QPRI

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Health
Environment

Québec

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EXECUTIVE SUMMARY

The Québec Pesticide Risk Indicator, identified by the acronym QPRI, is a diagnostic and decision-making tool designed to optimize pesticide management. It has a health component (**QPRI-Health**) and an environment component (**QPRI-Environment**).

This tool was developed through a comparison of pesticide risk indicators found in scientific literature. The selection and definition of criteria for the indicator are the result of close collaboration among

- le ministère de l'Agriculture, des Pêcheries et de l'Alimentation (MAPAQ)
- le ministère du Développement durable, de l'Environnement et des Parcs (MDDEP)
- l'Institut national de santé publique du Québec (INSPQ)

Both versions (2001 and 2004) of the approach recommended by the Norwegian Minister of Agriculture served as models for developing the QPRI, particularly its environment component. The health component had to be created from new criteria established by INSPQ, as no comparable system existed to date in Québec for the classification of toxicological data.

The health and environment components of the QPRI enable us to establish a **situational and progressive diagnostic of the risks of using pesticides at different levels**.

At the farmer's level
- Facilitates the choice of the least hazardous pesticides for human and environmental health

At the organizational or sectoral level
- Analysis of changes in risks linked to pesticides used by an organization or in an activity sector (e.g., vegetable farm, orchard, landscaping business, golf course)
- Consideration of risks linked to pesticides in seasonal planning of phytosanitary initiatives and strategies to fight against crop pests

At the provincial level
- Production of health and environmental risk trend indicators associated with pesticide use or sales
- Evaluation and monitoring of the impact of various pesticide risk mitigation measures

The QPRI also enables spatial and temporal monitoring of risks associated with pesticide use. In an integrated pest management effort, the QPRI identifies the risks associated with pesticides and promotes the identification of solutions to reduce these risks.

QPRI-Health

This toxicological risk indicator was developed by INSPQ. It draws on **acute** and **chronic** pesticide **toxicity** indexes and integrates their **bioavailability** potential. Furthermore, it takes into account some particularities of end-use products instead of relying exclusively on characteristics of the active ingredients. Thus, variables such as active ingredient concentration, formulation type, the application rate of end-use products and application techniques are considered in the determination of the QPRI-Health.

QPRI-Environment

This indicator of ecotoxicological risk and potential environmental impacts was jointly developed by MAPAQ and MDDEP. It takes into account the properties of pesticides that determine their environmental fate and behavior, as well as their **ecotoxicological** potential (that is, their toxic effects on many animal and plant species).

The following parameters are considered in the determination of an environmental risk indicator:

- Impact on terrestrial invertebrates
- Impact on birds
- Impact on aquatic organisms
- Mobility
- Persistence in soil
- Bioaccumulation potential

In addition, the QPRI-Environment considers some characteristics linked to end-use products, such as application rate and type of crop.

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Acronym	Meaning
A	Impact on aquatic organisms
B	Bioaccumulation
BCF	Bioaccumulation factor
C	Concentration of the substance in diet
CFEP	Compensation factor for the end-use product
EC_{50}	Effective concentration for 50% of an experimental population
ERI	Environmental risk index
$ERI_{active\ ingredient-w}$	Environmental risk index of weighted active ingredient
ETE	Estimated daily intake
F_{int}	Interception factor for plant cover
FIR	Food intake rate
FPer	Persistence factor
GENEEC	Generic estimated exposure concentration
GUS	Groundwater ubiquity score
HRI	Health risk index
$HRI_{active\ ingredient-w}$	Health risk index for weighted active ingredient
K	Coefficient of distribution set at 2/3 for all pesticides
K_{OC}	Organic carbon coefficient of adsorption
LC_{50}	Lethal concentration for 50% of an experimental population
LD_{50}	Lethal dose for 50% of an experimental population
M	Mobility
m_{avail}	Mass available for adsorption
m_{es}	Total mass of pesticides in surface water
$m_{unavail}$	Mass unavailable for adsorption
O	Impact on birds
P	Persistence in soil
PEC	Predicted environmental concentration
PestRI-E	Pesticide risk indicator for the environment
PestRI-H	Pesticide risk indicator for health
$PIEC_{soil}$	Predicted initial environmental concentration
P_{ow}	Octanol-water partition coefficient
Qhc	Hazard quotient for contact exposure
Qho	Hazard quotient for oral exposure
RUD	Residue unit dose
SAD	Standardized area dose
T	Impact on terrestrial invertebrates
T_{bee}	Impact on bees
TD_{50}	Half-life
TER	Toxicity/exposure ratio
T_{ew}	Impact on earthworms
TRI	Toxicological risk index of active ingredient
WFa	Weighting factor considering application rate
WFf	Weighting factor for the type of formulation

Pesticides, by their nature, represent risks for the environment and human health. They have multiple toxicological, physical, chemical and biochemical properties for which we must limit the undesirable effects. For this reason, it was important to develop a tool to characterize the risks associated with pesticides used in Québec and to promote the use of products with little impact, with a view to integrated pest management and the reduction of risks.

A number of tools were proposed to evaluate the potential impacts of pesticide use on health and the environment. These tools are called pesticide risk indicators. Each of them has its particularities and is designed for very specific needs and uses.

Québec used many criteria in the choice of a risk indicator. The indicator must

- Be simple, easy to use, credible and based on a rational approach
- Be precise and robust
- Be dynamic and perfectible
- Be based on available, reliable and accessible variables
- Be successful and efficient
- Integrate data on pesticides collected at different levels (e.g., crop, farm business, province)
- Take into account information on the toxicological nature of the pesticide, risks of contamination of water and soil, the effects and risks on human health as well as on terrestrial and aquatic organisms, the effects and risks of spray drift, persistence and other environmental and health impacts linked to provincial priorities such as those aiming to rationalize and reduce pesticide use
- Measure the reduction of risks linked to agricultural pesticides used in Québec
- Contribute to the monitoring of the objectives for the Stratégie phytosanitaire
- Help the pesticide user to make more appropriate choices for the protection of health and the environment

The selection of an indicator for Québec is based on a review of existing indicators (Duchesne *et al.*, 2003). Fifteen indicators were inventoried and analyzed in three comparative studies (Day, 2002; Demers, 2001; Reus *et al.*, 1999). Most of these indicators were developed in European countries (Germany, Denmark, France, Italy, Norway, Netherlands, Sweden, etc.) and a few in the United States. Some aspects of a recent comparative study by Devillers and his collaborators (Devillers *et al.*, 2005) were also considered.

After analyzing various indicators characterizing the potential impacts of pesticides on health and the environment, Ministère de l'Agriculture, des Pêcheries et de l'Alimentation (MAPAQ), Ministère du Développement durable, de l'Environnement et des Parcs (MDDEP) and Institut national de santé publique du Québec (INSPQ) selected the Norwegian risk indicator (NAIS, 2000; NAIS, 2004) as a tool to develop a Québec indicator. The main criteria that guided this selection were technical feasibility, perfectibility, availability of data and the possibility of generating two indicators (one for human health and one for the environment).

Finally, it is important to distinguish between "risk assessment" and "risk indicator." The risk assessment is used to quantify with precision the risk for various **exposure scenarios** while minimizing uncertainties as much as possible. The risk indicator is a tool destined to facilitate decision making and the establishment of assessments of pesticide use in terms of risks to health and the environment. To reach its objectives the risk indicator does not include any specific exposure scenario and does not have to incorporate all the risk assessment parameters. It is a simplified representation of reality designed to assist decision making. Risk assessment is a complex tool that leaves little room for approximations and is used to establish directions and regulations (e.g., registration). The risk indicator should be used as a supplement of risk assessment, as it has different objectives. Even though it occasionally uses data arising from risk assessment, it should not be confused with the latter.

1 NORWEGIAN RISK INDICATOR

The Norwegian risk indicator takes into account many critical variables specific to a pesticide. It attributes a score to these variables before integrating them into the calculation. It is therefore an aggregate of critical variables. The indicator produced two distinct indexes used to monitor the evolution of risks for health and the environment separately.

The health risk indicator proposed by Norway allowed us to produce a health risk index **(H)** for each registered pesticide in that country. When combined with annual data on pesticide sales, this indicator allows us to monitor the evolution of health risks. It uses parameters relative to acute and chronic toxicity of active ingredients and integrates the potential toxicity of end-use products. The data comes from "risk phrases" indicated on the labels of pesticides commercialized in Europe. A hazard factor is assigned to these phrases that refer to potential toxic effects observed during experiments or epidemiological studies. The hazard index for end-use products is then determined by summing up the factors of the different risk phrases. Furthermore, the index assumes that combined or repeated use of pesticides in a farming season is cumulative.

The environmental risk indicator proposed by Norway also allows us to produce an environmental risk index **(E)** that uses parameters relative to active ingredients (half-life, K_{oc}, solubility, etc.). It takes into account the end-use products, the type of crop (ground level crops, trees, etc.) and the use area (greenhouses, fields, etc.). The indicator is calculated for each active ingredient included in the end-use products by reasserting the hypothesis that the combined or repeated use of pesticides in a farming season is cumulative. Combined with annual pesticide sales data, the risk indicator enables the monitoring of the evolution of risk for the environment.

2 QUÉBEC PESTICIDE RISK INDICATOR

2.1 Nature of the QPRI

The Québec pesticide risk indicator (QPRI), like the Norway risk indicator (NAIS, 2000; NAIS, 2004), is based on the realistic worst case scenario, although it hypothesizes that good management practices are normally applied and that the combined or repeated use of pesticides is cumulative.

With its two components, the QPRI enables us to produce a health risk indicator and an environmental risk indicator. These indexes are tools that assist in choosing pesticides with a lower risk level. The QPRI also enables diagnosis through assessment of the evolution of the risk of using pesticides at a treatment and farm business level as well as province-wide

At the treatment and company scale, the QPRI will make it possible

- To choose the pesticides least hazardous to health and the environment
- To take risks into account when planning seasonal action strategies and pest control treatments
- To evaluate the evolution of risks linked to pesticide use by farm businesses and organizations

At the provincial scale, the QPRI will make it possible

- To monitor the evolution of risks associated with pesticides using data stemming from MDDEP's pesticide sale statements
- To ensure monitoring of the impacts of different mitigation measures applied to farm businesses and organizations

2.2 QPRI Structure

The first step in developing a risk indicator is to determine a specific weighted risk index for each active ingredient considering the characteristics of end-use products. Combined with data on pesticide use or sales, the index becomes an indicator, the **PestRI**, that analyzes the evolution of risk.
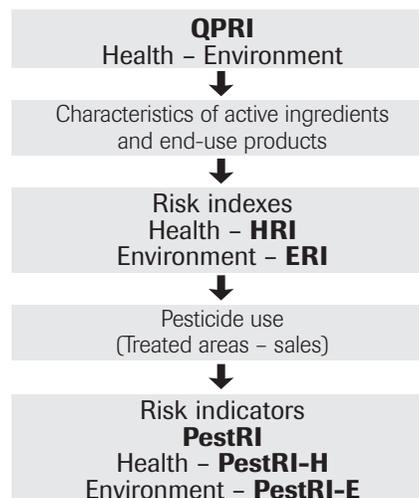
Figure 1: QPRI structure

Section 1 of this document developed by INSPQ presents the health component parameters. The parameters for the environment component, developed by MAPAQ and MDDEP, are presented in Section 2. Section 3 describes the methods of application of the QPRI.

