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The assessment of farmworkers exposure to pesticides

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To sum up

The objective of this chapter is presenting the so-called "Wesseling pathway". It consists of relevant data and relationships to calculate comparatively the "human cost of pesticides" for agricultural workers. It is based on expert knowledge.

Outlook

1. Some constraints of the assessment of pesticides health risk

Assessing the magnitude of health risks from pesticide exposures in the workplace is of the utmost interest. Nevertheless, it is difficult to do for many reasons. Exposures are usually intermittent and pesticide metabolites have a short half-life. Nonetheless, available scientific evidence strongly suggests that pesticides cause cancer and other health damages in both people who use the pesticides directly and people who are exposed because of applications made by others. The problem may well be more extreme in developing countries because regulatory controls are weaker or non-existent, and because safe methods of handling pesticides and safety practices are often lacking.

In this chapter, we explain the reasons for developing a decision support tool to help decision makers. The tool's objective is to classify by anticipation different cropping systems, regarding their impact on farmworkers health. The generic tool would be applicable on the agricultural phase of the life cycle of any agricultural product. To date, we developed only one specific tool for banana plantations. For simplification sake, here we expose results about operators' (workers directly using pesticides) health only.

2. Links between cropping systems, pesticides and Human Health

Damages to operators' health caused by pesticides use are modulated and influenced by many different factors, which can be roughly depicted by the figure 1. To comply with country or market regulations, or because of new company policies (e.g. due to environmental/social labels) or cost reduction, variations can occur in the chain leading to damaging operator's health (figure 1).

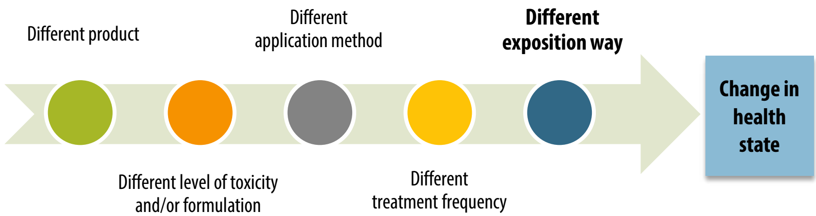


Figure 1: The change in damage to operator's health because of pesticides can have many causes

Consequently, the damage caused by pesticides to one operator's health can be modulated by:

- different levels of toxicity;
- different formulations, which may change the way of exposure (e.g. if one switch from liquid to powder, the exposure can evolve from a principal dermal exposure to a principal inhaling exposure);
- different application methods (when changing from aerial to terrestrial application, the level of exposure changes too);
- different treatment frequency. The more the treatment is frequent, the more the operator is liable to be exposed;
- different changes of exposure way (for instance from inhaling exposure to dermal exposure, with different quantities);
- etc.

The modulating factors are not independent. For instance, changing the product will consequently likely change the product formulation, which would lead to modification of the application technique, which entails a variation of level and exposure way.

If methods are able to discriminate cropping systems according to these different criteria, they are able to account for damage to operator's health because of pesticides.

3. Current methods to discriminate cropping systems thanks to assessment of pesticides impact

There are different current evaluation methods liable to contribute to the purpose of anticipating health state. A literature analysis highlights that they can be sorted out between two principal groups:

- Environmental-Life Cycle Impact Assessment (E-LCIA) methods,
- Risk Assessment (RA) methods.

3.1 E-LCIA methods

To date, E-LCIA methods are not designed to address health damages to certain target populations. In general, the target experiencing health damage in an "average human being". E-LCIA methods focus on the quantity of toxic substance emitted in different "environmental compartments" (like air, ground water, etc.).

E-LCIA methods are able to discriminate between different cropping systems relying on differences (table 1) in:

- **dose and treatment frequency**, because the total quantity of pesticide in use is taken into account in the inventory data of E-LCIA, as being the unitary dose per treatment x the number of treatments per year;
- **pesticide toxicity**, when the pesticide is present in the ELCA databases.

The advantage of E-LCIA methods is that they do not need other data than the ones in use to assess other environmental impacts.

