

# SPECIFICATIONS FOR PESTICIDES A TRAINING MANUAL

## PARTICIPANT'S GUIDE



World Health  
Organization



Food and Agriculture  
Organization of  
the United Nations

# **Specifications for pesticides: a training manual**

## **Participant's guide**



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# List of abbreviations used in the training course

CIPAC	Collaborative International Pesticides Analytical Council
CS	capsule suspension
EC	emulsifiable concentrate
EU	European Union
GC-FID	gas chromatography, using a flame-ionization detector
GHS	Globally Harmonized System of Classification and Labelling of Chemicals of the United Nations Economic Commission for Europe (UNECE), accessible under the Transport of Dangerous Goods heading at <a href="http://www.unece.org/trans/">http://www.unece.org/trans/</a>
HPLC-UV	high performance liquid chromatography, using an ultraviolet light absorption detector
IPCS	International Programme on Chemical Safety, a joint programme of WHO, the International Labour Organization (ILO) and the United Nations Environment Programme (UNEP)
ISO	International Organization for Standardization
JMPS	FAO/WHO Joint Meeting on Pesticide Specifications
LC-MS	high performance liquid chromatography, using a mass spectrometer as detector
LC-MS/MS	high performance liquid chromatography, using a tandem mass spectrometer as detector
LN	long-lasting insecticidal net
LOQ	limit of quantification
M1	Manufacturer 1 and/or the supporting data and test methods used by M1, which form the basis of a reference specification
M2	Manufacturer 2 and/or the supporting data and test methods used by M2, where a product of M2 is to be tested for equivalence with the corresponding product of M1
OECD	Organisation for Economic Co-operation and Development
OK	acceptable
OL	oil-miscible liquid
SE	suspo-emulsion
TC	technical material
TK	technical concentrate
UL	ultra-low volume (ULV) liquid
USEPA	United States Environmental Protection Agency
WG	water-dispersible granules
WHOPES	WHO Pesticide Evaluation Scheme

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# Background and preparation

## Why offer this course?

The International Code of Conduct on the Distribution and Use of Pesticides<sup>1</sup> promotes trade in, and use of, good-quality pesticides and discourages the distribution of poor-quality products. Specifications for pesticides are developed by the Food and Agriculture Organization (FAO) and by the World Health Organization (WHO) to enable good- and bad-quality products to be distinguished, using simple, robust and well-validated tests. The Code of Conduct further promotes the use of FAO/WHO procedures for the determination of equivalence.

The FAO/WHO Joint Meeting on Pesticide Specifications (JMPS) provides independent expert scientific assessment of the data supporting FAO and WHO specifications. The JMPS has developed standard procedures for assessment of pesticide data, including the determination of equivalence which minimizes the requirements for additional animal testing of pesticide hazards. The principles and practice of JMPS procedures are of utility to anyone involved in setting and ensuring standards for pesticide product quality, especially pesticide registration authorities. However, although simple in principle, JMPS procedures require extensive technical knowledge and expertise in practice, because almost every case is different.

## Who should take this course?

This course is intended for personnel with responsibility for defining and ensuring the acceptability of pesticide product quality.

## What is the purpose of the course and what are its objectives?

The purpose of this course is to provide an introduction to the principles and practice of defining acceptable quality and equivalence of pesticides, to assist both governments and industry to strengthen the underlying procedures required for quality control of pesticides used in agriculture and public health. The course does not address the procedure and requirements for adapting national pesticide registration systems to implement the principles of determination of equivalence, as promoted by the Code of Conduct,<sup>1</sup> but FAO and WHO recognize that this may involve a step-wise approach given the limited resources in many developing countries.

The objectives of the course are that participants completing it should understand the principles underlying specifications for pesticide quality control and be able to:

- apply well-established quality criteria to specific characteristics;
- apply well-established procedures where quality criteria must be defined case by case;

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<sup>1</sup> *International code of conduct on the distribution and use of pesticides* (revised version). Rome, Food and Agriculture Organization of the United Nations, 2002.

- determine whether or not different sources of an active ingredient, supported by different data, are equivalent;
- determine whether or not additional evidence or expert advice is required to support a decision on either equivalence or the acceptability of quality.

### **What approach is used to teach the course?**

The course is comprised of two main parts. The first is a plenary session, which provides an overview of the principles underlying specifications development and pesticide quality assessment. The second part involves model exercises, with participants working in teams to address typical cases and problems. The teams' solutions to each exercise are discussed before moving on to the next, so that lessons learnt can be put to good use immediately. However, the exercises are not repetitive and new problems are posed in each one. This reflects the real-life situation, where every case is different and some may present decision-making problems for which there is no precedent or model.

The course offers a step-by-step approach to acquiring the knowledge and skills needed for basic decision-making on development of pesticide specifications. Throughout the course, you should ask questions and discuss opinions freely. During the exercises, you should seek external help or clarification (from facilitator in lieu of a real manufacturer of the pesticide), if required, to reach a conclusion. This simulates real-life circumstances, where the pesticide manufacturer is often required to provide some additional information or clarification, and where it may also be necessary to consult published scientific literature or an independent expert in a particular discipline. This approach reflects the fact that, when dealing with technical data which invariably contain gaps and/or shortcomings, decisions must be based on inputs and opinion from a range of scientific disciplines. The importance of every detail of, or gap in, the data cannot be assessed by a single person, and an experienced team will have learnt to recognize when it requires additional expertise or information.

In addition to the technical issues addressed in the course, an underlying theme is to raise awareness of the delicate balance between maintaining the confidentiality of commercially-sensitive information and ensuring transparency of decision-making. Adoption of the internationally-recognized JMPS procedures is a first step towards achieving an appropriate balance in this respect. The second step is to maintain clear records of the basis for conclusions. Both are important where the basis for conclusions is not published, because the web of interdependent decisions leading to the overall conclusion may be forgotten quickly in complex cases. The documentation provided for the team exercises is designed to simplify and encourage recording of the basis for decisions.

### **Technical content of exercises**

The exercises are an essential part of the problem-based learning approach used in this course. The problems highlighted in the exercises were selected because of their frequency and/or importance in JMPS practice. The data in the exercises are not identifiable with any particular active ingredient or chemical structure, which minimizes preconceptions, bias and/or potential problems with confidentiality. You

should use your imagination and follow this through with a logical, scientific consideration of your ideas. *Evaluation tables* are provided, to assist you in a logical approach to the evaluation of data and a methodical approach to record-keeping.

As in real-life cases, the information initially provided in the exercises is not comprehensive. Considering each criterion in turn, teams should decide whether or not there is enough information to make a rational conclusion with respect to that criterion. One objective of the training is to help you to differentiate between problems which are unimportant and those which, unless resolved, will prevent the team from reaching a rational and defensible overall conclusion.

Teams are expected to identify gaps or problems in the information provided and to request additional information where the gap/problem prevents a decision being made. Facilitators are provided with supplementary information which can help to fill in the gaps or resolve problems. The supplementary information will be provided when a team asks the facilitator for help with a particular issue, but it would defeat the objective of the exercise if such details are provided without specific request. Facilitators will record the supplementary information provided to each team, to help in the post-exercise discussions.

You should note that, as in real-life cases, although the exercises have logical conclusions, different opinions can lead to different conclusions.

Commercially-confidential information is not included in the standard exercises. If appropriate, and with strict controls on participation and the maintenance of confidentiality, exercises may be conducted using real-life examples, to address locally-important issues. In such an exercise, everyone involved must have legitimate access to the data and no conflict of interest. Such exercises may follow the format of those given in this *training manual* but they are not part of the FAO/WHO training course and local organizers must accept responsibility for them.

## **Teamwork**

The multi-faceted nature of pesticide specifications issues require the combined expertise of a number of experts in various scientific disciplines, working together as an integrated team. Teamwork is therefore a key feature of the training course.

You should work in a team throughout the exercises. Each team should choose its own moderator, to coordinate discussions, and rapporteur, to record team decisions and the reasons for them.

All team members should contribute opinions and ideas freely, so that the team has a range of options to consider, before reaching conclusions. In these exercises, as in real-life cases, full participation by all team members will lead to better decisions and fewer mistakes. Superficially naive questions can sometimes challenge everyone to rethink their own assumptions and concepts.

Teams should record the reason(s) for decisions, or identify the information they would require before a decision can be made. The *Relevant impurities evaluation table* and *Equivalence evaluation tables* provided are designed to assist you towards logical overall conclusions.

### **What preparation is needed?**

The course is based upon the FAO/WHO document, *Manual on development and use of FAO and WHO specifications for pesticides*,<sup>1</sup> which provides a comprehensive coverage of the subject. The FAO/WHO specifications manual is supplemented by procedural updates, published annually in reports of the Joint Open Meetings of the Collaborative International Pesticides Analytical Council (CIPAC) and the JMPS, which are also available through the same web sites. Before the course, you should read the two chapters of the FAO/WHO specifications manual on: *Data requirements and procedures*; and *Aims, applicability and requirements of clauses*.

### **Other requirements for the course**

At the start of the course, you should have, or be provided with, a copy of the *Participant's guide*, preferably in a ring-binder. A ball-point pen (or pencil) and notebook (or paper) may also be required.

Tables of data and the appropriate blank *Evaluation tables* for exercises (Learning Unit G) will be distributed immediately before each exercise begins. At the end of each exercise, completed *Evaluation tables* will be distributed. The tables are intended to be kept with the *Participant's guide*, to complete it as a reference volume.

Each team of participants should have access to a suitable electronic calculator or spreadsheet program for the exercises (capable of calculating standard deviation values in Exercises 2–4).

Shortly before the end of the course, you will be given a course evaluation form. Please take a few minutes to complete it and return it to the local organizer before departing from the course.

A course completion certificate, if required by local custom, will be provided at the end of the course.

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<sup>1</sup> Available only on the Internet at <http://www.fao.org/agriculture/crops/core-themes/theme/pests/jmps/manual/en/> and <http://www.who.int/whopes/quality>

**LEARNING UNIT A**

# Introduction to the course

*Slide A-01*

## Importance of pesticides in food security and quality

- Pests and diseases are major causes of loss and quality degradation in agricultural production and food storage throughout the world.
- Migratory pests, such as locusts, can cause particularly dramatic losses within a region.
- The consequences, in terms of hunger, malnutrition and pressure to cultivate yet more land, are incalculable.
- Use of pesticides is a very important element in an integrated approach to control agricultural and food pests.

*Slide A-02*

## Importance of pesticides in controlling vector-borne diseases

- Vector-borne diseases are major causes of illness and death in many tropical and subtropical countries.
- Vector control has a key role in prevention and control of vector-borne diseases such as malaria, dengue and Chagas disease.
- Use of pesticides is the most important element in an integrated approach to vector control, especially during epidemics.

*Slides A-1 and A-2. Note that ...*

- (i) Pesticides, used judiciously, are essential tools in improving agricultural production and economies, as well as in vector and public health pest control. Pesticides are an important element in an integrated approach to pest/vector control.

*Slide A-03*

## Poor-quality pesticides ...

- are unlikely to serve the intended purpose;
- are likely to provide poor value to users;
- are likely to be more harmful, directly or indirectly, to humans and the environment;
- may be phytotoxic to treated crops or taint food.

*Slide A-04*

## Adverse effects of poor-quality pesticides

Blank slide: facilitator to insert examples

**Slide A-04. Examples of adverse effects of poor-quality pesticides ...**

- (i) Excessive level of a hazardous impurity increases risks of adverse effects on users, crops, food consumers and/or the environment.
- (ii) Insoluble particulates present in products intended for spray application may block nozzles and/or filters, delaying operations and increasing the risk of user exposure to active ingredient.
- (iii) Granular formulations that are too fragile may produce respirable dust when handled and applied, again increasing the risk of user exposure to active ingredient.
- (iv) Poor suspensibility of dispersions may produce uneven distribution of active ingredient in the spray tank and uneven application.
- (v) Poor retention/migration of insecticide through successive washes in a long-lasting insecticidal net (LN) leads to reduced personal protection of the user.
- (vi) If poor quality leads to poor efficacy, users may increase dose rates or the number of applications and unknowingly increase other risks.
- (vii) Users may dump poor-quality products into the environment, with potentially adverse effects on wildlife and drinking-water.
- (viii) Selectivity may be adversely affected.
- (ix) Any of the above consequences will usually have a negative impact on the marketability of a pesticide product and its registration could be withdrawn or restricted.

**As an aside to the Learning unit, but nonetheless very important, note that ...**

- (i) Even high-quality pesticides must be used carefully and judiciously, for good control of pests and vectors while avoiding adverse effects to people and the environment.