QPRI – Health
Calculation of the health risk index

Section developed by INSPQ (Onil Samuel and Louis St-Laurent)

3 INTRODUCTION

The Québec pesticide risk indicator for health (QPRI-Health), developed in Québec by Institut national de santé publique du Québec (INSPQ), is inspired by the Norwegian risk indicator. The QPRI-Health takes into account the main acute and chronic toxicity criteria of active ingredients as well as the persistence potential in the environment and the bioaccumulation potential in the human body. Furthermore, it considers some aspects of end-use products and application techniques, and takes into account amounts used in the determination of pesticide risk.

4 GUIDING PRINCIPLES

◼ 4.1 Sources of data

The Québec pesticide risk indicator for health (QPRI-Health) is inspired by two different versions of the indicator developed in Norway (NAIS, 2000 and NAIS, 2004). The principles guiding the proposed approach for Québec are the same as those used for the Norwegian indicator. However, the Québec indicator does not use the risk phrases used in Europe. Verifications carried out on many pesticides show that the risk assessment conducted from this information does not always correspond to the estimates made according to North American risk evaluation principles. Furthermore, it is difficult to find a reliable data set for risk phrases. The consultation of many reference works shows that the proposed risk phrases for a given end-use product can vary according to the source of information. In such a context, it was agreed that the Québec indicator should be compatible with the toxicological database developed by INSPQ's Centre de toxicologie du Québec. This database integrates the most up-to-date toxicity criteria proposed by the following assessment agencies: Health Canada's Pest Management Regulatory Agency (PMRA), the

Environmental Protection Agency (EPA, United States), the European Commission (EC) and the World Health Organization (WHO) – see Appendix I.

◼ 4.2 Independent quantification of toxicity indicators

Some pesticides can be acutely toxic without presenting any chronic risk, and vice versa. A multitude of combinations are therefore possible to categorize a pesticide's risk. If we take this reality into account, and because short and long term risks can be equally significant, it is necessary to select an approach that reflects these two levels of potential effects. To this end, the Québec indicator takes an approach more in line with the first version of the Norwegian indicator (NAIS, 2000).

◼ 4.3 Gradation of effects

The gradation system of the risk indicator must necessarily take into account different levels of severity for a single effect. Thus, the assigned score considers the level of severity and the weight of the scientific proof regarding this effect. In this context, particular attention is given to the validity of protocols that were used to determine toxicity criteria.

◼ 4.4 End-use product characteristics

Risk can be defined by a simple equation: the intrinsic toxicity of a product times the level of exposure to this product. Thus, the risk attributable to the end-use product is not necessarily equal to that of the undiluted active ingredient. The level of risk always varies as a function of the level of exposure. For example, the formulation type, the concentration of the active ingredient in the end-use product and the application rate can influence the level of exposure for users. Therefore, the proposed indicator will enable the adjustment of the value of intrinsic toxicity of the

active ingredient (toxicological risk index) based on characteristics specific to each end-use product.

5 PARAMETERS OF THE HEALTH RISK INDEX

The QPRI-Health calculates a health risk index (**HRI**). This index represents the potential risk of an active ingredient contained in a given end-use product according to its use. An active ingredient therefore does not necessarily have the same **HRI** from one end-use product to another.

■ 5.1 Toxicological risk index of active ingredients (TRI)

The toxicological risk index of active ingredients (**TRI**) is determined by summing together the scores assigned according to the different criteria retained for acute and chronic toxicity (tables 1 and 2). The sum of chronic risks is then multiplied by a factor linked with persistence (**FPer**) and the potential for bioaccumulation in humans. It provides a toxicological risk index that also takes into account bioavailability. Indeed, a substance that persists in the environment or in the human body can have greater bioavailability than a substance that is rapidly eliminated from these matrices. Therefore, this may lead to a higher probability of affecting some cellular mechanisms potentially involved in the development of long term toxic effects (Valcke *et al.*, 2005).

The toxicological risk index for active ingredients is defined according to the following formula:

$$\text{TRI} = [\Sigma \text{ acute risks} + (\Sigma \text{ chronic risks} \times \text{FPer})]^2$$

To obtain a wide distribution of values and put emphasis on pesticides presenting a greater risk, the sum of the variables is squared.

Tables 1 and 2 present the different criteria for acute and chronic toxicity and the scores assigned according to the level of severity of the documented effect. The justification of scores assigned for each toxicity criterion is presented in Appendix II. The factor linked to persistence and bioaccumulation (**FPer**) is attributed according to the criteria presented in Table 3.

■ 5.2 Adjustment according to end-use product characteristics

□ 5.2.1 Weighting factor for the type of formulation

During the preparation and application of pesticides, exposure is normally modulated by the amount of active ingredients in the end-use product, by the degree of dilution and by type of formulation. This last factor is of major importance in regards to exposure. The World Health Organization in fact identifies type of formulation as one of the main variables in the modulation of pesticide toxicity in its pesticide classification system (ICPS, 2005). According to their type of formulation, products can be divided into two groups: those with a low risk of exposure and those with a high risk of exposure. Table 4 presents the weighting factor selected according to the type of formulation of the end-use product (**WFf**).

□ 5.2.2 Weighting factor for the application rate and the amount of active ingredient in end-use products (WFa)

The application rate and the amount of active ingredient in end-use products represent important elements in the modulation of level of exposure to risk. It is therefore proposed to introduce a weighting factor that takes into account these variables in the calculation of risk for an end-use product. As presented in the following table, this factor (**WFa**) is determined based on the standardized area dose

Table 1: Acute toxicity criteria of active ingredients

Acute toxicity	Severity of the effects				
	Weighting points				
	8	4	2	1	0
	Indicator values				
LD_{50} oral (mg/kg)	≤ 50	> 50-300	> 300-2000	> 2000	
LD_{50} dermal (mg/kg)	≤ 200	> 200-1000	> 1000-2000	> 2000	
LC_{50} inhalation (mg/l)	≤ 0.5	> 0.5-1	> 1-5	> 5	
Dermal irritation	Severe to extreme irritant	Moderate irritant	Slight irritant	Little or no irritant	
Ocular irritation	Severe to extreme irritant	Moderate irritant	Slight irritant	Little or no irritant	
Sensitization	Yes	Potential			No

Table 2: Chronic toxicity criteria of active ingredients

Chronic toxicity	Severity of the effects					
	Weighting points					
	16	8	4	2	1	0
	Indicator values					
Carcinogenicity	Human carcinogen	Probable human carcinogen	Possible human carcinogen	Data inadequate for assessment of human carcinogenic potential		Not likely to be carcinogen to humans
Genotoxicity		Genotoxic for humans	Potential genotoxicity for humans		No or inadequate data	No evidence of human genotoxicity
Endocrine disruption		Evidence of endocrine disruption	Potential endocrine disruption		No or inadequate data	No evidence of endocrine disruption
Reproductive effects	Confirmed human effects	Suspected human effects	Confirmed animal effects	Suspected animal effects	No or inadequate data	No effects
Développement	Confirmed human effects	Suspected human effects	Confirmed animal effects	Suspected animal effects	No or inadequate data	No effects

Table 3: Weighting factor for environmental persistence and bioaccumulation potential in humans (adapted from Valcke *et al.,* 2005)

Classification of environmental persistence and bioaccumulation potential	FPer
Soil half-life ≥ 60 days or BCF* ≥ 1000	3.0
Soil half-life ≥ 30–60 days or 100 ≤ BCF < 1000	2.5
Soil half-life ≥ 15–30 days or BCF < 100	2.0
No data for the criteria	1.5
Soil half-life < 15 days and no bioaccumulation or BCF data	1.0

Source: Van Gestel *et al.,* 1985.

* BCF = $10^{\log BCF}$ where $\log BCF$ = $(0.79 \times \log P_{oe}) - 0.4$
BCF = Bioaccumulation factor
P_{ow} = Octanol-water partition coefficient

Table 4: Weighting factor for the type of formulation

Weighting factor for the type of formulation (WFf)*	
Scores assigned according to risk of exposure	
Low = 1	High = 2
• Tablet (TA) • Slow-release generator (SR) • Granular (GR) • Water-dispersible granules (WD) • Wettable granules (WG) • Soluble granules (SG) • Live organism (LO) • Particulate (PT) • Pellet (PE) • Paste (PA) • Dry flowable (DF) • Solid (SO) • Microcapsule suspension (MS) • Impregnated fabric (IF)	• Emulsifiable concentrate or emulsion (EC) • Liquid (L or LI) • Dust or powder (DU) • Wettable powder (WP) • Soluble powder (SP) • Pressurized product (PP) • Solution (SN) • Suspension (SU)

* Hydro soluble formulations in packets (HF) will be assigned 1 point as their presentation attenuates the level of risk. Formulations, liquid or solid, that are released in gas form (GAS) will receive 2 points.

(SAD) and allows us to compare products with each other on a uniform basis. This last point is all the more important as labels from different end-use products with a common active ingredient do not necessarily have the same prescription for application rates.

Table 5: WFa value according to the SAD

SAD (g or ml a.i./ha)	WFa
< 100	0.5
≥ 100-1000	1
≥ 1000-2000	1.5
≥ 2000	2

The standardized area dose (SAD) is determined for each active ingredient based on the labeling of the end-use product. At the enterprise scale (e.g., farm business), the SAD is by default the maximum rate for an end-use product in a given crop. At the provincial scale, the SAD is the maximum registered application rate providing the highest HRI for reference crops. The SAD is expressed in ml/ha or g/ha (Appendix VI).

6 CALCULATION OF THE HEALTH RISK INDEX (HRI)

6.1 General equation

The HRI for a weighted active ingredient ($HRI_{active\ ingredient-w}$) is calculated by multiplying the toxicological risk index (TRI) by the appropriate weighting factors: the formulation (WFf), the application rate and the amount of active ingredient in the end-use product (WFa). As the value obtained can be very high for some active ingredients with a high toxicological risk index, the result is divided by 10 to obtain an HRI with an acceptable order of magnitude.

$$HRI_{active\ ingredient-w} = \frac{TRI \times WFf \times WFa}{10}$$

The $HRI_{active\ ingredient-w}$ corresponds to the risk index of an active ingredient contained in a given end-use product for one treated hectare. It is also possible to present the index by mass unit by dividing this index by the application rate (SAD) that was used in the calculation. This index (HRI / SAD) represents the risk associated with the use of one kilogram of active ingredient.

Theoretically, the HRI for an active ingredient could be between 1.25 and 23 040. In practice, the HRI values are between 1.25 and 1560.

6.2 Calculation of the HRI for an end-use product

The HRI for end-use products must be calculated considering all weighted active ingredients present in the end-use product (See Example 1, Appendix VII).

$$HRI_{end-use\ product} = \sum_i HRI_{active\ ingredient-w}$$

However, it is important to note that the sum of $HRI_{active\ ingredient-w}$ of an end-use product assumes an aggregate of risk, which is not necessarily the case. Considering all risks for all active ingredients present in the end-use product helps us avoid underestimating an effect specific to an active ingredient in particular. This is a conservative approach to estimate potential risks.

The HRI mainly takes into consideration the toxicological characteristics of active ingredients and some other properties linked to an end-use product. With health protection in mind, this indicator allows us to compare pesticides in order to be able to make informed choices. For example, it can be used to determine use scenarios towards this objective and facilitate the selection of pesticides that are least harmful for health.

▶ APPLICATION MODES OF THE QPRI-HEALTH

Section 3 presents application modes for different scenarios of the QPRI-Health.

