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5. Identifying Priorities for Pesticide Residue Reduction

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Identifying Priorities for Pesticide Residue Reduction

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This study examines consumer dietary intake of pesticide residues to develop a ranking of priorities for development of alternative pest control programs. There are two ways the Federal government can manage dietary risks from use of pesticides: regulations that restrict farmers' use of pesticides and research to develop safer, alternative pest controls. Agricultural scientists have a long history of developing plants that resist insect and disease pests. With the advent of biotechnology, there are many new possibilities for developing pest control methods.

Little is known about how cost-effectively to reduce risks. Here we develop much of the information needed to focus research and regulatory resources efficiently to reduce risks from dietary residue intake. To accomplish this goal, we need a broad and detailed perspective of dietary risks. We need to be able to rank the different risks, establish their sources, and measure how much risks would change with different research choices. The more precisely sources of risk are identified, the more policies can be targeted to reduce risk.

We examine chronic dietary risks from a wide class of pesticide residues on commonly-consumed fruits and vegetables. Drawing on data from new large-scale surveys of pesticide residues and food consumption, dietary residue intake and risk indicators are estimated and ranked for the average consumer and for several sub-populations of consumers. Surveys of pesticide use show where these residues come from and how they link to farm and marketing production practices, revealing the sources of dietary risk.

The consumer sub-population we focus greatest attention on is children. The recent National Research Council report, *Pesticides in the Diets of Infants and Children* (1993), highlighted the greater vulnerability of children to health risks from pesticides in foods. Furthermore, children's and adult's diets have been changing over time, with possible consequences for dietary intake of pesticide residues.

The new data used in this report come from USDA's Pesticide Data Program (PDP) (1994). As part of the PDP, the Agricultural Marketing Service (AMS) of USDA works with state laboratories to collect pesticide residue data. In 1992, these data covered 50 pesticide residues on 10 commonly-consumed fruits and vegetables.

We estimate dietary intake of pesticide residues based on the AMS PDP residue data in combination with the USDA 1987/88 Nationwide Food Consumption Survey. Dietary residue intake is estimated as the product of the quantity consumed and the average residue concentration on each fruit or vegetable consumed.

We use the residue intake estimates to derive two indicators of potential health risks. For pesticides with threshold dose-response functions, we compare estimated dietary intake with the intake level recognized as safe. For non-threshold pesticides, we compare estimated dietary intake with the intake level which would lead to a negligible risk of cancer. The indicators make it possible to examine the relative contributions to dietary residue intake and risk from different commodities, from imported and domestic commodities, from on-farm and post-harvest pesticide use, and from currently-used and canceled pesticides (canceled registrations for use) that persist in the environment.

To set cost-effective priorities for risk reduction, risk indicators have to be compared with costs of government intervention. This latter step is beyond the scope of this report. However, researchers have estimated cost information covering wide classes of commodities and pesticides showing that cost information can be developed in tandem with risk information (Osteen and Kuchler 1987).

The following two sections show how residue levels and consumption each influence residue intake. Then, we present estimates and rankings of risk indicators. The concluding section offers implications for research priorities and data needs.

Sources of Residues: Examination of Detection Rates and Residue Averages

This section characterizes the distribution of pesticide residues on fruits and vegetables. We examine the quantity of residues on fruits and vegetables through detection frequencies (how often residues are present in foods), average residue levels, and residue levels relative to legal limits (tolerances). Also, the section shows the relative importance of the four sources of residues: domestic, on-farm pesticide use; post-harvest use; imported foods; and canceled pesticides that persist in the environment.

USDA Pesticide Residue Data

During 1992, the AMS PDP measured residues on samples of fresh fruits and vegetables, including apples, bananas, celery, green beans, grapefruit, grapes, lettuce, oranges, peaches, and potatoes.[2] The 10 commodities represent approximately 56 percent of total U.S. fruit and vegetable consumption by weight. Samples included both imported and domestic commodities. Commodities were included in PDP based on their level of consumption. Pesticides for which AMS PDP screened included 14 fungicides, 6 herbicides, and 30 insecticides.

The samples were drawn from terminal markets and large distribution centers in six states: California, Florida, Michigan, New York, Texas, and Washington. These states were selected because they cover a large portion (about 40 percent) of the U.S. population, thereby ensuring that the data give a good estimate of the prevalence of the 50 pesticides in a portion of the food supply. Testing laboratories treated samples as consumers would: washing, peeling, and coring samples as appropriate before measuring residues.

