers to pesticides than to understand the determinants of exposure, both in terms of risk factors (e.g. misuse of personal protective equipment, hygiene habits) and of determinants of risky behaviour (e.g. cost of protective equipment, social norm) (Feola, Rahn and Binder 2011)

4.3. Biomarkers

Bio-monitoring is a useful tool for assessing exposure to pesticides and for the evaluation of potential health risks (Araoud 2011). Biomarkers are measurable substances or characteristics in the human body that can be used to monitor the presence of a chemical in the body, biological responses, or adverse health effects. Biomarkers include detection of the chemical substance itself or its metabolites in human tissues or body fluids, changes in genetic material, and change in biologic function (Anwar 1997). Pesticides and their metabolites can be measured in biological samples, serum, fat, urine, blood, or breast milk. Three different types of pesticide exposure biomarkers can be distinguished

**Chemical substance**

The most specific exposure biomarker is direct measurement of the chemical in the body. Typically, measurement of the chemical is made in accessible biological matter (e.g. blood, urine).

**Metabolite**

Many chemicals are rapidly metabolized or difficult to measure. In these cases, a more stable breakdown product (metabolite) of the chemical may be measured to estimate exposure to the chemical. When a metabolite may derive from a number of different chemicals, additional information is needed to resolve to which chemical the person was exposed.

**Endogenous surrogate**

In some cases, a chemical or class of chemicals may result in an endogenous response (response within the body) that is highly characteristic of that chemical or class. Measures of that response can be used as a surrogate for direct measurement of the chemical or metabolite concentration when sufficient additional information is available. Since there are many factors that can influence endogenous responses, this type of exposure biomarker is accompanied by many uncertainties.

**Exposure vs. effect biomarkers**

In contrast to exposure biomarkers, effect biomarkers are indicators of a change in biologic function in response to a chemical exposure. Thus, they more directly relate to insight into the potential for adverse health effects compared with biomarkers of exposure.
One example of a biomarker cholinesterase in the blood, which can become inhibited following exposure to organophosphate and carbamate pesticides. Measuring cholinesterase levels can be a useful tool for monitoring agricultural workers and identifying workers that may potentially be overexposed to (organophosphate and/or carbamate) pesticides. Cholinesterase tests are relatively simple, cheap and fast, this in comparison to complicated, expensive and time consuming, laboratory test using chromatography.
5. Legislation and regulations

5.1. Introduction

The rules and regulations on pesticides are often very extensive and complicated. In Europe the legislation is already well developed and good compliance takes place. In Indonesia, there is room for improvement in pesticide legislation. Internationally in this section, a summary is given of both the European rules and regulations regarding pesticide use and the current legislation on pesticides in Indonesia.

5.2. European Union Framework

The EU defines pesticides as chemical compounds used to: 1) kill, repel or control pests to protect crops before and after harvest; 2) influence the life processes of plants; 3) destroy weeds or prevent their growth and 4) preserve plant products. The term “pesticides” covers insecticides, acaricides, herbicides, fungicides, plant growth regulators, rodenticides, biocides and veterinary medicines.

Authorisation of plant protection products

In the EU, no plant protection product can be used unless it has first been scientifically established that: 1) they have no harmful effects on consumers, farmers and local residents and passers-by; 2) they do not cause unacceptable effects on the environment; 3) they are sufficiently effective against pests.

Plant protection products are chemical formulations containing an active substance and other ingredients such as carriers, fillers etc. Active substances are the essential component of plant protection products. The EU has established a dual system for approval of pesticides: the active substances are approved by the Commission at EU-level, while plant protection products containing these substances are authorised at Member State level.

In 1993 the European Commission launched a work programme on the review for all active substances used in plant protection products within the European Union (Directive 91/414/EEC) (European Commission, Council Directive 91/414/EEC of 15 July 1991 concerning the placing of plant protection products on the market OJ L 230, 19.8.1991 1991). In this review process, each substance had to be evaluated as to whether it could be used safely with respect to human health and the environment. There were roughly 1000 active substances (and tens of thousands of products containing them) on the market at the time the Directive was adopted. After a first period in which harmonised technical requirements were set, the review programme was finalised in March 2009. After 2009 Directive 91/414/EEC regulated the evaluation, marketing and use of pesticides in plant protection through a comprehensive risk assessment and authorisation procedure for active substances and products containing these substances. It provides assurances that the substances currently on the market are acceptable for human health and for the environment, in accordance with European-wide criteria.


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Recently, new rules have been created in relation to Regulation (EC) No 1107/2009 to take into account current scientific and technical knowledge of active substances/plant protection products. The overall effect of these new rules will be the removal of active substances and plant protection products that are unsafe for human health or the environment. The new rules are laid down in Regulation EU 283/2013 (European Commission, Commission Regulation (EU) No 283/2013 of 1 March 2013 setting out the data requirements for active substances, in accordance with Regulation (EC) No 1107/2009 of the European Parliament and of the Council L93/1 2013a) setting data requirements for active substances (comes into force 1 January 2014) and Regulation EU 284/2013 (European Commission, Commission Regulation (EU) No 284/2013 of 1 March 2013 setting out the data requirements for plant protection products, in accordance with Regulation (EC) No 1107/2009 of the European Parliament and of the Council L93/85 2013b) setting data requirements for plant protection products (comes into force 1 January 2016).