QPRI – Environment
Calculation of the environmental risk index

Section produced by MAPAQ (Marie-Hélène April) and MDDEP (Sylvain Dion)

7 INTRODUCTION

The pesticide risk indicator for the environment (QPRI-Environment), developed by the MAPAQ-MDDEP working group, was adapted from two versions of the Norwegian risk indicator. The QPRI-Environment takes into consideration the physicochemical properties and ecotoxicological indicators of active ingredients as well as some characteristics associated with end-use products.

8 GUIDING PRINCIPLES

The QPRI-Environment takes into account various parameters linked to some properties of active ingredients, characteristics of end-use products, their area of use as well as type of crop. In fact, in addition to ecotoxicological parameters, the QPRI-Environment considers in the calculation of the environmental risk index the interception factor during pesticide application as well as leaching and runoff potential, etc.

■ 8.1 Active ingredient parameters

The active ingredient parameters relate to the following physicochemical properties and ecotoxicological indicators. The selection of this data is described in Appendix III.

Physicochemical and environmental fate properties

- Aerobic soil half-life, DT_{50} (day)
- Aerobic water half-life DT_{50} at a pH = 6–7 and a temperature of 20–25°C (day)
- Organic carbon adsorption coefficient, K_{oc} (ml/g)
- Water solubility (mg/l or ppm) with a pH = 6–7 and a temperature = 20–25°C
- Octanol-water partition coefficient, log P_{ow}

Ecotoxicological indicators

- LC_{50} for earthworms (mg/kg of soil)
- LD_{50} oral or contact for bees (μg/bee)
- LD_{50} (mg/kg) for birds (mallard duck or bobwhite quail)
- LC_{50} (μg/l) for fish (rainbow trout)
- LC_{50} or EC_{50} (μg/l) for aquatic invertebrate
- EC_{50} (μg/l) for algae (green algae)
- EC_{50} (μg/l) for vascular plants (duckweed)

■ 8.2 End-use product parameters and areas of use

- A standardized area dose (**SAD**) is determined for each active ingredient from the end-use product's label. At an enterprise scale (e.g., farm business), the **SAD** is by default the maximum application rate for an end-use product in a given crop. At the provincial scale, the **SAD** is the maximum registered rate giving the highest **ERI** for a reference crop. The **SAD** is expressed in ml/ha or g/ha (Appendix VI).
- The quantity of active ingredient either applied or sold is considered at the enterprise and provincial scale.
- The types of crops on which pesticides are applied are low crops, bushes and fruit trees (Table 6).

9 PARAMETERS OF THE ENVIRONMENTAL RISK INDEX (ERI)

The QPRI-Environment calculates a risk index for the environment (**ERI**). This index represents the potential risk of an active ingredient composing an end-use product considering its use. An active ingredient thus does not necessarily have the same **ERI** from one end-use product to another. Equally, according to type of use (e.g., targeted crop) the **ERI** of an active ingredient for the same end-use product may vary. The organisms selected for the calculation of the index are those regularly used as sentry species for ecotoxicological risk assessments.

The **ERI** stems from six variables:

Ecotoxicological
$\begin{cases} \textbf{T} & \text{Impact on terrestrial invertebrates} \\ \textbf{O} & \text{Impact on birds} \\ \textbf{A} & \text{Impact on aquatic organisms} \end{cases}$

Physicochemical
$\begin{cases} \textbf{M} & \text{Mobility} \\ \textbf{P} & \text{Persistence in soil} \\ \textbf{B} & \text{Bioaccumulation} \end{cases}$

■ 9.1 Impact on terrestrial invertebrates (T)

The impact on terrestrial invertebrates is represented by the **T** variable in the calculation of the **ERI** for an active ingredient. The terrestrial invertebrates selected are earthworms and bees. The score given to the **T** variable is therefore equal to the higher of the two variables, i.e., T_{ew} (impact on earthworms) or T_{bee} (impact on bees).

□ 9.1.1 Impact on earthworms (T_{ew})

The score for the Tew variable is determined from a toxicity/exposure ratio (**TER**).

$\text{TER} = \text{Toxicity} / \text{PIEC}_{soil}$
where
Toxicity = 14 day exposure LC_{50} for earthworms
PIEC_{soil} = Predicted initial environmental concentration

The PIEC_{soil} is determined using the following equation (FOCUS 1997):

$$\text{PIEC}_{soil} = \text{SAD} \times (1 - f_{int}) / (100 \times \text{depth} \times \text{density})$$

where
SAD = Standardized area dose (ml/ha or g/ha)
f_{int} = Interception factor for plant cover
Depth = Depth of penetration of the pesticide into the soil (default value of 5 cm)
Density = Soil density (default value of 1.2 g/cm³)

The interception factor of crops influences the amount of pesticide found in the soil. This factor is modulated by type of crop and density of vegetation. A lower ground cover density is considered for herbicides, as plant growth generally starts at the stage of this type of treatment. When using insecticides, fungicides and growth regulators, a higher ground cover density is assumed because of the level of growth normally attained by plants. Soil fumigants are generally used on bare ground, without interception. The values of the interception factors are presented in Table 6.

Table 6: Interception factor (f_{int}) of the crop according to type of pesticide

Type of crop	Interception factor			
	Herbicide	Insecticide/fungicide	Growth regulator	Soil fumigant
Low level field crop (≤ 50 cm)	0.10	0.5	0.5	0
Bush (> 50-200 cm)	0.20	0.5	0.5	0
Fruit tree (> 200 cm)	0.25	0.4	0.4	0

Examples: – Low-level field crop: carrot, strawberry, wheat
– Bush: raspberry, blueberry corymbs
– Fruit tree: apple, plum

The score attributed to the T_{ew} variable is determined according to Table 7. A limit of 100 was established by the European and Mediterranean Plant Protection Organization (EPPO, 2003) and a limit of 10 by the European Commission (EC, 1994).

Table 7: Value of T_{ew} according to toxicity/exposure ratio based on a 14 day exposure LC_{50}

TER	T_{ew}
> 100	0
> 10-100	2
≤ 10	4

Sources: NAIS, 2000; NAIS, 2004.

□ 9.1.2 Impact on bees (T_{bee})

The T_{bee} score is based on hazard quotients for oral exposure (**Qho**) or contact exposure (**Qhc**) for bees (EC, 1994):

Qho or Qhc = SAD / Toxicity
where
SAD = Standardized area dose (ml/ha or g/ha)
Toxicity = Oral or contact LD_{50} (µg/bee)

Table 8 presents the distribution of scores according to quotient intervals. Adverse effects on bees are considered negligible when under 50 (EC, 1994).

Table 8: Value of T_{bee} according to oral exposure (**Qho**) or contact exposure (**Qhc**) quotient for bees

Qho or Qhc	T_{bee}
< 50	0
≥ 50-1000	2
≥ 1000	4

Sources: NAIS, 2000; NAIS, 2004.

■ 9.2 Impact on birds (O)

The potential impact on birds is determined by using an acute toxicity criterion (LD_{50}) for the mallard duck and, if need be, the bobwhite quail. These two sentry species present in Québec are the most cited in literature. The **O** variable is determined by a toxicity/exposure ratio (**TER**).

TER = Toxicity / ETE
where
Toxicity = LD_{50} (mg/kg of body weight) of the mallard duck or the bobwhite quail
ETE = Estimated daily intake (mg/kg of body weight)

The European guide for the evaluation of risks for birds and mammals (EC, 2002) takes a multilevel approach to evaluate risk. The QPRI-Environment uses the first tier, defined as a realistic worst case scenario approach, to quantify the exposure of herbivorous birds. Appendix IV details the calculation of exposure.

Table 9 presents the distribution of points according to the **TER** (EC, 1994).

Table 9: Value of **O** according to toxicity/exposure ratio for birds

TER	O
> 10	0
> 5-10	1
> 1-5	2
> 0.1-1	3
≤ 0.1	4

Sources: NAIS, 2000; NAIS, 2004.

■ 9.3 Impact on aquatic organisms (A)

Pesticides can contaminate surface water, mainly by spray drift, surface runoff or runoff into drainage systems. The European Union Working Group (FOCUS, 2002) recommends a multilevel method of calculation to determine pesticide concentration in surface water. The first tier of calculation, "Step 1," judged to be too conservative by the MAPAQ-MDDEP working group, combines spray drift, surface runoff and runoff into drainage systems on the day of application (Day 0). The second tier, the one selected by the working group, evaluates the concentration due to spray drift and runoff as a series of individual events; the concentration due to spray drift is calculated immediately after application and the concentration due to runoff is calculated 4 days after application. The details of the parameters linked to spray drift, surface runoff and runoff into drainage systems are presented in Appendix V.

The impact on aquatic organisms is represented by the A variable in the calculation of the ERI of an active ingredient. The toxicity/exposure ratio (TER) determines the score assigned to this variable.

$$TER = Toxicity / PEC_{max}$$

where

Toxicity = LC_{50} or EC_{50} for algae, aquatic plants, aquatic invertebrate or fish

PEC_{max} = Maximum predicted environmental concentration observed after 4 days.

The method of calculating the PEC_{max} is explained in a document from the EC working group (FOCUS, 2002).

The score assigned to variable A (Table 10) was established based on limit values (EC, 2002). The TER is calculated for fish and aquatic invertebrate as well as algae and aquatic plants using the PEC_{max}. The ratio with the smallest value is used to determine the score for A. Thus, the indicator can generate a result for this variable, notwithstanding the absence of values for one or more aquatic species mentioned above.

Table 10: Value of A according to toxicity/exposure ratio for aquatic organisms

TER for fish and aquatic invertebrates	TER for algae and aquatic plants	A
> 100	> 10	0
> 10-100	> 1-10	1
> 1-10	> 0.1-1	2
> 0.1-1	> 0.01-0.1	3
≤ 0.1	≤ 0.01	4

Sources: NAIS, 2000; NAIS, 2004.

9.4 Mobility (M)

The mobility of an active ingredient is represented by the M variable in the calculation of the ERI for an active ingredient and is determined based on its leaching potential. The GUS index (groundwater ubiquity score; Gustavson, 1989) is used to estimate the potential of a pesticide to contaminate groundwater by leaching and surface water by infiltration via drainage systems. The GUS is based on two active ingredient properties: organic carbon adsorption coefficient (K_{oc}) and aerobic soil half-life (TD_{50}). These properties are used in the following equation:

$$GUS = \log (TD_{50}) \times (4 - \log(K_{oc}))$$

The GUS index is interpreted as follows:

GUS < 1.8   Low leaching potential
GUS ≥ 1.8-2.8   Moderate leaching potential
GUS ≥ 2.8   High leaching potential

The application rate is put into relation with the GUS index in order to determine a potential risk of contamination by leaching or infiltration of drainage systems. Table 11 presents scores for the M variable according to the GUS index and the standardized area dose (SAD).

Table 11: Value of M according to the GUS index and application rate

GUS	SAD (g or ml a.i./ha)			
	< 100	≥ 100-1000	≥ 1000-2000	≥ 2000
< 1.8	0	0	0	0
≥ 1.8-2.8	1.25	1.5	1.75	2
≥ 2.8	2.5	3	3.5	4

Source: NAIS, 2000.

9.5 Persistence in soil (P)

Persistence in soil is represented by P in the calculation of the ERI of an active ingredient. Aerobic soil half-life in aerobic conditions (TD_{50}) and the standardized area dose (SAD) are used to determine the value of P. Table 12 presents scores for the P variable.

Table 12: Value of P according to half-life and application rate

TD_{50} (days)	SAD (g or ml a.i./ha)			
	< 100	≥ 100-1000	≥ 1000-2000	≥ 2000
< 10	0	0	0	0
≥ 10-30	0	0	0.5	1
≥ 30-60	0.5	1	1.5	2
≥ 60-90	1.5	2	2.5	3
≥ 90-180	2.5	3	3.5	4
≥ 180	4	4	4	4

Sources: NAIS, 2000; NAIS, 2004.