Detections, Actual Residues, and Tolerances

When commodities are screened, a residue may 1) not be detected, 2) be detected but too small to measure accurately, or 3) be detected and measured. The PDP showed 61.2 percent of samples contained detectable residues. PDP detection rates by commodity and pesticide are shown in Table 5.1. It shows the highest detection rates and ranks rates by pesticide-commodity pairs. Out of the nearly 500 pesticide-commodity pairs examined in PDP, only five showed detection rates greater than 50 percent. Most detection rates were zero.

The technology of detecting and measuring residues poses a problem for estimating typical dietary intake levels. Any detection data will be censored: many samples will show no detectable residues and we will be uncertain how to interpret those findings in a quantitative sense. To estimate average resi-

TABLE 5.1 Rankings of Residue Detection Frequency, Average Residues, and Average Residue as a Percent of Tolerance by Pesticide and Crop, 1992

Samples with Residues			Average Residue			Average Residue as a Percent of Tolerance[b]		
Pesticide	Crop	Percent	Pesticide	Crop	ppb[a]	Pesticide	Crop	Percent
Thiabendazole	Oranges	63.8	Chlorpropham	Potatoes	835	Benomyl	Bananas	12.0
Chlorpropham	Potatoes	59.3	Iprodione	Peaches	424	Thiabendazole	Bananas	8.9
Thiabendazole	Apples	56.5	Dichloran	Peaches	390	Imazalil	Bananas	7.4
Iprodione	Peaches	54.4	Thiabendazole	Apples	351	Chlorpyrifos	Peaches	5.7
Thiabendazole	Grapefruit	54.0	Diphenylamine	Apples	256	Ethoprop	Bananas	4.8
Dicloran	Peaches	46.7	Thiabendazole	Oranges	165	Acephate	Green Beans	4.4
Permethrin	Celery	38.6	Acephate	Green Beans	131	Methamidophos	Green Beans	4.0
Chlorothalonil	Celery	32.3	Iprodione	Grapes	87	Thiabendazole	Apples	3.5
Azinphos-methyl	Apples	31.4	Captan	Grapes	82	Diphenylamine	Apples	2.6
Diphenylamine	Apples	30.5	Chlorothalonil	Celery	80	Myclobutanil	Grapes	2.3

[a] Parts per billion.

[b] Legal tolerances are published in the Code of Federal Regulations, title 40, part 180, July 1, 1992.

dues, we followed EPA guidelines (U.S. EPA 1992), filling in values for the censored data by assumption.

Average residues (the largest are shown in Table 5.1) follow the same general pattern as detections. Relatively frequent detections imply relatively high average residues. Further, residues are generally very low in relation to tolerances.

Dietary Intake of Pesticides Comes from Four Sources

There are four sources, or uses, of pesticide residues that can be identified in the AMS data: domestic, on-farm use; post-harvest treatments; imported foods; and banned pesticides that persist in the environment. Each contributes to the residues in consumers' diets.

Residues from Domestic, On-Farm Use and Post-Harvest Treatments. Many of the frequently-used pesticides show up in the residue set, but at rates far smaller than their use would suggest. For example, captan is the most heavily used fungicide on apples, with 52 percent of apple acreage receiving 7.3 treatments. Captan was found (at any level) on 7.3 percent of apple samples. (This proportion also reflects post-harvest captan use and thus may overstate the importance of farm use.)

Time and exposure to the elements reduce many pesticide residues (Eichers et al. 1971, Elkins 1989, Gonzalez et al. 1989). Post-harvest residues are not exposed to the elements and are detected frequently. The pesticide detection frequency ranking in Table 5.1 shows the top six pesticide-commodity pairs result from post-harvest treatments. For some commodities almost all the pesticide residues detected are realized from post-harvest treatments. For bananas, grapefruit, and oranges, 98, 90, and 88 percent of the residue detections, respectively, are from post-harvest pesticide uses. Across all 10 commodities, 38 percent of detections are from post-harvest use.

Residues on Imported Foods. Among the 10 AMS PDP commodities, only peaches and grapes had significant numbers of samples from both domestic production and imports. This characteristic makes the commodities useful for contrasting the residues on domestic produce and imports.

Comparing average residues is not straightforward because any average residue point-estimate has to be made under some assumption about the distribution of residues that are too small to accurately measure. We can bound what is physically possible for average residues. Two sets of assumptions allow us to calculate averages that are as small and as large as the data permits. First, assume that all residues below the detection limit are zero and all samples below the limit of quantitation are at the limit of detection. Those assumptions make the non-measured samples as small as possible and the calculated average residue as small as possible. Second, assume that all residues below the detection limit are at the limit of detection and that all samples below the limit of quantitation are at the limit of quantitation. Average residues calculated under these assumptions yield estimates that are as large as possible.

