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Documentation and Applications of TOC-Dietary Risk Index

The Organic Center's "Dietary Risk Index "

Tracking Relative Pesticide Risks in Foods and Beverages

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I. INTRODUCTION AND SUMMARY

Over the last 20 years, hundreds of consumer surveys have shown that the desire to reduce pesticide dietary exposures has been among the top three reasons why people switch to organic foods, and usually it is reason number one. Extensive government pesticide residue testing in food has been underway for nearly 20 years and has shown, consistently, that fresh fruits and vegetables account for the lion's share of pesticide exposure and risk. This is largely why organic brands account for around 10% of fresh produce sales in the United States, according to the most recent market place survey conducted by the Organic Trade Association.

New science published in the last five years has established strong linkages between prenatal pesticide exposures and developmental problems in infants and children (Bouchard et al., 2010), especially cognitive deficits (Rauh et al., 2011; Engel et al., 2011; Bouchard et al., 2011; Marks et al., 2010), smaller brains (Whyatt et al., 2004), reproductive problems (Christiansen et al., 2009), asthma (Hernandez et al., 2011) and increased risk of overweight (Adigun et al., 2010) and diabetes (Lim et al., 2009). Emerging science has both reinforced long-simmering concerns over pesticides and created new worries, especially those linking pesticides to overweight and type 2 diabetes (Patel et al., 2010).

The widely accessible "Dirty Dozen" and "Clean 15" lists of foods issued by the Environmental Working Group have also driven home key messages –

- The frequency and number of pesticides in food varies dramatically across foods,
- Some common fruits and vegetables rarely contain pesticide residues, and
- Consumers lacking access to, or the income needed to purchase organic fruits and vegetables regularly should concentrate their organic purchasing power on those foods on the "Dirty Dozen" list.

New data on pesticide residues in food have also highlighted a growing concern – the shift in residues and risk to imported foods. Research carried out by The Organic Center shows that U.S. fruit and vegetable farmers have made steady progress in reducing produce-related pesticide risk, while risks have not come down nearly as much in most imports, and have actually risen in some imported produce items (Benbrook, 2008).

Pesticide residues in food, and risks posed by dietary exposures, are bound to continue driving growth and shaping the market for organic foods, especially fresh fruits and vegetables, juices, and fruit and vegetable-based products like tomato sauce and salsa, catsup, jams and jellies, cranberry and applesauce, and dried fruits.

Quantifying Pesticide Risk:

Pesticide dietary risk is a function of exposure and toxicity. Exposure is determined by how frequently pesticide residues appear in food, how many different residues are in a given serving of food, by the distribution of residue levels in those foods that contain residues, and by how much of a given food an individual eats in a given day. In general, most pesticide dietary risk is caused by the relatively few residues at the upper end of the distribution of residue levels in a given food (i.e., the proverbial "hot" potato).

Toxicity to humans is determined by the innate biological activity of a pesticide when present in mammalian systems and tissues, as well as by the timing of exposures and tissue-specific patterns of exposure.

The Organic Center has developed a "Dietary Risk Index" (DRI) to quantify relative pesticide dietary risk levels for specific food-pesticide combinations. Conceptually, the DRI is the ratio of exposure via residues in food consumed in a day, relative to the maximum amount of a pesticide that can be eaten by a person in a day without exceeding the Environmental Protection Agency's (EPA) "level of concern." EPA's "level of concern" is exceeded in cases where the agency determines there is no longer a "reasonable certainty of no harm" following a pesticide exposure episode.

For a given pesticide-food combination, the DRI value is the average residue level in food divided by the maximum amount that can be in the food, based on EPA's current assessment of each pesticide's chronic toxicity.

The numerator in the DRI ratio is simply the mean residue level of a given pesticide in a food or beverage, based on all positive samples of the food/beverage in a given year (often referred to as the "mean of the positives"). Mean residue levels are expressed in milligrams of pesticide per kilogram of food, or parts per million (ppm).

The DRI denominator is the maximum concentration of a pesticide, also expressed in milligrams of pesticide per kilogram of food, that can be present in a daily serving (or servings) of a food/beverage, without exposing an individual to a dose of the pesticide that exceeds his or her personal limit. In the case of chronic exposures and risk, this dietary exposure limit is referred to as the "chronic Reference Concentration," or cRfC.

Chronic Reference Concentrations are calculated for each pesticide using a formula driven by chronic Reference Doses (cRfD), or chronic Population Adjusted Doses (cPAD), key exposure limits that are set by EPA as part of the agency's review of the toxicological data submitted by registrants. The cPAD for a pesticide is calculated using the pesticide's cRfD, and is equal to the cRfD divided by any additional safety factor imposed to more fully protect uniquely vulnerable population groups.

The 1996 "Food Quality Protection Act" (FQPA) included a novel, added safety factor provision intended to better assure a "reasonable certainty of no harm" for all population groups. This historically significant provision directed the EPA to incorporate an additional safety factor, up to ten-fold, when setting cPADs, in order to take account of the heightened vulnerability of pregnant women, infants, and children to the toxic effects of pesticides. The FQPA implemented, essentially verbatim, the core recommendations in the 1993 National Academy of Sciences report *Pesticides in the Diets of Infants and Children.*

Maximum Allowed Exposures Versus Maximum Acceptable Concentrations

The concepts used in monitoring and regulating pesticide dietary risks can be confusing. It is essential to understand the differences between the maximum amount of a pesticide that a person can ingest in a day without triggering EPA's "level of concern," in contrast to the maximum level, or concentration, of a pesticide that can be present in a serving of food, without overexposing that certain individual.

EPA-set cRfDs and cPADs for a given pesticide are expressed in milligrams of pesticide per kilogram of a person's bodyweight per day. These key parameters refer to the total amount of a pesticide that a person of known size can consume in a day, and still face "a reasonable certainty of no harm" as a result. These measures of pesticide toxicity also determine the volume in each pesticide's "risk cup," a concept advanced by EPA to help stakeholders understand how cRfDs and cPADs establish maximum exposure limits that must be compared to total exposures from all sources (food, drinking water, the air).

The chronic Reference Concentration (cRfC), on the other hand, is a measure of the level, or concentration, of a pesticide in a serving of food, sufficient to deliver a dose of the pesticide equal to the cRfD or the cPAD for a person of known size, consuming a known amount of food. Accordingly, the cRfC concept used in the Center's DRI serves as a linkage between the level of residues found in a certain food and the maximum level of residues that can be present in the food, without overexposing an individual and triggering the EPA's "level of concern."

