

**SUMMARY REPORT OF THE OECD PROJECT ON PESTICIDE TERRESTRIAL RISK
INDICATORS (TERI)**

JUNE 2004

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FOREWORD

This report summarises the findings of the Terrestrial Risk Indicators (TERI) Project, carried out under the OECD Pesticides Programme. It is based on individual reports prepared by participants of an expert group (Belgium, Denmark, Germany, Italy, Norway, and Switzerland) on their results of testing the selected TERI indicators with national pesticide sales and use data. These country reports, along with other documents from the OECD Pesticide Risk Indicators projects are available from the OECD web-site: www.oecd.org/env/pesticides.

This report was prepared by Flemming Møhlenberg of DHI Water & Environment, Denmark, and financed by the Danish Environmental Protection Agency.

The OECD Working Group on Pesticides (WGP) generally agrees with the conclusions from the TERI project and approved this report. The WGP wishes to emphasise the following: 1) the conclusion that the indicators tested in the project were primarily driven by the quantity of pesticide use -- which was true for the pilot testing -- may not apply to pesticide risk indicators in general; and 2) the conclusion that tremendous efforts in collecting actual use data might be justified only if pesticide risks are to be measured on a sub-national scale and for indicators that take account of varying exposure risks within a country, may be valid in some cases (e.g. in countries where pesticide sales and use data are not highly variable at the national level) but may not apply to cases of countries with a wide variety of crops and pesticide use patterns.

BACKGROUND

The initiative to develop Pesticide Risk Indicators was taken at the OECD Workshop held in Copenhagen in April 1997. The purpose of the indicators was to be used by government authorities to measure risk trends.

The workshop emphasised that indicators would be used to complement - not duplicate - pesticide risk assessment and registration. The workshop agreed on a set of principles for development of pesticide risk indicators. They included:

- indicators should be scientifically robust and user friendly;
- indicators should link hazard and exposure data with pesticide use data; and
- indicators should address risks to human health and to different compartments of the environment separately rather than having a single indicator reflecting the overall risk of pesticide use.

At the Second OECD workshop on Pesticide Risk Indicators held in Braunschweig in June 1999, the pesticide Aquatic Risk Indicators (ARI) were evaluated and the importance of certain of the Copenhagen principles were stressed:

- indicators should be neither too simple nor too complex;
- the methodology used in the indicators should be clear and the data put into them should be available and reliable;
- the outputs of indicators should be easily understood by government officials and stakeholders; and
- all terminology should be explained clearly.

The Risk Reduction Steering Group (RRSG) formed an Expert Group (EG) that carried out the ARI Project from 1998 to 2001. In the first phase of the project, EG developed, tested and evaluated three indicators for tracking aggregate aquatic risk resulting from agricultural pesticide use. In the second phase of ARI, six OECD countries tested and evaluated the indicators developed by the EG as well as indicators developed in member countries.

The project examined several issues such as: the impact of data gaps on indicator results; the use of sales statistics as a basis for estimating pesticide use; the driving forces of pesticide risk indicators; simplicity vs. complexity in indicator design; and presenting indicator results. Two workshops were organised. The final results were presented in the ARI project summary report.

The ARI project also produced a user-friendly computer program to maintain the required pesticide data and run the three indicators, and an accompanying user guide. Once the data have been entered, the program makes it easy to produce graphs showing risk trends calculated by the three indicators. The programme and all the reports (both ARI and TERI) are available at password-protected RRSG web site. The ARI project demonstrated that both simple and more complex indicators showed the same general trends in risks when used at a highly aggregated level, because they were driven by the same variables, i.e. pesticide sale and toxicity. It was further found that the use of complex indicators that are relevant to calculate risks at lower level of aggregation are often hampered by availability of data, e.g. pesticide use at a regional level.

Building on the ARI Project and on a survey of terrestrial indicators carried out in 2001, the RRSG initiated the pesticide Terrestrial Risk Indicators (TERI) Project in 2002. At the First meeting of the TERI Project held in Frick, Switzerland in May 2002, four indicators were selected for further evaluation based on the following set of criteria, that indicator should:

- be feasible;
- take into account pesticide toxicity, exposure and area treated;
- provide meaningful information;
- be coherent with the context of pesticide registration;
- aggregate at the right level;
- track temporal trends;
- communicate well;
- be ecologically relevant;
- be suitable as a policy tool; and
- be currently in use.

Three of the indicators selected, the Dutch, the Norwegian and the Danish Load Index, met most of the criteria listed above. In addition, the Danish Frequency of Application indicator was also included in the evaluation, due to its ease to use.

CHARACTERISTICS AND PURPOSE OF THE TERI INDICATORS

The indicators included in the evaluation have been used for several different purposes. The **Danish Frequency of Application (FA)** and the **Norwegian Indicator (NI)** are used as indicators of the general environmental impact of pesticide use. FA has been applied as an operational tool to set reduction goals for pesticide use in Danish agriculture. FA was developed in the mid-1980s, as it was realised that the increasing use of low-dose products was not reflected in the Danish statistics on sold amount of active ingredients. Thus, a drop in sales of active ingredient can easily take place, while the number of applications - and pesticide load on the environment - increases.