The largest differences between domestic and imported produce are for fungicide residues on grapes. There are three fungicides (captan, iprodione, and vinclozolin) for which the smallest possible imported average residue value is larger than the largest possible domestic average residue value. Also, the differences are large compared to the range of physically possible average values. Captan residues on imported grapes range from 9 to 22 times higher than domestic grapes. Iprodione residues are 2 to 4 times higher on imported grapes. Vinclozolin residues are 13 to 30 times higher on imported grapes. Dicloran and myclobutanil residues are higher on domestic grapes, but detection rates and average residue ranges are lower for both domestic and imported grapes than for the other three fungicide residues.

Residues from Banned and Persistent Pesticides. Some of the chemicals for which AMS screened, namely anilazine, DDT, demeton, and HCB, are no longer used. AMS also screened for two degradation products of DDT: DDE and TDE. TDE residues were not detected in the 10 commodities. Although legal use of DDT ended in 1972, both DDT and DDE were found in samples of celery, lettuce, and potatoes. DDE residues were found in apples and green beans, and DDT residues were found in peaches.

These detections could be the result of use that occurred up to 50 years ago.

The largest number of DDT and DDE detections among the 10 commodities were in potatoes. These two persistent chemicals accounted for 12 percent of residue detections in potatoes, similar to the 15 percent of detections from pesticides currently used on farm; 73 percent of detections were from post-harvest chemicals.

An Indicator of Risk is Needed

While post-harvest pesticides leave the highest residues, this does not mean they are the most important contributors to pesticide residue risk. The potential for adverse health effects from a chemical depends on both dietary intake of the chemical and the toxicity of the chemical (Chaisson et al. 1991). Examining detection frequency and average residues tells nothing about toxicity and does not address dietary intake. Dietary intake depends on the concentration of pesticide residues on foods and the quantity of each food consumed. The next section will show how consumption differs among consumer sub-populations and how that variance influences intake. Then, residue concentrations and consumption will be used in risk indicators.

Dietary Patterns and Implications for Pesticide Residue Intake

Data and Methodology for Commodity Consumption Estimates

Estimates of commodity consumption are based on USDA/ARS 1987-88 Nationwide Food Consumption Survey (NFCS), converted to raw agricultural commodity equivalents using TASDIET^{TM} software. This conversion allows us to examine consumption of the commodity from a variety of dietary sources, including foods consumed as part of processed mixtures. For example, a meal including pizza is converted to the equivalent consumption of tomatoes, wheat, olives, and other ingredients. The total consumption of each raw agricultural commodity is then summed up for each individual. This conversion is necessary because research to develop alternative pest controls is carried out in fields and orchards, rather than on foods as consumed.[3]

Children's Consumption Patterns and Changes in Consumption

Here we compare consumption of ten fruits and vegetables for the U.S. population as a whole and for one-year-old children, adjusting for body-weight differences; we also examine changes in consumption of these commodities over time. Table 5.2 shows children's consumption per-body-weight is several times the U.S. average for many commodities. On a per-body-weight basis, one-year-olds consume nearly 8 times as much apples as the average population, nearly 6 times as much bananas, 5 times as much grapes, 4 times as much green beans and peaches, and over twice as much oranges and potatoes.

Further, young children's consumption of several of these commodities has increased more rapidly than the U.S. average since 1977/78, as shown in Table 5.2, columns 4 and 5. Consumption of apples by one-year-olds has doubled, and consumption of grapes has tripled. For the population as a whole, consumption of these commodities increased about 40 percent each.

These results support the need to consider the dietary intake levels of young children carefully in assessment of health implications in pesticide residues. Because children's consumption patterns are so

TABLE 5.2 Consumption Per Body Weight of Fruits and Vegetables

	Consumption Per Body Weight[a], 1987/88 (mg/kg/day)		Percentage Change 1977/78 to 1987/88	
Commodity	U.S. Average[b]	1-Year-Olds	U.S. Average	1-Year-Olds
Apples	986	7,719	41	102
Bananas	250	1,455	7	0
Celery	61	75	-2	4
Green Beans	161	747	42	201
Grapefruit	203	160	-21	58
Grapes	334	1,711	41	41
Lettuce	188	56	-17	-32
Oranges	1,925	4,278	54	0
Peaches	133	526	-38	-37
Potatoes	1,051	2,717	-6	5

Source: Based on NFCS 1977/78 and 1987/88, using Diet System Software by TAS, Inc.

[a] Consumption per body weight is estimated on an individual basis. The average body weight for all individuals in the NFCS sample was 158 pounds. The body weights are self-reported, or in the case of children, reported by parents.

[b] The U.S. Average includes individuals in the 48 contiguous states, of all ages, genders, ethnic groups, and regions, and includes all seasons.

different, pesticide residue intake levels are likely to be different, and the rankings of residues according to their potential health impacts could also be different.