Regarding the assessment of human cost of pesticides for operators' health, there are many drawbacks of E-LCA methods:

- in general, there is little consensus on the calculation of the impact "Human Health" in E-LCA. Especially the calculation of toxicity is challenging. The UseTox 1.0 method has tried to build a consensus;
- these methods have a limited validity for all regions that cannot be defined as well-developed temperate regions (Goedkoop et al. 2009, 5). Indeed, these methods are developed in Europe for the Europe itself, inasmuch they use European

Considered	Not considered
Dose	Dermal exposure
Treatments frequency	Tropical pathosystem
Pesticide toxicity (if the product is present in databases) !!	Application technique variation
	Cultivation system variation

Table 1: Synthesis of issues considered or not considered in E-LCIA

normalisation values (Goedkoop and Spriensma 2001; Guinée et al. 2002; Hauschild and Potting 2005);

- in the E-LCIA method, the main exposure way is inhalation, while the field exposure studies have shown that in the workplace, the main route of exposure is dermal exposure (Inserm 2013);
- E-LCIA does not consider the effects of the variation in the application technique.

Consequently, it is a necessity to search for another method allowing to quantify the "human cost of pesticides" for operators.

3.2 Risk Assessment

In Risk Assessment, distinction is made between acute and chronic toxicity. They are not evaluated with the same methods, given their radically different nature.

- In general, the assessment criteria for chronic toxicity are carcinogenicity, genotoxicity, endocrinal perturbation, reproduction perturbation and development perturbation.
- In general, the assessment criteria for acute toxicity are: DL_{50} oral (mg/kg), DL_{50} dermal (mg/kg), CL_{50} inhalation (mg/l), dermal irritation, ocular irritation, sensitization.

In Risk Assessment, known chronic and acute toxicity of the substance may be combined in the same calculation (e.g. in figure 2) with other criteria. The result of the mathematical formula (figure 2) is a figure, which stands for the value of the impact of the active substance (IRSA active substance).

IRSA active substance = IRTas x FPf x FCP x FPa

IRTas = [acute toxicity + (chronic toxicity x persistence factor)]²
FPf = weighting factor on formulation of commercial product
FCP = weighting factor on dose applied
FPa = adjustment factor on application technique

Figure 2: Example of Equation for Risk assessment

The value of the impact for the product in use (e.g. pesticide) is the total of the different active substances included in the formulation.

$$IRSA\ product = \sum IRSAas$$

To highlight the factors influencing the results from Risk Assessment, we take the example of the equation developed by Mghirbi et al. (2015) to assess the Health Risk Indicator for Operators (*Indicateur de Risque Santé Applicateur, IRSA*). In this approach, changes in formulation, dose and application techniques, entail changes in the result of the equation. Indeed:

- if the product applied changes, then all parts of the equation will change;
- if the application technique changes while keeping the same product, consequently it will change the adjustment factor FPa, and possibly the applied dose (which modifies the value for FCP);
- if only the formulation is different, it will change FPf at least;
- if there is variation of the cultivation system, and if we assume it entails a variation of application techniques or formulation or products, we turn back to the cases above.

Theoretically, the IRSA equation is able to assess the variations of impacts between different pesticides. Nevertheless, the construction of the equation can be criticized from different points of view.

1) First of all, by squaring the factor (IRTas) standing for toxicity, IRSA equation gives primacy to substance toxicity. Moreover, the other terms of the equation are only weighting or adjustment factors. The equation therefore addresses health impacts through mainly toxicity of the substance. Nevertheless, on the practical side, there is some evidence that workers behave differently regarding the toxicity of the pesticide at hand. They lower their level of exposure when they think that the pesticide is very toxic, and they increase their level of exposure when they deem the pesticide not to be dangerous. So, toxicity cannot be the unique principal factor taken into account when assessing health risks for workers.
2) Chronic toxicity assessment is more difficult and inaccurate than acute toxicity assessment. There may be an underestimation of the chronic toxicity (if you are not aware of the disease/risk, you do not care/there is no prevention).
3) Regarding the weighting factor to account for the formulation issue (FPf) it is not clear how to calculate it. It is based on Samuel et al. (2012). At page 5 of the report there is a table (table 4) stating that the more severe exposition route is the inhalation one, despite in the field of pesticides, the worst way of exposure is dermal contact.