<i>Slide A-05</i>	<p><b>Goal of the training course</b></p> <ul style="list-style-type: none"> <li>• To enable you to make sound decisions about the control of quality of pesticides used in agriculture and/or public health.</li> </ul>
<i>Slide A-06</i>	<p><b>Objectives of the training course</b></p> <p>By the end of this course you should be able to:</p> <ul style="list-style-type: none"> <li>• apply well-established quality criteria for specific characteristics;</li> <li>• apply well-established procedures where quality criteria must be defined case by case;</li> <li>• determine whether or not different sources of an active ingredient, supported by different databases, are equivalent;</li> <li>• determine the additional evidence or expert advice required to support decisions on equivalence or the acceptability of quality.</li> </ul>

*Slide A-02. Note that ...*

- (i) The purpose of this course is to provide an introduction to the principles and practice of defining acceptable quality and equivalence of pesticides, to assist both governments and industry to strengthen the underlying procedures required for quality control of pesticides used in agriculture and public health. The course does not address the procedure and requirements for adapting national pesticide registration systems to implement the principles of determination of equivalence, as promoted by the Code of Conduct,<sup>1</sup> but FAO and WHO recognize that this may involve a step-wise approach due to the limited resources in many developing countries.
- (ii) The principles and procedures described in this course have been developed by the FAO/WHO Joint Meeting on Pesticide Specifications (JMPS). Although FAO and WHO are not international regulatory authorities, the JMPS principles and procedures are expected to be broadly applicable within most regulatory systems. Part of the overall purpose is therefore to encourage harmonization of registration requirements and procedures.
- (iii) The technical issues involved in dealing with each active ingredient and formulation tend to differ, and therefore the JMPS procedures must be applied intelligently and according to the requirements of each particular case. However, the following general principles are applicable in all cases:
  - (a) maintenance of commercial confidentiality;
  - (b) transparency of decision-making procedures;
  - (c) basing decisions on inputs from a team of scientists with expertise and experience in a range of appropriate disciplines;
  - (d) basing decisions on sound science and the best evidence available;
  - (e) keeping clear records of decisions and the rationales for decisions, especially where the decisions are made case by case.

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<sup>1</sup> *International Code of Conduct on the distribution and use of pesticides* (revised version). Rome, Food and Agriculture Organization of the United Nations, 2002.

**LEARNING UNIT B**

# Introduction to specifications for pesticides

Slide B-01

## Learning objectives

After this *Introduction*, you should understand:

- what is a pesticide specification, its aim and general requirements.

Slide B-02

## What is a pesticide specification?

- A list of basic quality criteria for distinguishing between products (of the same type) having acceptable and non-acceptable quality.
- It does **not** define the best product, **nor** is that the product suitable or safe for a particular purpose.

Slide B-02. **Note that ...**

- (i) A pesticide specification does not include all possible chemical and physical properties of a pesticide product but only the parameters critically related to their identity and quality.
- (ii) A specification should be brief but unambiguous and supported by appropriate test methods.
- (iii) Safety and suitability for purpose are the responsibility of registration authorities.
- (iv) Deciding which product is the best available for the purpose is the responsibility of the buyer or the buyer's advisers.

Slide B-03

A pesticide specification includes criteria for properties in some or all of the following categories ...

- description of the product
- active ingredient identity and content
- relevant impurities
- physical properties
- storage stability

Slide B-03. **Note that ...**

- (i) These categories and criteria will be addressed in more detail later in the training course.
- (ii) Specifications do not include clauses to control inherent properties of the active ingredient, which are not influenced by product quality. Information on such

properties is provided in the evaluations which are published in support of FAO and WHO specifications.

*Slide B-04*

Test methods supporting specifications

- Widely-accepted, well-validated test methods are essential.
- Test methods should be straightforward and robust.
- Well-trained technicians and a suitably-equipped laboratory are required for reliable results.

*Slide B-04. Note that ...*

- (i) Clearly defined, widely-accepted and/or well-validated methods are essential for making reliable, reproducible and comparable physical and chemical measurements. This is true both for developing specifications in the first place and for subsequent compliance testing. In the case of physical tests, methods must be applied without deviation, because the physical properties involved are defined by the method of measurement.
- (ii) Various international organizations provide the means by which test methods can be validated to an acceptable standard. CIPAC has provided the majority of well-known methods for compliance testing of physical and chemical properties of pesticide products (see [www.cipac.org](http://www.cipac.org)). Other organizations such as AOAC International and ASTM International also provide methods. Test methods for the physical properties of active ingredients tend to be those adopted by OECD, USEPA and the EU but, while these methods provide important supporting information for evaluating specifications, they are not appropriate for compliance testing because pesticide specifications do not define the properties of the active ingredient.

*Slide B-05*

FAO and WHO specifications

- FAO and WHO specifications are international points of reference for quality of agricultural pesticides (FAO) and public health pesticides (WHO).
- FAO/WHO development of specifications has changed to a "new procedure" in recent years.

*Slide B-05. Note that ...*

- (i) FAO/WHO specifications form international points of reference in those cases where the standards have been developed. For pesticide products for which FAO/WHO specifications do not exist, the general provisions of the FAO/WHO specifications manual apply. Although more limited and less detailed in scope, the provisions of the FAO/WHO specifications manual provide certain basic points of reference which are expected to apply to most, if not all, pesticide products.
- (ii) The "new" procedure for development of pesticide specifications, which was introduced by FAO in 1999 and by WHO in 2002, links specifications to the products of manufacturer(s) whose data package(s) on the manufacturing process and chemical and hazard profiles have been evaluated by the JMPS. In

contrast, FAO and WHO specifications developed under the "old" procedure apply to the products of all manufacturers, irrespective of whether or not their products had been evaluated. Evaluations conducted under the "old" procedure were also less detailed than those of the "new" procedure. Existing FAO and WHO specifications developed under the "old" procedure remain valid until reviewed under the "new" procedure.

- (iii) Check list and data requirement for submission of application for development of FAO and or WHO specifications are presented in Annex 1.
- (iv) FAO/WHO specifications alone are not sufficient to establish equivalence at national level. Establishment of, and access to data/information of reference profile is essential for this purpose, as it will be discussed later in the course.

**LEARNING UNIT C**

# Specifications for technical grade active ingredients

Slide C-01

## Learning objectives

After completing this *Learning unit*, you should understand:

- the structure and aims of specifications for technical grade active ingredients and their role in the development of specifications for formulated products;
- data requirements for developing specifications for technical grade active ingredients and why it may be necessary to work with incomplete information;
- the need for confidence in the validity of data evaluated;
- the concept of “reference profiles”;
- the importance of openness and transparency in decision-making, while maintaining confidentiality of secret information.

Slide C-02

## Specifications for technical grade active ingredients

- Technical grade pesticides are relatively pure active ingredients, used to prepare formulations.
- TC = technical material; TK = technical concentrate
- TC is usually  $\geq 900$  g/kg active ingredient with solvent(s) removed during synthesis and no solvent added subsequently;
- TK contains  $< 900$  g/kg active ingredient and may contain solvents or diluents.

Slide C-02 **Note that ...**

- (i) TC and TK are international codes for technical grade active ingredients, as defined by the CropLife International coding system, e.g. deltamethrin TC 985 g/kg and pyrethrum TK 200 g/kg.
- (ii) Some technical grade active ingredients do not clearly fall into either of these categories and may require expert judgement.
- (iii) TC is usually the final product from preparation of the active ingredient, which may contain a stabilizer and/or anti-caking or anti-static agents (if required) but no other additives. It is the purest form of active ingredient that is economic for use in formulations.
- (iv) TK may also be the final product from preparation of the active ingredient but it may contain additives (not formulants) in addition to a stabilizer, for example as

safety agents. TK may also contain solvent(s) (including water), either deliberately added to a TC or not removed during preparation. TK may be preferred where TC preparation is uneconomic, unnecessary, particularly hazardous, or destabilizes the active ingredient.

Slide C-03

Why distinguish between TC and TK?

- TC specification has only a lower limit for active ingredient content;
- TK specification has upper and lower limits;
- Increasing the purity of a TC does not increase its hazard significantly and may rather decrease it;
- Higher content of active ingredient in TK may increase hazard.

Slide C-03 Note that ...

- (i) Both TC and TK specifications have lower limits for active ingredient content, but TK specifications have also an upper limit..
- (ii) The terms “hazard” and “risk” tend to be defined similarly, or used interchangeably, in many dictionaries and some technical literature. For those involved in hazard and risk assessment, as well as for the purposes of developing pesticides specifications, the terms are applied with different meanings. Various definitions of both “hazard” and “risk” have been proposed to clarify the distinction, but the following definitions have been published by IPCS.<sup>1</sup> “Hazard: an inherent property of an agent or situation having the potential to cause adverse effects when an organism, system, or (sub)population is exposed to that agent.”
- “Risk: the probability of an adverse effect in an organism, system, or (sub)population in reaction to exposure to an agent.”
- (iii) FAO and WHO wish to encourage production of the highest purity active ingredients, because an increase in active ingredient content (say) from 900 g/kg to 990 g/kg in a TC will not significantly increase hazards due to active ingredient (because the content is raised by only 10%), whereas hazards associated with impurities may be greatly reduced (on average by a factor of 10 in this case).
- (iv) The concentration range in a TK represents a compromise for economic synthesis of an active ingredient, stability in storage and transportation, suitability for subsequent formulation and control of hazard. The upper limit in a TK specification will ensure that the TK hazard cannot be increased significantly (potentially by more than 10%), should the content of active ingredient be unexpectedly high.

<sup>1</sup> International Programme on Chemical Safety. *IPCS risk assessment terminology. Part 1: IPCS/OECD key generic terms used in chemical hazard/risk assessment. Part 2: IPCS glossary of key exposure assessment terminology.* Geneva, World Health Organization, 2004 (available at: <http://www.inchem.org/documents/harmproj/harmproj/harmproj1.pdf>; accessed April 2013).

Slide C-04

Importance of developing specifications for technical grade active ingredients

- Pesticide formulations are generally produced from technical active ingredients.
- Specifications should be related to the hazard data for the source of active ingredient under consideration.

Slide C-05

Information to support specification for technical grade active ingredient of a specific source

- Active ingredient identity;
- Manufacturing route, materials and conditions;
- Five batch analytical data and manufacturing limits;
- Methods of analysis.

Slide C-05 Note that ...

- (i) Identity is defined by a common name which is allocated by the International Organization for Standardization (ISO). Some active ingredients consist of isomers; the composition of these isomers must be clearly identified and conform with those defined by international organizations, such as ISO.
- (ii) The information on the manufacturing process and starting materials is indispensable to fully understand the 5-batch analysis data and manufacturing limits;
- (iii) Analytical methods and their validation data are required to determine the content and identity of active ingredient and impurities, in support of 5-batch analysis data and the manufacturing limits.

Slide C-06

Information to support specification for technical grade active ingredient of a specific source

- Physico-chemical characteristics of pure and technical grade active ingredient;
- Guidelines including sub-methods for determination of physico-chemical characteristics.

Slide C-06 Note that ...

- (i) Data on physico-chemical characteristics, such as vapour pressure, melting point, octanol-water partition coefficient of the pure and technical grade active ingredient is required for development of specification for technical grade active ingredient and formulations. For example, a fast hydrolysis, at a certain pH, may justify limiting pH range in the specifications; or dissociation characteristics may influence the behaviour of the active ingredient under specific analytical conditions.

Slide C-07

Information to support specification for technical grade active ingredient of a specific source

- Full toxicology and ecotoxicology data package

Slide C-07 Note that ...

- (i) Data on acute, sub-chronic and chronic toxicity based on purity of the material under consideration elaborated using generally accepted guidelines are required.
- (ii) FAO and WHO specifications are not developed unless the hazards, and risks in one or more applications, have been assessed as acceptable by at least one more national authority or by WHO (for certain public health pesticide products). It is very important to recognize that this does not mean that risks will be acceptable in all possible use scenarios. All registration authorities should satisfy themselves that the risks involved in the intended uses of a particular product within their country or region are acceptable before permitting such uses.

Slide C-08

Data are evaluated to ...

- Verify minimum purity of the active ingredient;
- Identify relevant impurities and their limits;
- Establish “reference profile”;
- Ensure that specification clauses and limits are valid quality criteria and supported by evidence.

Slide C-08 Note that...

- (i) Relevant impurities are by-products of the manufacture or storage of an active ingredient which, **compared with the active ingredient**, are toxicologically significant to health or the environment, phytotoxic to treated crops, cause taint in food, affect the stability of the pesticide, or cause any other adverse effect. Water may be a relevant impurity if it can adversely affect pesticide stability or formulation quality. Insoluble material may also be a relevant impurity in a TC or TK if the subsequent formulations would fail a wet sieve test and be likely to block sprayer filters and nozzles in use, for example.

Relevant impurities will be dealt with more fully in Learning Unit E.

- (ii) “Reference profiles” are the purity/impurity, physico-chemical and hazard data associated with active ingredient from the source that is supported by the most comprehensive hazard data available. The “reference specifications” also relate to the product from this source. Reference profiles are used for the determination of equivalence, which is addressed in Learning Unit F.

Slide C-09

What expertise is needed to evaluate the data?

