A hazard-ranking system for pesticides used in Greek agriculture based on their adverse health effects.

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Abstract—Pesticide exposure is a major health and safety issue among farmers across the world. In occupational toxicology and epidemiology, information on exact doses and exposure rates is necessary, in order to identify specific risks at the individual and/or community level. Using a hazard-ranking scheme that takes into account both pesticide use and the possibility of adverse health effects (e.g. cancer, reproductive toxicity and endocrine disruption) can prioritize agrochemicals based on "weighted" estimates of corresponding risks. Here, we have used this methodological approach to assign health hazards for pesticides used in Greek agriculture. Based on this analysis, i) Atrazine, ii) Alachlor, iii) 1,3 Dichloro-propene, iv) Chlorotanolil and v) Metoalachlor were the top five hazard-adjusted pesticides, as regards the carcinogenic risk; whereas as i) Atrazine, ii) Alachlor, iii) Glyphosate, iv) Mancozeb and v) Fenthion, the top five in the list of endocrine-disruption risks. These data can be used effectively as reference to future occupational/epidemiological studies that focus on adverse health outcomes in agricultural communities.

Keywords—hazard, ranking system, pesticide, Greek, agriculture, health, occupational exposure.

Introduction

Pesticides are used extensively in modern agriculture, as a means to controlling parasites and maximizing crop yields. Global marketing of agrochemicals escalated in the second half of the 20th century, growing into a multi-billion dollar enterprise. Some 2.6 million tons of pesticides are applied annually, with the majority being used in developing countries [1]. Yet, despite the obvious economical benefits, pesticides pose a significant risk to both farmers and agricultural communities around the world.

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One major obstacle in conducting pesticide exposure research is the extensive variety of plant protection products that are being used, which results in the need of extensive sampling and analyses costs [7]. Many scholars have tried to resolve this issue, by using crude amounts of pesticides applied in a region, but this approach introduces significant biases [8]. Namely, the effect of less potent pesticides could be exaggerated, whereas the impact of some highly toxic pesticides could be missed.

Consequently, listing pesticides based on quantities alone is far from being an efficient method for estimating true exposure risks. On the other hand, a hazard-ranking scheme that takes into account both pesticide use and exposure could essentially provide more accurate estimates. The present study uses this approach to prioritize pesticide health hazards in Greek agriculture for a 12-year period (1992-2003). The top-ranking pesticides for i) carcinogenic risk and ii) endocrine-disrupting potential are presented and specific recommendations concerning the safe use of these products are provided.

Methods

Data on pesticides used in Greek agriculture were collected from official resources provided by Eurostat [9]. The dataset contains detailed information on the active ingredients used, the quantities applied, and the types of crops treated. IARC and EU-classification schemes were used to attribute a "class" from 1 to 10 to all pesticides with respect to carcinogenic potential [10, 11]. Cancer slope factors (mg kg-1 day-1) were retrieved from the Integrated Risk Information System (IRIS), and they were used to assign a cancer "potency" weight [12]. The volatilization "flux" (day-1) for each pesticide was calculated using the vapor pressure, water solubility, and soil absorption coefficient, as previously described [13]. Field dissipation half-life (t1/2 days) was employed to assign a "persistence" weight [14].

Table 1 Parameters used in the calculation of carcinogenic hazard

	CLASS	POTENCY	FLUX	PERSISTENCE	
WEIGHT	IARC	EU	mg kg-1 day-1	Volatilization day-1	t1/2 days
10	1	Carc. 1A	>1	>10-1	>100
8	2A	Carc. 1B	>0.1-1	>10-3-10-1	76-100
5	2B	Carc. 2	>0.01-0.1	>10-5-10-3	51-75
3	3	Carc. 3	0.001-0.01	10-5-10-7	25-50
1	4	N/A	<0.001 or N/A	<10-7	<25 or N/A

NA=Not available

Cancer risk was calculated using the information in Table 1, according to the equation (1):

Cancer Hazard Factor = (Class × Potency × Flux × Persistence)/1000   (1)

The hazard-adjusted pesticide use was then computed by multiplying the cancer hazard factor by the average amount of pesticides applied over the 12-year period, according to the equation (2):

Hazard-Adjusted Pesticide Use = Cancer Hazard Factor × Amount Used (tons)   (2)

EU-classification of endocrine-disrupting chemicals was used to attribute a "class" from 1 to 10 to all pesticides [15]. Reference Doses (RfDs) were retrieved from the Integrated Risk Information System (IRIS), in order to assign a "potency" weight [16]. Volatilization "flux" (day-1) and "persistence" (t1/2 days) for each pesticide were the same as described above.