In addition to monitoring environmental risks, the NI (that also includes elements of aquatic risk and leaching potential) is used for applying different tax rates to pesticides according to their risk potential to human health and the environment. The **Danish Load Index (DLI)** has been used to track changes in the intrinsic properties of pesticides on the market, resulting from registration/re-registration procedures. The **Dutch Indicator (DI)** has been used to evaluate the extent of reduction in environmental impacts due to the reduction in pesticide use by nearly 50% after the adoption of the “Multi-Year Crop Protection Plan”.

The indicators differ in complexity and especially in the amount of input data needed to calculate indicator values. For example, the Danish Indicators require little data while the Dutch and Norwegian indicators require much more input data (Table 1).

Table 1 **Data requirements of indicators**

Parameter	Danish FA	Danish LI	Dutch	Norwegian
Total usage/sale	(+)	+	+	
Sprayed area ¹	+			+
Dosage	(+)		+	+
Organic matter in soil (OM)			+	
PEC soil			+	+
Food intake of partridge			+	+
DT50				+
Plant cover				+
Log Kow				+
Toxicity earthworm		+	+	+
Toxicity bird dietary		(+)		+
Toxicity bird oral		+	+	+
Toxicity bee (contact)		+		+
¹ : Calculated as $Sprayed\ area = \frac{Total\ sale}{Dosage}$				

The **Frequency of Application** (FA) is the calculated average number of pesticide applications per year. The indicator considers the quantities of each active ingredient sold, the standard dose of each active ingredient in each crop/crop type, and the area of arable land:

$$FA = \sum_{all\ active\ ingredients} \left(\frac{SA_{active\ ingredient}}{SD_{croptype}} \right) \frac{1}{AGRA_{year}},$$

where;

SA denotes Sold Amount of individual active ingredients per year,

SD denotes a defined Standard Dose for each individual active ingredient in each crop/crop type, and

AGRA is the area of arable land.

FA is regarded as an indicator for the spraying intensity as well as an overall indicator of the environmental impact of pesticides. Because FA is based on a standard dose that relates to the biologically active field dose, it is assumed to reflect the direct effect on target organisms as well as the indirect impacts on ecosystems, which result from changes in the quantities and species found in the food chain.

The **Danish Load Index** (DLI) is the calculated number of toxic doses in the sold amount of pesticides. DLI calculates the ratio between *Total sale of different pesticides* and *Toxicity* that are summed for all active ingredients to follow if number of toxic doses has changed as a result of either changes in sales and/or toxicity:

$$DLI = \sum_{\text{all active ingredients}} \frac{\text{Sales}_{\text{each active ingredient}}}{TOX \cdot AGRA_{\text{year}}},$$

where TOX represents acute or long-term LC50 or LD50 values.

DLI is calculated separately for mammals, birds, earthworms, bees, (and fish, crustaceans, algae) using a value (average, min. or max.) for toxicity of individual pesticides. The calculated values are designated as "load indices for mammals", "load indices for fish", etc. DLI provides a relative measure of environmental load concerning specific type of toxicity. In line with most indicators, LI is not a measure of actual effects on populations or ecosystems in the field but calculates a relative risk that can be compared between years.

The **Dutch Indicator** (DI) encompass two separate indicators calculating the relative risks of pesticide use to earthworms and birds, where partridge is used as a model for bird exposure. The indicators are based on the quotient of the predicted environmental concentration (*PEC*), divided by the toxicity of the species and multiplied by the scaled area treated with pesticides:

$$DI = \sum_{\text{all active ingredients}} \frac{PEC_{ai1}}{TOX_{ai1}} \cdot \frac{AREA_{ai1}}{AREA_{tot}},$$

where;

PEC_{ai1} is the predicted environmental concentration of an active ingredient,

TOX_{ai1} represents acute or long-term LC50 of an active ingredient,

$AREA_{ai1}$ is the area treated with a particular active ingredient, and

$AREA_{tot}$ is the total arable area.

The predicted environmental concentration is basically calculated from sales and area treated, but modified according to properties of the soil (earthworm indicator only). The calculations of risks to earthworms rely on dose rates used on the fields that are treated and toxicity values corrected for differences in soil concentration of organic carbon. The daily intake of pesticides in partridge is calculated from the energy expenditure of a "standard-sized" bird. The calculated toxicity quotients are combined with the *relative area* treated with the different pesticides to arrive at a relative risk value for different pesticides that are subsequently summed for all the pesticides.

In contrast to the DLI and DI, the **Norwegian Indicator** (NI) is a compound indicator summing effects on earthworm, bird and bees, and taking account of persistence and bio-accumulation. In addition, while the DLI and DI calculate the "risk impact" monotonously by the ratio between predicted concentration and toxicity, the NI uses scores for each element (i.e. earthworm, bird, bees, persistence and bio-accumulation) which are added together, cubed and multiplied by the area treated:

$$NI = \sum_{\text{all active ingredients}} \left[\sum_{\text{scoring}} (\text{Earthworm, Bird, Bee, Persistence, Bioaccumu.})^3 \right] \cdot \text{Sprayed area}$$

Prior to scoring for earthworm, the concentration of active ingredients in soil (PEC_{soil}) is calculated from the application rate (corrected for interception by crop canopy), mixing depth (e.g. 5 cm) and the soil density. The Toxicity Exposure Ratio (TER) for earthworms is then calculated by dividing toxicity (14 days LC50) by the PEC_{soil} and scored into 3 classes. The breakpoints between scores are adapted from EU's Uniform Principles.