- Team of scientists with sound knowledge and experience in many areas of chemistry and physical properties, toxicology and ecotoxicology.

Slide C-09 Note that ...

- (i) Assessment of data/information in support of development of pesticide specifications is complex. As the package includes data on pesticide chemistry and toxicology, expertise in these disciplines and working as a team is essential.

Slide C-10

Data quality

- Verify the validity and completeness of the supporting data, including use of appropriate and well-established test guidelines and methods.
- Data obtained from published literature may be of little use in assessing the TC or TK of another manufacturer.

Slide C-10 Note that ...

- (i) Data generated by inappropriate test guidelines or analytical methodology are of limited or no value and are considered as a data gap. Checking the validity of test methods and data is not a trivial part of the overall job of data evaluation but it is important to be aware of the soundness, or otherwise, of the data used as the basis for decisions.
- (ii) If data submitted are identical to those in published sources, the origin of the information should be verified. If there is any doubt about the source or validity of data, the manufacturer should be asked to provide the full study report(s).
- (iii) If batch-analysis or manufacturing specifications data add up to exactly 1000 g/kg, or if there is essentially no batch-to-batch variation, the data should be checked in the full study reports. Although such occurrences are not impossible, they are unusual and should be investigated.

Slide C-11

Manufacturing limits and 5-batch analytical data

- Purity/impurity profile is based on manufacturing limits, not values for individual batches (often provided as a series of 5).
- Basis of manufacturing limits should be explained.
- Apparent conflicts between 5-batch data and manufacturing limits may not be a problem if there is a rational explanation.
- Levels of some impurities may be more variable than others and may be not well reflected in the 5-batch data.

*Slide C-11 Note that ...*

- (i) Manufacturing limits may be set statistically (for example, the average  $\pm 3$  standard deviations from 5-batch data) or on the highest/lowest values found in quality control data, for impurities or active ingredient, respectively.
- (ii) The manufacturing limits cannot correspond to the component profile in any one batch. All components cannot be present at their limits in a single batch.
- (iii) The manufacturing limits may not appear to correspond to the 5-batch analysis data. This is not unusual, but the manufacturer should explain extreme cases. The 5-batch data are unlikely to be fully representative of all batches and, in certain cases, may represent batches produced over a relatively short time period (which is not a problem if between-batch variation is random). Bearing these limitations in mind, a useful method for deciding when to question manufacturing limits is to check whether the limit for an impurity exceeds the 5-batch average plus 3 standard deviations. If it does so, it may indicate that the impurity is poorly controlled, which may not be a problem if the impurity poses no special hazard. Alternatively, if the manufacturing limit for an impurity is lower than that implied by the 5-batch data, perhaps the manufacturing process has been refined to control that impurity. Similarly, refinements in the manufacturing process can lead to active ingredient of greater purity than that implied by the 5-batch data.
- (iv) Sums of individual batch data usually do not add up exactly to 1000 g/kg, due to uncertainty in measurements. Generally, the greater the number of analytical methods involved in the analysis of a technical material, and the more technically challenging the procedure, the greater will be the contribution of analytical variation (and perhaps bias) to the measurement of batch-to-batch variations in active ingredient and impurity content.
- (v) In general, individual batch data sums in the range 980 to slightly >1000 g/kg indicate acceptable material accountability. That is, no significant component has been missed or seriously underestimated. Sums outside this range should be considered case by case. Sums <980 g/kg may indicate that significant components have been missed or under-estimated, although if only 1 or 2 of the 5 sums is <980 g/kg, this could be due to analytical variation. Sums significantly >1000 g/kg may indicate poor analytical control or poor accuracy, with one or more components being overestimated.
- (vi) Manufacturing limits must not be summed, because the sum has no meaning.

*Slide C-12*

Links between purity/impurity and hazard profiles

- Manufacturing limits represent the worst-case for every component - a statistical "envelope" for purity/impurity that does not describe any single batch or blend of batches;
- Choice of specific batch to be used in hazard testing is a challenging task that needs to be well justified and documented.

**Slide C-12 Note that ...**

- (i) Manufacturers tend to select a batch for toxicology testing, taking into consideration expected effects of impurities present (realistic worst-case situation in terms of hazard). In such a batch every component of a technical material cannot be present at its manufacturing limit.

**Slide C-13**

**Links between purity/impurity and hazard profiles**

- Most hazards are derived from the active ingredient because it is by far the most abundant component of a technical material.
- Relatively small variations in the high level of active ingredient content cannot produce big differences in hazard.
- Correspondingly large variations in impurity content could produce big differences in hazard if the impurity is much more hazardous than the active ingredient.

**Slide C-13 Note that ...**

- (i) The purity of technical material used to generate the hazard data is very important information because hazard data generated from exceptionally pure material may exclude a contribution, otherwise made by impurities, to the hazard. However, hazard data generated from active ingredient of lower purity than the manufacturing specification may be helpful, being more likely to represent a worst-case scenario.
- (ii) Chemical structures associated with exceptional hazards are mostly well-known, e.g. nitrosamines and certain reagents like dimethylsulphate, for which evaluations on their mutagenic potential have been published by International Agency for Research on Cancer (IARC)<sup>1</sup>.

Relevant impurities are identified in FAO/WHO specifications. Some national authorities also publish lists of relevant impurities in technical material. Non-relevant impurities are kept confidential.

**Slide C-14**

**Links between purity/impurity and hazard profiles - Further considerations**

- If the manufacturing process has evolved and/or the manufacturer sets up a new plant, manufacturing limits may require revision.
- If the hazard data are purchased with process and rights to produce active ingredient, but the process is changed, manufacturing limits may be different.
- The changes in manufacturing limits weaken the links with the original hazard data.

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<sup>1</sup> [www.iarc.fr](http://www.iarc.fr).

Slide C-15

Records of evaluations

- Outcome of assessments and basis for decisions should be recorded and preferably published;
- Manufacturing process, non-relevant impurities and their associated analytical methods are kept confidential;
- FAO/WHO evaluations are published on the Internet, recording non-confidential data and the basis for all decisions.

Slide C-15 Note that ...

- (i) All JMPS decisions on relevant impurities, equivalence, non-standard clauses and limits are explained in published evaluations which are integral part of FAO/WHO specifications.
- (ii) FAO/WHO specifications for technical material should not be applied indiscriminately to manufacturers whose products have not been evaluated.
- (iii) Given the limited resources available to most registration authorities, and for the purposes of transparency in decision-making, sharing of information and the publication of evaluations are encouraged.

**The following clauses are included in FAO/WHO specifications for technical grade active ingredients.**

Slide C-16

TC and TK specification clauses

Description

- Physical appearance and chemical form (e.g. salt, ester) – simplest and most rapid test.
- Stabilizer, if critical, is identified and a validated test method is provided.
- If the identity and/or quantity of stabilizer is not critical, the clause indicates only that a stabilizer is present.
- If a solvent is added (TK only), a clause and analytical method are not usually required for the solvent.

Slide C-16 Note that ...

- (i) If the material visibly does not match the specified description, it has failed the specification and there is no point in further, more expensive, tests. For example, if the material presented is a viscous brown liquid and the specification indicates that it should be a white crystalline solid, it is non-compliant.
- (ii) If a solvent is present, the manufacturer must ensure that the active ingredient cannot react with it. For example, methanol may not be a suitable solvent for esters because of potential for a transesterification reaction.

Slide C-17

TC and TK specification clauses

Identity

- Unambiguous name ... can be problematic for mixtures, especially if derived from plants or microorganisms and also for some pyrethroids.
- Primary identity test usually based on measurement of active ingredient content; back-up test required for cases of doubt.
- If the active ingredient is a salt, ester or other derivative, it may be necessary to identify the derivative component.
- No external validation of identification methods required, except where the active ingredient is a mixture of defined ratio.

Slide C-17 Note that ...

- (i) For example, an unambiguous name is difficult in the case of neem-based pesticides. The FAO specifications are identified as azadirachtin A, but this is a “marker compound” and azadirachtin, in the broad sense, is the name given to an incompletely defined group of compounds extracted from seeds or leaves of *Azadirachta indica*, for use as an insecticide. Among synthetic pesticides, some pyrethroids also pose problems, as a name may apply to one or several of the possible stereo-isomers or, in some cases, only to a specific ratio of those isomers.
- (ii) It is only necessary to identify the specific salt or other derivative present if that particular form of active ingredient is critical for product stability or performance.
- (iii) Identity tests for specific ratios of isomers must be quantitative and validated by inter-laboratory study.

Slide C-18

TC and TK specification clauses

Active ingredient content

- Analytical methods validated by collaborative study.
- Limit based on manufacturing specification, not 5-batch data.
- Limit applies to the average of measured values.
- Content expressed as g/kg of appropriate chemical form (e.g. free acid, sodium salt, marker compound, etc.).

Slide C-18 Note that ...

- (i) Various international organizations (e.g. CIPAC, AOAC International) elaborate and publish validated test methods for pesticides.
- (ii) Where FAO/WHO specifications exist for a product, national authorities are encouraged to adopt the test methods referenced in those specifications.

Slide C-19

TC and TK specification clauses

Relevant impurity content

- Analytical methods peer-validated in minimum 3 laboratories.
- Limit based on manufacturing specification, not 5-batch data.
- Limit applies to the average of measured values.
- Content expressed as g/kg.

Slide C-19 Note that ...

- (i) Relevant impurities will be considered in detail later in the course.
- (ii) Peer-validated methods for certain relevant impurities are provided free of charge by CIPAC.

Slide C-20

TC and TK specification clauses

Other clauses

- Acidity, alkalinity or pH range, if required.
- Other characteristics, if critical for TC, TK or formulation quality.
- Storage stability is not specified, because manufacturers can usually re-purify an aged TC or TK.
- If a TC or TK is sold to end-users as a “formulation” (e.g. certain UL), the formulation specification applies and storage stability is specified.

Slide C-20 Note that ...

- (i) Acidity, alkalinity or pH range resemble relevant impurities and are also dealt with later in the course.

**An example of a specification for TC follows.**

Slide C-21

HAPPYFOS TECHNICAL MATERIAL

WHO Specification 999/TC (January 2013\*)

*This specification, which is PART ONE of this publication, is based on an evaluation of data submitted by the manufacturer whose name is listed in the evaluation report (999/2007). It should be applicable to TC produced by this manufacturer but it is not an endorsement of those products, nor a guarantee that they comply with the specifications. The specification may not be appropriate for TC produced by other manufacturers. The evaluation report (999/2007), as PART TWO, forms an integral part of this publication.*

**1 Description**

The material shall consist of happyfos together with related manufacturing impurities and shall be a viscous yellow-to-brown liquid, containing not more than a trace of insoluble material, and shall be free from extraneous matter and added modifying agents.

- (i) The name “happyfos” is fictional. FAO/WHO specifications use a standard coding system, explained in the FAO/WHO specifications manual. The number “999” represents the CIPAC number of the active ingredient – a fictional number is used in this example.
- (ii) The “header note” (given in *italics*) is standard information, drawing attention to the published evaluation and indicating that the specification applies only to products evaluated by FAO/WHO.

Slide C-22

<p><b>2 Active ingredient</b></p> <p><b>2.1 Identity tests</b> (999/TC/M/2, CIPAC Handbook X, p.193, 2003)The active ingredient shall comply with an identity test and, where the identity remains in doubt, shall comply with at least one additional test.</p> <p><b>2.2 Happyfos content</b> (999/TC/M/3, CIPAC Handbook X, p.193, 2003) The happyfos content shall be declared (not less than 930 g/kg) and when determined, the average measured content shall not be lower than the declared minimum content.</p> <p><b>3 Physical properties</b></p> <p><b>3.1 Alkalinity</b> (MT 191, CIPAC L, p. 143, 2005) Maximum: 0.5 g/kg calculated as NaOH.</p>
<p>Note 1...</p> <p>* <i>Specifications may be revised and/or additional evaluations may be undertaken. Ensure the use of current versions by checking at: <a href="http://www.who.int/whopes/quality/en">http://www.who.int/whopes/quality/en</a>.</i></p>

Slide C-22 Note that ...

- (i) Test methods are clearly referenced, including any appropriate coding. Code numbers for active ingredients are published by CIPAC, but the code number 999 for happyfos is fictional. Two-letter codes for technical and formulated products are produced by industry.
- (ii) The simple existence of a CIPAC code number for an active ingredient does not necessarily mean that either FAO/WHO specifications or CIPAC test methods have been published for it. The reference to CIPAC Handbook X is fictional and intended only to reflect the fact that CIPAC handbooks, containing test methods, are identified alphabetically in the sequence published.
- (iii) “Notes” may be required, for example to explain the function or meaning of a clause, or how the clause or test method should be applied.
- (iv) The asterisk (\*) note provides a standard warning that the specification, or its status, may be subject to change over time.