EU System for approval of pesticides is organized as follows:
1. Application is done to an EU country called Rapporteur Member State (RMS);
2. RMS verifies if the application is admissible by checking if the applicant has provided a complete dossier with tests and study reports;
3. For each substance an initial draft scientific risk assessment report (DAR) is produced by the designated RMS;
4. The RMS’s risk assessment is peer reviewed by EFSA in cooperation with all Member States;
5. EFSA drafts a conclusion on the active substance;
6. Standing Committee for Food Chain and Animal Health votes on approval or non-approval;
7. The European Commission takes a legislative decision whether or not to include the substance in the Union’s list of approved active substances;
8. Publication of a Regulation in the EU Official Journal

The risk assessment of pesticides evaluates whether, when used correctly, these products can be shown to have no direct or indirect harmful effect on human or animal health, e.g. through drinking water, food or feed and do not adversely affect groundwater quality. In addition, the environmental risk assessment aims to evaluate the potential impact on non-target organisms when the products are correctly used.

It takes 2.5 to 3.5 years from the date of admission of the application to the publication of a Regulation approving a new active substance. This time varies greatly depending on how complex and complete the dossier is. An EU list of approved active substances is established, and Member States may authorise only plant protection products containing active substances included in this list.

Sustainable use of Pesticides
In order to reduce the risks and impacts of pesticide use on people's health and the environment the EU sets rules for the sustainable use of pesticides. These rules are laid down in Directive 2009/128/EC (European Commission, Directive 2009/128/EC of the European Parliament and of the Council of 21 October 2009 establishing a framework for community action to achieve the sustainable use of pesticides L309/71 2009b). Its overall objective is “to establish a framework to achieve a sustainable use of pesticides by reducing the risks and impacts of pesticide use on human health and the environment and promoting the use of Integrated Pest Management and of alternative approaches or techniques such as non-chemical alternatives to pesticides”. National authorities have to adapt their laws to meet these goals, but are free to decide how to do so.

The Directive comprises the following actions:
- National Action Plans: Each EU country draws up a national action plan setting objectives and timetables to reduce risks and impacts of pesticide use;
- Training: Professional pesticide users, distributors and advisors get proper training. EU countries establish competent authorities and certification systems;
- Information and awareness raising: Member States shall take measures to inform the general public and put in place systems to gather information on acute poisoning incidents and chronic poisoning developments;
- Aerial spraying: Aerial spraying is prohibited. EU countries may allow it under strict conditions after warning people;
- Minimising or banning: EU countries minimise or ban the use of pesticides in critical areas for environmental and health reasons;
- Inspection of equipment in use: All pesticides application equipment will have to be inspected at least once by 2016 to grant a proper efficient use of any plant protection product;
- Integrated pest management (IPM): Promotion of low pesticide-input management including non-chemical methods. Professional users will have to apply general principles of IPM from 1 January 2014.

Rules and criteria related to the classification, packaging and labelling (CLP) of dangerous substances and preparations have been harmonised in Directive 1999/45/EC (European Commission, Directive 1999/45/EC of the European Parliament and of the Council of 31 May 1999 concerning approximation of laws, regulations and administrative provision of Member States relating classification, packaging and labelling of dangerous preparations L200/1 1999) in order to ensure the protection of health and the environment, as well as the free movement of products. This directive is being gradually replaced by CLP-Regulation (EC) No 1272/2008 (European Commission, Regulation (EC) No 1272/2008 of the European Parliament and of the Council of 16 December 2008 on classification, labelling and packaging of substances and mixtures, amending and repealing Directives 67/548/EEC and 1999/45/EC L353/1 2008). This new regulation on classification, labelling and packaging (CLP Regulation) contributes to the GHS aim that the same hazards will be described and labelled in the same way all around the world. From 1 June 2015 pesticide classification and labelling must be consistent with the new rules (see Figure 4).

![Figure 4: Old and new labels according to Directive 1999/45/EC and Regulation (EC) No 1272/2008](image-url)
Maximum Residue Levels
All foodstuffs intended for human or animal consumption in the European Union (EU) are subject to a maximum residue level (MRL) of pesticides in order to protect animal and human health. Maximum Residue Levels (MRLs) are the upper legal levels of a concentration for pesticide residues in or on food or feed, based on good agricultural practice and the lowest consumer exposure necessary to protect vulnerable consumers.


The risk assessment carried out for approval and placing on the market of pesticides includes assessment to determine the threshold above which an active ingredient’s concentration in food products presents a risk for humans and animals. The EFSA issues an opinion including the anticipated limit of determination for the pesticide/commodity combination, and a risk assessment for cases where the admissible daily intake is exceeded. Based on the EFSA’s opinion, the Commission issues a Regulation to establish a new MRL or to amend or remove an existing MRL.

Member States carry out checks on pesticide residues to ensure compliance with the MRLs. These checks entail taking samples, analysing them and identifying the pesticides and respective pesticide levels present therein.

5.3. Rotterdam Convention
The Rotterdam Convention (FAO/UNEP 1998) regulates the import and the export of certain hazardous chemicals and pesticides. It is based on the fundamental principle of Prior Informed Consent (PIC), meaning that under the Convention, a chemical listed in the Convention may only be exported with the importer’s prior consent. The Indonesian government adopted the Rotterdam convention as legislation (no 10/2013) on 18 May 2013.

