OECD Survey of National Pesticide Risk Indicators, 1999-2000

COUNTRY, MINISTRY
United States U.S. Department of Agriculture and U.S. Environmental Protection Agency

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INDICATOR NAME
Pesticide Persistence Index (PERSIST), Pesticide Chronic Toxicity Units Index (CHRONIC-TU), Pesticide Acute Toxicity Units Index (ACUTE-TU), Pesticide Chronic Toxicity-Persistence Units Index (CHRONIC-TPU), Pesticide Acute Toxicity-Persistence Units Index (ACUTE-TPU)

WHEN AND WHY WAS THE INDICATOR DEVELOPED?
The indicators were developed as alternative measures of pesticide use to look theoretically at pesticide use trends and risks over time, and should not be construed as official USDA indicators. Traditionally, pesticide weight measured in kilograms per acre applied has been used in the U.S. as a measure of pesticide use. Rough assessments have been made of risk trends over time looking at pesticide use based on weight. But pesticide weight as a measure of pesticide use has drawbacks when used for evaluating the potential harm to human health and the environment (i.e., does not account for toxicity per unit of weight or persistence in the environment). Different conclusions may be reached when the toxicity and persistence are factored into an analysis. Alternative measures of pesticide use were developed as toxicity- and persistence-adjusted units to look theoretically at trends in use over the 1964-1992 period. The trends indicated by the toxicity- and persistence-adjusted units analyses were compared to trends indicated by measuring

use according to weight alone, and each was dramatically different from the other. It was a goal to provide a quantitative assessment of the change in risk over time.

HOW HAS THE INDICATOR BEEN USED?

The indicators have been used in research and analysis.

The indicators have not been incorporated into published Federal statistics or policy implementation, and should not be construed as official USDA indicators.

DESCRIPTION OF THE INDICATOR:

TYPES OF RISK

Human, Fate

ROUTES OF EXPOSURE

Not explicit.

VARIABLES INCLUDED

Pesticide Active Ingredient:

(i) Physicochemical and fate properties:

$DT50_{soil}$; first soil half-life.

(ii) Toxicity:

mammalian chronic NOEL (mg ai/kg body weight/day; this is the value that was used to calculate the Reference Dose)

Reference Dose: formerly known as the acceptable daily intake or ADI. The Reference Dose represents the maximum daily human exposure to that pesticide that results in no appreciable risk. The Reference Dose for each pesticide is determined from the no-observed-effect-level (NOEL) multiplied by a safety factor where NOEL is the maximum dose level (amount of pesticide/amount of body weight/day) at which no effects attributable to the pesticide under examination can be found.

mammalian acute oral LD50 (mg ai/kg body weight)

Pesticide use:
number of kilograms of pesticide active ingredients (ai) applied per year (kg); determined from use surveys (i.e., USDA collection of pesticide use data from farm operators)

Soil/site data:
Not used.

Fate:
Not used.

Other:
Not used.

METHODS OR FORMULAE FOR COMBINING VARIABLES:

I. PERSIST UNITS: are based on soil half-life, and are calculated as follows:

Pesticide Persistence Index; $PERSIST_i = [\sum_i(\chi_i \, a_{it})/\sum_i(\chi_i \, a_{i(base)})]$ (1)

where:
i = a pesticide active ingredient

χ_i = first soil half-life ($DT50_{soil}$, days) of one kilogram of pesticide active ingredient "i" (χ_i is the midpoint of the range of data found in scientific studies; data found at the following web site have been used: http://www.arsusda.gov/rsml/ppdb.html)

t = a period in time (in this case, year)

a_{it} = number of kilograms of pesticide active ingredient "i" applied in period "t"

$a_{i(base)}$ = number of kilograms of pesticide active ingredient "i" applied in the base period

II. TOXICITY UNITS (TUs): are based on indices of the toxicity of each individual pesticide active ingredient, and are calculated as follows:

Pesticide Chronic Toxicity Units Index; $CHRONIC\text{-}TUs = [\sum_i(\gamma_i \, a_{it})/\sum_i(\gamma_i \, a_{i(base)})]$ (2)

where:
γ_i = the number of Reference Doses contained in one kilogram of pesticide active ingredient "i". γ is the inverse of the Reference Dose. [i.e., 1/(NOEL x safety factor)]