The scoring for bees in NI rely on hazard quotients for oral exposure or for contact exposure of bees calculated as the application rate ($g\ ha^{-1}$) of an active ingredient divided by the oral or contact toxicity

respectively (LD_{50} , $\mu\text{g bee}^{-1}$). Using a threshold value of 50 (EU's Uniform Principles), hazard quotients are scored (1-4) using logarithmic distributed breakpoints.

The scoring for birds in NI is based on TER's calculated from Predicted Initial Environmental Concentration ($PIEC = \text{Application rate (kg ha}^{-1}) \times 30$) and toxicity values (preferentially from diet studies, alternatively acute oral LD_{50} values may be used after correcting for daily intake). Using a threshold value of 10, calculated TER's are scored in 2 classes (2 & 4).

The scoring for persistence in NI is based on the half-life in soil (DT_{50}) and the application rate of pesticides. The scores varies from 0 ($DT_{50} < 10$ days) to 4 ($DT_{50} > 365$ days).

The scoring for bio-accumulation in NI relies on two properties of pesticides: log Kow and the persistence (DT_{50}) in soil that are linked by multiplication. The combined scores vary from 0 ($DT_{50} < 1$ day or log Kow < 3) to 4 ($DT_{50} > 200$ days and log Kow > 4).

PILOT TESTING OF THE TERI INDICATORS

At the Frick workshop, eight countries¹ agreed to participate in testing the selected TERI indicators using their national use data. The progress of pilot testing was discussed at two workshops held in Paris (January 2003) and in Bilthoven, Netherlands (September 2003). At a follow-up teleconference in December 2003, the TERI participants decided to conclude the project with preparing individual country reports on their final testing results by January 2004². These country reports along with the report from the teleconference constitute the background for this summary report.

The overall scope of the national pilot tests is summarised in Table 2. The data on pesticide use were, with one exception, calculated from pesticide sales. Because of stockpiling of pesticides in certain countries (e.g. in anticipation of bans or increased tax) year-to-year variation in risk estimates can be expected. To that end, two countries used a 2-3 year running average of sales. In testing the indicators, the Swiss participants estimated pesticide use from interviews (accounting for 3-5% of the arable area) and GIS-supported routines to estimate pesticide use in the areas considered. Among the participants, Switzerland was the only country that tested the indicators at a local scale (3 lake basins). The remaining participants tested the TERI indicators at the national level.

The number of pesticides included in the pilot tests ranged from 20 to 259, representing between 75%-100% of sales for agriculture use. Importantly, however, several participants note that the most hazardous pesticides (or herbicides) were included. Most participants did not include copper (Cu), sulphur, mineral or vegetative oils, and none included seed dressing, though it was felt that seed dressings probably would pose the greatest risk to birds. While actual indicator values will depend on the inclusion or exclusion of certain compounds, temporal trends will be much less sensitive, provided that the same criteria for pesticide inclusions are used throughout a time series. The time span covered by individual participants was primarily limited by the availability of reliable data on sales or use.

¹ Belgium, Denmark, Germany, Italy, Netherlands, Norway, Switzerland, USA.

² Country reports were made available from September 2003 to 1 March 2004.

Table 2. Overall scope of pilot tests carried out by participant countries

Country	Use data ¹	Number of pesticides ²	Time span	Geographical scope
Belgium	Sales (1)	259 (93-99%)	1982,1985,1988,1991-2002	National
Denmark	Sales (1-2)	110 (100%)	1992-2002	National
Germany	Sales (1)	20 herbicides	1987,1994,1998,2000	National
Italy	Sales (1)	244 (about 60%)	1992-1999	National
Netherlands	Sales (1)	156	1996-2001	National
Norway	Sales (3)	61 (76%)	1996-2002	National
Switzerland	Survey (1)	76-155 ³	1997-2001	3 lake basins

Notes:

1. Values in brackets denote the basis of calculations, i.e., 1 = actual years sale, 3 = running 3 year average.
2. Values in brackets denote the percentage covered of the total sale excluding seed treatment product
3. Depending on year and lake basin.

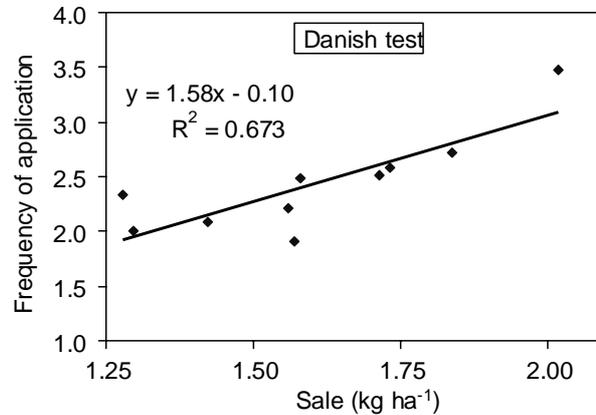
The six TERI participants (Belgium, Denmark, Netherlands, Italy, Norway and Switzerland) tested almost all the TERI indicators, which allows a comparison across indicators but within non-target species (i.e. earthworms, birds). Three participants (Belgium, Denmark and Norway) calculated indicators separately for herbicides, fungicides and insecticides, and three participants (Denmark, Italy, Norway) examined the relative importance of the different constituents of the NI. Finally, Denmark examined the robustness of indicators with variations in input data for toxicity and fate by combining data from the common data base to arrive at minimum or maximum impact.