The Convention establishes a procedure to disseminate the decisions taken by the importing countries, thus implementing the PIC principle in the international trade in chemicals. It contains provisions requesting detailed information on the chemicals so that these decisions may be taken once data are available on the properties and the incidence of these products in particular on human health and the environment. The aim is to promote a shared responsibility between exporting and importing countries in protecting human health and the environment from the harmful effects of chemicals.

Further reading on Rotterdam Convention: http://www.pic.int/

5.4. Stockholm Convention
The Stockholm Convention on Persistent Organic Pollutants is an international environmental treaty to protect human health and the environment from persistent organic pollutants (POPs) and that aims to eliminate or restrict the production and use of POPs. Indonesia signed the Stockholm Convention in 2001 and ratified it in 2009.

Parties to the convention have agreed to a process by which persistent toxic compounds can be reviewed and added to the convention, if they meet certain criteria for persistence and trans-
boundary threat. The Persistent Organic Pollutants Review Committee (POPRC) was established to consider additional candidates nominated for listing under the Convention.

The Stockholm Convention is perhaps best understood as having five essential aims: 1) eliminate dangerous POPs, starting with the 12 worst; 2) support the transition to safer alternatives; 3) target additional POPs for action; 4) clean up old stockpiles and equipment containing POPs; 5) work together for a POPs-free future.

Further reading on Stockholm Convention: http://chm.pops.int/

5.5. Indonesia Framework

The Indonesian government has planned to reach the targeted national food security. As part of this policy, farmers need to be protected from the loss of production as the results of pest attack. The efforts to protect the plant should be done in effective ways. It means the mechanism of the protection does not endanger human safety, natural resources and crops cultivated. Three protection ways to protect plants are preventing the pest from outside Indonesia, controlling, and eradicating the pest. The use of pesticide is recommended as a last point in legislation of Republic Indonesia no.6/1995 (Plant protection). The legislation emphasized that everyone who uses pesticide must control, prevent and tackle the negative effects on it. Applying the pesticide should be in proper application, i.e. proper type of pesticide, proper dosage, proper mechanism, proper target, proper time and type of land condition.

The Indonesia government has considered that pesticide jeopardises human health. The policy from the Minister of Health no. 1350/2001 regulated the activities on pesticide management, such as production, transportation, storage, demonstration, usage and disposal of pesticide. The organization that conducts these activities must comply with the health requirements. So, several technical points should be obeyed by the operator.

The government also has regulated the colour of pesticide labels on packaging by its physical appearance, entrance line into the body and its toxicity (see table 6).

<table>
<thead>
<tr>
<th>WHO Class</th>
<th>Description</th>
<th>Colour on label</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ia</td>
<td>Extremely hazardous</td>
<td>Dark brown</td>
</tr>
<tr>
<td>Ib</td>
<td>Highly hazardous</td>
<td>Dark red</td>
</tr>
<tr>
<td>II</td>
<td>Moderate hazardous</td>
<td>Dark Yellow</td>
</tr>
<tr>
<td>III</td>
<td>Slightly hazardous</td>
<td>Light Blue</td>
</tr>
</tbody>
</table>

The regulation appoints the local health government to coach the organization or people who have activities on pesticide management. Some terms and conditions that are related to health requirements are:

1. The production is located in free of flood, industrial estate, can be reach by ambulance, and fire department;
2. The building construction: floor must be water proof and easy to clean, provided with centralized exhaust vent, exit door, good lighting;
3. Sanitation facility: water storage, waste installation, toilet, wash stand, rubbish bin;
4. Lay out: separate room between formulator and production, office, canteen, raw material warehouse, finish good warehouse;

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5. Human resources should have good condition to work based on approval letter from doctor and regular pass the health check-up;
6. Minimum PPE is used by the workers such as hat, goggles, respirator, overall cloth, gloves, and footwear.

The safe spraying technique should be applied by farmers. Generally, the farmers are unaware of risk on pesticide. The local health government at district level is responsible for technical coaching, which includes:

a. Examination and supervision on type, quality, and quantity of pesticides, containers and tag colour and publication of pesticide;
b. Examination and supervision on materials, equipment used or produced in pesticide residue management;
c. Examination and supervision of materials that contain pesticide residues;
d. Medical check-up of pesticide managing personnel;
e. Supervision of pesticide waste disposal and abolition activities;
f. Precaution of pesticide usage;
g. Pesticide management development through counselling, education and training;
h. Recording and reporting on pesticide management coaching.

Many agriculture areas become target market of pesticide company especially in Indonesia. The policy from Minister of Agriculture about *Conditions and Procedures for Pesticide Registration (no. 24/2011)* revised many times because of the development in science. The scope of the law includes the classification kinds of license, condition of registration, procedure of registration, place and label of pesticides and administration sanction. The pesticide company who register the product should have complied with the requirements from the government. During the registration process, the Pesticide Commission (*Regulation of the Minister of Agriculture no. 847/2011*) has 3 main responsibilities to evaluate the pesticide information or data for registration that related with human health, environmental, and agriculture; to evaluate the pesticide information or data that already had registered and had allowed from Minister of Agriculture, which related with human health, environmental, and agriculture; and to help the head of commission pesticide by advising and considering the pesticides could be allowed or registered or not.

In the regulation of *Conditions and Procedures for Pesticide Registration*, the government controls classification type of pesticide, and the label and packaging of pesticide after the examination of the registered product. The goals of this regulation are:

1. To protect society and environmental from the negative effects as a result of pesticide storage, distribution and usage;
2. To increase the efficiency and effectiveness of pesticide usage;
3. To support the IPM implementation;
4. To assure the activities of production, supply, storage and distribution pesticide.