DRIs are always initially calculated for a specific pesticide-food combination, but they can be added together to quantify –

- Total dietary risks in a food, taking into account all pesticides found in the food during a given period;
- Total dietary risks stemming from all food uses of a given pesticide, based on all residues of the pesticide found in all foods tested for the pesticide in a given time period;
- Pesticide risks in domestically grown foods versus imports;
- Risks in organically grown food, versus food grown without any market claim, and presumably conventional;
- Relative pesticide risks across foods and food groups; and
- Differences in pesticide dietary risk levels over time.

The Organic Center has applied the DRI to all pesticide residues found in over four-dozen common foods since 1993, based on annual U.S. Department of Agriculture (USDA) pesticide residue test results. A set of tables has been developed setting forth pesticide risks by chemical, by food, over time, in domestically grown food versus imports, and organically grown food. These analyses provide a detailed accounting of pesticide risk levels, and the foods and chemicals accounting for the most worrisome residues and risks. In addition, they provide a solid, data-driven mechanism to project the impacts of organic farming on pesticide risk reduction.

This report explains the concepts, equations, and data used to calculate the DRI, and explains how the Center has resolved a number of technical challenges encountered in developing the DRI and applying it to the enormous pesticide residue dataset compiled by the USDA.

II. DIETARY RISK INDEX STRUCTURE AND DATA SOURCES

The formula for calculating The Organic Center's chronic Dietary Risk Index for a given food-pesticide combination is simple:

DRI = (Mean Residue Level Pesticide$_x$) ÷ (Chronic Reference Concentration Pesticide$_x$)

Issues arise with data quality and completeness in both of the key variables used in calculating the DRI. The most important considerations are discussed in this section. The DRI is only as accurate as the data used to compute it. In general, a higher level of confidence can be placed in the DRI's numerator – mean residue levels – than in the single measure of toxicity that underlies the DRI denominator.

This is because high quality, extensive pesticide residue data are now available for dozens of common foods, targeting those foods that contribute most significantly to the diets of infants and children. These data support reasonably accurate estimates of mean residue levels at the national level.

On the toxicity side of the equation, however, there is greater uncertainty. The risk-assessment methods relied upon by EPA produce a single estimate of a pesticide's chronic toxicity, and these estimates are vulnerable to considerable uncertainty given the limits of toxicological science. Some pesticides pose one or just a few risks, the worst of which may quickly dissipate as soon as exposures end. The adverse effects of other pesticides are essentially permanent and irreversible, and can play out over many years or even a lifetime.

Some pesticides pose risks to many organ systems, and/or at many stages of development. Actual risks will be driven by the timing of exposures and a person's general health status, as much as the levels of exposure and innate toxicity. Other pesticides appear to pose little or no risks to most organ systems. Yet in all of these cases, the EPA determines a single measure of potential toxicity, based on the one adverse impact triggered at the lowest dose in all the toxicology studies submitted to the agency by pesticide registrants.

A. CALCULATING MEAN RESIDUE LEVELS

The mean residue level used in calculating DRIs is the mean of the positive values reported by a residue-testing program over a specified period of testing (usually a calendar year). The Center's DRI relies on the pesticide residue data reported by the USDA's "Pesticide Data Program" (PDP). The PDP is widely (and appropriately) regarded as one of the highest quality pesticide residue datasets available worldwide. Moreover, the protocols of the PDP include a sampling scheme designed to reflect residues in food "as eaten," rather than at the farm-gate as is the case with most of the residue testing conducted by the Food and Drug Administration (FDA).

For example, the PDP tests bananas, pineapples, and melons after peeling them, but the FDA tests them with the peel. Obviously as a result, PDP results are more reliable than FDA residue data for purposes of pesticide dietary risk assessment.

The full, modern PDP started in 1993 and has been run continuously since. Each year 12-15 fresh foods, and another half-dozen to a dozen processed foods are selected for testing. Domestically grown and imported samples are tested roughly proportional to their respective market shares, allowing analysts to assess risk levels and trends in domestically grown food versus imports.

Each year a certain percentage of samples are recorded as "organic," although the USDA has significantly under-sampled organic produce relative to its market share. Other "market claims" recorded in PDP sampling include "pesticide free" and "IPM grown" (IPM = Integrated Pest Management).

Raw PDP data files have been downloaded for each program year. The PDP data is imported into the DRI database and analyzed for nomenclature issues. For example, the fungicide 1: 1-Naphthol is reported in the PDP data as "1 Naphthol" (with a space) in one year and "1-Naphthol" (with a hyphen) in other years. Such nomenclature discrepancies must be reconciled to prevent the DRI database from treating "1 Napthol" and "1-Napthol" as two distinct chemicals.

We resolve this issue through the use of a "Pesticide_Name_Matching" table that encompasses all pesticides tested by the PDP and all alternative names and spellings used to identify a given pesticide. This table matches each chemical name to a master list, and assigns a common name used in the DRI dataset, DRI calculations, and tables generated by the DRI system.

The insecticide cyhalothrin poses more complex nomenclature issues. Sometimes the chemical is listed as "Cyhalothrin, Lambda," while in other cases it is listed as "Lambda Cyhalothrin." A variety of isomers are also reported, including Lambda Cyhalothrin S ester. In some years, results for "Cyhalothrin, Total" are reported, with or without the results for the parent compound.

Additional data fields record the type of pesticide (e.g., herbicide, insecticide, fungicide) and family of chemistry (e.g., organophosphate insecticide, triazine herbicide).

A series of queries within Microsoft Access are used to construct a basic residue data file by crop/food, pesticide, country of origin, market claim, and year including –

- Total number of samples;
- The number of positive samples;
- The percent of samples that are positive; and
- The reported residue levels for all positive samples.

This file is then used to calculate the mean residue level among all positive samples for each pesticide-food combination. This is the "mean of the positives" used in the DRI formula.

Special Considerations on the Exposure Side

Rule of 10 For some foods from certain countries, very few samples are tested by the PDP in a given year. In a few cases, the PDP carries out a limited number of tests on a particular pesticide-food combination. In many years, there are very few organic samples of several foods included in the PDP. In such cases, we apply a "rule of 10" to assure there is an adequate number of samples to produce reasonably accurate, reliable mean residue levels. In any case were there are less than 10 samples, we do not calculate or report mean residue levels.