The Reference Dose (formerly known as the "acceptable daily intake", ADI) represents the maximum daily human exposure (i.e., 70 kg man) to that pesticide active ingredient (over a 70 year lifespan) that results in no appreciable risk. The reference dose for each pesticide active ingredient is determined from the no-observed-effect-level (mammalian chronic NOEL) multiplied by a safety factor where NOEL is the maximum dose level (amount of pesticide active ingredient/amount of body weight/day) at which no effects attributable to the pesticide active ingredient under examination can be found.

The other terms are as previously defined.

Pesticide Acute Toxicity Units Index; ACUTE-TUs = $[\sum_i(\text{☎}_i \cdot \text{👎}_{it})/\sum_i(\text{☎}_i \cdot \text{👎}_{i(base)})]$ (3)

where:
☎_i = the number of acute doses contained of one kilogram of pesticide active ingredient "i". ☎ is the inverse of the oral LD50. [I.e., 1/(acute oral LD50)]

The acute dose is the mammalian oral LD50 (mg ai/kg body weight).

LD50 is used to measure the oral and dermal toxicity of a chemical and is expressed in terms of weight of the chemical per unit of body weight (e.g., mg/kg). It measures the amount of the toxicant necessary to kill 50% of the organisms being tested within a specified time period.

The other terms are as previously defined.

The summation is across all pesticide active ingredients for all indices (1-3).

III. TOXICITY-PERSISTENCE UNITS (TPUs): are based on further adjustment of the TUs to account for the combined toxicity and persistence of each individual active ingredient.

CHRONIC-TPUs = $[\sum_i(\text{✂}_i \cdot \text{🖋}_i \cdot \text{👎}_{it})/\sum_i(\text{✂}_i \cdot \text{🖋}_i \cdot \text{👎}_{i(base)})]$ (4)

ACUTE-TPUs = $[\sum_i(\text{✂}_i \cdot \text{☎}_i \cdot \text{👎}_{it})/\sum_i(\text{✂}_i \cdot \text{☎}_i \cdot \text{👎}_{i(base)})]$ (5)

The terms are as previously defined.

IV. SUMMARY OF INDICES:

These five separate measures of pesticide use are created for comparison to kilograms of active ingredients. PERSIST measures the persistence of pesticides in the environment. CHRONIC-TU and ACUTE-TU measure (labeled toxicity units or TUs) adjust kilograms applied for two alternative measures of pesticide toxicity, chronic (relevant to daily exposure over an extended period) and acute (one-time exposures), respectively. These toxicity measures are further adjusted to account for persistence of individual a.i.'s in the environment. This adjustment, based on the soil half-life of the a.i., creates two additional measures called toxicity-persistence units (TPUs). The terms CHRONIC-TPUs and ACUTE-TPUs are used to distinguish the TPU measures based on the reference dose from the one based on oral LD50.

The TU and TPU indices are simple measures related to the potential for exposure to chemicals with health effects. They do not reflect actual exposures. For example, these indicators do not consider how product formulation (e.g., liquid and granular forms and/or carrying agents) or application equipment have changed, nor do they consider the proximity of humans who could be exposed. Such considerations would affect exposure and risk measures associated with chemical applications.

V. COMPARISON TO KILOGRAMS OF ACTIVE INGREDIENTS:

Aggregate pesticide use (for selected crops) in the United States was compared for the years 1964, 1966, 1971, and circa 1992. Comprehensive pesticide-use data (kg) for active ingredients were only available for these years. Pesticide use is compared first on the basis of kilograms of active ingredient applied, then on the basis of the two variations in the TUs and TPUs measures. For an example of this, see the table below in the section addressing how the indicator results are presented.

- **TOXICITY**

Data are drawn from the US EPA when the a.i. is available; otherwise from the WHO when available; otherwise the geometric mean of the chemical family is used.

- **EXPOSURE VARIABLES**

Not combined.

