OPERATOR EXPOSURE TO PESTICIDES

Graham Matthews from IPARC at Imperial College of Science, Technology and Medicine, Silwood Park, UK, gives an overview of exposure to pesticides at the various stages in pesticide use.

Introduction
Since the early studies of Durham and Wolfe (1962) operator exposure to pesticides during application has been a major factor considered by registration authorities, whether the pesticide is used on large scale farms, or by householders in their home or garden (Chester, 1993; Gilbert, 1995), yet comparatively little data on operator exposure has been published. Wolfe (1976) reviewed the early methods of measuring exposure to spray, but more recent studies have tended to use fluorescent tracers collected on whole garments (e.g. Sutherland et al., 1990). Other studies have used a dodecahedron of UV lights to visualise fluorescent deposits on clothing (Roff, 1994). In some studies, biomonitoring has been done with a low toxicity pesticide and its metabolites measured in urine samples (e.g. Krieger and Dinoff, 2000).

Under the new European approach to pesticide registration covered by Directive 91/414/EEC, the European Predictive Operator Exposure Model (EUROPOEM) will be used to estimate the amount of exposure for different situations (Glass et al., 2000). This prediction is compared with an Acceptable Operator Exposure Level (AOEL) to assess whether it is safe to apply a pesticide using recommended application techniques. This is based on toxicity study data, usually with rats, to determine a No Observed Adverse Effect Level (NOAEL), which is divided usually by 100† to allow for differences in sensitivity between the test animals and humans, and the variation between individuals. Although EUROPOEM as a tool for general exposure evaluation will be used when approved by member governments, more data is required to test the validity of the predicted exposure level in different situations, and field assessments have been carried out recently, especially in southern Europe (Machera et al., 2001). Actual exposure will vary at different stages of the treatment process, depending on the type of pesticide product being applied e.g. low concentration granule or a high concentrated liquid formulation, and on the handling and application procedures adopted. In order to reduce the need for personal protective clothing, emphasis has been put on engineering controls to minimise exposure.

† Factor of 100 is essentially made up of two x10 uncertainty factors (see From Risk Assessment to Risk Management: Dealing with uncertainty. (1999) Risk assessment and Toxicology Steering Committee, Institute for Environment and Health Leicester. Also Renwick (1991).

Preparation of spray
The majority of pesticides are applied as sprays so a key area of concern is when the concentrate is diluted to prepare a spray. There have been significant changes in container design to improve the ease of pouring pesticide and the extensive adoption of low-level induction bowls has also facilitated the transfer of the formulation into a sprayer (Figure 1). Tests reported by Glass et al. (2002) indicated usually less than 0.01ml per fill of the sprayer was on the operator, when pouring pesticide from a container into an induction hopper. In addition to coveralls and gloves,
personal protective equipment (PPE) at this stage usually includes an apron and face visor to avoid splashes on the coveralls or face. The risk of inhaling aerosols during mixing and loading is minimal in relation to overall exposure (Wolf et al., 1999). Cotton coveralls have in some cases been replaced by polypropylene disposable coveralls, as these also eliminate the need for laundering, but they are less comfortable to wear in very hot weather. Various special finishes to cotton fabrics are also been tried for use in tropical countries. Tests for the suitability of coveralls have been described by Gilbert and Bell (1990).

Ideally the pesticide is transferred to the sprayer by a closed transfer system, incorporating a measure, that meets the BS 6356 part 9. However closed transfer systems have not been widely adopted yet. This is partly due to need for different apparatus to meet the needs of a range of different formulations, including wettable granules as well as liquids. Most systems are linked to the use of multi-trip containers, but these have only received limited support. Some closed transfer systems will fit standard containers, and allow the empty container to be washed out.

In Third World Countries the situation as regards PPE during the preparation of spray is very different (Figure 2).