Units of Measure In most cases, the PDP reports residue levels in parts per million (ppm), but sometimes it uses parts per billion (ppb). A supporting table records the units of measure for each food/beverage and year combination and its unit of measure (ppm or ppb). When the reports are run, they automatically adjust the units to match across all the years for consistent reporting. For example, Corn Grain is reported as ppm in 2007 and ppb in 2008. All residue levels for all foods are converted to ppm prior to the calculation of mean residue levels and DRI values.

Other Sources of Residue Data Many grower groups, processors, retailers, and food companies periodically test samples of food grown in a specific region or from a given supplier for pesticide residues. These usually proprietary residue datasets may also be used in calculating DRI values.

The pesticide residue program of the State of California could be used in calculating DRI values for crops grown in the state, or for foods imported into the State. For states accounting for a significant share of the national production of a given crop, say cherries, we can extract from the PDP dataset all Michigan or California cherry samples, and then calculate mean residue levels for just these samples, creating state-specific DRIs. The ability to calculate state-crop specific DRIs is limited to those state-crop combinations in the PDP for which an adequate number of samples are available for a given year.

The U.K.'s Food Standards Agency carries out an extensive, high-quality residue program, which could be used to calculate DRIs. The FSA's program often does extensive testing of imports into the U.K. of a specific type of food. Such foods could include imports from the U.S. or foods from abroad that are also imported into the U.S. Indeed, for some imported foods on the U.S. market, the U.K. FSA dataset is the best source of publicly accessible residue data. Examples include tea, spices, and exotic fruits that have been tested in recent years by the FSA.

Certain ecolabel programs have also compiled extensive datasets on residue levels in certain foods. These data could also be used to develop DRI values, although access to such data is typically limited.

B. ACCOUNTING FOR PESTICIDE TOXICITY

The DRI is calculated using a pesticide's "chronic Reference Concentration" (cRfC) -- the maximum level of a pesticide that can be present in or on a given food without exceeding, or undermining, the Food Quality Protection Act's basic "reasonable certainty of no harm" standard.

The cRfC is a relative measure of a pesticide's dietary risk potential. Values will differ based on the weight of a given individual, as well as on how much of a given food the person consumes in a day. A person's bodyweight matters because chronic PADs and Reference Doses for pesticides are set per kilogram of bodyweight.

The amount of a specific food a person consumes in a given day is important, because the total weight of the pesticide ingested is a function of the concentration of the pesticide in the food, expressed in milligrams per kilogram of food, coupled with the serving size (i.e., the amount of food consumed). The serving sizes used in calculating cRfCs are taken from standard USDA data sources and reflect typical, single meal, adult serving sizes. In general, we use the same serving size for individual foods and beverages in calculating cRfCs for use in the DRI formula, as we incorporate in the center's "Nutritional Quality Index" (Benbrook and Davis, 2011).

Accordingly, cRfC values will vary as a function of the size of person used in the basic formula, as well as assumptions regarding typical serving sizes. In terms of accurate estimates of relative dietary risks, any combination of bodyweight and serving size can be used, as long as the same assumptions are embedded in the calculation of cRfCs for all pesticide-food combinations.

Given the EPA's conclusion that pesticide dietary risks are typically greatest for infants and children, the cRfC calculations used to estimate the Center's DRI are based on the diet of a child weighing 16 kilograms. The selection of 16 kilograms (35.2 pounds) corresponds to children around 3.5 years old, based on the 50th percentile of growth (see CDC growth chart noted in "References").

This bodyweight was chosen in order to reflect the age and size when most children are consuming a mix of foods close to that consumed by adults. It is also a time of rapid growth and significant food intake. By or around age 3.5 years, children are consuming their largest portions of individual foods per kilogram of bodyweight. For this reason, cRfCs based on children weighing 16 kilograms are conservative, in that most other population groups consume smaller quantities of individual foods per kilogram of bodyweight. Over protecting the typical healthy adult is a positive, secondary outcome of assuring that pesticide exposures among pregnant women, infants, and children meet the FQPA's "reasonable certainty of no harm" standard.

The formula used in calculating the cRfC for a given food-pesticide combination is:

cRfC Pesticide$_x$ (mg/kg food) x Serving Size Food$_x$ (grams/day) =
Weight of Person (kg) x cPAD for Pesticide$_x$ (mg/kg bw/day)

After dividing both sides of the equation by serving size:

cRfC Pesticide$_x$ (mg/kg food) =
[Weight of Person (kg) x cPAD for Pesticide$_x$ (mg/kg bw/day)]÷Serving Size Food$_x$ (kg/day)

Chronic "Population Adjusted Doses" or cPADs, are calculated by the EPA for purposes of dietary risk assessment for all pesticides registered for use on food crops. The cPAD for a given pesticide equals the pesticide's chronic Reference Dose (cRfD) divided by the applicable, additional safety factor (if any) imposed in the course of implementing the FQPA. Such FQPA safety factors are usually set at three or ten, and may be reduced to zero by the EPA in cases where the agency feels that the prenatal and developmental effects of pesticides, and pesticide exposure levels, are fully and accurately characterized and are already reflected in chronic Reference Doses.

The current EPA-set cRfD or cPAD for pesticide active ingredients are obtained from routine EPA data sources including Federal Register (FR) notices and Reregistration Eligibility Documents. For newly registered pesticides, these data are usually extracted from FR "Final Rules" announcing EPA approval of pesticide tolerance levels.

Dealing with Different Risk Endpoints

The Center's DRI is currently based on chronic exposures and risks – hence the use of cRfDs or cPADs. Given our focus on chronic risks, DRI values are based on typical or average (mean) residue levels, in keeping with general EPA dietary risk assessment science policies.

As noted earlier, DRI values reflect only a single toxicological endpoint and do not differentiate between a pesticide causing a relatively minor, reversible health impact at, for example, 0.01 ppm, compared to a pesticide that can cause a serious and irreversible health impact, also at 0.01 ppm. EPA cPADs and DRI values also do not vary as a function of the number of adverse health impacts linked to exposures to a given pesticide.

This is a generic weakness shared by all pesticide dietary risk assessment methods and is also a source of bias in regulatory decisions. If and when toxicologists and regulatory authorities reach consensus on better ways to account for all endpoints impacted by a pesticide and/or the severity and reversibility of such impacts, we will explore whether a cPAD adjustment factor is warranted.