- **TOXICITY AND EXPOSURE**

Exposure/toxicity ratio.

- **RISK AND USE**

Use x 1/toxicity; Use x Exposure.

AGGREGATION OF PESTICIDES AND CROPS

The indices were summed over pesticide active ingredients applied to selective crops, by year.

USE OF SCORING

No scoring was used.

TREATMENT OF MISSING DATA

Data were missing for toxicity and persistence. Assumptions and averaging were used to supplement the available information. The geometric mean for the chemical family of the a.i. was used.

HOW ARE THE RESULTS OF THE INDICATOR PRESENTED?

Results can be graphed or presented in tabular form.

Index (1964 = 100) of relative use of pesticide active ingredients for selected years, comparing kilograms with persistence, chronic toxicity, acute toxicity, and chronic and acute toxicity/persistence units.

Pesticide Type	Units	1964	1966	1971	1992

Herbicides	Kilograms	100	160	364	717
	PERSIST	100	198	493	1381
	CHRONIC-TUs	100	141	338	684
	ACUTE-TUs	100	136	246	321
	CHRONIC-TPUs	100	163	344	838
	ACUTE-TPUs	100	145	283	705
Insecticides	Kilograms	100	95	107	57
	PERSIST	100	94	68	18
	CHRONIC-TUs	100	126	104	43
	ACUTE-TUs	100	99	168	149
	CHRONIC-TPUs	100	125	75	5
	ACUTE-TPUs	100	382	115	111
Fungicides	Kilograms	100	98	139	159
	PERSIST	100	116	112	348
	CHRONIC-TUs	100	23	27	126
	ACUTE-TUs	100	361	377	509
	CHRONIC-TPUs	100	133	120	648
	ACUTE-TPUs	100	179	160	744
Other pesticides	Kilograms	100	85	112	404
	PERSIST	100	61	181	105
	CHRONIC-TUs	100	116	148	158
	ACUTE-TUs	100	95	142	327
	CHRONIC-TPUs	100	105	134	173
	ACUTE-TPUs	100	38	139	45
Total pesticides	Kilograms	100	109	171	264
	PERSIST	100	99	120	155
	CHRONIC-TUs	100	124	114	70
	ACUTE-TUs	100	100	168	155
	CHRONIC-TPUs	100	125	76	11
	ACUTE-TPUs	100	80	118	110

These estimates were based on the following crops: corn, soybeans, wheat, cotton, sorghum, rice, peanuts, potatoes, other vegetables and citrus. Comparisons can now be drawn between different years.

The specific pesticide data available for use in this analysis was collected by the USDA, from surveys of farm operators on a calendar year basis. Active ingredient use information was summarized by regions and the nation, and by crop.

Source: Agricultural Resources and Environmental Indicators, 1996-97. U.S. Department of Agriculture, Economic Research Service, Natural Resources and Environment Division. Agricultural Handbook No. 712. July 1997.

LESSONS LEARNED FROM WORKING WITH INDICATORS:
obstacles to overcome, successful approaches, benefits and limitations of indicators

This analysis was an attempt to think about the limits of using pesticide weight alone as an

indicator of pesticide use and effects on the environment over time. The study was limited by the availability of data on the chemicals evaluated (i.e., survey frequency and coverage was not ideal). Consistent data were not available across chemicals. There were gaps in the LD50, reference dose, and half-life data, thus assumptions and averaging were used to supplement the available information. Despite these limitations, the analysis demonstrated the problems in looking at chemical use in pounds versus measurements based on toxicity and persistence. It was also noted that there was uncertainty associated with point estimates of toxicity and persistence.

The TPU units are workable for analysis of historical trends at a national level, but are less than ideal. TPU units are superior to "weight" or "amount applied" of an active ingredient as an indicator of risk.

Additional work is planned in the future to update the analysis using a new database under development that will accumulate information on pesticide attributes including LD50s, RFDs and other information.

IMPORTANT REFERENCES:

Barnard, C., S. Daberkow, M. Padgitt, M.E. Smith, and N.D. Uri. 1997. Alternative measures of pesticide use. The Science of the Total Environment 203:229-244.