4) Analysing the adjustment factor on application technique (FPa), we deem that it is insufficient to take application technique into account only through an adjustment factor. Indeed, we know that many bad practices occur because of certain application techniques. This factor would deserve more accurate details.

In general, the model was created keeping the idea in mind that toxicity is the more important factor to evaluate.

Whatever the case, in the field of pesticides, **the real exposure is the major subject to investigate** (and consequently the application technique).

3.3 Synthesis

Regarding the damages caused by pesticides use to operators' health, Risk Assessment focus to different level of toxicity and/or different formulations, while E-LCIA focus on the assessment of different quantities of spread pesticides.

We therefore seek to complement these approaches by the Wesseling pathway, whose aim is to assess the **change in the operator's exposure way**, due to changes in the previously mentioned variables.

The figure 3 provides a synthetic picture of the principal factors highlighted by the three methods.

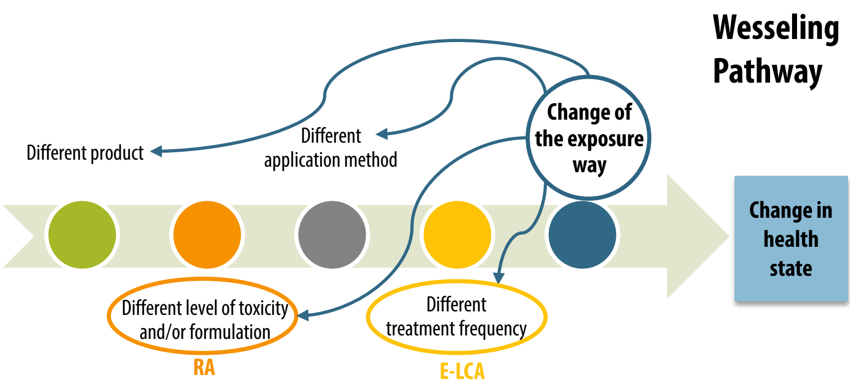


Figure 3: Different methods address different factors

4. *The Wesseling pathway focus on the exposure level*

Since the current methods do not allow to consider the actual practices on the ground, we propose a model that considers practices and which is usable to anticipate future impacts.

We took as object of study the **case of banana farmed to exportation**. Banana is the most commercialized fruit in the world. Moreover, the economies of several developing countries are dependent from this crop.

We based our work on experts (of banana plantations) elicitation. Indeed, to date, it is the only one way to account for the real practices on the ground. Expert elicitation refers to a systematic approach to synthesize subjective judgments of experts about one issue, when there is uncertainty due to insufficient data, or when such data are unattainable because of physical constraints or lack of resources.

We applied expert elicitation through a Delphi expert consensus method. The collected interviews testimony that – under some particular working conditions (e.g. heat and humidity) – the exposure risk becomes very high, because the use of personal protective equipment (PPE) is thwarted by the working conditions.

4.1 Knowledge trees

From the interviews, we designed knowledge trees. The aim was creating several cause/effect chains (one is represented by the figure 4) relating each cropping action that entails use of chemicals (mainly pesticides and fertilizers) to the potential health damage caused by acute toxicity.

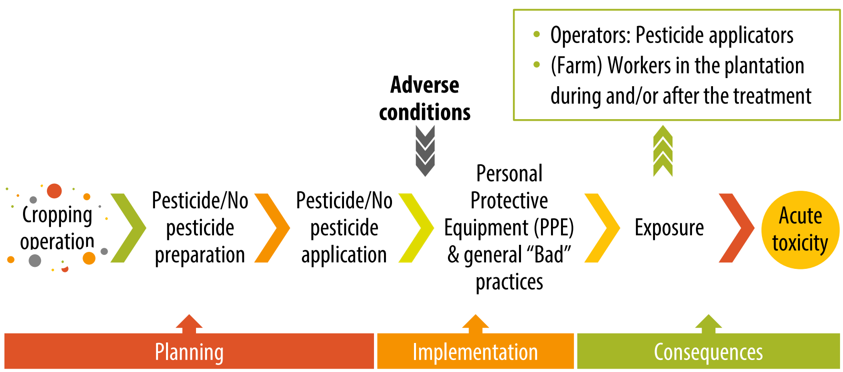


Figure 4: Generic drawing of one cause-effect relationship between one cropping operation and the potential health damage caused by acute toxicity

Exposure can occur through the preparation and application techniques of chemicals (e.g. pesticides), or during the cleaning step.