In future applications of the DRI, we may recalculate Reference Concentrations based on acute or subacute risks, cancer risks, or some other risk endpoint. Our ability to calculate new Reference Concentrations based on acute, cancer, or other risks is limited because EPA has not calculated acute Reference Doses, acute PADs, or cancer potency factors for all pesticide active ingredients.

The current calculation of DRIs does not encompass cancer risks, which for some pesticides may arise at dose levels lower than chronic Reference Doses or cPADs. Over the last three decades, EPA has taken many actions to reduce the presence of cancer-causing pesticides in food, and so fortunately, few pesticides remain on the market that pose significant, known dietary cancer risks.

Cancer risk associated with pesticide exposures via drinking water and beverages, however, can be of concern. Several pesticides found in drinking water are classified by EPA as possible or probable carcinogens, and one widely used corn herbicide, atrazine, is going through another re-evaluation by EPA, in part because of concern over breast cancer risks following exposures via drinking water.

III. KEY ISSUES IN TRACKING AND MANAGING PESTICIDE DIETARY RISKS

Organic farmers are prohibited from using all toxic (to humans), synthetic pesticides. A limited number of pesticides are allowed for use on organic farms, and most of these are derived from nature and are called "biochemical" pesticides by the EPA.

Most synthetic pesticides control pests by killing them, via a lethal mode of action, whereas most biochemical pesticides control pest populations through a non-lethal mode of action. Examples include pheromones that disrupt mating by confusing either male or female insects; *Bacillus thuriengensis (Bt)* insecticides that control several Lepidopteron insects by eating a hole in the lining of insect stomachs (leading to death via dehydration), and horticultural oils which coat the surface of fruits and vegetables, protecting them from bacteria and fungal spores.

A few pesticides are allowed for use by organic farmers that are manufactured with a partially synthetic process, e.g. copper fungicides. A few botanical insecticides that work through a lethal mode of action remain on the market and are approved for use by organic farmers. Pyrethrin is by the most commonly used botanical. The active ingredient in pyrethrin insecticides is derived from compounds in chrysanthemum flowers. Despite its relatively high acute toxicity to mammals, this pesticide poses little risk because it is applied at a very low rate and typically breaks down in the environment within 12 to 24 hours (Benbrook, 2008).

A. TREATMENT OF IMPORTS

DRI values have been calculated for all crops/foods tested for pesticide residues since 1993 by the USDA's "Pesticide Data Program." The DRI for a given food-pesticide combination can be calculated in four ways drawing upon different sets of PDP residue data – (1) those samples reflecting residues in domestically grown food only, (2) all imported samples, (3) imports by country (assuming the "Rule of 10" is satisfied), and (4) all samples combined.

DRIs can be calculated using any of the four country-of-origin dataset options. Unless otherwise specified, we report DRIs based on the most recent year a crop was tested by PDP and for domestically grown samples only.

The ability to assess dietary risks in imported food is important because imports account for a substantial share of fresh fruit and vegetable consumption, especially during the winter months when there are no or limited supplies of fresh produce grown in North America. The frequency and levels of pesticide residues vary markedly in some imports compared to domestically grown produce, and more often than not pose greater pesticide dietary risk per serving. For this reason, we sometimes calculate DRIs specific to just the imported samples of a given food, and compare pesticide dietary risks in domestically grown versus imported food. Such data are accessible in the PDP for most major fruits and vegetables for which imports dominate fresh consumption during off-season months (e.g., fresh grapes, spinach, tomatoes, pears, peaches, strawberries).

B. RESIDUES NOT LINKED TO FIELD APPLICATIONS

Some of the pesticide residues detected in a given food do not stem from applications of pesticides in the field during the growing season. In the case of some perishable fruits and vegetables, one-third to one-half of the residues found are from fungicides applied post-harvest, typically in storage facilities. Clearly, farmers have no control over these applications and residues.

Chlorinated hydrocarbon insecticides (e.g., DDT, toxaphene, chlordane) that were banned some 30 years ago still account for a significant share of residues in many animal products and some root and leafy green crops. Again, there is nothing farmers can do to avoid these residues when certain crops are grown in soils containing organochlorine residues , other than testing soils and avoiding contaminated fields.

A significant share of the residues found in organic food samples are from drift, contaminated fog or water, or residues bound in the soil (Baker et al., 2000; Benbrook, 2008). Growers also have little or no control over these sources of residues.

C. DEALING WITH ISOMERS AND METABOLITES

One of the most complex challenges in using the PDP dataset for assessment of dietary exposure/risk levels arises from changes over time in how the PDP tests for and reports residues for pesticide parent active ingredients, isomers, and metabolites. A few dozen pesticides have been handled differently over time in the PDP. In some years, results are reported just for parent compounds, while in other years, the results cover parent compounds, plus one or more isomer and metabolite. The nature and number of isomers/metabolites varies over time in some cases. Sometimes values are reported for the parent compound alone and in other cases they are not.

Each method for reporting pesticide-specific PDP results has been evaluated by year to determine the appropriate basis to calculate DRIs for a given pesticide-food combination in each year of PDP testing, beginning in 1993. For dozens of active ingredients, the PDP reports results separately for two or more isomers or metabolites of a pesticide active ingredient, as well as for the parent compound. In a smaller number of cases, the PDP also reports results for "Total" residues associated with a given parent active ingredient (e.g., "Total Endosulfans" and "Endosulfans," or "Total Permethrins" or "Permethrins"). These results reflect the presence of the parent compound, plus all metabolites/isomers also detected. In such cases, special care must be exercised to avoid double counting residues and risk in estimating DRIs.

In cases where the PDP reports results for individual isomers and metabolites, as well as "total" residues of the pesticide, DRI values are based just on the "total" residue results. When PDP reports values for the parent compound and one or more isomer or metabolite, a DRI value is calculated for each based on the residue data specific to the parent compound, isomers, and metabolites, and then added together to equal the total pesticide DRI.

For example, the 2008 PDP reports residues of endosulfan I, endosulfan II, and endosulfan sulfate. DRI values are calculated for each of these three forms of endosulfan and the values are added together to form the final, total endosulfan DRI value for a given food.

In the case of permethrin, in recent years the PDP has been reporting results for "Permethrin Total," as well as for two stereoisomers, permethrin cis and permethrin trans. In this case, DRI values are computed based on the residue data reported for "Permethrin Total." In earlier years, the PDP did not report residue data on total permethrins, and so DRIs are calculated and added together for the isomers of permentrin.