The government summarize the prohibited chemical to be used in pesticide, i.e.:

1. Class Ia and Ib based on WHO class
2. Active or additional ingredients which have effects on carcinogenic, teratogenic, mutagenic based on IARC, FAO, WHO, US-EPA etc.

The criteria of the limited chemical to be used in pesticide are:

1. Corrosive on eye, skin;
2. If the pesticide is used according the instruction manual, the pesticide still affected to human health (sub-chronic and chronic) as the result of pesticide exposure;
3. LC50 inhalation <0.05 mg/l for 4 hours of exposure;
4. Ozone depleting agent.

The specification of the pesticide package should be mentioned on the packaging such as volume, active ingredients, size, form, colour and packaging material. The label of storage, application, and safety instruction also should be clear on the label.

Based on the advice and consideration of the commission of pesticides, the Minister decides the license for each product, such as testing, temporary, and fixed license. The Minister also authorizes change the classification of the usage of:

- Restricted pesticides to become pesticide for general use or to become prohibited pesticide
- Pesticides for general purpose to become prohibited pesticides or restricted pesticide

There are 3 kinds of pesticides licenses (see Table 7):

Table 7: Pesticide Licenses

<table>
<thead>
<tr>
<th>License</th>
<th>Requirement</th>
<th>Validity</th>
<th>Product’s Status</th>
</tr>
</thead>
<tbody>
<tr>
<td>Testing</td>
<td>Evidence of claim about quality, affectivity and safety of registered pesticide</td>
<td>1 (one) year period and can extended once for 1 (one) year period</td>
<td>Cannot be distributed or used for commercial.</td>
</tr>
<tr>
<td>Temporary</td>
<td>Complete data and information follow decided technical and administration condition</td>
<td>1 (one) year and can be extended once for period 1 (one) year.</td>
<td>Can be produced/distributed and can be used in limited amount</td>
</tr>
<tr>
<td>Fixed</td>
<td>Fulfil all technical and administration conditions decided</td>
<td>5 (five) years</td>
<td>Can be produced, distributed and used.</td>
</tr>
</tbody>
</table>

The Pesticide Commission registered 350 brands of fungicide, 600 brands of herbicide, and 800 brands of insecticide which are registered as fixed license. These numbers exclude the illegal products which are found during pesticide monitoring. The execution of pesticide monitoring is conducted through production steps, distribution, storing, and usage as well as destroying. These activities are carried out by the Supervisor of Pesticide at Central, Province and Sub-District level. Each level should report the pesticide monitoring activities. The activities are reported to head of team at each level (see Table 8).
Table 8: Pesticide monitoring reporting

<table>
<thead>
<tr>
<th>Level</th>
<th>Reported to</th>
<th>Scope</th>
</tr>
</thead>
<tbody>
<tr>
<td>sub-District/</td>
<td>Head of District (Mayor) and to the Head of Team/Commission of Monitoring of</td>
<td>- Amount,</td>
</tr>
<tr>
<td>Town</td>
<td>the Province</td>
<td>- Type and quality of pesticide which is distributed,</td>
</tr>
<tr>
<td></td>
<td></td>
<td>- Effect of the usage of pesticide at farmer the level</td>
</tr>
<tr>
<td></td>
<td></td>
<td>- Other matters that are surfacing in the field;</td>
</tr>
<tr>
<td>Province</td>
<td>Governor and to Head of Commission of Pesticide</td>
<td>- The situation of the distribution of pesticide at sub-district/town</td>
</tr>
<tr>
<td></td>
<td></td>
<td>- Effect of the usage of pesticide</td>
</tr>
<tr>
<td></td>
<td></td>
<td>- Other matters that are surfacing in the entire sub-district/town in</td>
</tr>
<tr>
<td></td>
<td></td>
<td>one province</td>
</tr>
<tr>
<td>Central</td>
<td>Minister of Agriculture</td>
<td>- The production of pesticide,</td>
</tr>
<tr>
<td></td>
<td></td>
<td>- Export import of active material and formulation of pesticide,</td>
</tr>
<tr>
<td></td>
<td></td>
<td>- Development of permit/ registration number,</td>
</tr>
<tr>
<td></td>
<td></td>
<td>and result of evaluation of monitoring at area</td>
</tr>
<tr>
<td></td>
<td></td>
<td>also the matters at the entire Indonesia territory</td>
</tr>
</tbody>
</table>

The objects of the monitoring pesticide program are accident and work safety in production process, distribution, storing, transporting and using as well as disposal, residue, publication in the printed and electronic media, negative effect on public health and environment, efficacy and resistance. Monitoring the level residue pesticide is conducted by checking the pesticide residues of farm produce and environmental media. The monitoring of the printed/electronic media is conducted through investigation and monitoring the advertisement, label and brochure. The negative effects on public health, plant condition, animal and wild fauna are also monitored. All of the pesticide monitoring activities were regulated by the Minister of Agriculture no 42/2007.