Adults with High Consumption of Fruits and Vegetables

Consumption patterns and pesticide dietary intake of adults who consume relatively large amounts of fruits and vegetables are especially important to understand because government and private sector information programs currently are aimed at broadly increasing fruit and vegetable consumption. The "5 a Day for Better Health" program is the first national health promotion program to focus on the benefits of daily fruit and vegetable consumption (U.S. DHHS, Public Health Service, National Institutes of Health 1991). The program has been jointly promoted by the National Cancer Institute and the Produce for Better Health Foundation, representing the fruit and vegetable industry. Its goal is to increase per capita consumption of fruits and vegetables to 5 servings daily by the year 2000.

As consumers attempt to control disease through diet, they may expose themselves to more pesticides. If pesticide dietary intake risk were great enough, consumers might have to balance one risk against another, limiting their fruit and vegetable consumption. In this section, we compare fruit and vegetable consumption of adults in the 85th percentile of the consumption distribution with young children's consumption patterns to determine whether some adults may also warrant special consideration in determining priorities for reducing pesticide residue risk. Table 5.3 shows the eighty-fifth percentiles of adult consumption adjusted for body weight.[4] These percentiles are higher than children's consumption for only two commodities (celery and lettuce).

TABLE 5.3 Consumption of Fruits and Vegetables: Adults and Upper Percentiles of Adults Over 18, 1987-88 (Per Body Weight, in mg/kg/day)[a]

Commodity	U.S. Average	U.S. Average, Adults	85th Percentile, Adults
Apples	986	410	1,181
Bananas	250	175	2
Celery	61	58	112
Green Beans	161	123	0
Grapefruit	203	247	0
Grapes	334	254	156
Lettuce	188	201	531
Oranges	1,925	1,284	3,888
Peaches	133	79	40
Potatoes	1,051	839	1,952

[a] See notes for Table 5.2.

Dietary Residue Risk Indicators

This section presents two pesticide residue risk indicators, referred to as Fraction of Negligible Risk Intake (FNRI) and Fraction of Reference Dose (FRD). Both indicators are based on dietary intake estimates, where dietary intake is calculated as the product of estimated average residue and estimated consumption. Both indicators compare estimated dietary intake with dietary intake levels recognized as causing no significant health effects. Indicators by pesticide are presented for consumer sub-populations, and the contribution of each commodity is calculated.

Indicator Definitions

The FNRI is estimated for non-threshold pesticides, those believed to have no risk-free dietary intake level. Non-threshold pesticides are probable or possible human carcinogens. The numerator of the FNRI is the estimated dietary pesticide residue intake. The denominator of the FNRI is the level of dietary intake which would lead to a negligible risk of cancer. This level is derived using EPA data on the carcinogenic potency of the pesticide (Engler 1993) and is based on a common definition of negligible risk, which is a 1-in-a-million probability of cancer.[5]

The FRD is estimated for threshold pesticides, those for which very low levels of dietary intake (up to some threshold) cause no ill effect. These pesticides have potential non-cancer health effects such as tissue damage and neurochemical changes. The FRD is derived by dividing dietary residue intake by the Reference Dose established by EPA (U.S. EPA 1994). The Reference Dose is the level of average daily intake which is believed to be without health risk if ingested over a lifetime.

Indicator Estimates and Rankings

The FNRI was estimated for 10 non-threshold residues, including 9 pesticides (DDT, benomyl, captan, chlorothalonil, dichlorvos, lindane, o-phenylphenol, permethrin, and propargite) and one degradation product (DDE). The FRD was estimated for the remaining threshold residues.

TABLE 5.4 FNRI and FRD for Selected Consumer Sub-Populations

Pesticide	U.S. Average	1-Year-Olds	Adult Average	85th Percentile of Adults
Non-Threshold Pesticides				
DDE	0.38	1.19	0.29	0.50
Propargite	0.29	1.10	0.17	0.02[a]
Captan	0.18	1.06	0.11	0.16
Benomyl	0.10	0.65	0.05	0.11
DDT	0.20	0.54	0.15	0.34
Chlorothalonil	0.08	0.20	0.08	0.15
Permethrin	0.19	0.19	0.20	0.43
o-Phenylphenol	0.04	0.18	0.02	0.06
Threshold Pesticides				
Methamidophos	0.16	0.59	0.12	0.29
Thiabendazole	0.08	0.38	0.05	0.10
Dimethoate	0.06	0.31	0.04	0.14
Azinphos-Methyl	0.03	0.19	0.01	0.03
Ethion	0.03	0.19	0.01	0.30

[a] The distribution of FNRI values is highly skewed for propargite. Propargite was detected only on peaches, and only 27 percent of adults consumed peaches during the 3 survey days during the 1987-88 NFCS.