To sort through the various, sometimes-complex cases that arise, a set of decision rules are necessary. If roughly the same number of samples were tested for the presence of the parent compound and each isomer and metabolite, the pesticide's DRI is based on the higher of the parent compound DRI or the sum of DRIs across all isomers and metabolites. This eliminates the artificial inflation of risk levels, which would come about as a result of double counting the risk associated with certain residues.

D. IMPACT OF GRADUALLY FALLING LIMITS OF DETECTION

The mean of all positive residues found by PDP in a given crop is one of two key variables in calculating DRIs. The limits of detection (LOD) embedded in residue chemistry methods and equipment are important in determining mean residue levels. The more sensitive the analytical method (i.e. the lower the LOD), the more low-end positives will be found. As a result, incrementally lower LODs will lead to lower mean residue levels and lower DRIs.

Changes in LODs over time also impact DRI trends. In the case of PDP residue testing, incremental improvements in analytical methods have steadily reduced LODs, in some cases by 100-fold or more in the last 15 years. Such progress in the sensitivity of analytical methods tends to lower mean residue levels, and as a result, DRI values, even in cases where the upper end of residue distributions have not changed.

For this reason, special procedures may need to be followed if and when multiple residue datasets with different LODs are used in calculating DRIs across foods. One option to address this problem of variable LODs is to truncate datasets at some point in the distribution of values, e.g. at the highest LOD in all years of testing.

IV. APPLYING THE DRI TO ASSESS PESTICIDE DIETARY RISK LEVELS AND TRENDS

The higher the DRI value, the greater the relative risk, but how can DRI values be placed into perspective in light of EPA's determination of the maximum residue level that meets - or exceeds - the FQPA's "reasonable certainty of no harm" standard?

Whenever the mean residue level of a particular pesticide in a given food equals or exceeds the applicable chronic Reference Concentration or cPAD, individuals consuming a single serving of the food with such residues will ingest, on average, the maximum amount of the pesticide that EPA regards as consistent with the FQPA's "reasonable certainty of no harm" standard.

When a DRI value equals one, this means that the average residue level will fill the pesticide's risk cup. This implies, of course, that a segment of the population of individuals consuming the food will ingest residues above the maximum level consistent with the FQPA's safety standard, while another segment will consume residues and face risks below the FQPA threshold.

It is also important to recognize that the DRI value for a given food use of a pesticide, say on apples, is a measure of relative dietary risks from residues in apples compared to residues found in a serving of any other food. The DRI does not take into account how frequently a particular food is consumed, but it does take into account daily average food consumption levels from one or more servings.

A. AGGREGATING DRI VALUES

The DRI measures the pesticide risk associated with individual pesticide-food combinations, although DRIs can be added together in two ways :

- Across all the foods in which a particular pesticide was found, producing an aggregate, pesticide-specific DRI, and
- Across all pesticides found in a specific food, creating an aggregate, food-specific DRI reflecting all the pesticides found in a particular food in a given round of residue testing.

The EPA is required by the FQPA to base its dietary risk assessments on exposures from all applicable routes (food, beverages, the air), and all the foods and beverages in which a given pesticide may be found. For most herbicides, drinking water accounts for most residues and risk, since residues of herbicides in food are detected infrequently. For this reason, no one pesticide use on a single crop (e.g., chlorpyrifos on pears) can "use up" the entire "risk cup" available for the pesticide. In general, the more food crops a pesticide is applied on in ways leading to residues, the lower the acceptable level of residues in any individual food.

Several widely used fungicides and insecticides are found by PDP in one-third to one-half, or more of the foods tested by PDP annually. Twelve PDP-tested foods in 2009 contained chlorpyrifos residues, with apples posing the highest DRI value of 15.8. Aggregate chlorpyrifos DRI across the 12 foods was 32. In 2008, 12,000 samples of 26 fresh and processed foods were tested in the PDP. Nineteen foods were found to contain 361 residues of chlorpyrifos, accounting for an aggregate DRI of 81. A very high DRI in collard greens in 2007 (DRI = 158) drove the aggregate chlorpyrifos DRI up to 208.

As a general rule of thumb, no single pesticide-food DRI should exceed 0.1. If residues are managed down to this level, aggregate DRIs across all foods in which a given pesticide is found are not likely to exceed 1.0.

What Does a DRI>1 Mean?

DRI values greater than one do not mean inevitable toxic harm, but rather represent a reduction in the typical 100- to 1,000-fold margin of safety that EPA incorporates in its assessment of dietary risk and in the setting of pesticide tolerances. "DRI = 10" means, in effect, that EPA's typical 100-fold safety factor has been reduced to a 10-fold safety factor, for individuals consuming average residue levels. For those consuming above-average residues on any given day, their margin of safety is eroded further.

While the DRI is based on averages, the EPA strives to assure a "reasonable certainty of no harm" for nearly everyone. The agency strives toward this goal by assessing distributions of pesticide exposure and risk levels that take into account variation in the amount of different foods eaten in a day, as well as average residue levels in foods. EPA dietary risk assessment policy attempts to "protect" the person at the 99.9th percentile of the risk distribution curve. The agency deems this goal to be achieved when the exposure level for the person at the 99.9th percentile does not exceed that person's allowed daily dose of the pesticide.

The person at the 50th percentile of the same risk distribution curve will be over-protected by several-fold when the person at the 99.9th percentile is just at the maximum allowed exposure.

Any pesticide-food combination posing DRI risks equal to or above one almost certainly exceeds EPA's level of concern. Pesticide-food combinations with a DRI of less than 0.1 likely do not warrant EPA attention, at least not based on current knowledge and information. These benchmarks along the dietary risk continuum can serve as preliminary cutoffs for risk categories:

- Pesticide-food DRI values of 1.0 or higher – "Significant risk likely in need of mitigation"
- Pesticide-food DRI values between 0.1 and 1.0 – "Moderate risk"
- Pesticide-food DRI values below 0.1 – "Low risk"

In the vast majority of foods and years, relatively few pesticide-food combinations have DRIs over 1.0. In the case of apples and PDP testing in 2009, 3,553 residues of 51 different pesticides were found in 724 samples of domestically grown apples. These residues included pesticide parent compounds, isomers, and metabolites. Two pesticide-apple combinations in 2009 have DRIs over 1.0 – chlorpyrifos (15.8) and dicofol (12.2). Four have values over 0.1 but below 1.0 – diazinon (0.6), azinphos methyl (0.2), fenpropathrin (0.28), and dimethoate (0.11). The other 45 residues fall in the "low risk" category with DRIs below 0.1.