In 1996, the Minister of Health and Agriculture (no. 8/1996) established maximum residue level on product of agriculture to prevent and to protect people from the hazard of pesticide. There are 146 types of active ingredient which regulated in agriculture usage such as crops, horticulture, poultry, fisheries, and plantation. The level of residue pesticide can be detected by laboratory which appointed by Minister of Health and Agriculture. The minister of Health in the regulation of Safe Handling of hazardous material (no. 472 / 1996) added effort to minimalize the risk of hazardous material is informing the guidelines of handling those materials to public and private sector. The list of hazardous materials were published and informed to public and used by Directorate of Monitoring Food and Medicine (BPOM) for inspecting or monitoring the distribution of those products. The minister of Agriculture determines several numbers of banned active ingredients and several numbers of active ingredients of limited pesticide in Indonesia. The obsolete chemical cannot be imported to Indonesia and produced in Indonesia. There are 7 banned (aldrin, aldicarb, chlordimeform, dieldrin, DDT, methacrifos, mirex) and 5 limited (aluminium phosphide, paraquat dichloride, zinc phosphide, magnesium phosphate, methyl bromide) active ingredients included in the Regulation of the Minister of Agriculture no. 1/2007.

The demand of vegetables consumption promotes the international trading of fresh products between several countries. The issue of food safety arise with in import and export of fresh product of fresh food of plant origin (FFPO). The basic for the implementation of safety control of FFPO
imported and exported into and from the territory of Indonesia is standardized in *Regulation of the Minister of Agriculture no. 88/2011*. This aims of regulation avoid FFPO imported and exported into and from the territory of the Republic of Indonesia from the chemical contaminants exceeding maximum limit and thus safe and consumable or meet the requirements of destination country. Chemicals contaminants include pesticide residues, mycotoxin and/or heavy metals. The categories of FFPO, types and maximum limits of pesticide residues, mycotoxin and/or heavy metal contaminants as referred to:

- Annex I type of imported FFPO and maximum limit of pesticide residue, sampling procedures
- Annex II type of exported FFPO and contaminant maximum limit

The control of food safety on importation and exportation of FFPO can be carried out through:

1. Recognition of the FFPO safety control system of the country of origin
2. Equivalence agreement between Indonesia and the FFPO country of origin or destination country
3. Recognition of the FFPO safety control in the production site; or
4. Inspection toward every importing/exporting FFPO.
6. Lessons learned

6.1. Introduction

Numerous articles have been published on occupational pesticide exposure and correlated health effects due to inappropriate and unsafe use of pesticides. Despite the fact that almost all researchers agree that clearly something has to be done to reduce the occupational pesticide health risk in developing countries, hardly anyone has the ultimate solution to the problem or has proof for success stories.

The first and foremost solution that is being offered is education and training. However, education should not be the only way. Awareness is an important other route. An educated individual may know the health and environmental impacts due to pesticide use, but would not be aware of wearing protective clothing due to either poor economic conditions or hot climates (Atreya 2007). And even when awareness is included, then there are many other factors to take into account. In this section an attempt is made to give an overview of why people act like they do in relation to pesticide use in agriculture.

6.2. Knowledge, attitude and behaviour (KAB) surveys

Numerous articles can be found in the literature that discuss the result of knowledge, attitude and behaviour (KAB) surveys that have been conducted in many different developing countries around the world and focus on exposure to pesticides as a result of occupation and the associated risks and hazards. Some of the findings are summarized here.

First of all, the majority of the agricultural workers in developing countries do not take the necessary precautionary measures to prevent hazards associated with pesticide use (Sosan and Akingbohungbe 2009, Shalaby, Abdou and Sallam 2012, Plianbangchang, Jetiyanon and Wittaya-areekul 2009, Murphy, et al. 1999). Wearing of personal protective equipment is not a common practice, eating and drinking often takes place in the field and during spraying activities, and pesticides are improper stored and disposed. Unawareness of pesticide hazards is the main reason given for poor personal protection (Plianbangchang, Jetiyanon and Wittaya-areekul 2009).

In case agricultural workers were aware of the health hazards associated with pesticide use, mostly no significant positive relationship between awareness of health risks and use of protective measures was found (Sosan and Akingbohungbe 2009, Shalaby, Abdou and Sallam 2012, Sivayoganathan, et al. 1995, Leungo, et al. 2012). In this case the main reason for not using protective measures is discomfort of using PPE in a hot and humid climate. This also shows that human behaviour is not determined by access to information alone and the need for more in depth examination of the reasons why farmers don’t use protective measures, is essential for effective intervention programmes (Sivayoganathan, et al. 1995).

Correlations were found between the level of education and knowledge and awareness of the health risks of pesticides, environmental contamination and the need for using personal protective equipment (Sosan and Akingbohungbe 2009, Sivayoganathan, et al. 1995, Shalaby, Abdou and Sallam 2012, Leungo, et al. 2012, Mancini, Jiggins and O’Malley 2009). In fact, some farmers were even not in agreement with the measures recommended, implying that they were not convinced of the need for such practices (Sivayoganathan, et al. 1995). The labels on the pesticide cans are mostly ‘read’, but however are not always understood and instructions are not always followed (Sosan and Akingbohungbe 2009, Devi 2009). In Brazil farmers would by preference use pesticides coded ‘red’, a warning that these are the most hazardous. However farmers interpreted the label as the pesticide being most effective since it was most toxic (pers. communication Anvisa, 2010).
Many authors stress upon the need for training on pesticide safety measures and application instructions to improve and encourage safe use and handling of pesticides and awareness raising campaigns about health risks involved in misuse of pesticides (Sosan and Akingbohungbe 2009, Shalaby, Abdou and Sallam 2012, Plianbangchang, Jetiyanon and Wittaya-areekul 2009, Devi 2009).