Table 2 Parameters used in the calculation of endocrine disrupting hazard

	CLASS	POTENCY	FLUX	PERSISTENCE
WEIGHT	EU	mg kg-1 day-1	Volatilization day-1	t1/2 days
10	1	<0.001	>10-1	>100
8	2	0.001-0.01	>10-3-10-1	76-100
5	3a	>0.01-0.1	>10-5-10-3	51-75
3	3b	>0.1-1	10-5-10-7	25-50
1	N/A	>1	<10-7	<25 or N/A

NA=Not available

The endocrine disruption hazard was calculated using the information in Table 2, according to the equation (3):

Hazard Factor = (Class × Potency × Flux × Persistence)/1000   (3)

The hazard-adjusted pesticide use was then computed by multiplying the hazard factor by the average amount of pesticides applied over the 12-year period, using the equation (4):

Hazard-Adjusted Pesticide Use = Hazard Factor × Amount Used (tons)   (4)

In Table 3, the top-listing pesticides used in Greek agriculture (1992-2003) are shown. Glyphosate ranks first

(217.3 tons), followed by Fenthion (144 tons), Mancozeb (134.7 tons), 1,3 Dichloro-propene (101.8 tons) and Atrazine (89.6 tons).

Table 3 Top-listing pesticides based on absolute amounts used.

	PESTICIDE	AMOUNT (tons)
1	GLYPHOSATE	217.33
2	FENTHION	144.00
3	MANCOZEB	134.67
4	1,3 DICHLORO-PROPENE	101.75
5	ATRAZINE	89.58
6	PROPINEB	84.25
7	METOALACHLOR	77.50
8	MECOPROP	73.67
9	ALACHLOR	63.09
10	METAMITRON	34.17
11	FOSETYL	32.33
12	CHLORPYRIFOS	27.75
13	PARATHION METHYL	21.58
14	CHLOROTANOLIL	18.38
15	2,4-D	17.75

The ranking system differed substantially, when pesticide use was adjusted for carcinogenic potential. The top five pesticides by cancer hazard are presented in Table 4. Namely, Atrazine and Alachlor were 5th and 9th in the overall ranking for total amounts used, but ranked 1st and 2nd respectively, when cancer hazard-adjusted use was considered.

Table 4 Hazard-adjusted use of pesticides based on their carcinogenic potential

	PESTICIDE	AMOUNT USED	HAZARD FACTOR
1	ATRAZINE	89.6	3.2
2	ALACHLOR	63.1	0.6
3	1,3 DICHLORO-PROPENE	101.8	0.25
4	CHLOROTANOLIL	18.4	0.36
5	METOALACHLOR	77.5	0.08

Similarly, the top five pesticides for endocrine-disrupting potential were Atrazine and Alachlor followed by Glyphosate, Mancozeb and Fenthion (Table 5).

Table 5 Hazard-adjusted use of pesticides based on endocrine disrupting potential

	PESTICIDE	AMOUNT USED	HAZARD FACTOR
1	ATRAZINE	89.6	4.0
2	ALACHLOR	63.1	1.92
3	GLYPHOSATE	217.3*	0.225
4	MANCOZEB	134.7	0.27
5	FENTHION	144*	0.192

Estimated Amounts

Discussion

Based on this ranking system, the most dangerous pesticides, as regards cancer risk and endocrine disruption were identified. Neither the hazard factor alone (potency-weighted) nor the absolute amount used (quantity-weighted) could explain the calculated risk listing. The cancer hazard factors ranged from 0.08 (Metoalachlor) to 3.2 (Atrazine), and the hazard factor for endocrine disruption from 0.192 (Fenthion) to 4.0 (Atrazine). Based on this classification, Alachlor ranks second in hazard-adjusted use for both cancer and endocrine disruption, yet it is 9th in the list of absolute quantities used. On the other hand, Glyphosate is not as hazardous as Mancozeb based on endocrine-disrupting potential; however its widespread use (top of the list, 217.3 tons) places it higher in the hazard-adjusted scale for endocrine disruption.

The 'weight-adjustment" system presented here provides unprecedented information on pesticide use and exposure risks to agricultural professionals and rural communities. As this study shows, commonly used pesticides that are generally considered benign in comparison to organochlorines and organophosphates, such as Glyphozate and Mancozeb, carry a significant burden. Glyphosate and Mancozeb with "known" or "suspected" endocrine-disrupting potential are still widely used in Greek and European agriculture, and the same holds true for Chrolorotanolil and cancer risk. On the contrary, Atrazine, Alachlor and Fenthion are now banned by EU legislation.

Conclusively, the hazard-weighted pesticide use has created different priorities for occupation and environmental health. Prioritizing pesticides using this approach may provide better estimates on potential exposures. Moreover, the likelihood of adverse health effects is better sustained and points specifically to labels that pose the greatest risk.

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