B. TAKING THE FREQUENCY OF RESIDUES INTO ACCOUNT

DRIs for a given pesticide-food combination can be reported in two ways:

- The "Positive Sample Mean DRI," or DRI-M, and
- The "Food Supply DRI," or FS-DRI.

The DRI-mean is based on the mean of all positive samples, and does not take into account the frequency of residues. This formulation of the DRI compares relative risk associated with one food (e.g. apples) containing a given pesticide (e.g. azinphos methyl, or AZM), versus another food (e.g., melons) containing AZM. The percent of samples testing positive for AZM in apples might be 5%, while AZM residues might be present in 50% of the melon samples tested in the same year.

Let's assume the melon and apple serving sizes are the same and the same amount of melons and apples are consumed on an annual basis. Then, if the AZM mean residue level is the same in apples and melons, the DRI will also be the same. But given that residues appear in melons 10-times more frequently, AZM in melons would contribute more significantly than AZM in apples to overall AZM risk in the diet.

The "Food Supply DRI" is simply the DRI-Mean multiplied by the percent of samples testing positive. Accordingly, the FS-DRI takes into account both the mean residue level and how frequently residues are present. This measure of relative pesticide dietary risk is the functional equivalent of placing the nation's entire, annual fresh apple supply in a blender, in which a uniform mash is created. If a sample were taken of this mash and tested for AZM, the residue level found should produce roughly the same value as the FS-DRI.

These two forms of the DRI are designed for different purposes. The DRI-Mean compares risk levels in a serving of two foods, both known to contain residues of a single pesticide, or multiple pesticides. The FS-DRI, on the other hand, reflects average pesticide risk levels across many servings of a given food, or many servings of different foods, and takes into account the frequency of residues in addition to mean residue levels.

When DRI-Mean values are aggregated across all pesticides found in a given food, the resulting number reflects a usually implausible worst-case assumption – residues are present of each and every pesticide in all servings of a given food. Fortunately, this is rarely true.

Take AZM in 2008. AZM was found in six foods tested by PDP in that year. In two foods, less than 1% of samples tested positive. Other foods had "percent positive" levels of 1.2%, 4.2%, 5.2%, and 7.1%.

The aggregate AZM DRI-Mean across the six foods with residues was 1.1, just over the 1.0 significant risk threshold. But the Food Supply DRI was only 0.035, 31-times lower than the DRI-Mean. This big difference reflects the relatively low frequency of residues, even in the food with the highest percent positive (frozen blueberries).

When aggregating DRIs across foods or pesticides, it is far more realistic to add together FS-DRIs. In most applications of the DRI in assessing pesticide risk levels and trends, we will focus on the FS-DRI to avoid overstating risks.

Risk Distributions

Our analyses of PDP data over the last 15 years drives home a key point – pesticide risks are highly concentrated in a relatively few pesticide-food combinations. This is an important insight, since it suggests that the targeting of pest management research investments and regulatory interventions to just those pesticide-food combinations accounting for the largest shares of risk can markedly reduce overall risks, while minimizing the disruption in conventional, chemical-based control strategies.

To gain insight on risk distributions across foods and pesticides, we calculate the percent of total risks accounted for by individual foods and pesticides. The "Percent Food Supply DRI" for a given pesticide-food combination is simply ratio of the pesticide-food FS-DRI to the aggregate FS-DRI across all pesticides found in the food. It is not uncommon for the top pesticide-food combination to account for 50% or more of the risk, and it is rare for the top combination to account for less than 25% of aggregate risk.

C. STANDARD DRI REPORTS

DRIs are calculated within a Microsoft Access database via a series of queries. The system is programmed to produce four different versions of a set of standard tables. Each "table" is generated via a pre-programmed Access "report" that contains various data fields and calculations.

The standard tables vary by level of aggregation. Each table is run four times, and encompasses a different set of samples tested in a given year by the PDP. Each table is labeled with a number, followed by a letter that indicates the country of origin status of the samples incorporated in the table, as follows:

- A – All positive samples aggregated together, regardless of country of origin;
- B – All imported positive samples together;
- C – Imported samples disaggregated by country of origin, the case where the "rule of 10" often is invoked; and
- D – Domestic positive samples only.

The standard reports covering residues from 1993 through 2009 (the most recent year for which PDP results have been released) are:

- Table 2 – Food-pesticide combination DRI values by year, ranked by FS-DRI from highest to lowest.
- Table 3 – Pesticide-food combination DRI values by year, ranked by FS-DRI.
- Table 5 – Aggregate food DRI values by year, ranked by FS-DRI across all pesticides.
- Table 7 – Aggregate pesticide DRI values by year, ranked by FS-DRI across all foods.
- Table 8 – Organophosphates only, aggregate food DRI values by year, Ranked by FS-DRI.
- Table 9 – Organophosphates only, aggregate pesticide DRI values by year, ranked by FS-DRI.
- Table 10 – Aggregate FS-DRI values by food, without banned OC's.

- Table 12 – Organophosphates only, aggregate FS-DRI values by chemical.
- Table 14 – Aggregate FS-DRI values by chemical.

In both Tables 2 and 3, all data is presented chronologically, most recent year to the oldest. Summary statistics are also provided for each food-year and pesticide-year combination that show the total number of residues found, the average number of residues found per sample tested, and aggregate DRI-Mean and FS-DRI totals.

Each of the versions of Tables 2 and 3 contain significant information. Table 2a, for example, reports the DRI by food, based on all (combined) samples. The table is 245 pages long, while Table 2d is 222 pages. Table 3 presents DRIs by pesticide, across all foods in which the pesticide was found. Table 3d is 443 pages long.

The tables reporting aggregate, annual DRI totals by food and pesticide are much shorter, generally ranging from 10 to 30 pages. The full set of tables encompasses over 3,000 pages of information. Each year in the late winter or spring, we incorporate the results from just-released PDP testing and rerun all the tables, this time with one additional year of results (2010 PDP test results are expected in February-March, 2012).

Assessing Residues in Organic Foods

In addition to the standard tables described above, we also calculate DRIs applicable to just organic samples for those organic food-year combinations that meet the "rule of 10." For each PDP year, we extract out the organic samples and calculate for each food the number of samples tested, the number of residues found, and the average number of residues per sample.