**During spraying**

In large-scale agriculture, the operator is well protected inside the tractor cab (Figure 3), but must be careful not to take contaminated clothing into the cab, supplied with filtered air. In well designed cabs, filters remove at least 99% of aerosol particles larger than 3 µm (Hall et al., 2002). Care is needed if nozzles, the spray boom or other components need attention, when the hands in particular could be exposed to concentrated spray deposits. Most sprayers should now have a separate water tank for washing any spray off gloves (Figure 4) and separate lockers for clean and used PPE. Actual exposure during this period should therefore be minimal, although the period during which the operator may be exposed can be several hours.

The situation is quite different where manually carried equipment is used (Figure 5), especially on small farms in tropical countries, where relatively few farmers use PPE.
either due to its cost or lack of comfort in a hot climate, even when applying highly toxic pesticides. This applies not only to manually operated knapsack sprayers but also to units with a motorised pump and hose carried by the operator. Operators are not only exposed to the diluted spray for lengthy periods as they tend to walk through crops with the spray nozzle held in front of them, but poor quality equipment and lack of maintenance often results in leaks of pesticide over the operator's hands and back. In recognition of this problem, FAO has issued minimum requirements for sprayers in an effort to get better quality sprayers used (see http://www.fao.org/docrep/X2244E/X2244E00.htm). A pilot project has been started in Cameroon to develop a training programme that will facilitate adoption of these minimum requirements throughout Africa (Matthews, 2002).

Even if better quality sprayers do get used, emphasis is also put on reducing operator exposure, by at least wearing a long sleeved shirt and long trousers or the equivalent local clothing to minimise the area of skin exposed to the pesticide. In some areas simple plastic tabards are used to reduce direct exposure of the body yet provide adequate ventilation. Tests in India have shown that by controlling spray pressure, operator exposure was reduced (Shaw et al., 2000). Use of a coarser spray for an air induction nozzle can also reduce operator exposure (Wicke et al., 1999). Simply holding the nozzle downwind, as advocated with hand-carried rotary atomiser sprayers, widely used to control cotton insect pests, will reduce operator exposure. (Thornhill et al., 1996). Even when approved coveralls are used, the correct wearing of the protective clothing is an important factor determining its protective value to the wearer, as demonstrated by recent UK research sponsored by the Health and Safety Executive (HSE, 2002).

Generally in open fields, inhalation exposure is negligible due to the extremely small volume of spray in droplets small enough to be inhaled into the lungs. Nevertheless there is concern about downwind spray drift which may be deposited on bystanders, as this is the cause of some reports to the Health and Safety Executive. However, tests have shown that generally the exposure of unprotected bystanders is only a fraction compared with the spray operator (Gilbert and Bell, 1988). In practice people entering fields after treatment may be aware of certain spray treatments, if they smell vapour from the spray deposit on the crop, but exposure to the deposits, once they have dried will be depend on how dislodgeable they are by contact.

**After spraying**

Careful calibration is essential so that all the spray is applied to the treated area and the washing of the tank is within the
field. Extra water is added to the empty tank and the washings are ideally sprayed out on the last swath. By careful sprayer design, the amount of liquid remaining in the sprayer is kept to a minimum. Nevertheless, parts of the sprayer may have pesticide deposits, so particular care is needed to avoid exposure to the pesticides during maintenance of the equipment (Figure 6). Care is needed to avoid entry into and touching treated crops immediately after a spray application as the hands and other parts of the body touching treated surfaces may be wetted by spray deposits or later pick up dry, dislodgeable residues, especially when harvesting treated crops (Van Hemmen and Brouwer, 1997).

**Improving safety**

The effect of pesticides on spray operators and others working in treated areas is mostly due to dermal exposure, yet much of the emphasis on toxicology is related to the oral route. In consequence numerous assumptions are made in worker risk assessments. It has been suggested therefore that methods of assessing dermal absorption, including the use of human subjects, need to be improved and that more needs to be known about interspecies pharmacokinetics to determine an appropriate toxicology study regime to reflect intermittent worker exposure (Ross et al., 2001).

In many countries, responsible registration of pesticides has limited the use of the most toxic pesticides, or restricted their use to fully trained operators. This contrasts with many other areas of the world, where lack of enforced regulation has allowed untrained people access to highly toxic pesticides. The majority of the deaths caused by pesticides are either due to suicides or due to contaminated

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**Example of an estimate of operator exposure**

This example is to show the procedure in principle. The extent of operator exposure will vary with different equipment and the extent of operator training and care taken in practice.

