Thirty Years After the FQPA: Pesticide Regulation and Dietary Risk Protection in the United States

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Abstract

The year 2026 marks the 30th anniversary of the Food Quality Protection Act (FQPA). The act represented a major shift in U.S. pesticide policy by replacing traditional chemical-specific standards with a comprehensive health-based framework for regulating pesticide residues in food.

Under the FQPA, the U.S. Environmental Protection Agency (EPA), the Food and Drug Administration (FDA), and the U.S. Department of Agriculture (USDA) share responsibility for pesticide regulation. Together, these agencies establish residue standards, conduct dietary exposure assessments, and enforce requirements designed to protect public health. In practice, EPA applies a risk assessment framework that incorporates updated toxicological standards, aggregate exposure assessments, and additional protections for infants and children.

At the state level, the California Department of Pesticide Regulation (CDPR) independently monitors and evaluates food produced or sold in California. CDPR tracks pesticide use and evaluates residue data to assess whether a certain pesticide poses an unacceptable dietary risk. Throughout the corporation, federal and state agencies conduct a science-based regulatory process that protects food safety and strengthens public confidence in the safety of U.S. agricultural products.

This presentation reviews the history and key provisions of pesticide residues in food and examines how federal and state agencies carry out their responsibilities under the FQPA. It focuses particularly on pesticide regulation and dietary risk protection in the United States.

Keywords: Pesticide residue, Tolerance, Food Quality Protection Act, Dietary risk

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Acronyms

AMS: Agricultural Marketing Service
CalEPA: California Environmental Protection Agency
CDFA: California Department of Food and Agriculture
CDPR: California Department of Pesticide Regulation
CPRMP: California Pesticide Residue Monitoring Program
CSFII: Continuing Survey of Food Intakes by Individuals
EPA: Environmental Protection Agency
FCID: Food Commodity Intake Database

FDA: Food and Drug Administration
FFDCA: Federal Food, Drug, and Cosmetic Act
FIFRA: Federal Insecticide, Fungicide, and Rodenticide Act
FQPA: Food Quality Protection Act
FSIS: Food Safety and Inspection Service
NOAEL: No Observed Adverse Effect Level
MRL: Maximum Residue Limits
NHANES: National Health and Nutrition Examination Survey
NRDC: Natural Resources Defense Council
MOE: Margin of Exposure
OPP: Office of Pesticide Programs
PAD: Population Adjusted Dose
RfD: Reference Dose
TDS: Total Diet Study
UF: Uncertainty factors
USDA: U.S. Department of Agriculture
WWEIA: What We Eat in America

Pest(icide) Issue in Modern Agriculture

Modern agriculture's heavily relies on large-scale monoculture that create the conditions for pest outbreaks. In addition, moving crops into new regions can also elevate insect populations that were previously minor or localized, especially when natural predators or ecological checks are absent. These developments helped drive the need for pesticide regulation.

Due to the rise of pest issues and increasing needs for pesticides, pesticides have been churned out in the market. New York passed the nation's first pesticide regulation law in 1898. California followed in 1901, but both early laws only addressed a narrower issue: preventing consumer fraud in the sale of Paris green, an arsenic-containing pigment used to control insects in agricultural fields. These early regulations reflected a growing recognition that pesticides, although valuable for crop protection, required oversight to ensure they were used properly and safely.

The first federal law, the Federal Insecticide Act, was enacted in 1910. It focused primarily on protecting farmers from false or misleading claims, rather than addressing broader concerns about human health, wildlife, or environmental effects. The U.S. Department of Agriculture (USDA) was charged with ensuring product quality and effectiveness, but it paid little attention to the wider consequences of pesticide use.[1]

First Law for Food Safety

In 1906, Upton Sinclair's novel *The Jungle* exposed the terrible conditions inside Chicago meatpacking plants and shocked the public. The reaction pushed Congress and President Theodore Roosevelt to act out of concern for food safety. On June 30, 1906, Roosevelt signed the Food and Drug Act, which prohibited unsafe substances in food and created the Food and Drug Administration (FDA).[2]

The Food and Drug Act marked the beginning of modern food-safety regulation in the United States. It helped establish the idea that the government had a duty to protect consumers from adulterated or dangerous food. On the same day, Roosevelt also signed the Meat Inspection Act, which required the USDA to inspect a variety of livestock, such as cattle, swine, sheep, goats, and horses, before and after slaughter.