**LEARNING UNIT D**

# Specifications for formulated pesticides

Slide D-01

## Learning objectives

After completing this *Learning unit*, you should understand:

- the structure and aims of specifications for formulated products;
- data requirements for developing specifications for formulated products.

Slide D-02

## Formulations

What is a formulated pesticide?

- Active ingredient in the form sold for use.
- Active ingredient plus formulants (excipients, “inerts”) assembled to optimize delivery to target pest or vector, optimize activity, stabilize active ingredient, minimize user exposure, simplify use, etc.

Slide D-02 **Note that ...**

- (i) There are rare exceptions to the definition given in the slide. For example, in a few cases, a UL product intended for dilution with solvent by the user before application may contain essentially no formulants. Nonetheless, such products are required to conform to the appropriate formulation specification.

Slide D-03

## Prerequisites for formulation specifications

- A TC or TK specification is normally required, except in unusual cases where a TC or TK is not isolated.
- Because this ensures the strongest possible links to hazard assessments.

Slide D-03 **Note that...**

- (i) The issues of links to hazard and risks assessments was considered in the previous Learning Unit, especially slides C-12 to C-14.

Slide D-04

## Additional supporting data required?

Over and above data supporting the specifications for technical material, additional data are required:

- to support proposed specification clauses and limits;
- for novel or unique formulations.

**Slide D-04 Note that ...**

- (i) Summaries of physical and chemical studies are required in support of proposed clauses and limits for development of specifications for formulated pesticide products. In exceptional cases full study reports are needed to facilitate the assessment.
- (ii) For novel formulations of pesticides full study reports and additional data/information on manufacturing and product behaviour and performance are required for development of specifications.

**Slide D-05**

**Scope of formulation specifications**

- Similar to TC and TK specifications but also specify physical properties, synergists or safeners (if applicable) and storage stability.
- Essential additives for safety or stability.
- Unlike FAO and WHO, national authorities should control formulants.

**Slide D-06 Note that ...**

- (i) Emetics, stabilizers or other additives essential for product safety or stability may be referenced in a “Note” appended to the specification. Where the identity and content of the additive are critical, a peer-validated test method must be provided.
- (ii) Adjuvants, added by the user, are not within the scope of FAO/WHO specifications.
- (iii) FAO/WHO specifications do not provide clauses for control of formulants (“inerts”) or formulant impurities. Information on formulants are confidential. Many formulants are complex materials which, although having appropriate physical characteristics, may vary in composition, over time and around the world. National registration authorities may provide controls for the identity and content of formulants, although identification and quantification of certain formulants are technically challenging. Formulants and their impurities are generally indirectly controlled through the physical properties and storage stability of the formulated product.

**Slide D-06**

**Specifications for mixed active ingredients**

- In most cases, separate specifications apply to each active ingredient.
- Where the ratio of active ingredients is critically important, a specification may be developed for an individual formulated product.

**Slide D-06 Note that ...**

- (i) FAO/WHO specifications normally refer only to a single active ingredient. Where two or more active ingredients are co-formulated, the specification for each active ingredient is expected to apply. Manufacturers should therefore ensure that the limits provided in two or more proposed specifications are mutually compatible. In cases where the ratio of co-formulated active ingredients (e.g.

insecticides with a synergist or a herbicide with a safener) is critical for efficacy, an FAO or WHO specification may be developed for a co-formulated product.

**The following clauses are included in FAO/WHO specifications for formulated products.**

<i>Slide D-07</i>	<b>Description clause</b>
	<ul style="list-style-type: none"><li>• Physical appearance of product and chemical form of the active ingredient.</li><li>• Provides a simple and rapid means to determine compliance.</li><li>• Corresponding TC or TK specification is referenced.</li></ul>

<i>Slide D-08</i>	<b>Active ingredient identity and content</b>
	<ul style="list-style-type: none"><li>• Test methods similar to those for TC and TK, but extraction (and purification for identification) of active ingredient may be required.</li><li>• May be necessary to identify the counter-ion, etc., if it is critical for product stability or performance.</li><li>• Analytical test methods for determination of content validated by international collaborative study, to provide evidence of the reliability of the methods and the data provided.</li></ul>

*Slide D-08 Note that ...*

- (i) Various international organizations (e.g. CIPAC, AOAC International) elaborate and publish validated test methods for pesticides.
- (ii) An existing CIPAC method for an active ingredient in one formulation may be “extended” to another formulation, using a simpler form of validation. Requirements and procedures for extension of CIPAC methods can be found on the CIPAC web site at <http://www.cipac.org>.
- (iii) One of the requirements for “extension” of an FAO/WHO specification to another manufacturer’s *equivalent* product is confirmation that analytical and test methods referenced in the existing specification are suitable for use with the “new” product.
- (iv) Where FAO/WHO specifications exist, national authorities are encouraged to adopt the test methods for active ingredient referenced in those specifications.

Slide D-09

Tolerances for active ingredient content	
Declared content, g/kg or g/l	Tolerance
up to 25	± 15% of declared content for "homogeneous" product (EC, SC, SL)
	± 25% of declared content for "heterogeneous" product (GR, WG)
above 25 up to 100	± 10% of declared content
above 100 up to 250	± 6% of declared content
above 250 up to 500	± 5% of declared content
above 500	± 25 g/kg or g/l

Slide D-09 Note that ...

- (i) Tolerances apply to the average measured value and are intended to take into account variations arising from manufacturing, sampling and analysis. However, sample sizes must be practical for analysis and meaningful in terms of product use. For example, variation in results due to sampling (statistical "sampling error") is minimized by maximizing sample size but excessively large samples increase analytical costs and could obscure variation significant to the user.

Slide D-10

Relevant impurities
<ul style="list-style-type: none"> <li>• Criteria as for TC and TK but insolubles (particulates) and acidity/alkalinity are treated as physical properties.</li> <li>• Limits usually based on active ingredient content but may be higher if concentrations can increase in storage or through reactions with formulants.</li> <li>• An impurity relevant in TC or TK may become non-relevant in formulations containing only low levels of active ingredient, e.g. if the impurity concentration is diluted to a level too low to measure.</li> </ul>

Slide D-10 Note that ...

- (i) Limits for relevant impurities are usually expressed on the basis of active ingredient content, because they are usually correlated with TC or TK content (which cannot be measured but is similar to the active ingredient content, in the case of TC).
- (ii) Analytical methods for relevant impurities must be peer-validated for the formulation, to provide evidence that the methods and data are reliable.
- (iii) Various international organizations (e.g. CIPAC, AOAC International) elaborate and publish peer-validated analytical methods for relevant impurities. However, a few peer-validated methods for relevant impurities are published on the FAO and WHO web sites.
- (iv) Where FAO/WHO specifications exist for a product, national authorities are encouraged to adopt the analytical methods for relevant impurities referenced in those specifications.
- (v) Relevant impurities will be considered in more detail in Learning Unit E.

Slide D-11

Physical properties

- Specified properties are the minimum to distinguish between products having acceptable and non-acceptable quality.
- Clauses and limits may differ from FAO/WHO guidelines, if justified for a particular product.
- Test methods for physical properties are simple models; they do not demonstrate field performance.
- Results are method-dependent, so test methods must be performed exactly as described.
- If the test method for a physical property has not been suitably validated and/or published, the specification cannot be developed.

Slide D-11 Note that ...

- (i) The physical properties controlled by FAO/WHO specifications represent a basic minimum required to define product quality. If required, appropriate additional physical properties may be incorporated into national or manufacturer's specifications for the purposes of monitoring product quality.
- (ii) Test methods for physical properties do not measure performance in the field, because this is dependent on local conditions and practices.
- (iii) Alternative test methods are likely to require different limits for distinguishing between good and bad products, and their use should be avoided.
- (iv) Most physical test methods for pesticide formulations are validated under the auspices of, and/or published by, CIPAC. A few are ASTM International, ISO or European Pharmacopoeia standards. A few are "convention" methods, which are published but validated primarily through long or widespread use. The use of "convention" methods may be necessary to measure unstable physical characteristics that are not amenable to normal validation procedures.
- (v) Where an FAO/WHO specification exists for a formulation of an active ingredient, national authorities are encouraged to adopt the test methods for physical properties referenced in that specification.

Slide D-12

Low temperature storage stability

- Storage test at 0 °C required for liquid formulations, which may grow crystals, aggregate particles or develop separate phases.
- CS formulations may require freeze-thaw test to show that capsules are not weakened by freezing.

Slide D-13

High temperature storage stability

- Test required for all formulations.
- Simulates two years' storage under "warm" conditions.
- Standard requirement is 54 °C for 14 days.
- If 54 °C is not appropriate for the product, alternative conditions are:
  - 45 °C for 6 weeks
  - 40 °C for 8 weeks
  - 35 °C for 12 weeks
  - 30 °C for 18 weeks.

Slide D-13 Note that ...

- (i) Formulations are intended to be stored away from direct sunlight in cool, well-ventilated conditions.
- (ii) The alternative temperature-time regimes correspond approximately to the same extent of ageing, based on the Arrhenius equation for chemical reaction rates.

Slide D-14

Post-storage tests required

- Active ingredient content – usual minimum is  $\geq 95\%$  of pre-storage level.
- Relevant impurities, if they could increase in storage.
- Physical properties, if they could worsen with storage.

Slide D-14 Note that ...

- (i) The usual requirement of  $\geq 95\%$  for storage stability of the active ingredient in formulations takes into account the normal range of analytical and sampling variation and thus essentially corresponds to an assessment of "no significant decline". In cases where a significant decline is unavoidable and a lower limit is justifiable, it should be supported with experimental data and the stored product must remain acceptable for use.
- (ii) Most physical properties do not improve with ageing but, for example, persistent foam is not tested post-storage because surfactants are not expected to improve with storage and therefore persistent foaming is unlikely to increase.

**An example of an FAO specification for a formulation follows.**

Slide D-15 HAPPYFOS WATER DISPERSIBLE GRANULES

FAO Specification 999/WG (January 2013\*)

*This specification, which is PART ONE of this publication, is based on an evaluation of data submitted by the manufacturer whose name is listed in the evaluation report (999/2007). It should be applicable to relevant products of this manufacturer, and those of any other formulators who use only TC from the evaluated source. The specification is not an endorsement of those products, nor a guarantee that they comply with the specification. The specification may not be appropriate for the products of other manufacturers who use TC from other sources. The evaluation report (999/2007), as PART TWO, forms an integral part of this publication.*

**1 Description**

The material shall consist of a homogeneous mixture of technical happyfos, complying with the requirements of FAO specification 999/TC (January 2013), together with carriers and any other necessary formulants. It shall be in the form of granules for application after disintegration and dispersion in water. The product shall be dry, free-flowing and free from visible extraneous matter and hard lumps.

Slide D-15 Note that ...

- (i) The “header note” (given in *italics*) is standard information, drawing attention to the evaluation and indicating that the specification applies only to products evaluated by FAO/WHO. The “header note” differs from that applied to TC or TK specifications, and two alternative forms of wording are used for formulation specifications. The general “header note”, shown above, is used for most formulation specifications. The alternative “header note” is used for specifications such as those for slow-release CS and LN, explaining that it may not be appropriate for the products of any other formulator (even those using TC or TK from evaluated sources), because active ingredient release and bioavailability are likely to be product-dependent.
- (ii) FAO/WHO specifications for TC and TK should not be applied indiscriminately to manufacturers whose products have not been evaluated. With the exception of certain slow-release CS and LN, FAO/WHO specifications for formulations apply to the products of any formulator who uses active ingredient from a source to which the corresponding TC or TK specifications apply.
- (iii) FAO specifications should not be applied to public health products, and WHO specifications should not be applied to agricultural products. Users should always adhere to recommendations given on the product label, even in cases where the FAO and WHO specifications are similar, because the product may be inappropriate for other uses.

Slide D-16

**2 Active ingredient**

**2.1 Identity tests** (999/WG/M/2, CIPAC Handbook X, p.196, 2003) The active ingredient shall comply with an identity test and, where the identity remains in doubt, shall comply with at least one additional test.

**2.2 Happyfos content** (999/WG/M/3, CIPAC Handbook X, p.196, 2003)

The happyfos content shall be declared (g/kg) and, when determined, the average content measured shall not differ from that declared by more than the following amounts.

Declared content, g/kg	Tolerance
above 100 up to 250	± 6% of declared content
above 250 up to 500	± 5% of declared content

**3 Physical properties**

**3.1 pH range** (MT 75.3, CIPAC Handbook J, p. 131, 2000)  
pH range: 5.0 to 7.0.

**3.2 Wettability** (MT 53.3, CIPAC Handbook F, p. 165, 1995)  
The formulation shall be completely wetted in 5 seconds without swirling.

Slide D-16 Note that ...

- (i) In FAO specifications, the active ingredient concentration ranges reflect agricultural products in the market. In WHO specifications, the active ingredient content is restricted to the concentrations evaluated by WHOPES.