Table 5.4 shows estimates of the highest FNRI and FRD values for the U.S. average consumer (based on U.S. average consumption level of the 10 commodities over an assumed 70-year lifetime dietary intake), for the average adult consumer, for adults in upper percentiles of the intake distribution, and for the one-year-old children's cohort (usually the FNRI largest among children's cohorts). Chemicals were included in Table 5.4 if any of the children's cohorts (ages 1-6) showed an indicator value above 0.10.[6]

All FNRI for the average consumer and adult sub-populations are below 1, suggesting that dietary intake of these residues from the AMS PDP 1992 commodities are all below negligible risk intake levels. For the U.S. average consumption level, the highest FNRI is 0.38 for DDE. That is, estimated intake of DDE residues from ten fruits and vegetables is 38 percent of the negligible risk intake level, assuming no loss of residues in processing. Although indicator values are not shown for all children's cohorts, indicator values are uniformly higher for young children than for adults and rankings are different for some residues. These differences in magnitude reflect children's higher consumption per-body-weight of many commodities.

For the U.S. average consumer, the largest FRD is for methamidophos, with an indicator value of 0.16 and 0.59 for one-year-old children. The FRD estimates shown in Table 5.4 are all below 1, suggesting that dietary intake of these residues from the AMS PDP 1992 commodities are all below the EPA reference doses.

Adults in Upper Percentiles

Table 5.3 showed that a small fraction (but a large absolute number) of adults consume a larger quantity of some fruits and vegetables than young children, on a body-weight basis. While the larger fruit and vegetable consumption of these adults means higher dietary intake of some pesticide residues, it does not automatically translate into dietary intake levels above negligible risk intake levels or reference doses. Table 5.4 shows the FNRI and FRD estimates for the 85th percentiles of pesticide residue intake for adults. Note that the percentiles of pesticide residue intake include different individuals from the corresponding percentiles of commodity consumption. Further, the 85th percentile for intake of one pesticide includes different individuals than the 85th percentile for intake of another pesticide.

The highest ranked non-threshold pesticide is DDE, just as it is for one-year-olds. The ranking of the remaining pesticides differs somewhat from the ranking for children. Permethrin appears as the second-ranked pesticide, while it was close to the bottom of the list for young children. This difference results from dietary differences between adults and children. Permethrin residues were found by AMS primarily on celery and lettuce, which is consumed in small amounts by children, but in large amounts by some adults.

The top-ranking threshold pesticide for 85th percentiles is ethion. This differs from the ranking for children and the U.S. average, in which methamidophos is the top-ranked threshold pesticide. The FRD value is also higher for these adults than for one-year-old children. Other pesticides ranked similarly for upper percentile adults as for one-year-olds. While rankings are different for children and adults in upper percentiles, indicator values are, except for ethion, all lower for adults in the 85th percentiles than for one-year-old children.

The comparison between adults and children provides some insight into whether some adults may warrant special consideration in priorities for residue risk reduction. The fact that values for the most exposed adults are almost all lower than for one-year-old children suggests that special consideration for children's diets would protect most other individuals in the population as well.

Potential Residue Intake from Five Servings of Fruits and Vegetables Per Day

FNRI and FRD indicators are estimated here for two hypothetical diets which would provide five servings per day of the AMS-tested fruits and vegetables. We estimated dietary intake from different combinations of fruits and vegetables.[7] The first is a diet which would add up to 5 total servings of fruits and vegetables, in the same proportions as current consumption.[8] Estimates based on the 1987-88 NFCS suggest that the average adult consumption of the ten commodities studied here adds up to 2.3 servings daily. Thus, a diet providing 5 servings daily from these commodities in the same proportions would roughly double the current average consumption of each commodity.

The second set of hypothetical diets consists of one serving each of the five commodities with the highest average residues per serving for each pesticide. These diets illustrate the highest possible residue intake levels from diets meeting the objective of five servings of different fruits and vegetables per day. Note that the second set of diets all consist of the same five fruits and vegetables daily for a lifetime, and the indicators so estimated must be unrealistically high.

Results suggest (Table 5.5) that increasing fruit and vegetable consumption to meet health recommendations should not cause concern about dietary intake of pesticide residues. All indicators from the illustrated diet of five servings in current proportions are below 1, meaning that non-threshold residues are all below negligible risk intake levels and threshold residues are below reference doses. Indicator values from the "upper bound" diets are higher, although all values are below or close to 1. The only value exceeding 1, for DDT, is still within the range of negligible risk.