A commonly recommended solution is to provide health education and training to promote the use of protective equipment and teach farmers to handle pesticides carefully. However, there is no linear relationship between the transfer of knowledge and a change in behaviour, as many of the factors that contribute to pesticide poisonings in developing countries are out of workers’ control (Kishi, et al. 1995). Furthermore, besides education awareness also plays an important role (Atreya 2007). Some researchers argue that different approaches are needed to prevent acute pesticide poisonings and advocate for proper registration and regulation of pesticides and the banning of highly toxic pesticides is also suggested as a measure to limit access to the pesticides and the associated hazards (Sosan and Akingbohungbe 2009, Murphy, et al. 1999). Especially all class I and II pesticides according to WHO classification should be banned from the market and should not be applied using a knapsack sprayer. Implementation of alternative agricultural methods to reduce the use of pesticides like e.g. Integrated Pest Management is also advocated as a possible solution (Sosan and Akingbohungbe 2009, Plianbangchang, Jetiyanon and Wittaya-areekul 2009).

6.3. Why farmers continue to use pesticides injudiciously

Despite the large increases in food production brought about by chemical inputs such as pesticides, the agricultural, environmental and health costs arising from pesticide use are high. Wilson & Tisdell discuss several reasons “why farmers continue to use pesticides despite environmental, health and sustainability costs” (Wilson and Tisdell 2001). These reasons are summarised as:

1. **Negative impact of pollution on production**: Unsustainable techniques such as pesticide use lower current costs and boost yields in the short run, but eventually result in lower yields and raise costs of production, as increased chemical inputs cause pollution. The pollution has a negative impact on production. In order to boost production, increasing amounts of chemical inputs have to be used, not only increasing the costs of inputs, but also increasing pollution. This creates a vicious circle.

2. **Non-adopters need to adopt**: Initially, the use of pesticides could increase supply and reduce market prices thereby forcing non-adopters to adopt despite their reservations. Therefore, farmers not using pesticides may be forced to use it to avoid economic losses and to ensure their economic survival. Once the new technique is adopted, it may be impossible to revert to the previous process, except at a high cost, even when the cost of production employing the new technique eventually rises above that of the old.

3. **Ignorance about unsustainability**: There may be ignorance about the unsustainability of pesticide use. Its use may be believed to be more sustainable than is in fact the case.

4. **High yielding varieties**: Pesticides are an integral part of commercially grown high yielding varieties and without the use of pesticides, high yields may not be sustained. Furthermore, chemical companies selling the pesticides have an incentive to push their use by advertising and promotion and this may create a bias in favour of their use.
5. **Damage is not immediately visible**: Damage to agricultural land from the use of pesticides occurs over a period of time. Hence, costs arising may not initially look serious. Furthermore, farmers do not compensate for the numerous externalities except in the case of production externalities.

6. **Long term health effects are not visible and difficult to prove**: It is also likely that in the majority of cases, the short-term health effects arising from pesticide are underestimated by farmers. This is because the real health effects resulting from exposure to pesticides accrue over a period of time. Furthermore, lack of diagnosis attributed to pesticide exposure often ignores the dangers of pesticide use. Ill health then is attributed to another cause. Besides, long-term relationship between pesticide exposure and health effect is complicated and because of the time involved is less easy to prove.

7. **Farmers become locked in to unsustainable agriculture**: When chemical agricultural systems are adopted, agricultural yields or returns become dependent on them despite the very high costs, and thus impose an ‘economic barrier’ to switching to organic systems. Thus farmers become locked into ‘unsustainable’ agricultural systems once pesticides are adopted. This is because of the heavy initial costs of switching to more sustainable systems and the need for all to act simultaneously in the switching process if economic losses are to be avoided.

8. **To be the only one to practice biological control is not possible**: The use of chemicals affects biological pest control strategies by killing the predators of pests. Hence, even if some farmers decide to adopt biological pest control strategies, they would be affected due to externalities of pesticides arising from neighbouring farms.

In his dissertation ‘Learning from Carchi – Agricultural Modernisation and the Production of Decline’ Sherwood sketches a similar analysis of the problem of pesticide use in rural societies and why farmers continue to use highly toxic pesticides even though they are harmful (Sherwood 2009). Carchi is a province in the North of Ecuador, an area well known for its potato production. During the Green Revolution the area was transformed into an ‘industrial’ like agriculture: potato cultivation was intensified by mechanized tillage and introduction and increased reliance on external inputs and agrochemicals. This resulted in external input intensive monoculture cultivation, a destabilised biological system and soil degradation. Farmers came to believe that they need pesticides in order to have good yields in their potato crops. However, they also saw that pest problems were increasing. Increasingly, farmers began to lose money on their crops and at the same time, farmers and families suffered harmful effects from acute and chronic exposure to chemicals. In summary, agricultural modernisation undermined the ecosystems and eventually worked against the health and economic well-being of the rural people (Sherwood, 2009).

After introduction of a Farmer Fields School (FFS) approach in Carchi and despite much cross-disciplinary learning and practice, the outcome was that the vast majority of rural people in Carchi continued to be chronically exposed to pesticides, and as a result, they suffered neurological damage that even affected farm productivity and family well-being. FFS provoked new thinking and creative practice at the farm level, however the methodology faced limitations at leveraging institutional change. Sherwood came to the conclusion that the major obstacles to change were not due to mere lack of information, knowledge, technology, or alternatives, as experts and policy makers commonly argue. Instead more social forces were at play.

