A Method for Evaluating the Suitability of Pesticides in an Integrated Pest Management Program

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To reduce the potential risks posed by pesticides used in operations, the City of Seattle is implementing a comprehensive pesticide reduction strategy. The strategy calls for eliminating the most hazardous products and reducing overall pesticide use. This paper describes health and environmental criteria that were used by the city to evaluate pesticide products. These criteria included acute toxicity; presence of carcinogens, reproductive or developmental toxicants, or endocrine disruptors; persistence and mobility in soil; and hazards to off-target species. A checklist system was developed to place pesticides into three tiers according to potential hazards. Pesticides (except fungicides) that fall into Tier 1 cannot be used unless an exception request is granted. Results of the pesticide screening process are presented, including tier assignments by pesticide group and active ingredient, and a breakdown of which criteria were triggered most frequently. Excluding golf courses, pesticide use by the city declined by 36% the year after the policy went into effect. Including golf courses, the decline was 26%.

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The City of Seattle manages over 110,000 acres of public land, of which 12,000 acres are highly developed and managed grounds that include greenhouses, specialty gardens, roadsides and medians, golf courses, playfields, and hundreds of miles of electrical transmission rights-of-way. To reduce the potential risks posed by pesticides used in operations, the city is implementing a comprehensive pesticide reduction strategy, developed in 1999.[1] This strategy is an outgrowth of the Seattle Environmental Management Program, which was adopted to promote environmental stewardship in city operations. The Chemical Use Policy contained in the Environmental Management Program establishes a framework for evaluating hazardous materials used by the city and prioritizing products for phase-out and replacement with less hazardous alternatives.[2]

Seattle contracted with the Washington Toxics Coalition to assist the city in translating the general criteria contained in the Chemical Use Policy into pesticide-specific criteria. These criteria were then applied to the pesticides used by the city in order to prioritize products for phase-out. Products were categorized into three tiers, ranging from greatest potential hazard (Tier 1) to least potential hazard (Tier 3). New products considered for use undergo the same analysis, and product tier designations will be reevaluated as additional information becomes available. This information is used to inform product choices when a chemical pesticide is determined necessary through the city's Integrated Pest Management (IPM) Program. This paper describes the methodology chosen to evaluate the pesticide products, the results of the evaluation, and resulting changes in pest management procedures.

Methods

The method used to identify the most potentially hazardous pesticides is a hazard assessment, rather than a risk assessment. Hazard identification is the first step in a risk assessment but does not include product use rates and predicted quantitative human or environmental exposures. Given the large number of products to be evaluated (more than 200), the lack of information on "inert" ingredients in most products, and the screening nature of this review, a hazard assessment was considered to be a precautionary approach. Product and active ingredient characteristics were catalogued and screened against checklist criteria. Table 1 shows the product and ingredient characteristics that were considered, and the sources of information used.

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Table 1. Product and ingredient characteristics and information sources

Characteristic	Source
Restricted-use pesticide	Determined from product label
USEPA hazard category (I-IV)	Determined from product label
Acutely hazardous waste	Washington State list of hazardous wastes[a]
Dioxin-containing pesticide*	Determined from product label listing of ingredients shown in table note*
Persistent bioaccumulative toxic (PBT)	USEPA PBT Strategy, Washington Department of Ecology Draft PBT Strategy[b]
Carcinogen	USEPA, National Toxicology Program, International Agency for Research on Cancer, State of California[c]
Reproductive/developmental toxicant	State of California[d]
Endocrine disruptor	State of Illinois EPA[e]
Soil persistence	Oregon State University Extension Pesticide Properties Database[f]
Soil mobility	Groundwater Ubiquity Score[f]
Hazard to birds	Determined from product label
Hazard to aquatic species	Determined from product label
Hazard to bees	Determined from product label

*Product contains tri-, tetra-, or pentachlorophenols or their chlorophenoxy derivate acids, esters, ethers, amine or other salts. These are considered indicators of contamination by polychlorinated dibenzo-p-dioxins or polychlorinated dibenzofurans, as specified in USEPA RCRA waste category F027 (US Code of Federal Regulations, 1999, *Identification and Listing of Hazardous Waste,* 40 CFR Part 261.31).

[a] State of Washington, 1998, *Dangerous Waste Regulations: Discarded Chemical Products List, "P" Chemical Products,* WAC 173–303–9903, Olympia, WA.