◼ 9.6 Bioaccumulation (B)

The bioaccumulation potential is represented by the **B** variable in the calculation of the **ERI** of a weighted active ingredient. Aerobic soil half-life (TD_{50}) and the logarithm for the octanol-water partition coefficient ($\log P_{ow}$) are used to determine the score given to **B** (Table 13).

Table 13: Value of **B** according to soil half-life and $\log P_{ow}$

TD_{50} (days)	Octanol–water partition coefficient ($\log P_{ow}$)		
	< 3	3-4	> 4
< 10	0	0	1
≥ 10-90	0	0	2
≥ 90-180	0	1	3
≥ 180	0	2	4

Sources: NAIS, 2000; NAIS, 2004.

10 CALCULATION OF THE ENVIRONMENTAL RISK INDEX (ERI)

◼ 10.1 General equation

The aggregate variables presented previously correspond to the risk index of active ingredients contained in a given end-use product for one treated hectare ($ERI_{\text{active ingredient-w}}$). To obtain a greater distribution of values and to bring to the fore pesticides with a greater risk, the sum of variables is squared; the maximum rating possible of 31 then becomes 961. A larger scale allows us to better differentiate the risk of one pesticide compared to another.

A greater weight is given to variables of terrestrial impact. Terrestrial organisms are the most directly affected by the application of pesticides that initially affect their milieu. The **T** and **O** variables are therefore multiplied by 1.75. This multiplicative value was chosen to carry the proportion of variables relative to ecotoxicological impacts (**T**, **O** and **A**) to 60% of the **ERI** equation. The variables related to environmental fate (**M**, **P** and **B**) therefore compose 40% of this equation. The general equation is as follows:

$$ERI_{\text{active ingredient-w}} = [1.75 \times (T + O) + A + M + P + B + 1]^2$$

◼ 10.2 Specific cases

Specific cases concern the uses or occupational sectors described below:

Treated seeds

Considering the little information presently available on toxicity to bees of active ingredients used to treat seeds, the T_{bee} variable is not considered in the calculation of the **ERI** for this type of use.

$$ERI_{\text{active ingredient-w}} = [1.75 \times (T_{ew} + O) + A + M + P + B + 1]^2$$

Pesticides used in greenhouses

Because of the particular environment in greenhouses, the active ingredients used have a limited impact on terrestrial invertebrates, birds, aquatic organisms and bioaccumulation. However, considering the potential discharge of contaminated greenhouse water, two variables relative to environmental fate—mobility and persistence—are considered in the calculation of the **ERI**.

$$ERI_{\text{active ingredient-w}} = [M + P + 1]^2$$

Pesticides used in warehouses and microbial pesticides

In light of actual knowledge and because of the areas of use as well as the properties of microbial pesticides with a weak known impact, a score of 1 is given to these products.

Pesticides used in warehouses:	$ERI_{\text{active ingredient-w}} = 1$
Microbial pesticides:	$ERI_{\text{active ingredient-w}} = 1$

The $ERI_{\text{active ingredient-w}}$ corresponds to the risk index for an active ingredient contained in a given end-use product for a treated hectare. It is also possible to present the indexes by mass unit by dividing by the standardized area dose (**SAD**) that was used in the calculation. This index (**ERI / SAD**) represents the risk linked to the use of one kilogram of active ingredient.

■ 10.3 ERI calculation for an end-use product

The **ERI** for end-use products must be calculated considering all weighted active ingredients included in this product (Example 1, Appendix VII).

$$\text{ERI}_{\text{end-use product}} = \sum \text{ERI}_{\text{active ingredient-w}}$$

However, it is important to note that the summation of the **ERI**$_{\text{active ingredient-w}}$ of an end-use product presupposes a summation of risks, which is not necessarily the case. Considering all risks for all active ingredients present in the end-use product allows us, however, to avoid underestimating an effect specific to an active ingredient in particular. It is thus a conservative approach to estimating potential risks.

The ERI mainly takes into consideration ecotoxicological characteristics and physicochemical properties of active ingredients, as well as some other characteristics linked to end-use products and crops. This indicator allows us to compare pesticides with each other in order to be able to make informed decisions to protect the environment. For example, it can be used to determine use scenarios that allow us to attain this objective and thus facilitate the choice of the least hazardous pesticides for the environment.

▶**MODES OF APPLICATION OF THE QPRI-ENVIRONMENT**

Section 3 presents the modes of application for different scenarios of the QPRI-Environment.

3

QPRI – Health and Environment
Application methods

SECTION

Section developed by MAPAQ (Marie-Hélène April), MDDEP (Sylvain Dion) and INSPQ (Onil Samuel and Louis St-Laurent)

11 INTRODUCTION

The **HRI** and **ERI** indexes give us an appreciation of the potential risk for health and the environment for an active ingredient in an end-use product considering its use. They allow us to compare active ingredients or a combination of active ingredients in order to be able to make informed choices for treatments with a view to protecting health and the environment. Thus, the user can better focus pest management activities, for example by comparing different scenarios to better take into account the global risk of a treatment.

The HRI and ERI are not calculated using the same variables, and their weighting is not equivalent. These indexes can therefore not be compared to each other for the same weighted active ingredient. Each index only allows us to compare an active ingredient or a combination of active ingredients on the basis of health effects, independently of effects on the environment.

12 THE APPLICATION OF HRI AND ERI IN THE CHOICE OF TREATMENTS

■ 12.1 HRI$_{treatment}$

On a treatment scale, risk of exposure is influenced by many factors, such as the surface treated and especially the method and area of application. On a business scale, the information required to integrate an adjustment factor taking into account the technique or area of application (**WFa**) is easily accessible. **When the technique and/or area of application are known, an adjusted index may advantageously be used in place of the HRI$_{end-use product}$.** Three levels of risk are therefore considered (Table 14). A high risk is attributed to the use of an air blast sprayer for high level targets (orchards), while a low risk is considered when the target is at is low level (market gardening and large crops) or when a sprayer with an anti-drift system is used. The risk is also qualified as low when a horizontal boom spray unit is used. For all incorporation, the risk is qualified as very low because of the lower level of exposure expected. Furthermore, the use of previously treated seed is considered as a lower

Table 14: Weighting factor associated with application technique

Weighting factor according to technique and/or place of application (WFa)		
Score		
1	**1.5**	**2**
• Use of pretreated seed • Incorporation	• Horizontal boom spray unit • Air blast sprayer with ground directed spray • Sprayer with anti-drift system	• Air blast sprayer with high position directed spray • Treatment of seed in a closed area • Treatment in a closed area

exposure risk than the treatment of seed in a closed area. In addition, the use of pesticides in a closed space (such as a greenhouse or a warehouse) is considered as high level exposure, regardless of the application technique.

The results from the multiplication of **HRI** and the weighting factor for the technique and/or place of application (**WFa**) translates into an adjusted health risk index (**HRI**$_{adjusted}$) of the end-use product for a given treatment for one treated hectare (Example 2, Appendix VII).

$$\text{HRI}_{adjusted} = \text{HRI}_{end-use\ product} \times \text{WFa}$$

In order to calculate a risk index for health associated with a treatment (**HRI**$_{treatment}$), the **HRI**$_{adjusted}$ of all end-use products used during treatment are added (Example 3, Appendix VII).

$$\text{HRI}_{adjusted} = \sum_{1}^{i} \text{HRI}_{adjusted}$$

■ 12.2 ERI$_{treatment}$

In order to calculate an environmental risk index associated with a treatment (**ERI**$_{treatment}$), the **ERI** of all end-use products applied for the treatment are added (examples 3 and 4, Appendix VII).

$$\text{ERI}_{treatment} = \sum_{1}^{i} \text{ERI}_{end-use\ product}$$

13 APPLICATION OF THE QUÉBEC PESTICIDE RISK INDICATOR TO ASSESS AND ANALYZE THE EVOLUTION OF RISK (PestRI)

While indexes (HRI and ERI) facilitate the selection of lower risk pesticides for health and for the environment, risk indicators (PestRI-H and PestRI-E), combined with use or sale data allow us to analyze the evolution of risks associated with pesticides at different levels.

When they are put into relation with use or sale data, **HRI** and **ERI** allow us to obtain indicators for monitoring the evolution of risk for health (**PestRI-H**) and the environment (**PestRI-E**). These risk monitoring indicators serve as a tool for analysis of the evolution of risks associated with pesticides used by a farm business, a group of farmers or any other organization with data on use or sales of pesticides. By attributing a value to each active ingredient that reflects the risk for health (**H**) and the environment (**E**), the use or sale data are thus modulated according to the potential risk that pesticide use represents. It is thus possible to conduct assessments of health and environmental

risks at the scale of a business (vegetable farm, orchard, golf course, etc.) and at the provincial scale by sector of use (e.g., agricultural production, maintenance of green spaces), by type (e.g., insecticides, herbicides) and by pesticide chemical group.

■ 13.1 Calculation of the indicators (PestRI-H and PestRI-E) according to type of data

All equations that follow concern health as well as environment components. In order to streamline the text, only examples of equations for health are presented. To obtain the formula for the environment, simply replace **HRI** with **ERI** and **–H** with **–E**.

□ 13.1.1 Data on pesticide use

The multiplication of **HRI**$_{treatment}$ by the area in hectares on which the treatment was applied allows us to obtain **PestRI-H**$_{treatment}$ (Example 5, Appendix VII).

$$\text{PestRI-H}_{treatment} =$$
$$\text{HRI}_{treatment} \times \textbf{treated area (ha)}$$

The summation of health indicators linked to specific treatments used by a farm business allows us to obtain a health indicator for pesticides used throughout the farm business (**PestRI-H**$_{farm\ business}$).

$$\text{PestRI-H}_{farm\ business} = \sum_{1}^{i} \text{PestRI-H}_{treatment}$$

In order to obtain the health indicators linked to a group of growers, for example, we simply add the indicators from all farm businesses in the group (**PestRI-H**$_{group}$).

$$\text{PestRI-H}_{group} = \sum_{1}^{i} \text{PestRI-H}_{farm\ business}$$

□ 13.1.2 Data on pesticide sales

The calculations of risk indicators differ according to whether the data available concern sales or use of pesticides. Québec does not have specific data on areas of use for these products but does have data on end-use product sales.

NOTE – This information on sales does not correspond to data on pesticide sales , but is rather an indicator of use. Furthermore, most pesticides have more than one registered use. However, the following basic premise is used to estimate use based on sales data: the total amount of a pesticide sold during the year is completely used during that period according to the standardized area dose (**SAD**) giving us the highest **HRI** and **ERI** for the reference crop. The reference crop

for a pesticide is determined from the decision-making diagram in Appendix VI. It is important to note that this reference crop will also determine the height and place of application in the calculation of the **ERI**. The areas treated with an active ingredient contained in a given end-use product are therefore estimated using the following equation:

$$\text{Areas (ha)} = \frac{\text{Sales (kg a.i.)}}{\text{SAD (kg a.i./ha)}}$$

Multiplication of the $HRI_{\text{active ingredient-w}}$ by the area in hectares over which the active ingredient is applied gives us the $PestRI\text{-}H_{\text{active ingredient-w}}$

$$PestRI\text{-}H_{\text{active ingredient-w}} = HRI_{\text{active ingredient-w}} \times \textbf{area (ha)}$$

By using the equation applied to estimate areas from sales and the **SAD**, the equation of **PestRI-H** is the following:

$$PestRI\text{-}H_{\text{active ingredient-w}} = HRI_{\text{active ingredient-w}} \times \frac{\text{Sales (kg a.i.)}}{\text{SAD (kg a.i./ha)}}$$

The $PestRI\text{-}H_{\text{active ingredient-w}}$ is thus the health risk indicator of an active ingredient contained in an end-use product for a given year at a provincial scale. This equation also shows that dividing the $HRI_{\text{active ingredient-w}}$ by the **SAD** gives an indexed value for one kilogram of active ingredient (**HRI / SAD**). In order to obtain the indicator for monitoring the health risk for Québec for all active ingredients of all end-use products sold during a given year, all $PestRI\text{-}H_{\text{active ingredient-w}}$ are added according to the following equation (Example 7, Appendix VII):

$$PestRI\text{-}H_{\text{Québec}} = \sum_{1}^{i} PestRI\text{-}H_{\text{active ingredient-w}}$$

14 ELEMENTS OF RISK COMPARISON

All equations that follow concern the health as well as the environment components. In order to streamline the text, only examples of equations for health are presented. To obtain the formulas for the environment, simply replace **–H** with **–E**.