TABLE 5.5 FNRI and FRD for Simulated Diets Providing Five Fruits and Vegetables Per Day[a]

Pesticide	Current Adult Diet	Lifetime Average of Five Servings Per Day of 10 Commodities in Same Proportions as Currently Consumed[b]	Lifetime Average of One Serving Each of Five Commodities with Highest Residues Per Serving[b]
Non-Threshold Pesticides[c]			
DDE	0.29	0.62	0.71
Permethrin	0.20	0.44	0.97
DDT	0.15	0.32	1.33
Captan	0.11	0.24	0.76
Chlorothalonil	0.08	0.17	0.63
Benomyl	0.05	0.11	0.41
o-Phenylphenol	0.02	0.05	0.08
Threshold Pesticides			
Methamidophos	0.12	0.26	0.73
Thiabendazole	0.05	0.10	0.20
Dimethoate	0.04	0.09	0.19
Ethion	0.01	0.03	0.08
Azinphos-Methyl	0.01	0.02	0.09

[a] Values are rounded to 2 decimal places after all calculations are completed.
[b] Estimates based on serving sizes in USDA Agricultural Handbook 8 (USDA 1982 and 1984).
[c] Propargite is omitted because residues were found on only one commodity.

The benefits of increasing fruit and vegetable diet shares exceed the potential effects of slight increases in pesticide residue intake. Epidemiological studies have shown that incidence of many cancers is lower by a factor of two or more for consumers with high fruit and vegetable consumption than for those with low consumption (Block et al. 1992). Thus, reducing pesticide dietary intake could only improve the benefits of high fruit and vegetable consumption.

Sources of Pesticide Dietary Intake

This section examines the sources of residues and how closely residues can be linked to particular uses. Chemicals selected for analysis are those reported in Tables 5.4 and 5.5. In addition, acephate is included because its degradate methamidophos is selected, and acephate use is a potential source of methamidophos residues.

In examining sources of risk, we focus on risks to one-year-olds because the FNRI and FRD estimates are relatively larger in this sub-population. Table 5.6 shows the decomposition of the FNRI and FRD estimates from Table 5.4 for the selected chemicals, revealing the commodity sources of pesticide dietary intake for one-year-old children. For example, the FNRI for DDE is 1.19, with 59 percent of that value coming from potatoes, and 34 percent from apples.

TABLE 5.6 Sources of Threshold and Non-Threshold Dietary Intake Risk

Pesticide	One-Year-Olds' FNRI	Principal Commodity Dietary Source (Percent)	Principal Pesticide Use Source	U.S. Regions Where Pesticide is Used
Non-Threshold Pesticides				
DDE	1.19	Potatoes (59)	Canceled	
		Apples (34)		
Propargite	1.10	Peaches (100)	Imports	
Captan	1.06	Apples (45)	Farm or post-harvest	East, North Central
		Grapes (47)	Imports	
Benomyl	0.65	Apples (69)	Farm	East, North Central
		Bananas (23)	Imports	
DDT	0.54	Potatoes (57)	Canceled	
		Apples (43)		
Chlorothalonil	0.20	Green Beans (51)	Farm	All
Permethrin	0.19	Peaches (36)	Farm	East, North Central
o-Phenylphenol	0.18	Apples (68)	Post-harvest	
		Oranges (31)		
Threshold Pesticides				
Methamidophos	0.59	Green Beans (87)	Farm	Southeast (used as acephate)
Thiabendazole	0.38	Apples (71)	Post-harvest	
Dimethoate	0.31	Apples (46)	Farm	East, North Central
		Grapes (38)	Imports	
Azinphos-methyl	0.19	Apples (87)	Farm	All
Ethion	0.19	Apples (93)	Farm	West

Table 5.6 shows children's dietary intake is often primarily from one to two commodities, reflecting their less varied diet. Peaches are the only source of propargite dietary intake considered here because residue testing was limited to one commodity. Apple consumption by one-year-olds represents approximately half the captan and benomyl intake levels. Grapes are the other principal source of captan residue intake; bananas account for most other benomyl intake. Potatoes and apples account for 93 percent of DDE residue intake for one-year-olds. Green bean consumption accounts for most of the dietary intake of methamidophos. Apples are the principal source of dietary intake for the other selected threshold risk chemicals.

Imported peaches, grapes, and bananas are sources of dietary intake for some of these chemicals. All of the estimated dietary intake of propargite results from residues on imported peaches. Most of the dietary intake of captan on grapes is a result of residues found on imported samples. Grape consumption accounts for 47 percent of the captan FNRI, and most of this intake comes from imports. All banana samples were imported and 23 percent of the benomyl FNRI comes from banana consumption. A major component (38 percent) of the dimethoate FRD comes from grape consumption and imported grapes are the source of most intake.