In most cases, there are relatively few samples and even fewer positives. In 2009, the PDP decided to carry out an intensive sampling of organic lettuce. A total of 318 domestic samples were tested. Fifty-five residues were found, 51 of which were of biochemical pesticides approved for use by organic farmers. On average, each organic sample tested contained only 0.17 residues (so about 8 in 10 had no resdiues). The DRI-Mean was 0.075 and the Food Supply DRI was 0.001.

Conventional lettuce was last tested in 2005. There were on average 3.9 residues in each of 735 samples, with a DRI-mean of 2.5 and a FS-DRI of 0.12. Accordingly, the lettuce FS-DRI was 120-times higher in conventional lettuce in 2005 compared to organic lettuce in 2009. Ideally, such comparisons should be made using samples tested in the same year, but this is often not possible, given the limited scope of PDP testing on a year-to-year basis.

APPENDIX. SAMPLE PAGES IN TWO STANDARD DRI TABLES

Two sample pages follow showing the standard format and contents in Table 2 and Table 3. Both tables reflect residues in domestic samples only, and hence are from Tables 2d and 3d.

All DRI tables are formatted to print in landscape orientation, and hence the two sample pages follow on the subsequent pages.

Table 2d: Food-Pesticide Combination Dietary Risk Index Values by Year for Domestic Samples, Ranked by "Food Supply DRI", PDP Data 1994-2009 [All Market Claims; No Banned OC's; Rule of 10 Imposed]

Food	Pesticide	PDP Year	Total Samples	Number of Positives	Percent Positive	Mean Residue (ppm)	cRfC (ppm)	Serving Size (grams)	Positive Samples DRI-M	Food Supply (FS) DRI	Percent FS DRI
Almonds	Chlorpyrifos	2008	173	66	38.2%	0.004	0.017	28	0.2506	0.09559	98.033%
Almonds	Dichlorvos (DDVP)	2008	173	8	4.6%	0.010	0.286	28	0.0366	0.00169	1.737%
Almonds	Phosmet	2008	173	10	5.8%	0.013	6.286	28	0.0020	0.00012	0.120%
Almonds	Piperonyl butoxide	2008	173	69	39.9%	0.018	91.429	28	0.0002	0.00008	0.079%
Almonds	MGK-264	2008	173	10	5.8%	0.010	34.857	28	0.0003	0.00002	0.016%
Almonds	Methoxyfenozide	2008	173	15	8.7%	0.005	57.143	28	0.0001	0.00001	0.008%
Almonds	Boscalid	2008	173	5	2.9%	0.015	124.571	28	0.0001	0.00000	0.003%
Almonds	Cypermethrin	2008	173	2	1.2%	0.008	34.286	28	0.0002	0.00000	0.003%
Almonds	Pyriproxyfen	2008	173	1	0.6%	0.008	200.000	28	0.0000	0.00000	0.000%
	Average Number of Samples:		173								
	Total Pesticide/Metabolites Detected and Aggregate DRI:			186					0.2902	0.0975	
	Average Detections per Sample:			1.08							
Almonds	Chlorpyrifos	2007	351	166	47.3%	0.004	0.017	28	0.2510	0.11871	99.259%
Almonds	Dichlorvos (DDVP)	2007	351	2	0.6%	0.028	0.286	28	0.0980	0.00056	0.467%
Almonds	Piperonyl butoxide	2007	351	209	59.5%	0.020	91.429	28	0.0002	0.00013	0.107%
Almonds	Phosmet	2007	351	16	4.6%	0.011	6.286	28	0.0017	0.00008	0.065%
Almonds	Iprodione	2007	351	3	0.9%	0.023	3.429	28	0.0067	0.00006	0.048%
Almonds	MGK-264	2007	351	28	8.0%	0.013	34.857	28	0.0004	0.00003	0.026%
Almonds	Boscalid	2007	351	67	19.1%	0.011	124.571	28	0.0001	0.00002	0.015%
Almonds	Methoxyfenozide	2007	351	19	5.4%	0.006	57.143	28	0.0001	0.00001	0.005%
Almonds	Cyhalothrin-L & R157836 epime	2007	351	1	0.3%	0.001	0.571	28	0.0018	0.00001	0.004%
Almonds	Esfenvalerate+Fenvalerate	2007	351	2	0.6%	0.006	11.429	28	0.0005	0.00000	0.003%
Almonds	Endosulfan sulfate	2007	351	2	0.6%	0.001	3.429	28	0.0004	0.00000	0.002%
	Average Number of Samples:		351								
	Total Pesticide/Metabolites Detected and Aggregate DRI:			515					0.3610	0.1196	
	Average Detections per Sample:			1.47							
Apple Juice	Thiabendazole	2008	71	32	45.1%	0.061	6.452	248	0.0095	0.00428	31.438%
Apple Juice	Azinphos methyl	2008	214	9	4.2%	0.008	0.096	248	0.0855	0.00360	26.404%

Table 3d: Pesticide-Food Combination Dietary Risk Index Values by Year for Domestic Samples, Ranked by "Food Supply DRI", PDP Data 1994-2009 [All Market Claims; with OC's; Rule of 10 Imposed]