■ 14.1 One hectare basis

In order to obtain a comparative basis, it is justified to translate the pressure on health and the environment exerted by pesticides without considering area. It is then important to be able to compare the annual variations of risk indicators on a comparative basis, thus for one hectare. The **PestRI-H/ha** is obtained by dividing the **PestRI-H** by the total area cultivated (examples 6 and 8, Appendix VII).

$$PestRI\text{-}H/ha = \frac{PestRI\text{-}H}{\text{Cultivated areas (ha)}}$$

■ 14.2 One kilogram basis

This indicator represents an average indexed value per kilogram that is modulated by the total amount of active ingredients used or sold according to the case. It can be used to compare annual variations on the basis of one kilogram. Contrary to risk indicators per hectare, these indicators can be determined for all types of pesticide groupings (by type of pesticide, chemical group) identified in the pesticide sale statements produced by Ministère du Développement durable, de l'Environnement et des Parcs (Gorse 2005). The **PestRI-H/kg** is obtained by dividing the **PestRI-H** indicator by the total amount of active ingredient used or sold (Example 9, Appendix VII).

$$PestRI\text{-}H/kg = \frac{PestRI\text{-}H}{\text{Total amount (kg a.i.)}}$$

15 SYNTHESIS OF INDEXES AND INDICATORS

The following table summarizes the entire set of indexes and indicators presented in the previous sections.

Table 15: Definitions of the indices and indicators of the **QPRI**

Index and indicator	Definition	Application	Calculation
HRI **ERI**	Health risk index (HRI) or environment risk index (ERI) represented by the use of active ingredients on a hectare	Comparison of indexes in order to facilitate the choice of the least hazardous treatment for health and the environment	Health component (Section 1) and environment component (Section2)
HRI/SAD	Health risk index (HRI) or environment risk index (ERI) represented by the use of one kilogram of active ingredient	Use in the calculation of indicators to monitor risk	$\dfrac{(\text{HRI } \mathbf{or} \text{ ERI})}{\text{SAD}}$
PestRI-H **PestRI-E**	Health (-H) or environment (-E) risk monitoring indicator represented by the use of all active ingredients used or sold in one year	Quantification of total risk and monitoring of risk in one entity or on a given territory (company, group, province-wide)	$\sum (\text{HRI } \mathbf{or} \text{ ERI}) \times \text{treated surface}$ $\dfrac{\sum (\text{HRI } \mathbf{or} \text{ ERI}) \times \text{sales}}{\text{SAD}}$
PestRI-H/ha **PestRI-E**/ha	Health (-H) or environment (-E) risk monitoring indicator represented by the use of all active ingredients used or sold one year in relation to the area cultivated	Evolution of risk in an entity or in a given territory taking into account cultivated areas and comparison of risk between entities or territories of different cultivated areas	$\dfrac{\text{PestRI-H } \mathbf{or} \text{ PestRI-E}}{\text{Cultivated areas (ha)}}$
PestRI-H/kg **PestRI-E**/kg	Health (-H) or environment (-E) risk monitoring indicator represented by the use of all active ingredients used or sold one year in relation to the total amount used or sold	Evolution of risk in an entity or in a given area in relation to the total amount and comparison of risks between entities or areas using different amounts	$\dfrac{\text{PestRI-H } \mathbf{or} \text{ PestRI-E}}{\text{Total amount (kg a.i.)}}$

16 CONCLUSION

The QPRI developed by MAPAQ, MDDEP and INSPQ is divided into two components: QPRI-Health and QPRI-Environment. The indexes extracted from QPRI indicators will serve as a decision-making tool in order to choose pesticides representing the least risk to health and the environment.

Thanks to the QPRI, Québec now has a risk comparison tool for products presenting lower levels of risk. This innovative tool plays an important role in an integrated pest management effort to reduce pesticide risks. Thus, the QPRI allows us to diagnose health and environmental impacts by evaluating the evolution of risk of pesticide use at different scales. Finally, it is useful for monitoring the impact of mitigation measures over time according to pesticides used.

The toxicity parameters selected for the application of the risk indicator come from the toxicological database developed by Centre de Toxicologie du Québec. The most recent and comprehensive data were compiled from the following documentary sources:

- Decision-making documents: PMRA (evaluation documents), EPA (RED, IRED, TRED, Toxicology chapters, Human Health Risk Assessment)
- Recent monographs (WHO: ICPS INCHEM: JMPR Pesticide Residues in Food, EHC, ATSDR)
- European decision-making documents (Europa – European Union)

When these reference documents did not provide the required data, other specialized or general documents were consulted:

- Acute toxicity: WHO Classification (*The WHO Recommended Classification of Pesticides by Hazard*)
- Cancer: IARC and EPA Classification list, California EPA; European Commission Classification
- Reproduction and development: *Health Care Series* (Reprotox and Reprotext, *SHEPARD'S Catalog of Teratogenic Agents*), TERIS (*The Teratogen Information System*)
- General:
  – *Chemknowledge – Tomes Plus*
  – *Pesticide Manual*
  – *Extoxnet*
  – *Agritox*
  – *Farm Chemical Handbook*
  – Identification sheets

II Selected toxicity criteria

1 ACUTE SYSTEMIC TOXICITY

Many classification systems for acute systemic toxicity are proposed in the scientific literature. The criteria selected are those proposed in *The Globally Harmonized System of Classification and Labeling of Chemicals* (GHS) (ILO 2005).

Table II-1: Acute systemic toxicity criteria

Acute systemic toxicity	Severity of the effect			
	Severe to extreme toxicity	Moderate toxicity	Slight toxicity	Little or no toxicity
Oral LD_{50} (mg/kg)	≤ 50	$> 50\text{-}300$	$> 300\text{-}2000$	> 2000
Dermal LD_{50} (mg/kg)	≤ 200	$> 200\text{-}1000$	$> 1000\text{-}2000$	> 2000
Inhalation LC_{50} (mg/l)	≤ 0.5	$> 0.5\text{-}1$	$> 1\text{-}5$	> 5

2 DERMAL IRRITATION

The criteria selected for dermal irritation are those used by PMRA (Health Canada 2005) and the United States Environmental Protection Agency (U.S. EPA 2005).

Table II-2: Dermal irritation criteria

Level of dermal irritation	PMRA	EPA
	Mean for rashes/eschars and for edema for 24, 48 and 72 hour evaluations for all animals tested (Draize scale)	American classification from the *Federal Insecticide, Fungicide and Rodenticide Act* (FIFRA)
Severe or extreme irritant	$\geq 5.1\text{--}8.0$	Corrosive (destruction of tissues)
Moderate irritant	$\geq 3.1\text{--}5.0$	Severe irritation for 72 hours
Slight irritant	$\geq 1.6\text{--}3.0$	Moderate irritation for 72 hours
Little or no irritant	< 1.6	Weak to slight irritation for 72 hours

3 OCULAR DAMAGE AND IRRITATION

The criteria selected for ocular damage and irritation are those used by PMRA (Health Canada 2005) and the United States Environmental Protection Agency (U.S. EPA 2005).

Table II-3: Criteria for ocular damage and irritation

Level of ocular damage or irritation	ARLA — Maximum Draize point for effects on the cornea, iris and conjunctiva for each animal. Mean for evaluations at 24, 48 and 72 hours. The observation period for which the maximum value is generated is compared on the Draize or Kay and Calandra scale.	EPA — American classification from the *Federal Insecticide, Fungicide and Rodenticide Act* (FIFRA)
Severe or extreme irritant	≥ 50–110	Corrosive; corneal opacity irreversible after a 7 day period
Moderate irritant	≥ 25–49	Corneal opacity reversible after a 3 day period or severe irritation after a 7 day period
Slight irritant	≥ 15–24	No corneal opacity or reversible moderate irritation after a 7 day period
Little or no irritant	< 15	No irritation.

4 CANCEROGENICITY

The principal classification systems of the carcinogenic potential of pesticides are those of the International Agency for Research on Cancer (IARC 2004) and the United States Environmental Protection Agency (U.S. EPA 2004). As neither of them covers all active ingredients and as the classifications differ slightly and are complementary, both systems were used in order to include as many products possible. It is important to also note that the EPA has modified its classification system twice in 20 years and that considering the significant lag in product reevaluation, certain pesticides may still be classified based on a previous version. For this reason, all versions are considered.

Table II-4: Carcinogenic risk classification criteria

Carcinogenic risk level	1986 EPA classification	1996 EPA classification	1999 EPA classification	IARC classification
Human carcinogen	(A) Human carcinogen		Human carcinogen	Group 1. Human carcinogen
Probable human carcinogen	(B) Probable human carcinogen (B1, B2)	Probable human carcinogen	Probable human carcinogen	Group 2A. Probable human carcinogen
Possible human carcinogen	(C) Possible human carcinogen	Cannot be determined	Suggestive evidence of carcinogenicity, but not sufficient to assess human carcinogenic potential	Group 2B. Possible human carcinogen
Data inadequate for an assessment of human carcinogenic potential	(D) Not classifiable as to human carcinogenicity	Cannot be determined	Data inadequate for an assessment of human carcinogenic potential	Group 3. Not classifiable as to human carcinogenicity
Not likely to be carcinogenic to humans	(E) Evidence of non-carcinogenicity for humans	Not likely to be carcinogenic to humans	Not likely to be carcinogenic to humans	Group 4. Probably not carcinogenic to humans

5 GENOTOXICTY

There is no standardized classification system for pesticide genotoxicity. In fact, organizations that conduct assessments base their conclusions on the overall weight of evidence from experimental data. Thus, decision-making documents do not modulate risk on a quantifiable basis, as required by the use of the QPRI-Health. In order to be able to attribute a genotoxicity risk classification to each product, selection criteria based on the weight of evidence are developed.

Table II-5: Genotoxicity risk classification criteria

Level of genotoxic risk	Attribution criteria
Human genotoxicity	• Genotoxicity activity of a product is expressed by a health effect or a hereditary mutation. The relationship between the genotoxicity potential and the effect must be demonstrated clearly and without ambiguity by appropriate bioassays (e.g., micronucleus, sister chromatid exchange, DNA adducts, DNA un-programmed synthesis).
Potential human genotoxicity	• Certain *in vivo* tests conducted on an adequate methodological basis show clear and unambiguous genotoxic activity on mammal cells.
No or inadequate data	• All the studies needed to evaluate the genotoxicity of a product were not carried out or the experimental protocols used were not adequate.
No human genotoxicity	• A majority of experimental tests respecting methodological requirements for registration were negative. • The potential genotoxicity expressed in *in vitro* tests is not expressed in *in vivo* tests.