In the following sections, the outcomes of the pilot testing are evaluated in quantitative terms by comparing the temporal variation of indicator values between years and their correlation to pesticide sales/use.

Correlation between pesticide sales and FA

The Danish and Norwegian data showed a highly significant correlation between pesticide sales (corrected for treated area) and FA (see Figure 1). This indicates that, on average, no major changes between low and high dose pesticides took place during the period 1992 - 2001. However, such correlation was verified only the Belgian sales data for fungicides. If major changes in pesticide use patterns occur, a simple linear relation between sales and FA would not be expected.

Figure 1. Correlation between pesticide sale (ha^{-1}) and FA: Data from the Danish test (1992-2001)

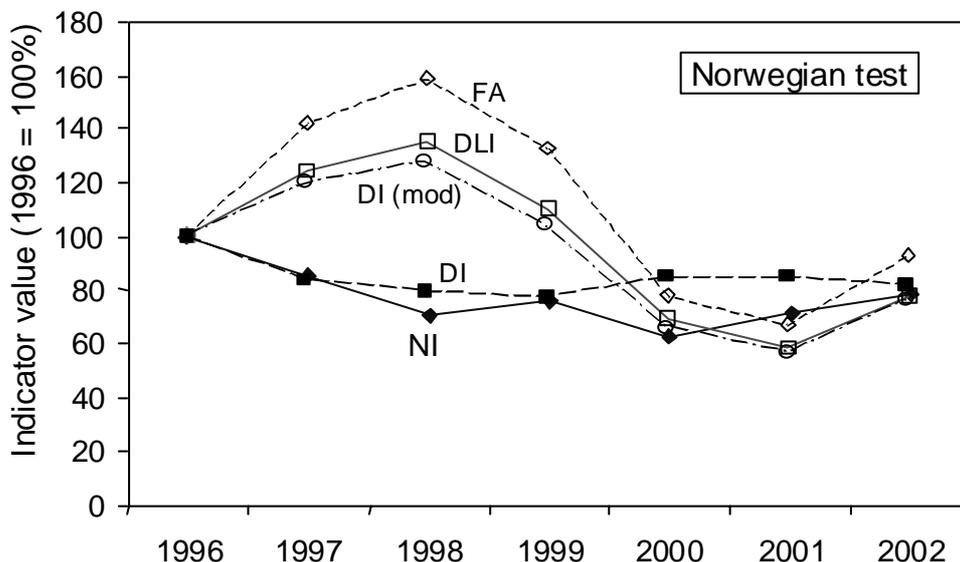


Correlation between the indicators for earthworms

Most tests on earthworm indicators showed a good agreement between FA (or Use) and DLI as demonstrated by the Norwegian test (Figure 2). In comparison, DI shows an opposite trend of the total area treated (= FA): the risk decreases when FA increases, and *vice versa*. In calculating the DI, the cumulative area treated with one compound is divided by the total area treated by all compounds (i.e. the indicator is scaled by fraction). This results in unreasonable risk variations if there are large year-to-year variations in sales data, such as in the Norwegian data. DI is strongly influenced by variations in high volume, but not necessarily high-risk pesticides. In reality, DI is an “unscaled” indicator, which calculates the average intensity of the pesticides used every year, not taking into account the total amounts used or sold. If “the area treated” is not divided by the “total area”, when calculating DI, the trends (DI mod) closely tracks DLI and FA (Figure 2).

The earthworm component of the combined NI showed minor variation during the period 1996-2002, but was overall unrelated to FA or DLI. The contribution of the earthworm component was negligible in NI (< 1%) (see below), which may explain uncoupling to FA.

Figure 2. Comparison of temporal variation in earthworm indicators and FA



Notes:

Two versions of Dutch Indicators shown, DI = “unscaled” and DI (mod) omitting the division with the “total area”. Data are normalised values in 1996. From the Norwegian test.

The results of all testing efforts on earthworm indicators are summarised in Table 2. The direction of change in indicator values (and pesticide use) between consecutive years is indicated by “ + ” (for increase), by “ — “ (for decrease) and by “ ± “ for insignificant changes. Notice that only the direction of change and not the change in value of the TERI indicators is shown. In the lower part of the table, the summed agreement for each national test (or area) between individual indicators (DLI, DI, NI) and either FA or pesticide use, and the agreement between DLI and DI are shown.

Overall, the other participants’ tests confirmed the results of the Norwegian test. Based on all observations between consecutive years (n = 36) the DLI was in agreement with FA (or Use) in 68% of the observations, while the corresponding agreement between DI and FA was 33%. The agreement between the direction of change of DLI and DI was 40%.

The correspondence between FA (use) and NI was in-between the DLI and DI at 50% (n = 22).