The other sources of dietary intake are primarily the result of on-farm use. A few chemicals, like captan, are registered for both on-farm and post-harvest use, and thus the source of residues cannot be distinguished. Of the 14 chemicals selected, 9 pesticides have on-farm uses: acephate, azinphos-methyl, benomyl, captan, chlorothalonil, dimethoate, ethion, methamidophos, and permethrin.

Many of the chemicals in Table 5.6 have large portions of dietary intake from apple consumption and are used on apples in specific producing regions. Forty-five percent of the captan FNRI and 69 percent of the benomyl FNRI comes from apple consumption. Use of captan and benomyl in apple production is in the Eastern and Lake States (Michigan, New York, Pennsylvania, Virginia, North and South Carolina, and Georgia); there is little use in the western apple-producing states (Washington, Oregon, California, and Arizona).

Sources of risk created by dietary intake of dimethoate follow the same general pattern as those of captan and benomyl. Apples carry the largest proportion of FNRI from dimethoate and dimethoate use on apples is primarily in the Mid-Atlantic and Lake States: North Carolina, Virginia, Pennsylvania, New York, and Michigan.

The major contributor to the ethion FNRI (0.19) is apples (93 percent). Ethion use in Washington appears to be the dominant source of this dietary intake level; it is the only major apple-producing state with quantifiable ethion use. Use even in Washington is fairly rare, with 2 percent of the acreage treated an average of 1.2 times (USDA, NASS and ERS 1992). This suggests that while the FRD for ethion on apples is still far below 1, any measurable increase in ethion use on Washington apples could be associated with a substantially higher FRD.

Most other risks are also largely due to region-specific pesticide use on particular commodities. Green bean consumption is the source of the largest share of FNRI from chlorothalonil. While green beans are produced across the U.S., chlorothalonil is important to green bean production only in the South: North Carolina (83 percent of acreage treated), Georgia (76 percent), and Florida (44 percent). Its use is modest outside the South, with 16 percent of acreage treated in California and less in other states (USDA, NASS and ERS 1993).

The calculated FRD for acephate is .02 for one-year-olds, indicating that its risk is a small portion of negligible. However, acephate degrades to methamidiphos residues and the latter pesticide has an FNRI of .59, mostly coming from green bean consumption. Acephate use on fresh green beans is important to production only in the South: Florida (39 percent of acreage treated) and Georgia (36 percent).[9]

There are two chemicals in Table 5.6 that show little regional differentiation in use on the commodities that result in dietary intake. The insecticide azinphos-methyl is one of the few pesticides that is used in all apple producing regions. Apples are the major contributor to azinphos-methyl FRD for one-year-olds. The pesticide is used on 57-90 percent of apple acreage in major producing states, and 2.5-6.5 times per acre. It is a major contributor to insect control on apples across the U.S. Permethrin is another chemical that is used throughout the U.S. Peaches, green beans, celery, and lettuce all contribute to the permethrin FNRI. There are few obvious differences in use regionally for any of the four commodities.

Conclusions

The analysis here makes two unique contributions towards setting priorities for research to reduce dietary risks from pesticide residues. First, risk indicators are used to rank relative risks. Second, the sources of risk are identified through disaggregation of the indicators by commodity and type of pesticide use. This information can be used to direct research to develop alternative pest control methods or other measures to reduce dietary risks from pesticide residues.

The results presented here show that pesticide residue detections, average residues relative to tolerance, and tolerance violations are not good indicators of risks from dietary intake of pesticide residues. In general, the more frequently detected pesticides were not the chemicals that had the highest indicator values. Thus, frequent detections do not necessarily indicate greater dietary risks, as risks depend on the level of dietary intake and the toxicological properties of the particular chemical. Similarly, average residues as a percent of tolerance tend to rank very differently than risk indicator values. These comparisons underscore the value of a risk indicator in setting priorities for risk reduction.

The indicator values are consonant with other studies which suggest risks for the average consumer are very low or non-existent. Furthermore, increasing consumption to the recommended '5 a day' servings of fruits and vegetables does not result in pesticide dietary intake estimates exceeding recognized safe or negligible risk levels. Among all consumer sub-populations examined, risk indicators are relatively higher for children, reflecting the fact that children consume more food per body weight and consume a less varied diet than adults. Even the highest children's indicators, however, are within the range of negligible risk.