6 ENDOCRINE DISRUPTIONS

There is no standardized classification system for potential endocrine disruptions due to pesticides. In fact, organizations conducting assessments base their conclusions on the overall weight of evidence from experimental data and more rarely on clinical or epidemiological data. Thus, decision-making documents do not modulate risk on a quantifiable basis, as required by the use of the QPRI-Health. In order to be able to attribute an endocrine risk classification to each product, selection criteria based on the weight of evidence are developed.

Table II-6: Endocrine disruption risk classification criteria

Endocrine risk level	Criteria
Evidence of endocrine disruption	• Observation of histopathological changes in the structure of the endocrine glands in animal models as well as structural and functional changes in many animal species. • Functional deficiencies or structural changes tied to endocrine disruption that can be linked to the human endocrine system. • Human clinical or epidemiologic evidence.
Potential endocrine disruptor	• Endocrine disruption observed during experimental studies with animals and related to well-known endocrine effects.
No or inadequate data	• All the studies needed to evaluate the endocrine disruption potential of pesticides were not carried out or the experimental protocols used were not adequate.
No evidence of endocrine disruption	• No positive tests or conclusive experiments can be linked with well-known endocrine effects observed during experimental or epidemiological studies (e.g., embryonic development, postnatal development and growth, reproductive performance, morphology and function of the endocrine glands).

7 REPRODUCTION

There is no standardized classification system for the potential risk of pesticides on reproduction. In fact, assessment organizations base their conclusions on the overall weight of evidence from experimental data and more rarely on clinical or epidemiological data. Thus, decision-making documents do not modulate risk on a quantifiable basis, as required by the use of the QPRI-Health. When conclusions from reference documents are unclear, the selection criteria based on the weight of evidence are developed in order to be able to attribute to each product a risk classification on a quantifiable basis.

Table II-7: Reproductive risk classification criteria

Level of reproductive risk	Criteria
Effect on humans confirmed	• Effects on reproduction confirmed in humans (unknown no observed effect level). • Effects on reproduction confirmed in humans (known no observed effect level).
Effect on humans suspected	• Effects on reproduction suspected in humans but unconfirmed, as little clinical or epidemiological data exist.
Effect on animals confirmed	• Multiple effects on reproduction observed in animals, but absence of data on humans. • Effects on reproduction observed in more than one animal species but absence of data on humans.
Effect on animals suspected	• A few minor effects on reproduction observed in one animal species at a nontoxic dose for the parents, and absence of data on humans.
No or insufficient data	• Absence of data. • All studies necessary for the assessment of the risk potential for reproduction were not carried out or the experimental protocols used were not adequate.
No effect reported	• Products known as not affecting reproduction in animals and no data on humans. • Products known as not affecting human reproduction.

8 DEVELOPMENT

There is no standardized classification system for the potential risk of pesticides on development. In fact, organizations that conduct assessments base their conclusions on the overall weight of evidence from experimental data and more rarely on clinical or epidemiological data. Thus, decision-making documents do not modulate risk on a quantifiable basis, as required by the use of the QPRI-Health. In order to be able to attribute a risk classification for development to each product, selection criteria based on the weight of evidence are developed.

Table II-8: Critères d'appréciation des risques pour le développement

Level of developmental risk	Criteria
Effect on humans confirmed	• Effects on development confirmed in humans (dose without unknown effects). • Effects on development confirmed in humans (dose without known effects).
Effect on humans suspected	• Effects on development suspected in humans but unconfirmed, as little clinical or epidemiological data exist.
Effect on animals confirmed	• Multiple effects on development observed in animals, but absence of human data. • Effects on development observed in more than one animal species with absence of data on humans.
Effect on animals suspected	• A few minor effects on development observed in only one animal species and absence of data on humans.
No or insufficient data	• Absence of data. • All studies necessary for the assessment of the risk potential for development were not carried out or the experimental protocols used were not adequate.
No effect reported	• Products known as not affecting development in animals but no data on humans. • Products known as not affecting human development.

III Selection of physicochemical and ecotoxicological data on pesticides

The QPRI uses many active ingredient properties to calculate the environmental risk indicator. All physicochemical properties and toxicity indicators (non-target species) selected are part of the data necessary for the registration of pesticides by the PMRA and the EPA except for those that concern earthworms.

1 DATA SELECTION

Data was collected using four basic sources:

1. Decision and evaluation document of the Pest Management Regulatory Agency (PMRA) and the EPA[7] as well as unpublished data from the PMRA
2. **Tomlin, C.D.S.** *The e-Pesticide Manual*, 13th edition, The British Crop Protection Council, 2003, CD-ROM Version 3.0 2003–04
3. **EXTOXNET**, Extension Toxicology Network (Oregon State University) http://extoxnet.orst.edu/ghindex.html
4. **Gorse, I.** *et al.* *Répertoire des principaux pesticides utilisés au Québec*. Les Publications du Québec, 2002, 476 pages

For each active ingredient parameter, the first source was consulted. If it did not contain any data, the second source was then consulted and so on. When no data for a parameter was mentioned in any of these four sources, additional sources were consulted.

When no data at all existed anywhere, the mean data of the chemical group, as established by MDDEP (Grégoire 1998), was used.

2 PROCESS FOR THE INPUT OF PHYSICOCHEMICAL DATA ON PESTICIDES

Pesticides present in soil and water behave differently according to their physicochemical properties. For example, it is possible to evaluate the level of degradation in soil according to aerobic soil half-life (TD_{50} **soil**), water half-life (TD_{50} **water**), mobility in soil expressed by the adsorption coefficient K_{oc}, water solubility as well as bioaccumulation tendencies (P_{ow}) in living organisms.

Considering the often wide distribution of soil half-life and of water half-life, it appears excessive to retain the highest value. Consideration must also be given to the fact that soil half-life is directly used in the attribution of scores of persistence (**P**) and bioaccumulation (**B**), and, therefore, using the highest values will have exaggerated and unrealistic repercussions on the **ERI**. The method used for the selection of data is similar to that proposed by the SCI-GROW model of the U.S. EPA (U.S. EPA 2001).

■ Aerobic soil half-life – TD_{50} (days)

Soil half-life in aerobic conditions (TD_{50}) designates the time necessary for 50% of the initial concentration of an active ingredient to degrade. The half-life of an active ingredient is a property that varies considerably according to the conditions in which it is measured. In fact, type of soil, aerobic conditions, acidity and level of organic matter will influence the persistence of a product in soil.

It is not rare to find a source that presents more than one value for that property.

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[7] The EPA qualifies studies that were used to determine the values of the physicochemical properties and the values of toxicity indicators. Data from core studies that fulfill data requirements are selected over data from supplemental studies . Data from studies considered as unacceptable are not selected.

Choice of data

- If there are two values, the mean is selected.
- If there are three values, the intermediate value is selected.
- If there are four values, the mean of the two intermediate values is selected.

■ Aerobic water half-life – TD$_{50}$ (days)

Water half-life in aerobic conditions (TD$_{50}$) designates the time necessary for 50% of the initial concentration of an active ingredient to degrade in water.

Choice of data

- If there are two values, the mean is selected.
- If there are three values, the intermediate value is selected.
- If there are four values, the mean of the two intermediate values is selected.
- If no value is available, the soil half-life value in aerobic conditions times 2 is used.

■ Organic carbon adsorption coefficient – K$_{oc}$ (ml/g)

The organic carbon adsorption coefficient (K$_{oc}$) is an indicator of the adsorption potential of an active ingredient by soil particles. Contrary to soil half-life, the K$_{oc}$ is not used directly in the attribution of points to the **ERI**. In fact, the score for mobility (**M**) is determined using the **GUS** index. This data is thus selected according to a realistic worst case scenario using the smallest value published in a given source. The amount of data available for an active ingredient may vary according to experimental protocols on measuring the adsorption coefficient.

Choice of data

- If there is more than one value from one source, the smallest is selected.

■ Water solubility (mg/l or ppm)

Amount of substance dissolved per liter of water. In general, substances that are highly soluble are less likely to be adsorbed by particles in soil.

Choice of data

- The selected solubility data is generally a pH of 6–7 at a temperature of 20–25 °C.

■ Octanol-water partition coefficient – log P$_{ow}$

The octanol-water partition coefficient is measured at temperatures of 20–25 °C. It is usually expressed in terms of log P$_{ow}$. It represents the bioaccumulation potential of an active ingredient.

Choice of data

- The data on the octanol-water partition coefficient is generally a pH of 6–7.

Table III-1: Summary table – physicochemical parameters

Parameters of the active ingredients	Unit	Selection in each source
Soil half-life (**TD$_{50}$**) in aerobic conditions	Day	If 2 values: mean If 3 values: intermediate value If 4 values: mean of intermediate values
Water half-life (**TD$_{50}$**) in aerobic conditions	Day	If 2 values: mean If 3 values: intermediate value If 4 values: mean of intermediate values
Organic carbon adsorption coefficient (**K$_{oc}$**)	ml/g	Smallest value
Water solubility	mg/l	Data at a pH = 6–7 and temperature = 20–25 °C
Octanol-water partition coefficient (**log P$_{ow}$**)	–	Greatest value

3 PROCESS FOR THE INPUT OF ECOTOXICOLOGICAL DATA ON PESTICIDES

Data from toxicity indicators for non-target species is selected according to a realistic worst case scenario using the smallest value published in a given source.

■ Earthworms

The LC_{50} is expressed in mg/kg of soil.

Choice of data

• A 14 day exposure LC_{50} is selected.

■ Bees

The oral LD_{50} or contact LD_{50} for domestic bees is expressed as µg/bee.

Choice of data

• The lowest of the oral or contact toxicity values is selected.

■ Birds

The acute LD_{50} for birds is expressed in mg/kg of body weight.

Choice of data

• The mallard duck (*Anas platyhynchos*) is chosen as the main species. If no data is available for this species, the acute LD_{50} for the bobwhite quail (*Colinus virginianus*) is used.

■ Fish

The acute LC_{50} for fish is expressed in µg/l (ppb).

Choice of data

• The LC_{50} for rainbow trout (*Onchorynchus mykiss*) where time of exposure is 96 hours is selected. If no 96 hour LC_{50} value is mentioned in any of the four basic sources, another value may be selected while specifying source and time of exposure.

■ Aquatic invertebrates

The LC_{50} or EC_{50} of daphnia is expressed in µg/l (ppb).

Choice of data

• The LC_{50} or EC_{50} of daphnia (*Daphnia magna*) where time of exposure is 48 hours is selected.

■ Algae

The EC_{50} for algae is expressed in µg/l (ppb).

Choice of data

• The lowest EC_{50} between two algae species, *Scenedesmus subspicatus* and *Selenastrum capricornutum*, where time of exposure is generally 72 to 120 hours is selected.

■ Vascular plants

The EC_{50} for vascular plants is expressed in µg/l (ppb).

Choice of data

• The EC_{50} of the vascular plant *Lemna gibba* is selected.