Sherwood concluded that too many people benefit from the pesticide business and therefore do not want to recognise or take responsibility for the problems. The farmers themselves were even blamed for their improper use of pesticides. Government and pesticide companies preferred campaigns to promote and raise awareness on the safe use of pesticides. However, Sherwood has from own experience found that such safe-use-of-pesticide programmes are ineffective. One of his study’s conclusions is that farmers will only stop using highly toxic pesticides if the government imposes restrictions on their use. However, the government will only do this if it is forced to, possibly by international regulations and control measures.
List of useful websites

Codex Alimentarius
http://www.codexalimentarius.org/

EU Pesticide database
http://ec.europa.eu/sanco_pesticides/public/index.cfm

EU Legislation on Pesticides

European Food Safety Authority

FAO International Code of Conduct on the Distribution and Use of Pesticides

Indonesia – Pesticide Registration
http://www.deptan.go.id/pengumuman/berita/regulasi-pestisida.htm

International Labour Organisation – safety and health at work

OECD - Agricultural pesticides and biocides
http://www.oecd.org/chemicalsafety/pesticides-biocides/agriculturalpesticides.htm

Pesticide Action Network (PAN) - Pesticide Database
http://www.pesticideinfo.org/

Pesticide Action Network (PAN) – List of Lists
http://www.pan-uk.org/List%20of%20Lists.html

Rotterdam Convention
http://www.pic.int/

Stockholm Convention
http://chm.pops.int/

World Health Organization – Pesticides
http://www.who.int/topics/pesticides/en/
References


veglIMPACT Report 2 – Occupational Pesticide Exposure - A literature and policy review