Thanks to the experts' interviews, we were able to relate the different situations with application techniques, and workers behaviours concerning PPE when they practice pesticide application. All these practices impact on the health of three populations at least: operators, farmworkers working in the plantation during the treatment, and farmworkers entering the field after the treatment.

4.2 "Human cost of pesticides" equations

For one cropping action

Starting from the knowledge trees, we built "human cost" equations for the three farmworkers' population affected. **The main contribution of experts is providing the wj (degree of operators exposure) terms for diverse conditions**. The general equation allowing to calculate the average human cost of pesticides for operators **for one cropping action** is depicted as below:

$$Human\ cost_{operators}\ for\ one\ action = \left(\sum_{j=1}^{3} k_j N_j w_j \frac{1}{AOEL_j}\right)$$

with:

- j means one among three tasks: preparation, application or cleaning;
- k_j represents the number of operators involved in this task;
- N_j denotes the number of times the task is repeated, under the same conditions, on the perimeter of the space-time computation;
- **w_j reflects the degree of operator exposure, and is found out in the knowledge trees based on a specific task at a specific point of the production system, and for certain conditions;**
- $1/AOEL_j$ stands for the toxicity of the product used in the task j.

For several cropping actions

The calculation of pesticide human cost can be achieved following temporal and spatial aggregations of several "costs of one cropping action":

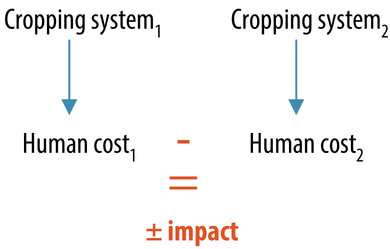
- for the entire lifespan of a plantation (5-30 years);
- for the cycle corresponding to a single crop (9 months to 12 months in routine);
- for all transactions for a year on a routine plantation (about 52 crops per year);
- by parcel, per hectare, or per any area of the plantation.

Interpretation of the results of pesticide human cost calculations should be done only by comparing at least two scenarios implemented with the same temporal and spatial scales. Indeed, the result of a calculation alone is meaningless in the absolute.

4.3 Usage of equations for social LCA

The method is useful to compare different cultivation systems for the same crop, or to compare systems for different crops.

Given two cropping systems (1 and 2) for the same crop, and that could be implemented in the same place (e.g. convenient soil and climatic conditions), we can calculate their respective "human cost". Here, the cropping system1 is the currently implemented one. It is our baseline system.



The difference between the two "human costs" (human cost 2 – human cost 1) provides the health impact of the change when replacing the cropping system 1 (the baseline) by the cropping system 2.

For instance, if the change is caused by change in the variety of the crop (which entails many consequences in terms of cropping system), the difference (human cost 2 – human cost 1) is the change in human cost caused by the change in the variety.

Conclusions

To conclude, the **strengths of the method** are that it is based on the real (and sometimes "bad") practices implemented in the plantations. All necessary data can be simply gathered. Moreover, the collect of data concerning the quantity of pesticide to which workers are exposed (which is especially difficult to capture) is not mandatory. The wj factor stemming from experts elicitation already takes this information into account.

Nevertheless, the Wesseling pathway is a simplified model of reality.

The Wesseling pathway is currently implemented for banana, but could be adapted to other agricultural products also.

We named this pathway from the name of Dr. Catherina Wesseling (see Wesseling et al. 1993) who spent her life to investigate health damage because of pesticides, with special attention paid to workers in banana plantation in Costa Rica.

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