Table III-2: Summary table – ecotoxicological parameters

Parameter of the active ingredients	Unit	Selection in each source
LC_{50} for earthworms	mg/kg of soil	14 day test
Oral or contact LD_{50} for bees	µg/bee	Lower, oral or contact
Acute LD_{50} for birds	mg/kg	If available: mallard duck; if not, bobwhite quail
Acute LC_{50} for fish	µg/l	Rainbow trout, 96 hours
LC_{50} or EC_{50} for daphnia	µg/l	*Daphnia magna*, 48 hours
EC_{50} for algae	µg/l	*Scenedesmus subspicatus* or *Selenastrum capricornutum* Variable exposure: 72, 96, 120 hours
EC_{50} for vascular plants	µg/l	*Lemna gibba*

IV Parameters linked to the calculation of the impact on birds (O)

Impact on birds is measured using acute toxicity expressed by the **LD$_{50}$** of the mallard duck, or if need be the bobwhite quail. The European guide for the evaluation of risks for birds and mammals (EC 2002) is used to define the parameters linked to these birds. The parameters for large herbivorous birds with a mean weight of 1 360 g are chosen to represent the mallard duck, and the same parameters for herbivorous birds with a mean weight of 170 g to represent the bobwhite quail.

The calculation for oral exposure considers the amount of pesticide ingested daily by the birds:

ETE	=	[**FIR / body weight**] $\times$ **C**
FIR	=	Food intake rate
Body weight	=	1 360 g for the mallard duck and 170 g for the bobwhite quail
C	=	Substance concentration in the diet (mg/kg)

According to the calculation tables in the European Guide (EC 2002), the food intake rate (**FIR**) for birds 1 360 g and 170 g are respectively 718.08 g and 147.05 g. The body weight/**FIR** ratios are thus 0.528 for the mallard duck and 0.865 for the bobwhite quail. The residue unit dose (**RUD**), used to calculate pesticide residues in the diet, is taken from Table 4 of the European guide (EC 2002). This dose is 142 g for large herbivorous birds of average size (bobwhite quail). In order to obtain the **C** variable, the **RUD** is multiplied by the amount applied on the hectare expressed as kg/ha. To do this, the standardized area dose (**SAD**) expressed as g/ha is divided by 1 000. The equations are the following:

Mallard duck

ETE = 0.528 $\times$ 142 $\times$ SAD / 1 000

Bobwhite quail

ETE = 0.865 $\times$ 87 $\times$ SAD / 1 000

The **ETE** value allows us to calculate the toxicity/exposure ratio (**TER**) and thus obtain an **O** score determined according to Table 9 in Section 2.

APPENDIX

V

Parameters linked to spray drift, surface runoff and runoff into drainage systems: Calculation of the A variable with "Step 2"

(From *FOCUS Surface Water Scenarios* […], 2002)

1 DRIFT

Contamination caused by drift occurs at the time of application. It is distributed daily between surface water and sediments according to the K_{oc} of the pesticide and the depth of sediments. The pesticide present in surface water is distributed into two theoretical components on the basis of availability of the product for adsorption in sediments, according to the following formula:

$$m_{avail} = m_{sw} \times K$$

$$m_{unavail} = m_{sw} \times (1 - K)$$

$$m_{sw} = \text{Total mass of pesticides in surface water (mg/m}^2\text{)}$$

$$m_{avail} = \text{Mass available for adsorption (mg/m}^2\text{)}$$

$$m_{unavail} = \text{Mass unavailable for adsorption (mg/m}^2\text{)}$$

$$K = \text{Distribution coefficient set at 2/3 for all pesticides}$$

This method assumes that the balance between concentration in water and sediments is reached 24 hours after application. Tables V-1 and V-2 indicate default values used to characterize the body of water in the calculation of the **PEC** and deviation values according to treatments (seeds treated and pesticides incorporated) and type of crop (ground level crops, bushes and fruit trees).

Table V-1: Default value for body of water

Parameter	Value
Depth of water (cm)	30
Depth of sediments (cm)	5
Effective depth of sediments (cm)	1
Organic carbon in sediments (%)	5
Sediment density (g/cm³)	0.8
Field ratio in relationship to body of water	10

Table V-2: Default parameters for spray drift used in the "Step 2" FOCUS model

Treatment or crop	Distance between crop and body of water (m)	Drift (% of application)
Seeds treated or pesticides incorporated	1	0
Ground level crop (≤ 50 cm)	1	2.8
Bush (> 50-200 cm)	3	8.0
Fruit tree (> 200 cm)	3	15.7

Adapted from FOCUS 2002 – Step 2: Input into surface water via spray drift

Examples: – Ground level crops: carrot, strawberry, wheat
– Bushes: raspberry, blueberry corymbs
– Fruit trees: apple, plum

2 SURFACE RUNOFF AND EVALUATION OF DRAINAGE WATER

Contamination caused by surface runoff and evacuation of drainage water is distributed between the aqueous phase and the sediments during runoff. Thus a pesticide with a weak K_{oc} is mainly dissolved in runoff water while a pesticide with a high K_{oc} is mainly adsorbed in soil particles. According to *Portrait agroenvironnemental des fermes du Québec* (BPR 1998), the maximum erosion potential varies according to region, from low to very high. A low level corresponds to a mean soil loss of 15 t/ha/year, while a very high level corresponds to losses of more than 60 t/ha/year. For Québec, the percentage of soil loss by runoff is fixed at 1.5%. The following table illustrates soil loss in t/ha/year and in percentage considering a soil density of 2 400 t/ha over 20 cm of depth.

Table V-3:   Soil loss according to level of risk

Level of risk	T/ha/year	%
Low	15	0.625
Very high	60	2.5
Value used in the QPRI-Environment		1.5

The interception factor of crops influences the amount of pesticide found in the soil. The interception values used are the same as those selected for the calculation of the T_{ew} variable (Table 6).

The **HRI** and **ERI** indexes as well as the **PestRI-H** and **PestRI-E** indicators are calculated based on application rates of active ingredients contained in end-use products and treated areas. Thus, at a province-wide level, areas are estimated based on a standardized area rate (**SAD**). This parameter is determined by order of importance of crops for which the end-use products are registered. The priority is established according to the following order:

1. Corn (excluding sweet corn) or soybeans
2. Potatoes, apples or strawberries
3. Other crops (carrots, blueberries, grass, etc.)

The **SAD** is the value that, when registered in a given culture, gives the highest **HRI** and **ERI** values according to the order of importance mentioned above.

Example:

Although Gramoxone^R (paraquat) is registered for many crops, the SAD used for the calculation of HRI, ERI and area is the highest level permitted for corn and soybeans. In fact, according to the process established previously, corn and soybeans are selected because of the significant cultivated areas and amounts of active ingredients that may be used for these crops compared to other registered potential crops.

The following diagram describes the decision-making process for selecting the **SAD** linked with one of the established reference crops.

Decision-making process diagram
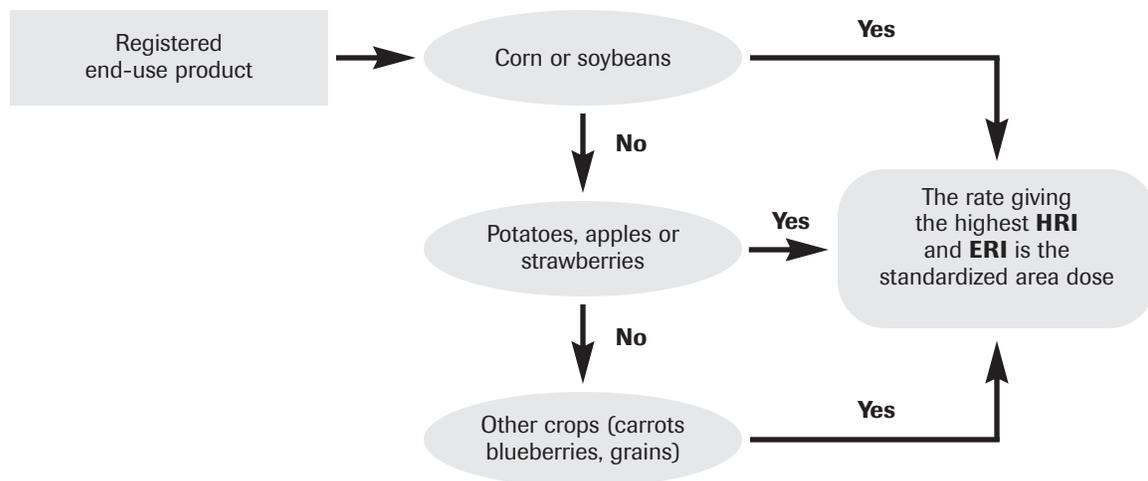
All calculations presented in Appendix VII were developed based on data corresponding to end-use product that are currently registered. However, as it was impossible to present examples for all products of the same nature in this document focusing on methodological approaches, the real names of end-use products have been replaced by fictitious names in order to avoid any discrimination with respect to products.

Attention: Certain HRI, ERI and PestRI calculations have been rounded.

1 EXAMPLE OF AN HRI AND ERI CALCULATION FOR AN END-USE PRODUCT

The pre-emergence EP-1 herbicide in **corn** is used as an example in the calculation of **HRI** and **ERI** for a end-use product. This herbicide contains two active ingredients and its maximum application rate is 4 500 g/ha.

The **HRI** for this use of EP-1 is equal to the summation of the weighted **HRI** of the ai-A and ai-B.

$$HRI_{EP-1} = HRI_{ai-A-w} + HRI_{ai-B-w}$$

Similarly, the **ERI** for this use of EP-1 is calculated by adding the weighted **ERI** of ai-A and ai-B.

$$ERI_{EP-1} = ERI_{ai-A-w} + ERI_{ai-B-w}$$

Table VII-1: HRI and ERI of weighted active ingredients as well as those of end-use product EP-1

Active ingredient/ end-use product	Rate (g or ml/ha)	HRI	ERI
ai-A / EP-1	1 210	270	182
ai-B / EP-1	697	24	16
EP-1	4 500	294	198

2 EXAMPLE OF A CALCULATION OF THE ADJUSTED HRI FOR AN END-USE PRODUCT (HRI$_{ADJUSTED}$)

In this example, the EP-1 herbicide is applied with a boom sprayer. According to Table 14 in Section 3, the adjustment factor (**WFa**) for this type of application is 1.5.

$$HRI_{adjusted\ EP-1} = HRI_{EP-1} \times WCF$$

$$HRI_{adjusted\ EP-1} = 441$$

3 EXAMPLE OF A CALCULATION OF THE HRI AND ERI FOR A PEST CONTROL TREATMENT

A pre-emergence herbicide treatment in corn using EP-1 + EP-2 is used as an example of a calculation of **HRI** and **ERI** for a pest control treatment (Table VII-2). The EP-1 herbicide is used with a maximum application rate of 4 500 g/ha and the EP-2 herbicide with a maximum application rate of 1 750 g/ha.