<table>
<thead>
<tr>
<th>Tractor sprayer with hydraulic nozzles</th>
<th>Knapsack sprayer</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Product concentration</strong></td>
<td>250 mg/ml</td>
</tr>
<tr>
<td><strong>Concentration in use</strong></td>
<td>0.5 mg/ml</td>
</tr>
<tr>
<td><strong>Spray volume</strong></td>
<td>200 l/ha</td>
</tr>
<tr>
<td><strong>Work rate</strong></td>
<td>50 ha/day</td>
</tr>
<tr>
<td><strong>Number of tank loads</strong></td>
<td>20 /day</td>
</tr>
<tr>
<td><strong>Contamination of hand</strong></td>
<td>0.01 ml</td>
</tr>
<tr>
<td><strong>per mixing operation, so</strong></td>
<td>0.2ml/day</td>
</tr>
<tr>
<td><strong>With gloves 5 % reaches the skin</strong></td>
<td>0.01 ml/day</td>
</tr>
<tr>
<td><strong>During spraying over</strong></td>
<td>5 h</td>
</tr>
<tr>
<td><strong>Contamination of body</strong></td>
<td>10 ml/h</td>
</tr>
<tr>
<td><strong>With gloves</strong></td>
<td>34.6 ml/day</td>
</tr>
<tr>
<td><strong>Absorbed dose during mixing</strong></td>
<td>0.25 mg/day</td>
</tr>
<tr>
<td>with gloves</td>
<td>[0.01 x 250 x 0.1**]</td>
</tr>
<tr>
<td>or without gloves</td>
<td>5 mg/day</td>
</tr>
<tr>
<td><strong>during application</strong></td>
<td>1.73 mg/day</td>
</tr>
<tr>
<td><strong>Inhalation exposure</strong></td>
<td>0.01 ml/h</td>
</tr>
<tr>
<td><strong>Inhalation absorbed dose</strong></td>
<td>0.025 mg/day</td>
</tr>
<tr>
<td><strong>Thus total predicted exposure</strong></td>
<td>2.01 mg/day</td>
</tr>
<tr>
<td><strong>[0.25 + 1.73 + 0.025] with PPE.</strong></td>
<td>0.033 mg/kg bw/day</td>
</tr>
</tbody>
</table>

This last value is compared with the AOEL of the pesticide being applied.

If NOAEL is 800mg/kg bw/day, then a systemic AOEL would be set at 0.8 mg/kg bw/day. If total systemic exposure (i.e. the absorbed dose) was estimated at 0.03 mg/kg bw/day, this is 4% of the AOEL, whereas 1.128 is 141% ; and not acceptable. If with the knapsack, through improved glove performance/hygiene the amount reaching the skin is lowered to 1%, this reduces the exposure to 0.031 mg/kg bw/day, i.e. 39% of AOEL.

* This value is based on a trial with small-scale farmers asked to measure out a dye solution with a small 50 ml plastic cup (Craig and Mbevi, 1993). Different techniques of dispensing small quantities can significantly reduce operator exposure e.g. use of tablet formulation, water soluble sachets and containers with built-in measure.

** This assumes 10% absorption through the skin

## These values are used for illustration and may differ according to circumstances.
produce, but in relation to cases of exposure in the field, doctors in developing countries have had to deal with many cases of poisoning (e.g. Ngowi et al., 2001). With manually operated equipment requiring small quantities of active ingredient, much can be done to reduce the amount on the operators’ hands and by improving coveralls, improve protection of areas, such as the lower legs, exposed to spray while walking through crops. Spray operator training and certification will need to be increased, but is a major task in tropical countries with very many small farms. Clearly, with an increasing world population to be fed, pesticides will continue to be an important tool in IPM/ICM programmes, but for this to be more acceptable greater efforts are needed to minimise ill health due to operator exposure as well as minimising environmental pollution.

Further information

References

Pesticides Neus, 19, 3–5.