Table 3. Earthworm indicator agreement on temporal variation

Years	Danish test				Italian test				Norwegian test				Swiss test (Lac de Morat)			Swiss test (Greifensee)			Swiss test (Baldeggersee)			German test		
	FA	DL	DI	NI	Use	DL	DI	NI	FA	DL	DI	NI	Use	DL	DI	Use	DL	DI	Use	DL	DI	Use	DLI	DI
1992-93	-	-	-	+	+	+	±	+																
1993-94	-	-	+	+	±	-	-	-																
1994-95	+	+	-	+	+	+	+	+																
1995-96	-	-	-	-	-	-	-	-																
1996-97	+	+	+	+	+	±	-	-	+	+	-	-										+	+	-
1997-98	-	-	-	-	-	-	±	-	+	+	-	-	-	-	+	+	-	+	±	±	}			
1998-99	+	-	-	-	-	-	-	±	-	-	±	+	-	-	±	+	±	±	±	+	}			
1999-2000	-	+	+	+					-	-	+	-	±	-	-	-	+	+	+	+	}	-	±	-
2000-01	+	+	+	+					-	-	±	+	-	+	±	+	±	-	-	-	}			
2001-02									+	+	±	+												
Agreement with FA/Use		7/9	5/9	5/9		5/7	3/7	4/7		6/6	0/6	2/6		2/4	1/4		0/4	2/4		3/4	0/4		½	1/2
Agreement between DI/DLI		7/9				4/7				0/6				2/4		1/4				0/4			0/2	

Notes:

FA = Frequency of Application

Use = Pesticide sale or application rate

DLI = Danish Load Index

DI = Dutch Index (unscaled)

NI = Norwegian Index (isolated values for earthworms)

+ = increase

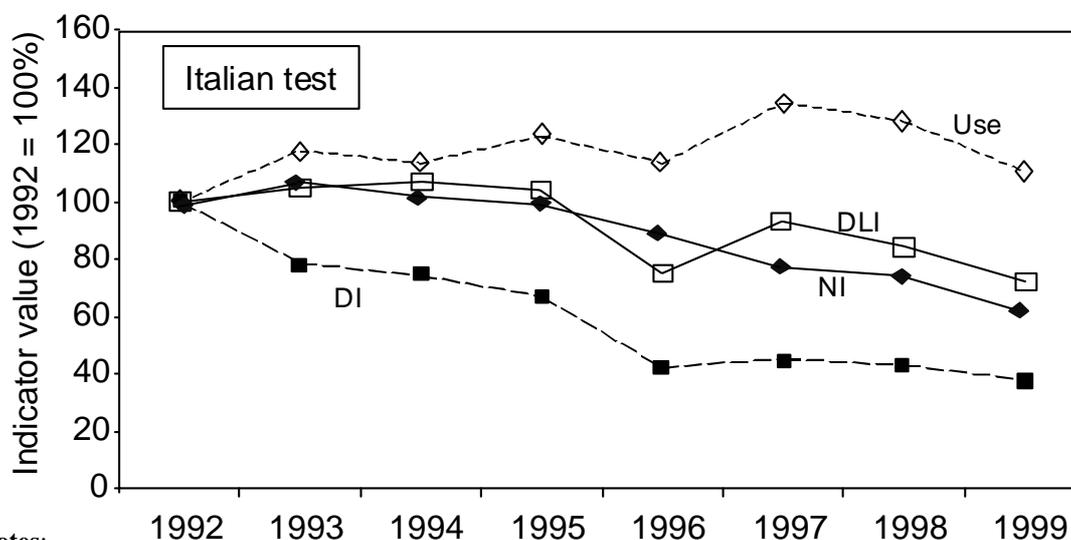
- = decrease

± = insignificant change

Correlation between the indicators for birds

As for the earthworm indicator tests, most tests on bird indicators showed a good agreement between FA (or Use) and DLI as shown by the Italian test (Figure 3). DLI did decrease during the period 1992-1999, while the use (kg on field) showed a small increase. Importantly, except for 1994 the development was parallel and DLI tracked most dips and increases during the period. The overall reduction in DLI was explained by substitution by less toxic compounds during the period. In comparison, both DI and NI steadily decreased during the period.

Figure 3. Comparison of temporal variation in bird indicators and Use (kg on field)



Notes:

Data are normalised values in 1992. From the Italian test

The results of all testing efforts on bird indicators are summarised in Table 4, using the same approach as in Table 3. Overall, the other participants' tests confirmed the results of the Italian test. Based on all observations between consecutive years (n = 41), the DLI was in agreement with FA (or Use) in 68% of the observations, while the corresponding agreement between DI and FA was 44%. The agreement between the direction of change of DLI and DI was low at 24%.

The correspondence between the bird part of NI and FA (use), and between NI (bird) and DLI was high at 81% (n = 22).