The **HRI** for this treatment is calculated by adding the **HRI** of EP-1 and EP-2.

$$HRI_{treatment} = HRI_{EP-1} + HRI_{EP-2}$$

Similarly, the **ERI** for this treatment is calculated by adding the **ERI** of EP-1 and EP-2.

$$ERI_{treatment} = ERI_{EP-1} + ERI_{EP-2}$$

Table VII-2: HRI and ERI for treatments including end-use products EP-1 and EP-2

End-use product	Rate (g or ml/ha)	HRI	ERI
EP-1	4 500	294	198
EP-2	1 750	188	64
Herbicide treatment		482	262

4 EXAMPLES OF COMPARISONS OF INDEXES IN ORDER TO FACILITATE CHOICE OF TREATMENT WITH A LOW RISK LEVEL FOR HEALTH AND THE ENVIRONMENT

Table VII-3: HRI and ERI for pre-emergence herbicide treatments in corn

#	Treatment (end-use products)	Treatment (active ingredients)	Rate (g or ml/ha)	HRI	ERI
1	EP-3 + EP-4	ai-C / ai-D + ai-F	216 + 3 500	310	92
2	EP-1 + EP-2	ai-A / ai-B + ai-E	4 500 + 1 750	482	262
3	EP-5 + EP-6	ai-A / ai-E + ai-G	4 000 + 4 500	1 304	413

Table VII-4: HRI and ERI for fungicidal treatments to eradicate apple scab

#	Treatment (end-use products)	Treatment (active ingredients)	Rate (g or ml/ha)	HRI	ERI
4	EP-7	ai-H	450	68	4
5	EP-8	ai-I	340	115	49
6	EP-9	ai-J	175	10	16

Table VII-5: HRI and ERI for insecticide treatments of Colorado beetle in potato

#	Treatment (end-use products)	Treatment (active ingredients)	Rate (g or ml/ha)	HRI	ERI
7	EP-10	ai-K	1 300	4	248
8	EP-11	ai-L	175	90	182
9	EP-12	ai-M	166	10	110

5 EXAMPLE OF A CALCULATION OF MONITORING INDICATORS PestRI-H AND PestRI-E WITH PESTICIDE USE DATA

Farm Business **A** (50 cultivated hectares) farmed corn on 20 hectares, apples on 10 hectares and potatoes on 20 hectares during years 1 and 2. This farm business is a member of the agro-environment Advisory Group **B** in which 340 hectares were cultivated during years 1 and 2 for all member farm businesses. These cultivated areas are divided as follows: 90 hectares of corn, 70 hectares of apples and 180 hectares of potatoes. Advisory Group **B** farm businesses chose a crop treatment from among 9 treatments presented in tables VII-3, VII-4 and VII-5.

Table VII-6 presents the treatments applied by Farm Business **A** and Advisory Group **B**. For example, for Year 1, Treatment 2 was applied on 20 hectares by Farm Business **A** and on 40 hectares in total in Advisory Group **B**. In the same year, Treatment 4 was applied on 10 hectares six times (x 6) by Farm Business **A**.

Table VII-6: Treatments by Farm Business **A** and Advisory Group **B** for years 1 and 2

	Year 1		Year 2	
	Treatment #	Area (ha)	Treatment #	Area (ha)
Farm Business **A**	2	20	1	20
	4 (× 6)	10	5	10
	7	20	9 (× 2)	20
Advisory Group **B**	1	50	1	90
	2	40	5	70
	4 (× 6)	10	8	100
	5	60	9 (× 2)	20
	7	80	9	60
	8	100		

The **PestRI-H** and **PestRI-E** indicators are calculated for Farm Business **A** and Advisory Group **B** for each year (Table VII-7). The **PestRI-H** and **PestRI-E** for each treatment are calculated simply by multiplying the risk indicator (**HRI** and **ERI**) of each treatment for the area treated.

For example, for Year 1, Treatment 2 (**HRI** = 482) was applied on 20 hectares by Farm Business **A**.

$$\textbf{PestRI-H}_{\text{Treatment 2}} = \textbf{HRI}_{\text{Treatment 2}} \times \textbf{area}_{\text{Treatment 2}} = \textbf{482} \times \textbf{20 ha} = \textbf{9 640}$$

Treatment 4 was applied 6 times during Year 1, giving a value of **PestRI-H**$_{\text{Treatment 4}}$ = 680. This value is then multiplied by six, once for every treatment.

$$\textbf{PestRI-H}_{\text{Treatment 4}} = \textbf{HRI}_{\text{Treatment 4}} \times \textbf{area}_{\text{Treatment 4}} = \textbf{(68} \times \textbf{10 ha)} \times \textbf{6} = \textbf{680} \times \textbf{6} = \textbf{4 080}$$

The **PestRI-H** and **PestRI-E** indicators for Farm Business **A** are obtained by adding all **PestRI-H** and **PestRI-E** of treatments applied during the year, which also includes Treatment 7.

For Year 1, **PestRI-H**$_{\text{Farm Business A}}$ = 13 800

For Year 2, refer to Table VII-7.

Table VII-7: PestRI-H and PestRI-E of Farm Business **A** and Advisory Group **B** for years 1 and 2

	Year 1		Year 2	
	PestRI-H	PestRI-E	PestRI-H	PestRI-E
Farm Business **A**	13 800	10 440	7 450	6 730
Advisory Group **B**	55 080	56 300	45 220	40 910

6 EXAMPLE OF THE CALCULATION OF MONITORING INDICATORS PestRI-H/HA AND PestRI-E/HA WITH DATA ON PESTICIDE USE

The **PestRI-H** and **PestRI-E** indicators can be divided according to total cultivated area by Farm Business **A** (50 ha) and Advisory Group **B** (340 ha). The results obtained are indicators allowing us to compare Farm Business **A** and Advisory Group **B** on the scale of one hectare. These indicators are called **PestRI-H** by hectare (**PestRI-H**/ha) and **PestRI-E** by hectare (**PestRI-E**/ha).

For Year 1:

$$\textbf{PestRI-H/ha}_{\text{Farm Business A}} = \textbf{PestRI-H}_{\text{Farm Business A}} / \textbf{cultivated area}_{\text{Farm Business A}} \textbf{ (ha)} = \textbf{13 800} / \textbf{50 ha} = \textbf{276}$$

Table VII-8: PestRI-H/ha and PestRI-E/ha for Farm Business A and Advisory Group B for years 1 and 2

	Year 1		Year 2	
	PestRI-H/ha	PestRI-E/ha	PestRI-H/ha	PestRI-E/ha
Farm Business **A**	276	209	149	135
Advisory Group **B**	162	166	133	120

Examples 7, 8 and 9 concern data on sales of pesticides. They use data from Table VII-11 for calculation purposes.

7 EXAMPLE OF THE CALCULATION OF MONITORING INDICATORS PestRI-H AND PestRI-E WITH DATA ON PESTICIDE SALE

The area treated with a pesticide is estimated by using sales and the SAD (in kg or l a.i./ha).

Area (ha) = sales (kg or l a.i.) / SAD (kg or l a.i./ha)
PestRI-H = Σ HRI $\times$ area
PestRI-H = Σ HRI $\times$ (sales / SAD) = Σ (sales / SAD) $\times$ sales

For Year 1: PestRI-H is calculated as follows:

PestRI-H$_{\text{Territory C}}$ = [(270 / 1.211) $\times$ 2421.0] + [(24 / 0.698) $\times$ 1395.0] + ...

The 14 entries in Table VII-11 for Territory **C** are added:

PestRI-H$_{\text{Territory C}}$ = 3 314 873

Table VII-9: PestRI-H and PestRI-E for Territory C for years 1 and 2

	Year 1		Year 2	
	PestRI-H	PestRI-E	PestRI-H	PestRI-E
Territory **C**	3 314 843	1 664 303	2 755 250	1 574 276

8 EXAMPLE OF THE CALCULATION OF MONITORING INDICATORS PestRI-H/HA AND PestRI-E/HA WITH PESTICIDE SALES DATA

The cultivated area in Territory **C** the first year is 15 000 ha and the second year 18 000 ha.

PestRI-H/ha = PestRI-H / cultivated area (ha)

For example, in Year 1: the PestRI-H/ha is calculated as follows:

PestRI-H/ha$_{\text{Territory C}}$ = PestRI-H$_{\text{Territory C}}$ / cultivated area$_{\text{Territory C}}$ (ha) = 3 314 873 / 15 000 ha = 221

Table VII-10: PestRI-H/ha and PestRI-E/ha for Territory C for years 1 and 2.

	Year 1		Year 2	
	PestRI-H/ha	PestRI-E/ha	PestRI-H/ha	PestRI-E/ha
Territory **C**	221	111	153	87

Table VII-11: Sales data on all pesticides sold in Territory **C**

The cultivated area is 15 000 hectares the first year and 18 000 hectares the second year.

End-use product	Active ingredient	a.i. content (%)	Reference crop according to Appendix VI	e.p. rate (kg or l/ha)	SAD (kg or l a.i./ha)	HRI	ERI	Sold Year 1 (kg or l a.i.)	Sold Year 2 (kg or l a.i.)
EP-1	ai-A	26.9	Corn	4.500	1.211	270	182	2 421.0	1 815.8
EP-1	ai-B	15.5	Corn	4.500	0.698	24	16	1 395.0	1 046.3
EP-3	ai-C	62.5	Corn	0.216	0.135	16	25	67.5	202.5
EP-3	ai-D	23.1	Corn	0.216	0.050	6	25	24.9	74.8
EP-4	ai-F	48.0	Corn	3.500	1.680	288	42	840.0	2 520.0
EP-5	ai-E	40.0	Corn	4.000	1.600	188	64	1 600.0	800.0
EP-5	ai-A	31.3	Corn	4.000	1.252	270	233	1 252.0	626.0
EP-6	ai-G	48.0	Corn	4.500	2.160	846	116	4 320.0	3 240.0
EP-8	ai-I	40.0	Apple	0.340	0.136	115	49	6.8	34.0
EP-9	ai-J	50.0	Apple	0.210	0.105	10	16	10.5	15.8
EP-10	ai-K	24.0	Potato	1.300	0.312	4	248	624.0	468.0
EP-11	ai-L	40.7	Corn	0.175	0.071	90	182	35.6	28.5
EP-12	ai-M	48.0	Apple	0.166	0.080	3	110	47.8	239.0
EP-13	ai-N	75.0	Apple	1.200	0.900	90	9	3 600.0	2 700.0
							Total	16 245	13 811

Type of crop for corn and potato: ground level crop
Type of crop for apple: fruit tree

9 EXAMPLE OF THE CALCULATION OF MONITORING INDICATORS PestRI-H/KG AND PestRI-E/KG WITH PESTICIDE SALES DATA

The amount of pesticides sold in Territory **C** the first year is 16 245 kg a.i. and the second year is 13 811 kg a.i.

PestRI-H/kg = PestRI-H / total sales (kg a.i.)

For Year 1: PestRI-H/kg is calculated as follows:

$$\text{PestRI-H/kg}_{\text{Territory C}} = \text{PestRI-H}_{\text{Territory C}} / \text{total sales}_{\text{Territory C}} \text{ (ha)} = 3\ 314\ 873 / 16\ 245 \text{ kg a.i.} = 204$$

Table VII-12: PestRI-H/kg and PestRI-E/kg for Territory **C** for years 1 and 2

	Year 1		Year 2	
	PestRI-H/kg	**PestRI-E/kg**	**PestRI-H/kg**	**PestRI-E/kg**
Territory **C**	204	102	199	114

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QPRI

The Québec Pesticide Risk Indicator, identified by the acronym QPRI, is a diagnostic and decision-making tool designed for the optimal management of pesticides. It has a health component (QPRI-Health) and an environment component (QPRI-Environment).

This tool was developed through a comparison of pesticide risk indicators found in scientific literature. The selection and definition of criteria for the indicator are the result of close collaboration among

- Ministère de l'Agriculture, des Pêcheries et de l'Alimentation (MAPAQ)

- Ministère du Développement durable, de l'Environnement et de Parcs (MDDEP)

- Institut national de santé publique du Québec (INSPQ).

The health and environment components of the QPRI enable us to establish a situational and progressive diagnostic of the risks of using pesticides at different levels, such as a company, a sector, a region or the entire Québec province.

The QPRI also contributes to the spatial and temporal monitoring of risks linked to pesticides. In efforts to ensure integrated pest management, the QPRI puts into perspective the risks associated with pesticides and promotes the identification of solutions to reduce these risks.

It is an innovative tool whose numerous applications will provide new information for an evermore responsible management of pesticides in Québec with a view to sustainable development.

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