[b] USEPA, Office of Pollution Prevention and Toxics, Persistent/Bioaccumulative, and Toxic (PBT) Chemical Program, 1999, *Priority PBTs,* http://www.epa.gov/opptintr/pbt/cheminfo.htm; Washington State Department of Ecology, 1999, *Questions & Answers on the Ecology Initiative on Persistent, Bioaccumulative, and Toxic Chemicals (PBTs),* http://www.state.wa.us/ecology/eils/bcc/bccfaq.html.

[c] USEPA, Office of Pesticide Programs, 1999, *List of Chemicals Evaluated for Carcinogenic Potential,* Washington, DC, 40 pp; National Toxicology Program/Report On Carcinogens, 1999, *National Toxicology Program Report On Carcinogens,* 8th edition, http://ntp-server.niehs.nih.gov/NewHomeRoc/CurrentLists.html; International Agency for Research on Cancer/IARC Monographs Programme on the Evaluation of Carcinogenic Risks to Humans, 1999, *Complete List of Agents, Mixtures and Exposures Evaluated and their Classification,* http://www.iarc.fr/; State of California, Office of Environmental Health Hazard Assessment/List of Proposition 65 Chemicals, 1999, *Chemicals Known to the State to Cause Cancer,* http://www.oehha.org/prop65/prop65_list/62201LSTB.htm.

[d] State of California, Office of Environmental Health Hazard Assessment/List of Proposition 65 Chemicals, 1999, *Chemicals Known to the State to Cause Reproductive Toxicity,* http://www.oehha.org/prop65/prop65_list/62201LSTB.htm.

[e] Illinois EPA, 1997, *Endocrine Disruptors Strategy,* Springfield, IL, 30 pp.

[f] P. A. Vogue, E. A. Kerle, and J. J. Jenkins, 1994, *Oregon State University Extension Pesticide Properties Database,* Oregon State University Extension Service, Corvallis, 18 pp.

Restricted-use pesticides are those whose use is allowed only by professional pesticide applicators. Their restricted status indicates particular health or environmental hazards that the United States Environmental Protection Agency (USEPA) has determined are not appropriate for consumer use. The city wishes to avoid restricted-use pesticides.

The USEPA hazard category reflects the acute toxicity or skin/eye irritation potential of pesticide products according to the criteria shown in Table 2.[3] The category assignment is based on the route of exposure with the most severe effect. The city wishes to avoid Category I products for reasons of worker safety.

The Washington State "acutely hazardous wastes" are discarded chemical products listed as dangerous wastes by the state on the basis of acute toxicity or reactivity. The city wishes to avoid purchasing any products that would qualify for such listing. Products containing a single active ingredient were flagged if that ingredient was on the list.

Dioxin-containing pesticide products are defined by USEPA as those with tri-, tetra-, or pentachlorophenol as ingredients.[4] No such products were found on the city's list.

The Washington State Department of Ecology launched an initiative to reduce persistent bioaccumulative toxic chemicals (PBTs) in the state.[5] They published a preliminary list of 27 PBTs that included most of the 12 chemicals designated as Priority PBTs by USEPA.[6] Occurrence of an ingredient on either list was considered an indication that it was a PBT.

Table 2. Criteria for USEPA pesticide hazard categories

	USEPA Category I	USEPA Category II	USEPA Category III	USEPA Category IV
Signal word	DANGER	WARNING	CAUTION	CAUTION
Oral LD50 (mg/kg)	<50	50 to 500	500 to 5000	>5000
Inhalation LC50 (mg/liter)	<0.2	0.2 to 2	2 to 200	>200
Dermal LD50 (mg/kg)	<200	200 to 2000	2000 to 20,000	>20,000
Eye effects	Corrosive; non-reversible opacity	Severe irritation; reversible opacity persisting 7 days	Moderate irritation; no opacity; reversible 7 days	No irritation
Skin effects	Corrosive	Severe irritation	Moderate irritation	Mild irritation

Several governmental agencies evaluate chemicals for carcinogenic potential, and each uses slightly different language to characterize the strength of the evidence. Since the lists of chemicals evaluated by each agency vary considerably, it is necessary to search all available lists and compare the results. For purposes of this project, a determination by any of the agencies that a chemical was known, probable, likely, or reasonably anticipated to be a human carcinogen was considered sufficient evidence. Inconsistent ratings between agencies were rare. In such cases, the higher cancer-likelihood rating was chosen as being most precautionary.