Table 4. Bird indicator agreement on temporal variation

Years	Danish test				Dutch test				Italian test				Norwegian test				Swiss test (Lac de Morat)			Swiss test (Greifensee)			Swiss test (Baldeggersee)			German test ¹		
	FA	DL	DI	NI	Use	DL	DI	NI	Use	DL	DI	NI	FA	DL	DI	NI	Use	DL	DI	Use	DL	DI	Use	DL	DI	Use	DLI	DI
1992-93	-	-	+	-					+	+	-	+																
1993-94	-	-	+	+					±	±	-	-																
1994-95	+	+	-	+					+	±	-	-																
1995-96	-	-	-	-					-	-	-	-																
1996-97	+	+	-	+	+	-	-	-	+	+	±	-	+	+	-	+										+	-	-
1997-98	-	-	+	-	+	-	-	-	-	-	±	-	+	+	-	+	-	-	+	+	-	±	±	±	-	-	-	-
1998-99	+	-	-	+	-	-	-	-	-	-	±	-	-	-	±	-	-	+	+	±	±	±	±	+	+	-	-	-
1999-2000	-	-	+	-	-	-	-	-					-	-	+	-	±	-	-	-	+	+	+	+	±			
2000-01	+	+	+	+	-	-	+	-					-	-	-	-	-	+	±	+	±	-	-	-	±			
2001-02													+	+	-	+												
Agreement with FA/Use	8/9	2/9	8/9	3/5	2/5	3/5	6/7	1/7	5/7	6/6	1/6	6/6	1/4	0/4	1/4	2/4	3/4	0/4	1/2	1/2								
Agreement between DI/DLI	3/9				4/5				4/7				0/6	2/4	2/4	1/4							2/2					

Notes:

1. Top 20 herbicides

FA = Frequency of Application

Use = Pesticide sale or application rate

DLI = Danish Load Index

DI = Dutch Index (unscaled)

NI = Norwegian Index (isolated values for birds)

+ = increase

- = decrease

± = insignificant change

Correlation between pesticide Use and the combined Norwegian Indicator

The Danish and Norwegian pilot test showed 100% match in trends between FA and NI, while tests by other participants were ambiguous (Table 5). In particular, the Swiss test on Greifensee showed heavy fluctuations in NI (100-300%), which was uncorrelated to pesticide Use (100-115%).

Table 5. Agreement between FA (Use) and combined Norwegian indicator on temporal variation

	Belgian		Danish		Italian		Norwegian		Swiss Lac de Morat		Swiss Greifensee		Swiss Baldeggersee	
	Use	NI	FA	NI	Use	NI	FA	NI	Use	NI	Use	NI	Use	NI
1991-92	+	-												
1992-93	-	-	-	-	+	+								
1993-94	-	-	-	-	±	-								
1994-95	+	+	+	+	+	±								
1995-96	±	+	-	-	-	-								
1996-97	-	-	+	+	+	+	+	+						
1997-98	+	+	-	-	-	-	+	+	-	±	+	-	±	+
1998-99	-	-	+	+	-	+	-	-	-	-	±	+	±	-
1999-2000	+	-	-	-			-	-	±	-	-	-	+	+
2000-01	-	±	+	+			-	-	-	+	+	-	-	+
2001-02	+	-					+	+						
Agreement between NI/FA(Use)	6/11		9/9		4/7		6/6		1/4		1/4		1/4	

Notes:

FA = Frequency of Application

Use = Pesticide sale or application rate

NI = Norwegian Index

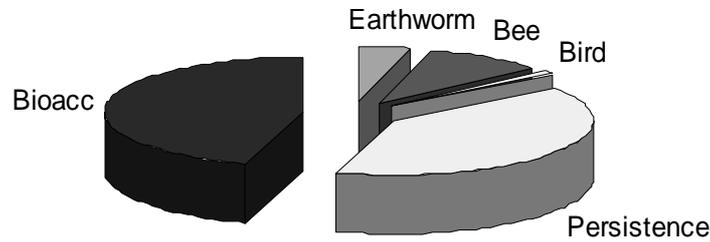
+ = increase

- = decrease

± = insignificant change

The Norwegian TERI Indicator was dominated by persistence and bioaccumulation as demonstrated in both the Norwegian and Danish tests (Figure 4). As explained in the Norwegian report, the relative importance of persistence and bio-accumulation is lower when aquatic risk and leaching potential are included. These elements that are additional constituents of the national Norwegian indicator were not taken into account when modifying the indicator to the TERI project.

Figure 4. **Relative importance of the different constituents of the combined Norwegian risk indicator**



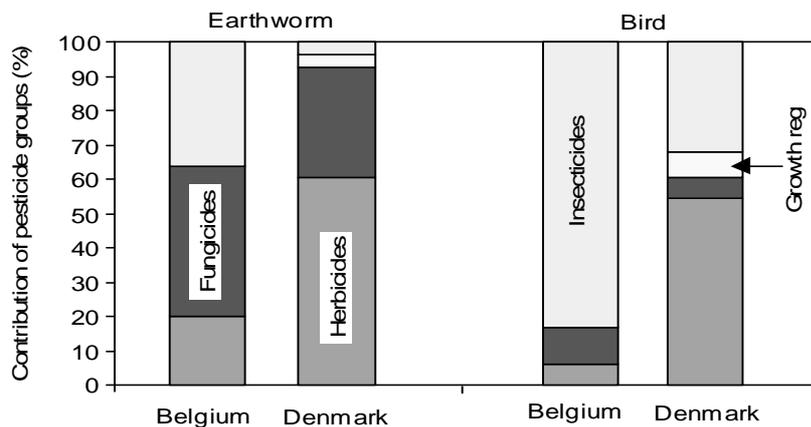
Notes:

Average for the period 1992-2001, from the Danish test

Pesticide types dominating the indicators

The types of pesticides dominating the indicators varied across participating countries, reflecting the composition of crops and thus the use of pesticides in terms of amounts and substances. In Norway and Denmark, high-volume low-toxicity herbicides with respect to earthworms and birds (applied on cereals) dominated the earthworm and bird indicators. In comparison, in countries where fruits, potatoes and vegetables play a larger role, insecticides were much more important for indicators (Figure 5). Several countries mentioned in their reports that several organophosphorus insecticides were banned during the period analysed. Given the high influence of insecticides, such changes in use patterns may be responsible for the “decoupling” of indicator values and the Use.