Although risks are low, the risk indicators and information provided by the PDP are useful in ranking research priorities for further risk reduction. An important lesson here is that research to develop on-farm pest control alternatives will not address all of the sources of dietary intake of pesticide residues. The top-ranked indicators for non-threshold pesticides are canceled pesticides with persistent residues. Clearly, research on alternative pest control methods will not reduce these risks. Research shows some fruits and vegetables concentrate residues of DDT from the soil (MacCormack et al. 1992). Further research could determine the potential for risk reduction from growing these crops only on low-residue soils.

Imported produce accounted for some of the top-ranked non-threshold risks, such as captan. Here, research is needed on factors leading to higher residues on some imported crops. Higher pesticide use and residues in exporting countries may result from climates that exacerbate pest pressure. Further, smaller producers in exporting countries may have difficulty obtaining information on U.S. pesticide standards.

The top-ranked threshold pesticides are almost all on-farm uses, and many are region-specific. Here, research to develop alternative pest control techniques can play an important role in reducing pesticide residue risks. Research can be targeted to pest problems where use is highest.

It should be noted, however, that criteria such as environmental impacts and worker safety are also important in setting priorities for research on pest control alternatives. Further, in a risk ranking across a broader set of health and safety problems, other hazards may pose greater risks and less costly solutions than pesticide residues in food.

Notes

[1] Food and Consumer Economics Division, Economic Research Service, U.S. Department of Agriculture. The opinions expressed here are those of the authors and do not necessarily reflect those of the U.S. Department of Agriculture.

[2] Broccoli and carrots were tested during the final months of 1992 and were not included in this analysis.

[3] Note that the estimates for dietary residue intake are intended to cover intake from both fresh and processed foods, while the AMS residue data covers only fresh fruits and vegetables. This means that residue intake is estimated as if residues on fresh and processed products are the same, accounting only for concentration due to water removal. Comparing total pounds of active ingredient applied, pesticide use data shows (at conventional levels of statistical significance) that insecticide and fungicide use is larger in fresh green bean production than in production intended for the processing market. Conversely, potatoes for processing receive more fungicides, herbicides, growth regulators, and soil fumigants than potatoes destined for the fresh market. The processing itself can wash away many residues, although it can create others as breakdown products. Further research is needed to refine the indicators to account for these differences.

[4] Estimates for the 85th percentiles of the consumption distribution for each of the 10 commodities are 3-day averages based on the 1987-88 Nationwide Food Consumption Survey, including consumers who did not consume the commodity during the 3 survey days. The distribution of individual 3-day averages gives upwardly biased estimates of the upper percentiles of the long run average intake. An unbiased methodology for estimating the distribution of usual intakes for foods from data on a small number of days per individual is still under development (Carriquiry et al. 1991).

[5] For carcinogenic residues, negligible risk intake for the average population is defined as the intake which would lead to a 1 x 10^{-6} probability of cancer over a 70 year lifespan. For children in one-year cohorts, the one-year risk level is considered more appropriate, and negligible risk is derived as 10^{-6} divided by a 70 year lifespan. This results in a one-year cancer probability of 14 x 10^{-9}, or 14 in a billion individuals. The one-year negligible risk intake is then the intake which would lead to that probability of cancer in one year.

To derive these intake levels, we make use of the conventional cancer risk equation and estimates of carcinogenic potency from EPA (Engler 1993):

$$(1) \qquad Cancer\ Risk_{ik} = Dietary\ Intake\ per\ Body\ Weight_{ik} \times Potency_i$$

Lifetime carcinogenic potency (Q*) is measured in tumors per milligram of toxin per kilogram of body weight consumed daily over a lifetime (National Research Council 1993). The one-year potency is Q*/70. From these potency values, the lifetime and one-year negligible risk intake levels can be solved for as follows:

$$(2) \qquad Negligible\ Risk\ Intake\ (Lifetime)_i = \frac{1 \times 10^{-6}}{Q_i^*}$$

$$(3) \qquad Negligible\ Risk\ Intake\ (One\text{-}year)_i = \frac{14 \times 10^{-9}}{(Q_i^* \ / \ 70)}$$

The difference in interpretation between lifetime and one-year FNRI is that the one-year FNRI may reveal the portion of consumers' lifetimes in which relatively large contributions to lifetime risks occur.

Thus, pesticides with a one-year FNRI for children greater than 1 and a lifetime FNRI less than 1 represent cases where contributions to lifetime risk are concentrated in early years.

[6] The FNRI estimates for propargite must be considered provisional as results were derived from a relatively small sample on a single commodity.

[7] Because propargite was detected on only one commodity, it was not appropriate for this part of the study focusing on residues in the context of the total diet.

[8] Serving sizes are based on the USDA Agricultural Handbook 8 (USDA 1982, 1984).

[9] It is also used frequently in California and the North Central and Lake States, for production of green beans for processing. We have no residue estimates for processed products.

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