Slide D-17

**3.3 Wet sieve test** (MT185, CIPAC Handbook K, p. 149, 2003)

Maximum: 0.5 % retained on a 75 µm test sieve.

**3.4 Degree of dispersion** (MT 174, CIPAC Handbook F, p. 435, 1995)

Dispersibility: minimum of 70% after 1 minute of stirring.

**3.5 Suspensibility** (MT 184, CIPAC Handbook K, p. 142, 2003)

A minimum of 50% shall be in suspension after 30 minutes in CIPAC standard water D at 30 ± 2 °C.

**3.6 Persistent foam** (MT 47.2, CIPAC Handbook F, p. 152, 1995)

Maximum: 10 ml after 1 minute.

**3.7 Dustiness** (MT 171, CIPAC Handbook F, p. 425, 1995)

Essentially non-dusty.

**3.8 Flowability** (MT 172, CIPAC Handbook F, p. 430, 1995)

At least 98% of the formulation shall pass through a 5 mm test sieve after 20 drops of the sieve.

Slide D-18

#### 4 Storage stability

##### 4.1 Stability at elevated temperature (MT 46.3, CIPAC Handbook J, p.128, 2000)

After storage at  $54 \pm 2^{\circ}\text{C}$  for 14 days, the determined average active ingredient content must not be lower than 95%, relative to the determined average content found before storage, and the formulation shall continue to comply with clauses for:

- pH range (3.1),
- wet sieve test (3.3),
- degree of dispersion (3.4),
- suspensibility (3.5),
- dustiness (3.7),
- flowability (3.8).

Note 1....

\* *Specifications may be revised and/or additional evaluations may be undertaken. Ensure the use of current versions by checking at:  
<http://www.fao.org/agriculture/crops/core-themes/theme/pests/jmps/ps-new/en/>.*

**LEARNING UNIT E**

# Relevant impurities

*Slide E-01*

**Learning objectives**

After completing this *Learning unit*, you should understand:

- The concept of relevant impurities;
- How to distinguish between relevant and non-relevant impurities;
- The principles of setting limits for relevant impurities;
- Why it is necessary to check the validity of data used to determine the relevance of impurities.

*Slide E-02*

**Impurities**

- Impurities derived from the manufacturing process and/or product storage are present in all pesticide active ingredients.
- Impurities in formulants are not dealt with here, although the same general principles apply.
- Designation of TC or TK components as relevant impurities is generally simple and only potentially problematic in a few special cases where they may be considered to be physical properties.

*Slide E-02 Note that ...*

- (i) Impurities in formulants are not considered in this course because the formulants incorporated into a product may vary in composition, over time and in different countries.
- (ii) The collective term “impurities” is simple and convenient for most purposes but, in a few cases, it can be difficult to decide whether a component or characteristic should be designated as an impurity or something else. For example, are acidity, alkalinity or pH physical properties or do they represent impurities?

*Slide E-03*

**Impurities**

- Cannot be eliminated but should be kept to a minimum.
- Manufacturing processes cannot be optimized for control of all impurities, so some will vary more than others, batch to batch.
- Tend to have physical and/or chemical characteristics similar to the active ingredient, but the hazards usually differ.
- May originate from starting materials or side-reactions occurring during active ingredient synthesis, or may increase during storage of formulations.

Slide E-04

Which impurities should be controlled?

- Depends on the consequences of their presence.
- Consequences depend on impurity hazards **relative to the active ingredient** and impurity concentration.
- For toxic hazards, impurity concentration is considered in terms of its contribution to the overall hazard of the active ingredient, not potential for exposure to the impurity, which is dependent on the application and conditions.
- Certain impurities are non-toxic in effect, but may have other adverse effects, e.g. water on product stability, particulates blocking sprayer nozzles, which may therefore be considered relevant impurity.

Slide E-05

A “grey area” between impurities and physical properties

- Some physical properties also represent hazards.
- The dividing line between hazards associated with physical properties and chemical impurities is not completely clear, so a few characteristics are designated by convention.
- For example, if required for product quality:
  - acidity, alkalinity, pH are designated as physical properties;
  - “insolubles” may be a relevant impurity in TC or TK but particulates become a physical property in formulations.

Slide E-05 Note that ...

- (i) In some cases, the terms “insolubles” and “particulates” may refer to the same solid materials, originally present in technical material and carried through to the formulation. Such solids are important in formulations intended for spray application, because of their potential to block sprayer filters and nozzles.
- (ii) In other cases, undesirable particulates in formulations, developing before or after dispersal in water and detected using a “wet sieve test”, may derive from either the formulants or the active ingredient, rather than from particulate impurities in the technical material. For example, crystals of active ingredient can grow during product storage or on standing of the diluted product. It is generally easier and/or more meaningful to control such particulates in the formulated product, rather than in the corresponding technical material.
- (iii) It may be difficult to measure the particulate content of certain oil-based formulations, such as EC (emulsifiable concentrate), UL (ultra-low-volume liquid) and OL (oil-miscible liquid). Therefore, solvents for incorporation into formulations intended for spray application should be filtered before use, to avoid introducing particulates into the product. Although particulates can be difficult to remove from a solid or viscous liquid technical material, it is usually easier to control them (as insolubles) at that stage than in oil-based formulations (as particulates).

Slide E-06

How is the relevance or non-relevance of an impurity determined?

- A relevant impurity is one which, at its maximum concentration, increases or extends the hazards of the active ingredient; otherwise it is considered non-relevant.
- Hazard contribution of the impurity **relative to the active ingredient** hazards is the key factor.
- In this context:
  - increased hazard = a quantitative increase in an effect of the active ingredient;
  - extension of hazards = a qualitatively different effect from those of the active ingredient;
  - the concentrations used to assess hazard contribution are the manufacturing limits for the impurity (i.e. the maximum permitted) and the active ingredient (i.e. the minimum permitted).

Slide E-06 Note that ...

- (i) "Increasing" the hazards of the active ingredient means that one or more hazards of the active ingredient is quantitatively increased by the presence of the impurity. "Extending" the hazards of the active ingredient means that the impurity presents one or more hazards that are qualitatively different from those of the active ingredient.
- (ii) For quality control purposes, "grey area" characteristics such as pH, acidity, alkalinity, insolubles and particulates should be assessed for relevance, irrespective of whether they are classified in specifications as relevant impurities or physical properties. As with other relevant impurities, these characteristics are capable of producing adverse effects in some cases and not in others, and therefore their relevance should be assessed in the context of the particular technical grade active ingredient and formulations.
- (iii) However, other aspects of "grey area" characteristics such as pH, acidity and alkalinity should also be taken into consideration. For example, these characteristics have no utility for quality control purposes if the measured value is due to the active ingredient itself. On the other hand if, for example, the active ingredient is stable in the form of a salt but unstable as the free acid (or base), pH control may be necessary. Although in such cases the characteristic would provide control of what is effectively a stabilizer, rather than an impurity, the same general approach may be used to determine the need for a clause and the limit(s) to be adopted.

Slide E-07

Relevance depends on more than just impurity hazards

- An impurity which occurs in two active ingredients may be relevant in one and non-relevant in the other, depending on the magnitude or type of hazards presented by the active ingredients.
- An impurity in a single active ingredient may be relevant in a formulation with high active ingredient content but not in another with low active ingredient concentration if, in the second case, the impurity concentration is too low for its hazards to be manifested.
- An impurity which could be present in principle, and which poses hazards that would otherwise qualify it as relevant, is not specified as relevant in any product (including TC or TK) in which it is known to be undetectable.

Slide E-07 Note that ...

- (i) Relevance depends on the relative hazards presented by the active ingredient and impurity, taking into account their relative concentrations. If it occurs in both, an impurity which is relevant in a low-hazard active ingredient may be non-relevant in a high-hazard active ingredient.
- (ii) If the concentration of an otherwise relevant impurity is too low for its hazards to be manifested, or too low for it to be measured by current analytical technology, it is considered non-relevant. However, in both cases, the specification incorporates a footnote alerting the user to the possibility that, in certain products, the impurity could occur at levels which would make it relevant. The following two examples illustrate these scenarios.
  - (a) FAO specifications for ethofumesate (2005) indicate in a footnote that "...there are no relevant impurities to be controlled in products of the manufacturer identified in evaluation report [but] ethyl methane sulfonate and/or *iso*-butyl methane sulfonate can occur as a result of certain manufacturing processes. If these impurities could occur at  $\geq 0.1$  mg/kg (relative to ethofumesate) in the products of other manufacturers, they would be designated as relevant impurities and clauses would be required to limit their concentration ...".
  - (b) The WHO specification for *d*-allethrin TC (2002) includes a clause to limit the relevant impurity chrysanthemic anhydride to 10 g/kg. However, the corresponding evaluation notes that, "... given the low level of active ingredient in...vaporizing mats and ... mosquito coil formulations and very low probability of substantial dermal contamination of users ... chrysanthemic anhydride should not be considered a relevant impurity in these formulations ...".

*Slide E-08* Effects of concentration on hazards of active ingredient, impurities and formulated products

- If active ingredient content of TC is increased from 900 g/kg to 990 g/kg (a 0.1-fold increase; 10%), it represents no significant change in hazards due to active ingredient... and hazards could actually decrease if impurities contribute to them.
- The hazard associated with increase in active ingredient content in a TC may not be carried through into formulations, as the formulation concentration is usually based on active ingredient content, not TC content.
- But if active ingredient content of the TC is decreased from 990 g/kg to 900 g/kg, total impurities increase from 10 g/kg to 90 g/kg (increasing impurity hazard contributions an average of 9-fold).
- The increase in impurity levels is carried through into formulations.

*Slide E-08 Note that ...*

- (i) A formulation contains 500 g/kg of zetypr, a herbicide, in a WG. The formulator uses active ingredient from two equivalent sources: M1 with 900 g/kg minimum, M2 with 950 g/kg. For M1, typically 555 g of zetypr TC are formulated per kg WG, with M2 526 g zetypr TC to produce one kg of WG.
- (ii) Both formulations have a target concentration of 500 g zetypr/kg and differ only in the amount of impurities carried forward from TC of M1 and M2 – 55 g for M1, 26 g for M2. As the TCs are equivalent, the two WGs meeting all specification clauses are equivalent as well.

*Slide E-09* Relative hazards of impurities and the active ingredient

- In most cases, impurity concentrations are low, relative to active ingredient.
- Therefore, in most cases an impurity must present significantly greater hazard than the active ingredient, to influence the overall hazard profile of the technical material.
- The lower the impurity concentration, the less likely that its potential impact will be manifested in practice.

Slide E-10

Default limits for relevant impurities

- FAO/WHO JMPS principles for control of relevant impurities are similar to guidelines of the Globally Harmonized System of Classification and Labelling of Chemicals (GHS); accessible at <http://www.unece.org/trans/>.
- GHS guideline limit is 10 g/kg (of active ingredient) for all toxic hazards except carcinogens, reproductive toxins and class I mutagens, for which the limit is 1 g/kg (of active ingredient).
- The JMPS uses these as default maximum limits, where a more refined approach is not possible.

Slide E-10 Note that ...

- (i) There are some unavoidable technical differences between GHS and JMPS guidelines.
- (ii) In GHS terminology, a “substance” (corresponding to TC, or a TK without diluent) is the starting point for hazard classification purposes and therefore limits are recommended for “substances”. In contrast, an important function of FAO/WHO specifications is to restrict the hazards of a “substance” (TC or TK) to those of the active ingredient, by limiting the content of relevant impurities.
- (iii) The specification limits of the GHS guidelines apply to both substances (alone) and “mixtures” of substances (corresponding to formulations or TKs with diluent). In contrast, FAO/WHO specifications for relevant impurities are normally based on the active ingredient content, to ensure that formulations are prepared from a good-quality TC or TK.

Slide E-11

Impurity data – concentration issues

- Manufacturing limits required only for impurities which can be present at or above 1 g/kg, unless exceptionally hazardous.
- 1 g/kg cut-off point corresponds to GHS guideline for the most hazardous chemicals.
- The cut-off point avoids costs and technical difficulties of identifying and measuring insignificantly low levels of impurities, except where justified by the exceptional hazard presented by the impurity.

Slide E-11 Note that ...

- (i) The 1 g/kg cut-off point is pragmatic, based on the following arguments.
  - (a) Detection, identification and measurement of impurities <1 g/kg can be difficult and very costly.
  - (b) Impurities occurring below 1 g/kg must be exceptionally hazardous if they contribute significantly to the overall hazard of the active ingredient. Although 1 g/kg is the maximum acceptable limit for well-known highly hazardous chemicals (such as dioxins, dibenzofurans, phenazines, terpyridines, some *N*-nitroso compounds and so on) and persistent organic pollutants (POPs), in practice lower limits are adopted for FAO/WHO specifications wherever practicable, as an additional precaution.