To identify reproductive and/or developmental toxicants, the California Clean Water Act (Proposition 65) list was used. This list provides a yes/no value. The City of Seattle recognizes that dose/response principles apply to this toxicological endpoint but wants to avoid using products associated with such serious health effects, even if the exposures are expected to be well below those known to produce the effects.

To identify chemicals with the potential to disrupt hormones in humans or wildlife, the list compiled in 1997 by the Illinois EPA was used. Although hormone disruption is a relatively new concern, many substances have not yet been tested, and the science is still controversial, the city wishes to take a precautionary approach to substances that may affect the delicate endocrine system. As USEPA moves forward with its endocrine disruptor testing program, and when better lists are available, this aspect of the screening process will be reevaluated.

Persistence of pesticides plays a role in many aspects of environmental toxicology, increasing the risk of off-target exposures through runoff and leaching, contact with plants or soil, and evaporation. We chose soil half-life as our benchmark, because the data are readily available for most ingredients, and soil is the principal medium that determines water pollution risk.

Mobility in soil is also a component of water pollution risk. Although a host of site-specific factors will always come into play, the inherent soil sorption of the compound itself is still a key factor that can be used to rank products. The so-called Groundwater Ubiquity Score (GUS) was chosen for its relative simplicity, availability of data, and general acceptance.[7] GUS was first devised to evaluate the potential of chemicals to move downward toward groundwater, but recent research suggests that it can also predict hazards to surface water through lateral movement.[8]

Hazards to non-target organisms were determined from USEPA-mandated label warning statements, which use the terms toxic, highly toxic, and extremely toxic, according to specific hierarchies for birds, fish, and bees.[9]

Table 3 shows how products were ranked into three tiers based on the values of the characteristics displayed in Table 1. Products were placed in Tier 1 if *any* of the conditions listed under the "Tier 1" column of Table 3 were met. Products were placed in Tier 3 if *all* of the conditions in the "Tier 3" column of Table 3 were met. Products not triggering either the Tier 1 or Tier 3 conditions fell into Tier 2, as indicated by the conditions shown in the "Tier 2" column of Table 3. Products for which insufficient information was available were placed into an additional Tier 4 (not shown in Table 3), and will be ranked as information becomes available.

Results

A total of 227 products were evaluated during the summer of 1999, including products currently in use, those used in the past, and products that may be considered for use in the

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Table 3. Values determining tier table assignments

Characteristic	Tier 1	Tier 2	Tier 3
Restricted-use pesticide	yes	no	no
USEPA hazard category	I	II	III or IV
Acutely hazardous waste	yes	no	no
Dioxin-containing pesticide*	yes	no	no
Persistent bioaccumulative toxic (PBT)	yes	no	no
Carcinogen	known probable likely anticipated	possible	unlikely evidence not carcinogenic not listed
Reproductive/developmental toxicant	yes	no	no
Endocrine disruptor	known probable	suspect	—
Soil persistence (soil half-life in days)	>100	31–100	<30
Soil mobility (GUS score)	>3.0	1.0–3.0	<1.0
Labeled hazard to birds	highly toxic extremely toxic	toxic	—
Labeled hazard to aquatic species	highly toxic extremely toxic	toxic	—
Labeled hazard to bees	highly toxic extremely toxic	toxic	—

*Product contains tri-, tetra-, or pentachlorophenols or their chlorophenoxy derivate acids, esters, ethers, amine or other salts. These are considered indicators of contamination by polychlorinated dibenzo-p-dioxins or polychlorinated dibenzofurans, as specified in USEPA RCRA waste category F027 (US Code of Federal Regulations, 1999, *Identification and Listing of Hazardous Waste,* 40 CFR Part 261.31).

future. The tier breakdown of products after the initial screening is shown in Table 4. Thus 40% of the insecticide products, 61% of herbicides, and 78% of fungicides were classified as Tier 1.

Table 5 shows which of the criteria resulted in Tier 1 rankings for the various types of products. For insecticides, off-target toxicity was by far the biggest reason (65%) for Tier 1 listing; for herbicides, mobility in soil (44%) was most frequent, and for fungicides, it was carcinogenicity (44%). The sum of each column may exceed 100% because some products matched more than one criterion.

Table 6 lists some examples of active ingredients that typically ranked in Tier 1, indicating the highest level of concern. Table 7 lists some of the active ingredients that typically ranked in Tier 2 (moderate concern). They include some botanicals, spray oils, borates, and a few synthetic ingredients, including glyphosate. Neem is a botanical oil listed as the active ingredient in several registered pesticides. The two rodent baits, diphacinone and chlorophacinone, were included because of their reduced risk of secondary poisoning compared to other available baits.