Pesticide/Isomer/ Metabollite	Type of Residue	Risk Group	Food	PDP Year	Total Samples	Number of Positives	Percent Positive	Mean Residue (ppm)	cRfC (ppm)	Serving Size (grams)	Positive Sample DRI-M	Food Supply (FS) DRI	Percent FS DRI
Chlorpyrifos	Parent	Chlorpyrifos	Cucumbers	2003	375	3	0.8%	0.010	0.009	52	1.0833	0.00867	1.423%
Chlorpyrifos	Parent	Chlorpyrifos	Mushrooms	2003	469	1	0.2%	0.007	0.006	78	1.1375	0.00243	0.398%
Chlorpyrifos	Parent	Chlorpyrifos	Butter	2003	729	1	0.1%	0.003	0.096	5	0.0281	0.00004	0.006%
			Total Number of Samples:		4,668								
			Total Detections/DRI Across All Foods:			166					22.6461	0.6091	
			Average Detections per Sample:			0.04							
Chlorpyrifos	Parent	Chlorpyrifos	Peaches	2002	276	34	12.3%	0.004	0.003	150	1.3364	0.16463	38.567%
Chlorpyrifos	Parent	Chlorpyrifos	Sweet Bell Peppers	2002	151	1	0.7%	0.079	0.006	75	12.3438	0.08175	19.150%
Chlorpyrifos	Parent	Chlorpyrifos	Broccoli	2002	724	18	2.5%	0.011	0.006	78	1.8056	0.04489	10.516%
Chlorpyrifos	Parent	Chlorpyrifos	Carrots	2002	501	23	4.6%	0.006	0.008	64	0.8035	0.03689	8.641%
Chlorpyrifos	Parent	Chlorpyrifos	Apples	2002	505	1	0.2%	0.059	0.004	128	15.7333	0.03116	7.299%
Chlorpyrifos	Parent	Chlorpyrifos	Spinach	2002	339	8	2.4%	0.020	0.016	30	1.2656	0.02987	6.997%
Chlorpyrifos	Parent	Chlorpyrifos	Cucumbers	2002	76	2	2.6%	0.007	0.009	52	0.7583	0.01996	4.675%
Chlorpyrifos	Parent	Chlorpyrifos	Celery	2002	701	21	3.0%	0.006	0.010	50	0.5754	0.01724	4.038%
Chlorpyrifos	Parent	Chlorpyrifos	Mushrooms	2002	647	1	0.2%	0.002	0.006	78	0.3250	0.00050	0.118%
			Total Number of Samples:		3,920								
			Total Detections/DRI Across All Foods:			109					34.9469	0.4269	
			Average Detections per Sample:			0.03							
Chlorpyrifos	Parent	Chlorpyrifos	Apples	2001	692	55	7.9%	0.043	0.004	128	11.4133	0.90713	55.857%
Chlorpyrifos	Parent	Chlorpyrifos	Peaches	2001	263	40	15.2%	0.007	0.003	150	2.1109	0.32106	19.769%
Chlorpyrifos	Parent	Chlorpyrifos	Nectarines	2001	359	8	2.2%	0.018	0.003	142	5.3990	0.12031	7.408%
Chlorpyrifos	Parent	Chlorpyrifos	Broccoli	2001	707	17	2.4%	0.029	0.006	78	4.7221	0.11354	6.992%
Chlorpyrifos	Parent	Chlorpyrifos	Tomato Paste	2001	364	31	8.5%	0.007	0.017	28	0.4083	0.03478	2.141%
Chlorpyrifos	Parent	Chlorpyrifos	Lettuce	2001	547	7	1.3%	0.019	0.008	57	2.3071	0.02952	1.818%
Chlorpyrifos	Parent	Chlorpyrifos	Grapes	2001	377	2	0.5%	0.015	0.003	151	4.7188	0.02503	1.541%
Chlorpyrifos	Parent	Chlorpyrifos	Carrots	2001	675	5	0.7%	0.025	0.008	64	3.3067	0.02449	1.508%
Chlorpyrifos	Parent	Chlorpyrifos	Oranges	2001	702	12	1.7%	0.005	0.004	131	1.2736	0.02177	1.341%

REFERENCES

Adigun, A.A. et al., 2010. "Neonatal Organophosphate Pesticide Exposure Alters the Developmental Trajectory of Cell-Signaling Cascades Controlling Metabolism: Differential Effects of Diazinon and Parathion," *Environmental Health Perspectives*, Vol. 118, pages 210-215

Baker, B.P., Benbrook, C.M., Groth, E., and K.L. Benbrook. 2002. "Pesticide residues in conventional, integrated pest management (IPM)-grown and organic foods: insights from three US data sets," *Food Additives and Contaminants*, Vol. 19, No. 5, pages 427-446

Benbrook, C. 2008. *Simplifying the Pesticide Risk Equation: The Organic Option*, The Organic Center, Boulder, CO., access at: http://www.organic-center.org/science.pest.php?action=view&report_id=125

Benbrook, C., and D.R. Davis. 2011. *Identifying Smart Food Choices on the Path to Healthier Diets: Documentation and Applications of TOC-NQI, Version 1.1.* The Organic Center, Boulder, CO., access at: www.organic-center.org/TOC-NQI

Bouchard, M., D. Bellinger, R. Wright et al. 2010. "Attention-Deficit/Hyperactivity Disorder and Urinary Metabolites of Organophosphate Pesticides," *Pediatrics*, Vol. 125, No. 6.

Bouchard, M.F., J. Chevier, K.G. Harley et al. 2011. "Prenatal Exposure to Organophosphate Pesticides and IQ in 7-Year-Old Children," *Environmental Health Perspectives*, Vol. 119, pages 1189-1195

Christiansen, S. et al. 2009. "Synergistic Disruption of External Male Sex Organ Development by a Mixture of Four Antiandrogens," *Environmental Health Perspectives*, Vol. 117, No. 2

Engel, S.M., J. Wetmur, J. Chen et al. 2011. "Prenatal Exposure to Organophosphates, Paraoxonase 1, and Cognitive Development in Childhood," *Environmental Health Perspectives*, Vol. 119, pages 1182-1188

Hernandez, A.F., T. Parron, and R. Alarcon. 2011. "Pesticides and Asthma," *Current Opinion in Allergy and Clinical Immunology*, Vol. 11, pages 90-96

Lim, S. et al. 2009. "Chronic Exposure to the Herbicide, Atrazine, Causes Mitochondrial Dysfunction and Insulin resistance," *PlosOne*, Vol. 4, Issue 4.

Marks, A.R., K. Harley, A. Broadman et al. 2010. "Organophosphate pesticide exposure and attention in young Mexican-American children: the CHAMACOS Study, *Environmental Health Perspectives*, Vol. 118, pages 1768-1774

National Research Council, 1993. *Pesticides in the Diets of Infants and Children*. National Academy Press, Washington, D.C.

Patel, C., et al., "An Environment-Wide Association Study (EWAS) on Type 2 Diabetes Mellitus," *PlosOne*, Vol. 5, Issue 5

Rauh, V., S. Arunajadai, M. Horton, et al.. 2011. "Seven-Year Neurodevelopmental Scores and Prenatal Exposure to Chlorpyrifos, a Common Agricultural pesticide," *Environmental Health Perspectives*, Vol. 119, pages 1196-1201

Whyatt, R.M., V.A. Rauh, D.B. Barr et al. 2004. "Prenatal insecticide exposure and birth weight and length among an urban minority cohort," *Environmental Health Perspectives*, Vol. 112, pages 1125-1132

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Documentation and Applications of TOC-Dietary Risk Index

The Organic Center's "Dietary Risk Index "

Tracking Relative Pesticide Risks in Foods and Beverages

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