- (c) In principle, there may be no lower limit to the levels at which impurities could be detected if unlimited resources could be devoted to the effort. However, there is no point in generating data on exceptionally low concentrations just because it becomes technically possible. Analytical costs and problems of sample handling and data interpretation all increase dramatically at very low concentrations so, unless such data are meaningful in terms of hazard or quality criteria, they have little or no value for quality control. Therefore, although FAO and WHO wish to encourage production of active ingredients with the highest purity practicable, the specified limit for a relevant impurity is usually based on manufacturing practicability – as long as this basis does not involve exceeding the maximum acceptable level for the hazard involved.

*Slide E-12*

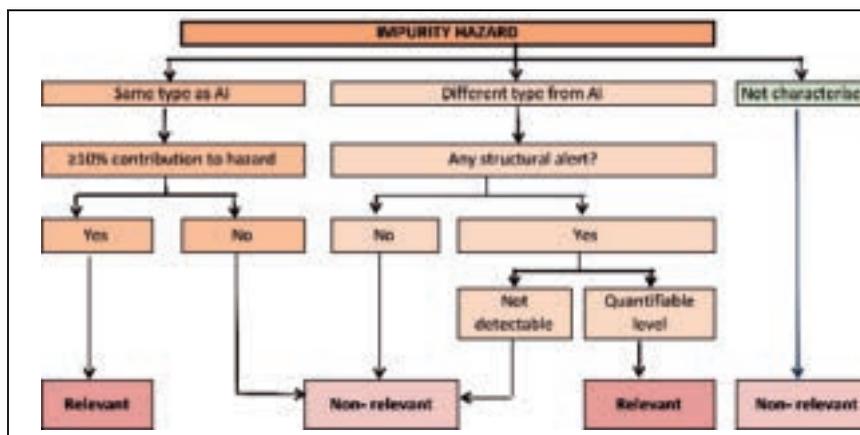
**Data checks**

- Are any of the data required missing or questionable?
- For each component of the TC or TK, has the analytical method been acceptably validated?
- Where hazard characteristics of impurities are reported, are the data considered sufficiently robust and is it known if the hazard is additive to that of the active ingredient?
- For any characteristic (identity, concentration, hazard), is there any reason to question the validity of the reported result?

*Slide E-12 Note that ...*

- (i) As with all other data evaluated in support of pesticide specifications, impurity data generated by test methods of questionable validity, or impurity data which are themselves of questionable validity, must be considered cautiously in decision-making. Checking the validity of test methods and data is not a trivial part of evaluating the relevance of impurities but it is important to be aware of the soundness, or otherwise, of the data used as the basis for decisions.
- (ii) The hazards posed by many impurities are essentially uncharacterized (though their contribution is included during tests for hazards of the technical grade active ingredient). However, the chemical structures associated with a wide range of hazards are now well-known and, where structural analogies are apparent, it may be possible to infer something about the hazards of a particular impurity. Where nothing can be inferred, it must be assumed that the impurity does not increase or extend the hazards of the active ingredient.
- (iii) The potential need for control of a particular impurity should be taken into account in deciding whether or not additional information is required on its identity, quantity or hazards, or on the validity of the test methods used.

Slide E-13



Slide E-13 Note that ...

- (i) The decision tree is a simplified way to determine the relevance of an impurity in a specific active ingredient. For estimation of the contribution of an impurity to the overall hazard where the type of hazard of the impurity is the same as that of the active ingredient and is additive, the procedures detailed in FAO/WHO Manual shall be used (see also Annex 2 to this training Manual).

Slide E-14

**Maximum acceptable limits for relevant impurities**

- GHS guidelines, 10 g/kg or 1 g/kg for exceptionally hazardous compounds.
- More refined estimates are preferred, if calculations, as described in Annex 2, are applicable.
- Limits lower than the maximum acceptable should always be adopted where practicable, as a precaution.

Slide E-14 Note that ...

- (i) Where active ingredient and impurity hazards are similar in nature and considered to be quantitatively additive, a more refined maximum acceptable limit for the impurity is based on a maximum of 10% increase in hazard relative to the active ingredient. Examples of the calculation are given in the following slides and in Annex 2.

Slide E-15

**Calculation of the relative hazard of the impurity (RelHaz<sub>imp</sub>)**

$$\text{RelHaz}_{\text{imp}} = (\text{Haz}_{\text{ai}}/\text{Haz}_{\text{imp}})$$

Haz<sub>imp</sub>: impurity hazard value; Haz<sub>ai</sub>: active ingredient hazard value

active ingredient/impurity mixture (MTIHaz),

as a proportion of active ingredient hazard ( $Haz_{ai}$ ), from the minimum purity (%) of the TC ( $\%ai_{min}$ ) and the corresponding theoretical maximum content (%) of the impurity ( $\%imp_{max}$ ).

$$MTIHaz = ((\%ai_{min} \times RelHaz_{ai}) + (\%imp_{max} \times RelHaz_{imp})) / (\%ai_{min} \times RelHaz_{ai})$$

*Slide E-17* **Calculation of the maximum limit acceptable for the impurity concentration ( $\%Imp_{maxaccept}$ )**

by substituting a limit of 1.1 (i.e. +10%) for MTIHaz and  $\%Imp_{maxaccept}$  for  $\%imp_{max}$ , in equation MTIHaz:

$$1.1 = ((\%ai_{min} \times RelHaz_{ai}) + (\%Imp_{maxaccept} \times RelHaz_{imp})) / (\%ai_{min} \times RelHaz_{ai})$$

and rearranging the equation:

$$\%Imp_{maxaccept} = ((1.1 \times \%ai_{min} \times RelHaz_{ai}) - (\%ai_{min} \times RelHaz_{ai})) / RelHaz_{imp}$$

## LEARNING UNIT F

# Determination of equivalence

Slide F-01

### Learning objectives

After completing this *Learning unit*, you should understand:

- the principles and practice of equivalence determination.

Slide F-02

### Determination of equivalence

- The objective is to determine whether or not the technical material of another manufacturer (identified in this Learning Unit and the exercises as "M2") is **not worse** than the technical material (produced by the manufacturer identified as "M1") on which the "reference" profile and specification are based.
- Note that the M2 product could be better than the M1 product but this is difficult to prove, so it is only practicable to show that it is not worse.
- Same principles of equivalence determination are applicable to different sources of technical material, e.g. new manufacturing site.
- Equivalence is a simple concept but determination is complex and requires a team of experts in various scientific disciplines.

Slide F-02 Note that ...

- (i) A general overview will be given first, allowing some of the complexity to be seen in context, before giving examples.

Slide F-03

### Data requirements for equivalence determination

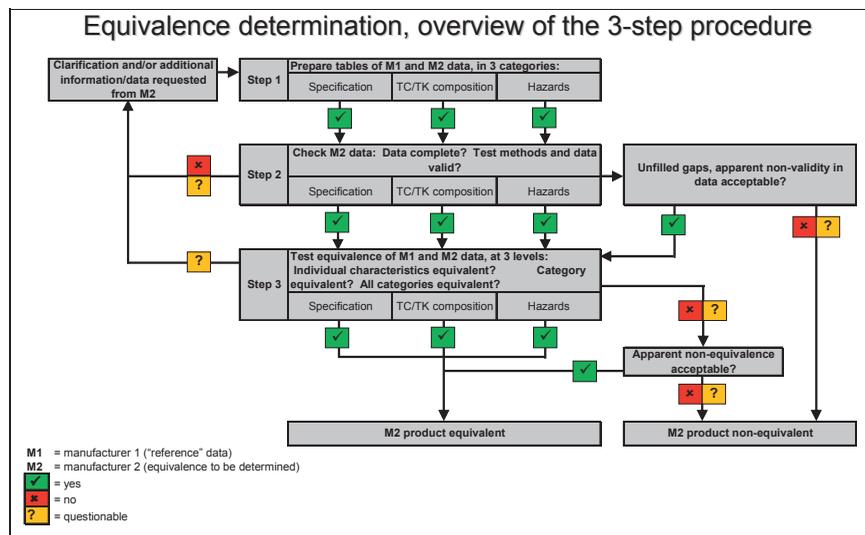
- Access to manufacturing process information and purity/impurity and hazard data from M1 and M2.
- The more data available for comparison, the greater confidence in equivalence decisions.
- Data are compared in a 3-step procedure – the complexity arises from gaps and inconsistencies which inevitably occur in the two sets of data.

Slide F-03 Note that ...

- (i) Although information on the manufacturing process is not used directly in the determination of equivalence, it provides the basis for understanding and assessing impurity profiles. Somewhat similarly, data on physico-chemical characteristics of the pure active ingredient are not used directly to determine equivalence but they form supporting information.

- (ii) Documentation of the basis for decisions is essential, because the determination of equivalence nearly always involves making one or more decisions based on data that are incomplete or problematic in some way.

Slide F-04



Slide F-04 Note that ...

- (i) The reference data ("reference profiles") for a particular active ingredient generally relate to the technical grade product supported by the most complete sets of toxicological and ecotoxicological data available (see *Manual on development and use of FAO and WHO specifications for pesticides*, 2010 and Annex 1).
- (ii) Other manufacturers' data are compared with the reference profiles. If the equivalence of several different sources of active ingredient is to be determined, each is compared separately against the reference profiles.
- (iii) FAO and WHO use a tiered approach for determination of equivalence. In cases where equivalence can be established based on chemical evidence (Tier-1), mutagenicity is the only hazard data required. However where establishment of equivalence is not possible in Tier-1, the standard acute toxicity and sensitization data are also required (Tier-2).
- (iv) By assembling the data into a table (step 1), missing or questionable data can be identified quickly and efforts can be focused on important problem areas which may arise in step 2.
- (v) Data will not be shown in the wide variety of forms in which they may be available prior to step 1. Although data submission templates are provided by FAO/WHO for manufacturers, the data may have to be extracted from relatively diffuse documentary sources.
- (vi) Validity of test methods and data supporting the reference specification (M1) should have been established before designating a set of data as the reference profiles. Therefore, in the determination of equivalence it is normally only necessary to check the validity of the M2 methods and data.

- (vii) It is possible that some problems in understanding M2 data may be resolved by seeking further expert advice, in addition, or as an alternative, to requesting more information from the manufacturer.
- (viii) ✖ and ? assessments appear on the right-hand side of the diagram at steps 2 and 3 because, if appropriate information and data cannot be obtained from the manufacturer, a decision on equivalence must still be made. If the team of experts evaluating the data considers that the data gaps and/or apparent non-equivalences leading to ✖ or ? assessments do not reflect, or obscure, some evidence that the M2 product is worse than the M1 product, the products may be considered equivalent.
- (ix) The TC or TK composition data used for equivalence determination are the manufacturing limits, not the 5-batch data. Note that, apart from exceptionally hazardous (relevant) impurities, data on impurities with manufacturing limits <1 g/kg are not considered in the determination of equivalence.

Slide F-05

Step 1, tabulate data		
Characteristic of the TC or TK	Manufacturer 1 (reference)	Manufacturer 2
<b>Active ingredient content</b>		
active ingredient, min. g/kg	930	950
<b>Impurity content</b>		
impurity 1, max. g/kg (relevant)	1	2
impurity 2	10	5
impurity 3	1	5
etc...	...	...
<b>Other specified characteristics</b>		
pH range	4-7	5-6
etc...	...	...
<b>Hazard data</b>		
acute oral LD <sub>50</sub> , mg/kg bw	500	650
acute dermal LD <sub>50</sub> , mg/kg bw	>2000	>3000
etc...	...	...

Slide F-05 Note that ...

- (i) Tabulating data in this way provides a simple overall picture in which data gaps and questionable data are easily seen and which helps to focus attention on problematic equivalence issues.
- (ii) In this example and those that follow, the Tier-2 approach for determination of equivalence of active ingredients is used;
- (iii) The TC or TK composition category should include all impurities reported by both manufacturers. The hazard category should include acute toxicity data (oral, dermal, inhalation, skin and eye irritation, skin sensitization), as a minimum. Any other hazard data provided by both manufacturers, if produced by comparable testing procedures, should also be included for assessment of equivalence.
- (iv) Units of measurement should be entered, because they may differ between manufacturers. For example, concentrations may be expressed as g/kg and mg/kg, or as mg/l and mg/m<sup>3</sup>, which could lead to confusion if the units are not included. Values must be converted to common units for comparison of the data,

but inclusion of both reported and converted data in the table makes it easier to spot conversion errors.

Slide F-06

**Step 2, data checks**

- Are any data missing from each category?
- For each component of the TC or TK, had the analytical method been acceptably validated?
- For each hazard characteristic, were the tests conducted to a widely accepted guideline?
- For any characteristic (composition, hazard, physical property), is there any other reason to question the validity of the reported result?

Slide F-06 Note that ...

- (i) Step 2 will be addressed in more detail later in this Learning unit.