## Annex 1

Table: Adverse health effects caused by selected classes of pesticides

<table>
<thead>
<tr>
<th>Chemical/chemical class</th>
<th>Examples of pesticides</th>
<th>Clinical presentation</th>
<th>Route of exposure</th>
</tr>
</thead>
<tbody>
<tr>
<td>Arsenicals</td>
<td>Arsenic trioxide, CCA, sodium arsenate</td>
<td>Abdominal pain, nausea, vomiting, garlic odour, metallic taste, bloody diarrhoea, headache, dizziness, drowsiness, weakness, lethargy, delirium, shock, kidney insufficiency, neuropathy</td>
<td>O, R, D (rarely)</td>
</tr>
<tr>
<td>Borates (insecticide)</td>
<td>Boric acid, borax</td>
<td>Upper airway irritation, abdominal pain, nausea, vomiting, diarrhoea, headache, lethargy, tremor, kidney insufficiency</td>
<td>O, R, D (broken skin)</td>
</tr>
<tr>
<td>Carbamates (insecticide)</td>
<td>Carbaryl, thiram, aldicarb, mecarbam</td>
<td>Malaise, weakness, dizziness, sweating, headache, salivation, nausea, vomiting, diarrhoea, abdominal pain, confusion, dyspnea, dermatitis, pulmonary oedema</td>
<td>O, D</td>
</tr>
<tr>
<td>Chlorphenoxy compounds(herbicides)</td>
<td>Di/tri-chlorophenoxyacetic acid, MCPP</td>
<td>Upper airway and mucous membrane irritation, abdominal pain vomiting, diarrhoea, tachycardia, weakness, muscle spasm, coma, acidosis, hypotension, ataxia, hypertonia, seizures, dermal irritation, headache, confusion, acidosis, tachycardia</td>
<td>O, D</td>
</tr>
<tr>
<td>Chemical/chemical class</td>
<td>Examples of pesticides</td>
<td>Clinical presentation</td>
<td>Route of exposure</td>
</tr>
<tr>
<td>------------------------------</td>
<td>---------------------------------</td>
<td>--------------------------------------------------------------------------------------</td>
<td>-------------------</td>
</tr>
<tr>
<td>Calciferol (rodenticide)</td>
<td>Cholecalciferol, ergocalciferol</td>
<td>Fatigue, anorexia, weakness, headache, nausea, polyuria, polydipsia, renal injury, hypercalcemia</td>
<td>O</td>
</tr>
<tr>
<td>Chloralose</td>
<td>Chloralose</td>
<td>Vomiting, vertigo, tremor, myoclonus, fasciculations, confusion, convulsions</td>
<td>O</td>
</tr>
<tr>
<td>Copper compounds (fungicide)</td>
<td>Copper acetate, copper oleate</td>
<td>Abdominal pain, vomiting, skin/airway/mucous membrane irritation, renal dysfunction, coma</td>
<td>O, R, D</td>
</tr>
<tr>
<td>Coumarins (rodenticide)</td>
<td>Brodifacoum, warfarin, pindone</td>
<td>Echymoses, epistaxis, excessive bleeding, haematuria, prolonged prothrombin time, intracranial bleed, anaemia, fatigue, dyspnea</td>
<td>O, D (possible)</td>
</tr>
<tr>
<td>Diethyltoluamide (insect repellent)</td>
<td>DEET (N,N-diethyl-meta-toluamide)</td>
<td>Dermatitis, ocular irritation, headache, restlessness, ataxia, confusion, seizures, urticaria</td>
<td>O, D</td>
</tr>
<tr>
<td>Dipyridil (herbicide)</td>
<td>Paraquat, diquat</td>
<td>Mucous membrane and airway irritation, abdominal pain, diarrhoea, vomiting, gastrointestinal bleeding, pulmonary oedema, dermatitis, renal and hepatic damage, coma, seizures</td>
<td>O, D (via broken skin)</td>
</tr>
<tr>
<td>Phosphonates (herbicide)</td>
<td>Roundup, glyphosate</td>
<td>Airway, skin, and mucous membrane irritation,</td>
<td>O, R</td>
</tr>
<tr>
<td>Chemical/chemical class</td>
<td>Examples of pesticides</td>
<td>Clinical presentation</td>
<td>Route of exposure</td>
</tr>
<tr>
<td>-------------------------</td>
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<td>-------------------</td>
</tr>
<tr>
<td>Fluoroacetate (rodenticide)</td>
<td>Sodium fluoroacetate</td>
<td>Vomiting, paresthesias, tremors, seizures, hallucinations, coma, confusion, arrhythmias, hypertension, cardiac failure</td>
<td>O, D (possible)</td>
</tr>
<tr>
<td>Mercury, organic (fungicide)</td>
<td>Methyl mercury</td>
<td>Metallic taste, paresthesias, tremor, headache, weakness, delirium, ataxia, visual changes, dermatitis, renal dysfunction</td>
<td>O, R, D</td>
</tr>
<tr>
<td>Metal phosphides (rodenticide, fumigant)</td>
<td>Zinc-, aluminium-, magnesium-phosphide</td>
<td>Abdominal pain, diarrhoea, acidosis, shock, jaundice, paresthesias, ataxia, tremors, coma, pulmonary oedema, tetany, dermal irritation</td>
<td>O, R, D</td>
</tr>
<tr>
<td>Halocarbons (fumigant)</td>
<td>Cellfume, Methyl bromide</td>
<td>Skin/airway/mucous membrane irritant, cough, renal dysfunction, confusion, seizures, coma, pulmonary oedema</td>
<td>O, R, D</td>
</tr>
<tr>
<td>Nitrophenolic and nitrocresolic herbicides</td>
<td>Dinitrophenol, dinitroresol, dinoseb, dinosarn</td>
<td>Sweating, fever, confusion, malaise, restlessness, tachycardia, yellow skin staining, seizures, coma, renal insufficiency, hepatic damage</td>
<td>O, R, D</td>
</tr>
<tr>
<td>Organochlorines (insecticide)</td>
<td>Aldrin, dieldrin HCB, endrin, lindane</td>
<td>Cyanosis, excitability, dizziness, headache,</td>
<td>O, R, D</td>
</tr>
<tr>
<td>Chemical/chemical class</td>
<td>Examples of pesticides</td>
<td>Clinical presentation</td>
<td>Route of exposure</td>
</tr>
<tr>
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</tr>
<tr>
<td>Organophosphates (insecticides)</td>
<td>Malathion, parathion, dichlorvos, chlorpyrifos</td>
<td>Restlessness, tremors, convulsions, coma, paresthesias, nausea, vomiting, confusion, tremor, cardiac arrhythmias, acidosis</td>
<td>O, D</td>
</tr>
<tr>
<td>Organotin (fungicide)</td>
<td>Fentin acetate, fentin chloride</td>
<td>Headache, dizziness, bradycardia, weakness, anxiety, excessive sweating, fasciculations, vomiting, diarrhoea, abdominal cramps, dyspnea, miosis, paralysis, salivation, tearing, ataxia, pulmonary oedema, confusion, acetylcholinesterase inhibition</td>
<td>O, R, D</td>
</tr>
<tr>
<td>Phenol derivatives (fungicide, wood preservative)</td>
<td>Pentachlorophenol, dinitrophenol</td>
<td>Skin, airway, and mucous membrane irritation, contact dermatitis, dyspnea, diaphoreses, urticaria, tachycardia, headache, abdominal pain, fever, tremor</td>
<td>O, R, D</td>
</tr>
<tr>
<td>Pyrethrins, Pyrethroids</td>
<td>Allethrin, cyfluthrin, permethrin</td>
<td>Allergic reactions, anaphylaxis, dermatitis, paresthesias, wheezing, seizures, coma, pulmonary oedema, diarrhoea, abdominal pain</td>
<td>R, D</td>
</tr>
<tr>
<td>Chemical/chemical class</td>
<td>Examples of pesticides</td>
<td>Clinical presentation</td>
<td>Route of exposure</td>
</tr>
<tr>
<td>----------------------------------------</td>
<td>------------------------</td>
<td>----------------------------------------------------------------</td>
<td>-------------------</td>
</tr>
<tr>
<td>Strychnine (rodenticide)</td>
<td>Strychnine</td>
<td>Muscle rigidity, opisthotonus, rhabdomyolysis</td>
<td>O</td>
</tr>
<tr>
<td>Thallium (rodenticide)</td>
<td>Thallium sulfate</td>
<td>Abdominal pain, nausea, vomiting, bloody diarrhoea, headache, weakness, liver injury, hair loss, paresthesias, neuropathy, encephalopathy, cardiac failure</td>
<td>O</td>
</tr>
<tr>
<td>Triazines (herbicide)</td>
<td>Atrazine, prometryn</td>
<td>Mucous membrane, ocular and dermal irritation</td>
<td>O, R, D</td>
</tr>
</tbody>
</table>

Route of exposure key: O = oral/ingestion; R = respiratory/inhalation; D = dermal/ocular
Abbreviations: CCA = chromated copper arsenate; HCB = hexachlorobenzene; MCPP = methyl chlorphenoxy propionic acid
Source: (Thundiyil, et al. 2008)