Ingredients typically ranked in Tier 3, shown in Table 8, included fatty acid soaps, *Bacillus thuringiensis* (*Bt*), some iron and sulfur compounds, corn gluten, potassium bicarbonate, citrus and mint oils, and insect growth regulators such as kinoprene and methoprene. Note that particular products with these ingredients could still be ranked in Tier 1 if the product was listed by USEPA as falling into hazard Category I. Corn gluten is the active ingredient in some recent pre-emergent herbicides that are exempt from USEPA registration. Potassium bicarbonate has been registered in several fungicides for control of powdery mildew on both ornamental and edible plants.

Discussion

Many types of scoring systems have been used over time to evaluate pesticides for use in IPM programs or for other purposes such as policy tools, eco-labeling, and purchasing criteria. There are many inherent difficulties in such enterprises, which are really models based on simplified views of the products and the ecosystems. Since it is impractical to

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Table 4. Tier rankings of pesticides by group

	Insecticides	Herbicides	Fungicides	Other[a]	Total
Tier 1	37	48	36	5	126
Tier 2	14	18	3	2	37
Tier 3	8	4	2	2	16
Tier 4	33	8	5	2	48
Total					227

[a]Rodenticides, molluscicides, etc.

Table 5. Reasons for ranking in Tier 1

	Insecticides	**Herbicides**	**Fungicides**	**Other[a]**
Restricted-use pesticide	19%	10%	3%	0%
USEPA hazard category	3%	19%	22%	0%
Acutely hazardous waste	14%	0%	3%	0%
Dioxin-containing pesticide*	0%	0%	0%	0%
Persistent bioaccumulative toxic (PBT)	3%	6%	0%	0%
Carcinogen	8%	13%	44%	20%
Reproductive/developmental toxicant	8%	6%	6%	0%
Endocrine disruptor	8%	29%	17%	0%
Soil persistence	5%	10%	25%	0%
Soil mobility	8%	44%	11%	20%
Hazard to birds, bees, or aquatic species (off-target toxicity)	65%	0%	0%	80%

*Product contains tri-, tetra-, or pentachlorophenols or their chlorophenoxy derivate acids, esters, ethers, amine or other salts. These are considered indicators of contamination by polychlorinated dibenzo-p-dioxins or polychlorinated dibenzofurans, as specified in USEPA RCRA waste category F027 (US Code of Federal Regulations, 1999, *Identification and Listing of Hazardous Waste,* 40 CFR Part 261.31).

[a]Rodenticides, molluscicides, etc.

Table 6. Examples of active ingredients placing in Tier 1 (highest concern)

Insecticides	**Herbicides**	**Fungicides**	**Other**
acephate	2,4-D	benomyl	metaldehyde
carbaryl	clopyralid	chlorothalonil	
chlorpyrifos	dicamba	etridiazole	
diazinon	dichlobenil	iprodione	
dicofol	diuron	mancozeb	
malathion	imazapyr	pentachloronitrobenzene	
permethrin	MCPA, MCPP	triadimafon	
propoxur	triclopyr (salt)	triforine	

model all aspects of a product's health and environmental risks, one is faced with selecting which potential hazards to consider, how to score them, and how to integrate many diverse factors with unlike metrics into a single decision-making system. A further difficulty is presented by data gaps, where lack of scientific data or confidentiality issues may prevent the inclusion of certain types of indicators in the model or prevent the complete ranking of certain products, even within a simplified model.

In an excellent review of systems to index or rank pesticides, Levitan concludes that particular classification systems are

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Table 7. Examples of active ingredients placing in Tier 2 (moderate concern)

Insecticides	Herbicides	Fungicides	Other
abamectin baits	benefin	fosetyl aluminum	chlorophacinone
borates	glyphosate	myclobutanil[a]	diphacinone
dormant oils	isoxaben	neem	
fipronil baits	napropamide	thiophanate methyl[a]	
neem	oryzalin		
pyrethrins[a]	sethoxydim		
	triclopyr (ester)		

[a]Since the initial screening in 1999, some additional products have been evaluated, and other products have been reclassified because of changes to USEPA's and California's lists of carcinogens and reproductive/developmental toxicants. Specifically, products containing pyrethrins and thiophanate methyl are now classified in Tier 1 due to carcinogenicity. Products containing myclobutanil are now in Tier 1 due to their developmental toxicity and male reproductive toxicity.