Slide F-07

**Step 3, equivalence tests of each characteristic**

- **Specification:** does M2 product comply with clauses and limits of the existing specification (based on M1)?
- **TC or TK composition:** is the manufacturing limit for any **non-relevant** impurity in M2 >3 g/kg or >50% higher (whichever is the greater) than the corresponding M1 limit?
- **Toxicity (Tier 2):** is M2 apparently >2x (or the factor from dosage intervals if >2) as hazardous as M1? Or, in the case of qualitative assessments, is M2 “worse” than M1?

Slide F-07 Note that ...

- (i) Non-toxic hazards are usually addressed within the “Other specified characteristics” category.
- (ii) The 2x factor reflects the inherent variability of results observed in acute hazard studies.
- (iii) The 1 g/kg cut-off limit for impurities can produce anomalies in the determination of equivalence. For example, if an impurity has a manufacturing limit of 0.1 g/kg in the M1 profile and 3 g/kg in the M2 profile, the products are considered equivalent by that criterion. However, if the same impurity is not reported in the M1 profile because it always occurs at some value below 1 g/kg, it would be regarded as a new impurity in the M2 profile if its limit is  $\geq 1$  g/kg.
- (iv) Step 3 will be addressed in more detail later in this Learning unit.
- (v) In special cases, it may be possible (or necessary) to incorporate a test for equivalence of efficacy, such as that performed by WHO for some public health pesticide products.

The **following five slides** show the three-step procedure applied to a fictional example.

Slide F-08

Step 1, tabulate data				
TC composition	M1 (reference)	M2	M2 data valid?	M2 equivalent?
	max./min. g/kg			
active ingredient	950	950		
impurity 1 (relevant)	0.001	–		
impurity 2 (relevant)	1	–		
impurity 3	32	ND		
impurity 4	10	15		
impurity 5	12	24		
impurity 6	9	ND		
impurity 7	11	9		
impurity 8	2	ND		
impurity 9	1	ND		
impurity 10	3	ND		
impurity 11	4	ND		
impurity 12	2	3		
impurity 13	–	6		
M1 = manufacturer 1 M2 = manufacturer 2 ND = not detected – = no data				

Slide F-08 **Note that ...**

- (i) For simplicity of presentation, equivalence determination is shown here only for TC composition (purity/impurity profiles). In real-life cases and the exercises, tests of equivalence of hazard data and various other specified characteristics are also essential steps in the overall procedure, as shown in the earlier slides.
- (ii) In this hypothetical example, imagine that the synthesis pathways used by the two manufacturers (M1 and M2) are broadly similar but that the processes differ in many details.
- (iii) M1 data should have been checked for completeness and validity already. It is only necessary to recheck M1 data if the M2 data raise questions which were not considered during the original evaluation of M1 data. This would be an unusual occurrence and highlights the need for good documentation of decisions.
- (iv) Maintenance of confidentiality is critical in all cases of equivalence determination and thus great care is required in all communications with either M2 or M1, when trying to resolve problems arising during step 2 (the data check).

Slide F-09

Step 2, check data				
TC composition	M1 (reference)	M2	M2 data valid?	M2 equivalent?
	max./min. g/kg			
active ingredient	950	950	✔	
impurity 1 (relevant)	0.001	–	?	
impurity 2 (relevant)	1	–	?	
impurity 3	32	ND	?	
impurity 4	10	15	✔	
impurity 5	12	24	✔	
impurity 6	9	ND	?	
impurity 7	11	9	✔	
impurity 8	2	ND	?	
impurity 9	1	ND	?	
impurity 10	3	ND	?	
impurity 11	4	ND	?	
impurity 12	2	3	✔	
impurity 13	–	6	✔	

✔ = checked validated method, data OK, impurity 13 consistent with process used  
? = unsure how to interpret the data

Slide F-09 Note that ...

- (i) Before asking M2 about relevant impurities 1 and 2, it is essential to check that they are likely to occur in the process used by M2. If not, their occurrence should not be revealed to M2 because the information is confidential to M1 – unless the specification based on M1 has already been published. However, assuming that they could occur in the M2 process, it is legitimate and essential to ask M2 for manufacturing limits for the two relevant impurities.
- (ii) It is impossible to know what is meant by “not detected” (i.e. it could mean <10 g/kg, <0.01 g/kg or almost anything else). For this reason, M2 should be asked to provide limits of quantification (LOQ) for the impurities which were “not detected”. We will assume that the method has been validated acceptably for these impurities.
- (iii) As with all other data evaluated in support of pesticide specifications, data generated by test methods of questionable validity, or data which are themselves of questionable validity, must be considered cautiously in decision-making. Checking the validity of test methods and data is not a trivial part of equivalence determination, but it is important to be aware of the soundness, or otherwise, of the data used as the basis for decisions.

The **following slide** incorporates the responses from M2, who also provided evidence of acceptable validation of the methods used for the relevant impurities.

Slide F-10

Step 2, check data - with additional information from M2				
TC composition	M1 (reference) max./min. g/kg	M2 max./min. g/kg	M2 data valid?	M2 equivalent?
active ingredient	950	950	✓	
impurity 1 (relevant)	0.001	0.002	✓	
impurity 2 (relevant)	1	<1	✓	
impurity 3	32	<1	✓	
impurity 4	10	15	✓	
impurity 5	12	24	✓	
impurity 6	9	<1	✓	
impurity 7	11	9	✓	
impurity 8	2	<1	✓	
impurity 9	1	<0.1	✓	
impurity 10	3	<1	✓	
impurity 11	4	<1	✓	
impurity 12	2	3	✓	
impurity 13	–	6	✓	

data in red = new data from M2  
 ✓ = yes (i.e. checked validated method, data OK)

The following slide begins the determination of equivalence.

Slide F-11

Step 3, equivalence tests				
TC composition	M1 (reference) max./min. g/kg	M2 max./min. g/kg	M2 data valid?	M2 equivalent?
active ingredient	950	950	✓	✓
impurity 1 (relevant)	0.001	0.002	✓	✗
impurity 2 (relevant)	1	<1	✓	✓
impurity 3	32	<1	✓	✓
impurity 4	10	15	✓	✓
impurity 5	12	24	✓	✗
impurity 6	9	<1	✓	✓
impurity 7	11	9	✓	✓
impurity 8	2	<1	✓	✓
impurity 9	1	<0.1	✓	✓
impurity 10	3	<1	✓	✓
impurity 11	4	<1	✓	✓
impurity 12	2	3	✓	✓
impurity 13	–	6	✓	✗

data in red = new data from M2  
 ✓ = yes (i.e. checked validated method, data OK, or equivalent by this criterion)  
 ✗ = no (i.e. non-equivalent by this criterion)

Slide F-11 Note that ...

- (i) Where M2 limits for impurities are <3 g/kg or <50% higher (whichever is the greater) than those of M1, the values are considered equivalent.
- (ii) The focus now shifts to impurities 1, 5 and 13, which indicate non-equivalence.
- (iii) The evaluation team should check with M2 (and the scientific literature if necessary) for any evidence that impurities 5 and 13 could increase or extend the hazards of the active ingredient (i.e. that they may be relevant impurities, see Learning Unit E). In the following slide, it is assumed that they could not.

Slide F-12

Step 3, equivalence tests				
TC composition	M1 (reference)	M2	M2 data valid?	M2 equivalent?
	max./min. g/kg			
active ingredient	950	950	✔	✔
impurity 1 (relevant)	0.001	0.002	✔	✘
impurity 2 (relevant)	1	<1	✔	✔
impurity 3	32	<1	✔	✔
impurity 4	10	15	✔	✔
impurity 5	12	24	✔	✘ → ✔
impurity 6	9	<1	✔	✔
impurity 7	11	9	✔	✔
impurity 8	2	<1	✔	✔
impurity 9	1	<0.1	✔	✔
impurity 10	3	<1	✔	✔
impurity 11	4	<1	✔	✔
impurity 12	2	3	✔	✔
impurity 13	–	6	✔	✘ → ✔

✔ = yes (i.e. checked validated method, data OK, or equivalent by this criterion)  
✘ → ✔ = not strictly equivalent but considered acceptable because no tangible change in hazards is implied

**Slide F-12 Note that ...**

(i) This leaves only relevant impurity 1 to consider, for which there are several possible consequential scenarios, such as the following.

Scenario A M2 could actually comply with a limit of 0.001 g/kg for impurity 1. This would change the assessment for this impurity, and overall conclusion, to ✔.

Scenario B M2 cannot comply with a limit of 0.001 g/kg for impurity 1 but, because 0.002 g/kg is well below the maximum acceptable (see Learning Unit E), the specification limit may be raised to 0.002 g/kg. The assessment therefore changes: ✘ → ✔, i.e. not strictly equivalent but considered acceptable because the increased limit implies no tangible change in hazards.

Scenario C M2 cannot comply with a limit of 0.001 g/kg for impurity 1 and 0.001 g/kg is the maximum acceptable for this impurity (see Learning Unit E). The assessment for the impurity and overall becomes ✘, because the M2 product is neither equivalent to that of M1 nor is it acceptable to develop a separate specification for it.

(ii) The reference profiles are not changed by a determination of equivalence and so, for any particular active ingredient, successive determinations of equivalence involve comparisons with the same reference data.

The previous slides and discussions related to TC and TK only. Before concluding this part of the overview, it is therefore appropriate to consider the equivalence of formulations.

*Slide F-13*

**Equivalence of formulations**

- If the source of TC or TK incorporated into the formulation has been assessed as equivalent, and ...
- If the formulated product complies with all clauses of the existing specification for that formulation ...
- The formulation is considered to be equivalent.
- But, this test of equivalence may not be sufficient for certain products, e.g. certain slow-release LN and CS, in which the release profile is critical for efficacy.

*Slide F-13 Note that ...*

- (i) Formulations of a particular pesticide are regarded as equivalent if they are prepared from equivalent technical materials and conform to the same specification, but this does not imply that they necessarily provide equal efficacy or present identical risk in a particular application. It should be noted that specification clauses and test methods are simple models to control quality of pesticide formulations. Monitoring and documenting performance of equivalent formulated products under operational conditions is essential.

## LEARNING UNIT G

# Team exercises, introduction

Slide G-01

### Learning objectives

After completing this *Learning unit*, you should:

- have some practical experience in assessment of relevant impurities and in the determination of equivalence;
- understand the importance of teamwork in these tasks.

Slide G-02

### Team exercises

- Participants will be grouped into teams.
- Teams will work in parallel on the exercises.
- Teams should ask facilitators for help them with problems they cannot resolve.
- At the end of the period allocated for work on each exercise, teams will present their overall conclusions in a plenary discussion session.

Slide G-02 **Note that ...**

- (i) Each team should appoint a moderator, to co-ordinate discussions and present the team's conclusions in plenary sessions, and a rapporteur, to record team decisions and conclusions. Teams may appoint a different moderator and rapporteur for each exercise.

**Lists of the participants allocated to each team will be distributed by the facilitator or local organizer.**

Slide G-03

### Time available for exercises

- Exercise 1, **relevant impurities**, ¼ hour introduction, 1½ hours teamwork, 1 hour presentations and discussion
- Exercise 2, **equivalence**, ¼ hour introduction, 1 hour teamwork, 1¼ hours presentations and discussion
- Exercise 3, **equivalence**, ¼ hour introduction, 1½ hours teamwork, 1½ hours presentations and discussion
- Exercise 4, **equivalence**, ¼ hour introduction, 1¼ hours teamwork, 1 hour presentations and discussion

Slide G-04

Exercises

- Exercise data are fictional but present typical problems in assessment of impurity relevance or product equivalence.
- To simplify these exercises, it is assumed that some (or all) test methods and data have already been checked as valid.
- If a gap in the information provided prevents your team from making a decision, **question the facilitators** to help to resolve it.
- Provide a brief explanation of each decision, so that you can show how and why the team reached its conclusions.

Slide G-05

Exercises

- A blank *Relevant impurities evaluation table* or *Equivalence evaluation table* will be distributed at the start of each exercise, to help you assemble the data quickly and to simplify decision-making by the evaluation team.
- After teams have presented their evaluations at the end of each exercise, a corresponding completed *Evaluation table* will be distributed for general discussion.
- All of these tables may be inserted into the *Participant's guide*, to assemble a complete reference volume.
- The blank *Evaluation tables* could be adapted for use in your work, to help with decision-making and record-keeping.

Slides G-04 and G-05 **Note that ...**

- (i) Before starting each exercise, it will be described briefly and the corresponding data and blank *Evaluation tables* will be distributed.
- (ii) The exercises have logical conclusions but, as in real-life, the conclusion may depend upon the information available and the opinions of the evaluation team. Any gaps or problems remaining unresolved, preventing the team from reaching what its members collectively consider to be a sound conclusion, should be recorded by the team and identified during the plenary discussion session.
- (iii) Ask facilitators for help with information gaps and problems in these exercises. This simulates normal working practice, where additional information is likely to be required from the manufacturer or other sources in some cases (such as published literature or independent experts). Remember the essential need to protect commercial confidentiality. Maintenance of commercial confidentiality may be simulated in the exercises if team members do not reveal, to other teams, their own team's additional information, conclusions and rationales until presented in the subsequent plenary discussion session.