Figure 5. **Relative contribution of herbicides, insecticides, fungicides and growth regulators to the risk indicators for earthworm and birds**



Notes:

Average for the period 1991-2002 (Belgium) and 1992-2001 (Denmark)

Conclusion from Pilot Testing

When evaluating the outcomes of the Pilot Testing, it must be kept in mind that the indicators tested have been developed for different purposes. It should thus be remembered that indicators by their nature are crude tools that do not provide exact measures of real risks. Simple indicators requiring little data may be

adequate for policy purposes, e.g. tracking risk trends at the national level. Simple indicators are inherently easy to communicate and understand for non-specialists. On the other hand, if differentiation of risk trends between regions within a country is needed, it calls for indicators that take account of regional variations in pesticide use and exposure risks. As noted in the conclusions from the ARI project, the use of complex indicators can be hampered by lack of data.

All pilot tests except the Swiss tests were carried out at the national level and used pesticide sales as a substitute for pesticide use. Norway and Denmark used 2-3 year running averages of sales to level out the effect of stockpiling, and the Belgian participant noted that using a running 2-3 year average of sales probably would have led to an improvement. Used at the highly aggregated (national) level, most pilot tests showed that indicators were primarily driven by the quantity of pesticide use.

Instead of relying on sales data and analysis carried out at the national level, the Swiss participant estimated pesticide use in three lake regions based on interviews. However, judged from the analysis of trends, the Swiss tests showed the least coupling between pesticide use and the TERI indicators (Tables 3-5). It is unknown to what extent the uncoupling is influenced by a small sample size (i.e. 2.5-5% of arable area represented in the three lake areas).

Theoretically, an improved measurement of risk trends would use real use data instead of sales data. However, tremendous efforts of collecting actual use data seem to be justified only if pesticide risks to be measured are on a regional scale, and the indicators take account of varying exposure risks. Germany, the Netherlands, Norway and Switzerland are following this path. Otherwise, simple indicators based on sales data reflecting risks at the national level can be sufficient for most purposes. As shown in the Pilot Testing, simple indicators can be improved if running averages of sales are used.

In the following section, each TERI indicator is discussed with reference to a suite of important criteria such as the Pesticide Use, species addressed and interpretability. A summary of these TERI characteristics is provided in Table 6.

Table 6. Selected properties of the five TERI indicators: Danish Frequency of Application, Danish Load Index, the Dutch Indicator and the combined Norwegian Indicator

	Danish Frequency of Application (FA)	Danish Load Index (DLI)	Dutch indicator (DI, scaled by number of hectares)	Norwegian Indicator (NI)
Does the indicator reflect changes in volumes used	Yes	Yes	Partly	Yes
Does the indicator reflect changes in intrinsic properties?	Field toxicity to target organisms	Toxicity to non target organisms (and other properties possibly)	Toxicity to non target organisms (other properties possibly)	Toxicity to non target organisms, LogKow, DT ₅₀ combined
Does the indicator include exposure?	Consumption, area treated, field dosages	Consumption only	Consumption, area treated, crop cover	Consumption, area treated, crop cover
Species addressed by the indicator	Target species (higher plants, fungi, insects)	Non target species (birds, bees, earthworms)	Non target species (birds, bees, earthworms)	Non target species (birds, bees, earthworms)
Is the indicator related to the agro-ecosystem reflecting risk of direct and indirect effects? ecosystem level	Yes	Yes/No* Not in general, as it does not include higher plants and fungi. May to some extent reflect indirect effects due to loss of food if bee and/or earthworm toxicity reflects effects on broader insect/worms groups that constitute major food items in the agro-ecosystem	Yes/No* Not in general, as it does not include higher plants and fungi. May to some extent reflect indirect effects due to loss of food if bee and/or earthworm toxicity reflects effects on broader insect/worms groups that constitute major food items in the agro-ecosystem	Maybe
Is the indicator easy interpret	Yes in terms of pesticide main groups: Yes in terms of spraying intensity. Yes in terms of number of toxic doses with respect to target organisms. Yes in terms of connection between FA and indirect effects. No in terms of the combined FA	Yes in terms of number of toxic doses with respect to birds, bees and earthworms.	Interpretation of risk trend not possible on the national scale (unless changes in use are small). In a scaled version, DI is similar to DLI, if so: Yes in terms of number of toxic doses with respect to birds, bees and earthworms.	The combined indicator is difficult to interpret, the constituents easy in terms of Toxicity to earthworm, birds, bees and persistence and bio-accumulation. The setting of breakpoints for scores will influence the responsiveness to changes in pesticide use and should be adapted to each country's specific needs.
Notes: * Depends on the non target group (e.g. less food and reduction of shelter is considered to be an indication of indirect effects)				