Table 8. Examples of active ingredients placing in Tier 3 (lowest concern)

Insecticides	Herbicides	Fungicides	Other
Bacillus thuringiensis	aquatic dyes	fungicidal soaps	iron phosphate
eugenol	corn gluten meal	potassium bicarbonate	mefluidide
insecticidal soap	herbicidal soaps	sulfur (some)	
kinoprene	iron sulfate (some)		

more appropriate for certain uses.[10] She identifies three basic types of methods for ranking pesticides: (1) decision tree, (2) algebraic equation, and (3) checklist. Checklist ranking systems are widely used by eco-labeling programs such as Green Seal, Blue Angel, and Environmental Choice.[11] They are also frequently used by purchasing/procurement programs of cities, counties, states, and the federal government.[12] Algebraic equations have been more widely applied in agricultural IPM.[13]

The method chosen by the City of Seattle for classifying pesticides into tiers is a checklist. However, this checklist is used within a well-defined decision-making structure in order to make pest management decisions. The checklist criteria reflect the city's concerns about worker and community health safety and environmental protection. Products classified in Tier 1 have been identified as potentially hazardous, and their use is discouraged. However, if groundskeepers feel that a Tier 1 product is needed for a particular use, they can apply for an exception. Exceptions can be granted for a one-time application or for a programmatic use, but only for a one-year period. The exception process requires extensive documentation of need and consistency with IPM program goals by the requestor, and review by a team that includes the Office of Sustainability and Environment and several departmental IPM coordinators. The checklist method allows these requests to be evaluated based on the specific potential hazards of the product and on the site conditions. For example, a product listed in Tier 1 due to fish toxicity concerns may be considered acceptable for limited use in a greenhouse environment.

Other evaluation systems could give quite different results. For example, algebraic equations that attempt to sum up environmental impact scores tend to average "bad" and "good" aspects, leading to moderate scores for many products that would fail a checklist approach. Systems that take into account product use rates would also give different results for some products. For example, the Environmental Impact Quotient and associated Field Use Rating, developed by Kovach et al.,[14] yields comparatively poor ratings for some "organic" controls such as sulfur that are applied at relatively high rates and perhaps more frequently than some synthetic pesticides (sulfur products generally ranked in Tier 3 of our evaluation). It is important to keep in mind, however, that the two systems discussed here are used for quite different purposes. As described by Kovach et al., their system might be used to estimate the relative impacts of two products or two IPM programs, with all products considered candidates for use. The Seattle system is intended to reduce pesticide use by identifying which products should not be used, based on a specific set of concerns.

It is tempting to give preference to a quantitatively based scoring system such as the algebraic equation because it appears more precise, more objective, and more able to take

account of tradeoffs between product characteristics. However, one must look carefully at how a quantitative system is structured, what data are used, and how the various components are combined. For example, in the Environmental Impact Quotient formula, which is specifically designed for agricultural chemical use, dermal exposure is given a central role, but inhalation exposure is not included, nor is the hazard from eye damage. Combining human health and environmental indicators in a single index can result in overlooking a serious problem, because the problem's effect on the index may be offset by completely unrelated factors. In the Environmental Impact Quotient, the extent of such compensation is affected by weighting factors in the model. The choice of these weighting factors thus becomes especially important when comparing products with very different characteristics, because they determine the extent to which tradeoff between these characteristics occurs. Ultimately, the choice of which rating system to use must be based on the purpose for which it will be utilized.

The criteria used by the City of Seattle do not specifically address the neurotoxicity of pesticides, particularly organophosphate and carbamate insecticides. Consideration was given to adding neurotoxicity to the list of rating criteria, but eventually the idea was abandoned because of the complexity of the mode of action, the multitude of chemical classes exhibiting neurotoxicity, and the absence of a standard regulatory list upon which to base the criterion. Further, it was realized that most neurotoxic pesticides would already be placed in Tier 1 because of toxicity to bees or fish. One should realize that broad-spectrum insecticides placed in Tier 1 only for environmental toxicity may also exhibit neurotoxic effects in humans.

Changes in Pesticide Use

The city met its target of eliminating general Tier 1 use by June 2000. This goal was achieved by replacing Tier 1 products with mechanical and cultural controls (modification of management practices) and Tier 2 or Tier 3 products. Fungicides, primarily used on golf courses, wer se not included in this target due to the lack of demonstrated alternatives.