## **ANNEX 1. CHECK-LIST FOR SUBMISSION OF APPLICATION FOR DEVELOPMENT OF FAO AND OR WHO SPECIFICATIONS**

FAO and WHO welcome submission of requests for development of pesticide specifications or for extension of existing FAO and or WHO specifications to products of other manufacturers. A formal application in hard copy (with electronic copy on a CD) shall be submitted. The data package requirements, as specified in the Manual on development and use of FAO and WHO specifications for pesticides and its amendments (available at <http://www.who.int/whopes/quality/en/>) shall be strictly followed.

A covering letter is required and shall include the following information:

- The name, address and contact point of the proposer(s) of the specification.
- An statement if the application is for development of a new specification or for extension of an existing specification. In the case of the former, specify if the proposal is for joint FAO/WHO specifications or for WHO specifications only. For extension of existing specifications, the source of TC/TK, as the sole source, shall be declared. In the case of WHO specifications, and where relevant, confirm that the formulation and manufacturing process are the same as those employed for the materials evaluated by WHOPES for efficacy.
- Confirm that current production complies with the limits identified in specifications as it relates to active ingredient content. Manufacturing maximum limits for impurities.
- Any other information that can facilitate review and assessment of the application.

Enclose:

- Completed electronic proposer's data entry form (available at <http://www.who.int/whopes/quality/en/>) and specifications in "standard format" and in Word file (**not** pdf). See also the checklist enclosed.
- Original study reports of physical and chemical properties of active ingredient.
- Study reports in support of each and every criteria (parameter) of the specifications for a formulated product.
- Validated test method for measurement of specification parameters of a new specification where FAO/WHO guideline specifications do not exist.
- A letter of authorization granting WHO and a registration authority to access the national registration data for comparison of confidential data (manufacturing process and purity/impurity profile).
- A brief description with necessary data/information of manufacturers internal quality assurance and control schemes.

The following check-list is to facilitate the collation of the data package. In case of doubt or questions, please refer to the relevant Sections of the Manual on development and use of FAO and WHO specifications for pesticides and its amendments. Please provide a copy of the check-list with your application and check (✓) the information/documents that are included with your submission.

**A. DATA REQUIREMENTS FOR PURE AND TECHNICAL GRADE ACTIVE INGREDIENTS (TC/TK)**

Y = data required; (Y) = conditional data requirement; and N = not required

Chapter 3, Manual	Requirements	For reference specification	For equivalence (extension of specifications for a TC or TK)	Check (✓) if included in the submission
A.1	<b>Identity of the active ingredient</b> (information only)			
	ISO English (E-ISO) common name and status	Y	Y	
	Any other common name or synonym.	Y	Y	
	Chemical name (IUPAC and CA).	Y	Y	
	CAS No. (for each isomer or the mixture of isomers, if appropriate).	Y	Y	
	CIPAC No.	Y	Y	
	Structural formula(e) (including stereochemistry of the active isomers).	Y	Y	
	Isomeric composition, if appropriate.	Y	Y	
	Molecular formula.	Y	Y	
	Relative molecular mass.	Y	Y	
A.2	<b>Physical and chemical properties of the active ingredient</b> (studies and end points), pure active			
	Entry (studies and endpoint), pure active			
	Melting point	Y	(Y)	
	Temperature of decomposition	Y	(Y)	
	Vapour pressure	Y	(Y)	
	Solubility in water	Y	(Y)	
	Octanol : water partition coefficient	Y	(Y)	
	Dissociation characteristics, if appropriate	Y	(Y)	
	Hydrolysis, photolysis and other degradation characteristics	Y	(Y)	
	Melting point of TC (active ingredients that are solids above 0 °C).	Y	(Y)	
	Studies and data for solubility in organic solvents at room temperature for pure or technical grade active ingredient.	Y	(Y)	

Chapter 3, Manual	Requirements	For reference specification	For equivalence (extension of specifications for a TC or TK)	Check (✓) if included in the submission
A3	Outline of the route of manufacture	Y	Y	
A.4	Minimum active ingredient content.	Y	Y	
A.5	Manufacturing maximum limits for impurities present at or above 1 g/kg, supported by batch analysis data (minimum 5 typical batches)(all confidential data).	Y	Y	
A.6	Manufacturing maximum limits for impurities proposed as relevant at < 1 g/kg.	Y	Y	
A.7	Information on relevant impurities, with explanations of the effects observed (for example, toxicological effects, or effects on the stability of the active ingredient). Limits set by the FAO/WHO Joint Meeting on Pesticide Residues (JMPR) and/or registration authorities should accompany this information, identifying the authority responsible for setting the limit.	Y	Y	
A.8	Identity and nominal content (g/kg) of compounds intentionally added to the TC/TK (confidential data).	Y	Y	

Chapter 3, Manual	Requirements	For reference specification	For equivalence (extension of specifications for a TC or TK)	Check (✓) if included in the submission
A.9	Toxicological summaries (including test conditions and results)	Y	(Y)	
A.9.1	Toxicological profile of the TC/TK based on acute oral, dermal and inhalation toxicity; skin and eye irritation, skin sensitization.	Y	(Y)	
A.9.2	Toxicological profile of the TC/TK based on repeated administration (from sub-acute to chronic) and studies such as reproductive and developmental toxicity, genotoxicity, carcinogenicity, etc. Equivalence: Data on in-vitro mutagenicity ( <i>S. typhimurium</i> . ) required in all cases including Tier-1 equivalence	Y	(Y)	
A.9.3	Eco-toxicological profile of the TC/TK based on toxicity to aquatic and terrestrial organisms (e.g. fish, Daphnia, algae, birds, bees), as appropriate to the intended use, and information of persistence.	Y	N	
A.10.1	WHO classification by hazard.	Y	N	
A.10.2	References to JMPR evaluations for toxicology, environmental fate and ecotoxicology should be given, where these exist.	Y	N	

**B. DATA REQUIREMENTS FOR FORMULATIONS (WHERE APPLICABLE;  
ALSO SEE GENERAL NOTE ABOVE)**

Chapter 3, Manual	Requirements	Check (✓) if included in the submission
B.1	Identify if the formulations are for public health or agriculture uses, or both.	
B.2	In the case of public health pesticides, confirm that the formulation and manufacturing process are the same as those employed for the materials evaluated by WHOPES for efficacy.	
B.3	List the main formulation types available and identify those for which specifications are sought.	
B.4	List the main countries where these formulations are registered and sold or, if there are very many, give the number of countries in each region or continent.	
B.5	Physical properties, as required by sections 5 to 9 of this Manual. If necessary, briefly explain why it is proposed that certain clauses should be deleted, new clauses should be inserted, or less stringent limits should be adopted compared with those given in the guideline specifications.	

**Note: Extension of specifications for some formulations (e.g. long-lasting insecticidal mosquito nets) requires additional data.**

**C. METHODS FOR THE ANALYSIS AND TESTING OF TC/TK AND FORMULATIONS INGREDIENTS (TC/TK)**

Y = data required; (Y) = conditional data requirement

Chapter 3, Manual	Requirements	For reference specification	For equivalence (extension of specifications for a TC or TK)	Check (✓) if included in your submission
C.1	At least two methods for testing identity of the active ingredient and one for testing the identity of the counter-ion or other derivative, if appropriate.	Y	(Y)	
C.2	Method for determination of active ingredient content. The method needs to be collaboratively validated.	Y	(Y)	
C.3	Methods of analysis for relevant impurities, in detail, including validation data, if not published. Give the principle of the methods of analysis used for non-relevant impurities in the TC/TK (GC with FID, for example).	Y	Y	
C.4	Reference test methods for physical-chemical properties.	Y	Y	
C.5	Information on validation completed, in progress or planned for methods listed under C.2 and C.3.	Y	Y	

## ANNEX 2. CALCULATIONS TO ESTIMATE THE RELEVANCE OF CERTAIN IMPURITIES

(Reproduced from the *Manual on development and use of FAO and WHO specifications for pesticides*, November 2010)

### Calculation of worst-case-possible contribution by an impurity to the toxic hazards of the active ingredient.

**Note:**

These calculations apply only where:

- (i) the nature of the toxic hazard presented by active ingredient and impurity is considered to be similar;
- (ii) the effects may be considered to be additive; and
- (iii) the toxicity of the impurity is known or can be approximated from data on analogous compounds.

If requirements (i) and (iii) are fulfilled but the effects are not additive, an appropriate calculation may be possible if the mathematical nature of the interaction is known.

The calculations are presented here in full, for clarity, but can be simplified by omitting the term for relative hazard of the active ingredient (=1).

### Calculations

- (i) Calculate the relative hazard of the impurity ( $RelHaz_{imp}$ ) from the hazard data for the impurity ( $Haz_{imp}$ ) and active ingredient ( $Haz_{ai}$ ).

$$RelHaz_{imp} = (Haz_{ai}/Haz_{imp})$$

The relative hazard of the active ingredient ( $RelHaz_{ai}$ ) is consequently 1.

- (ii) Calculate the maximum theoretical increase in hazard of the active ingredient/impurity mixture ( $MTIHaz$ ), as a proportion of active ingredient hazard ( $Haz_{ai}$ ), from the minimum purity (%) of the TC ( $\%ai_{min}$ ) and the corresponding theoretical maximum content (%) of the impurity ( $\%imp_{max}$ ).

$$MTIHaz = ((\%ai_{min} \times RelHaz_{ai}) + (\%imp_{max} \times RelHaz_{imp})) / (\%ai_{min} \times RelHaz_{ai})$$

- (iii) Calculate the maximum limit acceptable for the impurity concentration ( $\%Imp_{maxaccept}$ ) by substituting a limit of 1.1 (i.e. +10%) for  $MTIHaz$  and  $\%Imp_{maxaccept}$  for  $\%imp_{max}$ , in equation (ii):

$$1.1 = ((\%ai_{min} \times RelHaz_{ai}) + (\%Imp_{maxaccept} \times RelHaz_{imp})) / (\%ai_{min} \times RelHaz_{ai})$$

and rearranging equation (iii):

$$\%Imp_{maxaccept} = ((1.1 \times \%ai_{min} \times RelHaz_{ai}) - (\%ai_{min} \times RelHaz_{ai})) / RelHaz_{imp}$$

Where:

$Haz_{ai}$  = active ingredient hazard value;

$Haz_{imp}$  = impurity hazard value;

$RelHaz_{imp}$  = relative hazard of impurity compared with active ingredient;

$RelHaz_{ai}$  = relative hazard of active ingredient (=1);

$\%ai_{min}$  = declared minimum active ingredient content;

$\%imp_{max}$  = maximum theoretical content of impurity;

MTIHaz = maximum theoretical increase in hazard due to impurity;  
%imp<sub>maxaccept</sub> = maximum acceptable content of impurity.

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### **Example 1**

The acute oral LD<sub>50</sub> of an impurity is 100 mg/kg bw and that of the active ingredient is 1000 mg/kg bw. The minimum purity of the TC is 92%.

$$\text{RelHaz}_{\text{imp}} = 1000/100 = 10$$

MTIHaz =  $((92 \times 1) + (8 \times 10))/(92 \times 1) = 1.87$  (87% >10% increase, the impurity is **relevant**)

$$\% \text{Imp}_{\text{maxaccept}} = ((1.1 \times 92 \times 1) - (92 \times 1))/10 = \mathbf{0.92\%}$$

Rounding to 1 (or 1.5) significant figure, the maximum limit acceptable for the concentration of this relevant impurity is therefore 1% in the TC and 1% of the active ingredient concentration.

### **Example 2**

A biological pesticide TK has a minimum purity of 20%. The acute oral LD<sub>50</sub> of an impurity is 2000 mg/kg bw and that of the active ingredient is 1000 mg/kg bw. That is, the impurity is less hazardous than the active ingredient.

$$\text{RelHaz}_{\text{imp}} = 1000/2000 = 0.5$$

MTIHaz =  $((20 \times 1) + (80 \times 0.5))/(20 \times 1) = 3.0$  (200% >10% increase, the impurity is **relevant**)

$$\% \text{Imp}_{\text{maxaccept}} = ((1.1 \times 20 \times 1) - (20 \times 1))/0.5 = \mathbf{4\%}$$

The maximum limit acceptable for the concentration of this relevant impurity is therefore 4% in the TK or 20% of the active ingredient concentration.

### **Example 3**

The acute oral LD<sub>50</sub> of an impurity is 400 mg/Kg bw and that of the active ingredient is 600 mg/kg bw. The minimum purity of the TC is 98%.

$$\text{RelHaz}_{\text{imp}} = 600/400 = 1.5$$

MTIHaz =  $((98 \times 1) + (2 \times 1.5))/(98 \times 1) = 1.03$  (3% <10% increase, the impurity is **non-relevant**).



ask & communicate

PLEASE RECORD IN THE INSTRUMENT LOGBOOK!



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