The Danish indicator **Frequency of Application (FA)** is the simplest among the indicators tested, as it just sums the number of recommended dosages used per treated hectare. The “recommended dosage” expresses the dosage necessary to control the pest and is derived from field tests. The “tests” thus specify the target pests and related species, which the compound at the recommended dosage can control to a certain degree. The greatest direct ecological impact is likely to be associated with effects on non-target species belonging to the same or closely related taxonomic groups. Unlike other TERI indicators, FA does not relate to direct toxicity of the used pesticides to birds and earthworms. FA does however include toxicity towards insects, higher plants and fungi, which constitutes important elements in the agro-ecosystem. Independent tests have shown that FA also reflects indirect effects on an ecosystem level. In Denmark FA has proven to be

an efficient instrument for setting tangible national reduction goals that can be understood and implemented at the farm level, by breaking the national goals down to reduction goals for each main crop.

A major obstacle for a widespread use of FA, as noted in the Italian report, is that the use pattern for each active ingredient has to be known. Such information may be difficult to obtain especially in (larger) countries with a diverse distribution of crops. To that end, the Danish pilot testing included a simplified version of FA (FA_{light}) based on the use pattern of pesticides by calculating the FA for that crop only, which dominated the area use of each pesticide, and subsequently summing FA for all pesticides. The Danish testing demonstrated a strong coupling between FA and FA_{light}, however, as FA_{light} was not tested by other partners, the general applicability is unknown.

The **Danish Load Index (DLI)** calculates the number of toxic units used at the *national* level per year for a given test species (e.g. earthworms, bees, birds). Being a national level indicator, DLI does not include estimates of exposure risks as these are assumed to be constant through time. DLI reflects the potential toxicity to the test species of the total pesticide consumption based on sales figures. As such, DLI indicates the average toxicity of the sold compounds per year and not the proportion of compounds posing a high risk. Area treated is not considered in DLI but it can be included. DLI can be seen as an indicator of the *average* intrinsic properties of the active ingredients used/sold on the market. The ecological relevance of trends in indicator values has to be considered when interpreting the indicator.

The **Dutch TERI Indicator (DI)** is related to DLI as it calculates the number of toxic units. In contrast to DLI, DI includes an exposure calculation based on soil organic carbon (earthworm) and dietary uptake after spraying (bird). As such, DI can be applied at a regional (or even field) level if exposure characteristics differ among regions. Used at the national level, exposure risks can be regarded as constants through time and their inclusion in the risk calculation is thus superfluous. The major deviation from DLI is that DI calculates the contribution of each active ingredient as a fraction of total use measured as treatments per hectare divided by total number of treatments per hectare. The indicator thus reflects the *relative use* of a pesticide, and DI does not take account of the amount of pesticide used. Therefore, in case the spraying intensity changes it will not be reflected in the risk values. If the calculation of treated area as a fraction of total treated area is omitted in DI, the development and the indicator trend over time closely follows the DLI. In the Dutch test, DI and DLI were almost identical because of low variations in pesticide use in the Netherlands. In the Danish, Italian and Norwegian tests, DI deviated markedly from DLI because the use pattern changed during the period analysed.

The **Norwegian TERI Indicator (NI)** differs from the other indicators tested because it; 1) relies on scores, 2) includes persistence and bio-accumulation potential, and 3) combines the different elements including toxicity into one index value. The scoring implies that the index does not count reductions below the “no significant environmental impact limits”, assuming that the calibration of the scoring breakpoints is correct. As noted in the accompanying user manual for this indicator, the breakpoints can be changed according to specific needs. The Pilot Tests that “broke down” the NI into its constituents showed a total dominance of persistence and bio-accumulation, while the toxicity elements were of negligible importance. The Danish and Norwegian Pilot tests showed an overlap of active ingredients dominating the combined NI and the toxicity to bees (primarily pyrethroids), while herbicides were without importance. Therefore, NI does not reflect the risk from herbicide applications as important constituents of the agro-ecosystem. Again, breakpoints and weighting can be adapted to account for this. Overall, the combined indicator is not easy to interpret and understand due to the integration of several components and the relative weighting of the components.

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REFERENCES

National Reports for the TERI Pilot Project

Belgium: “Pesticide indicators for the Belgian data set” by Vincent Van Bol, Philippe Debongnie, Sara Claeys, Jean Marot, Walter Steurbaut, Henri Maraite, and Luc Pussemier

Denmark: “Summary of the report on Pesticide Terrestrial Risk Indicators - an examination of terrestrial indicators developed by Norway, Holland and Denmark based on Danish sales data from 1992-2001” by Flemming Møhlenberg, Niels Elmgaard, and Lene Gravesen.

Germany: “The German approach to the terrestrial risk indicators developed by the Netherlands, Norway and Denmark (IL)” by Volkmar Gutsche

Italy: “Terrestrial Environmental Risk Indicators tested in the Italian context” by Antonio Finizio and Alessandra Verin

Norway: “Terrestrial Environmental Risk Indicators tested with Norwegian pesticide sales data” by Erlend Spikkerud

Switzerland: “OECD terrestrial risk indicators for the use data from the three lake regions Baldeggersee, Greifensee, and Lac de Morat in Switzerland” by Andreas Fliessbach

“Thoughts about the differences between the indicators” by Robert Luttk

These reports are available at: www.oecd.org/env/pesticides.