In its effort to reduce overall pesticide use, the city has been evaluating new technologies primarily focused on pest prevention and alternative controls. Some examples include using beneficial insects, products designed to improve golf green disease resistance, and steam- and radiant-heat weeding devices.

Excluding golf courses, the city achieved a 36% reduction in pesticide use in 2000, and a 38% (i.e., an additional 2%) reduction in 2001 (based on pounds of active ingredient), when compared to a baseline averaged over the five previous years. Including golf courses, pesticide use was 26% lower in 2000 and 20% lower in 2001. While the pilot studies have helped demonstrate how alternative technologies can best be used as part of the IPM program, reducing pesticide use remains a challenge of doing more of what we already know works, such as low-maintenance landscape designs and more mulching. This is no small feat, given the size and diversity of landscapes that are under management.

To better understand how to manage public land over the long term with less reliance on pesticides, the city has designated 14 parks across the city as pesticide-free. Improvements, such as hard borders around beds and trees, increasing plant density, and concrete pads under picnic tables and fencelines, are being made in order to reduce maintenance needs. By analyzing the costs of the improvements and the maintenance impacts over time, the city will learn lessons that will help reduce pesticide use even further.

King County, which encompasses most of the Seattle metropolitan area, also adopted the Seattle pesticide ranking criteria in 1999 and uses the tier tables as decision-making tools in its IPM program for its own operations (parks, road maintenance, etc.). County policy calls for phasing out Tier 1 products to the "maximum extent practicable." Overall pesticide use by King County agencies decreased by 50% from 1999 to 2000, with a 62% decrease in use of Tier 1 products and a 34% increase in use of Tier 2 products. Tier 1 products are now used by King County mainly in targeted applications of herbicides for legally mandated noxious weed control.[15]

Notes

1. City of Seattle/Office of Sustainability and Environment, 1999, *City of Seattle Pesticide Use Reduction Strategy,* http://www.cityofseattle.net/environment/PesticideStrategy.htm.

2. City of Seattle/Office of Sustainability and Environment, 1999, *City of Seattle Chemical Use Policy,* http://www.cityofseattle.net/environment/CUP.htm.

3. US Code of Federal Regulations, 1997, *Labeling Requirements for Pesticides and Devices,* 40 CFR Part 156.10.

4. US Code of Federal Regulations, 1999, *Identification and Listing of Hazardous Waste,* 40 CFR Part 261.31.

5. Washington State Department of Ecology, 1999, *Questions & Answers on the Ecology Initiative on Persistent, Bioaccumulative, and Toxic Chemicals (PBTs),* http://www.state.wa.us/ecology/eils/bcc/bccfaq.html.

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7. P. A. Vogue, E. A. Kerle, and J. J. Jenkins, 1994, *Oregon State University Extension Pesticide Properties Database,* Oregon State University Extension Service, Corvallis, 18 pp.

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13. L. J. Penrose, W. G. Thwaite, and C. C. Bower, 1994, "Rating Index as a Basis for Decision Making on Pesticide Use Reduction and for Accreditation of Fruit Produced under Integrated Pest Management," *Crop Protection* 13:146–152; C. Bockstaller, P. Gitardin, and H. M. G. van der Werf, 1997, "Use of Agro-ecological Indicators for the Evaluation of Farming Systems," *European Journal of Agronomy* 7:261–270; J. A. W. A. Reus and G. A. Pak, 1993, "An Environmental Yardstick for Pesticides," *Med. Fac. Landbouww. Univ. Gent* 58:249–255; W. W. Pease, J. Liebman, D. Landy, and D. Albright, 1996, *Pesticide Use in California: Strategies for Reducing Environmental Health Impacts,* An Environmental Health Policy Program Report, Center for Occupational and Environmental Health, School of Public Health, California Policy Seminar, University of California, Berkeley; risk assessment model in appendix 1, pp. 63–93; T. R. O'Bryan and R. H. Ross, 1988, "Chemical Scoring System for Hazard and Exposure Identification," *Journal of Toxicology and Environmental Health* 25:119–134; J. Kovach, C. Petzoldt, J. Degni, and J. Tette, 2001, *A Method to Measure the Environmental Impact of Pesticides,* http://www.nysaes.cornell.edu/ipmnet/ny/program_news/EIQ.html.

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15. King County IPM Steering Committee, 2001, *Integrated Pest Management in King County: A Status Report Through the Year 2000 on the Implementation of the King County IPM Executive Order,* Seattle, WA, 32 pp., available online at http://www.metrokc.gov/hazwaste/ipm/IPMkc00.pdf.

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