Focus Turns to Pesticide Residues on Food

Food safety concerns extended beyond spoiled meat. In the early 1900s, pesticide residues on fruits and vegetables became an important public issue as farmers increasingly relied on chemical sprays to protect crops.

In 1919, a Boston city inspector noticed a fruit stand with pears covered in white powder. The powder was later identified as arsenic, which had been sprayed onto the fruit trees to control insects.

In December 1925, British consumers became ill after eating American-grown fruit, and authorities began testing imported shipments. The investigation found arsenic residues above the allowable level. The British Health Ministry then warned people not to eat imported apples and stated (CDPR 2001),

> especially … apples grown in dry foreign climates, where the apples are repeatedly sprayed during growth or the rainfall is not sufficient to wash off the deposit.

The warning finally caused a major economic effect. California fruit sales fell sharply, and state regulators began testing produce for pesticide residues. In 1927, the FDA set the first federal limits (aka tolerances) for arsenic residues on apples and pears in interstate commerce and for export. By the 1940s, monitoring expanded beyond arsenic to include DDT and other organic compounds.

Registration and Tolerance (1940s–1950s)

The Federal Insecticide Act of 1910 set standards for chemical quality and protected consumers from fraudulent products, but it did not address the growing concern that widespread insecticide use could harm people, wildlife, or the environment.[3] In 1947, Congress passed the Federal Insecticide, Fungicide, and Rodenticide Act (FIFRA), which gave the federal government authority to register pesticides and evaluate whether they were effective and safe enough to be sold.

The Federal Food, Drug, and Cosmetic Act (FFDCA), which passed in 1938, expanded federal oversight by allowing regulators to set legal limits for pesticide residues on food and animal feed. In the United States, these limits are called tolerances. They define the maximum amount of a pesticide residue that may remain on a crop after harvest. In many other countries, the same idea is called Maximum Residue Limits (MRLs).

Under the FFDCA, a pesticide could not be registered for crop use before the FDA set a tolerance showing that the residue was at a level considered safe. This requirement laid the foundation for modern residue monitoring and enforcement programs.

In 1958, the Delaney Clause added another layer of protection by banning any food additive found to cause cancer in humans or laboratory animals. However, under this amendment, tumors in animal tests for new pesticides would prohibit products considered safer and would not allow replacing older, more toxic pesticides. The paradoxical outcome when applying the Delaney Clause to pesticide residues in processed foods is also known as the “Delaney Paradox”.

From Environmental Movement to Risk Assessment (1960s - 1980s)

In the 1950s, attention to pesticide exposure increasingly shifted toward occupational risks, particularly for field workers who came into contact with residues on treated foliage. As pesticide use expanded and application methods evolved, concerns grew about the potential health effects among agricultural workers who were routinely exposed during harvesting, pruning, and other field activities.

In 1962, Rachel Carson's *Silent Spring* captured the public's attention, raised awareness of environmental issues, and called for a ban on numerous pesticides. In response to these concerns, Congress created the Environmental Protection Agency (EPA) in 1970 and shifted the responsibility for regulating pesticides from the U.S. Department of Agriculture (USDA).

Further reforms followed. The 1972 amendments to FIFRA established a clear distinction between general-use pesticides, which pose relatively lower risk, and restricted-use pesticides. Restricted pesticides can only be applied by certified applicators due to their potential hazards. This classification system remains central to modern pesticide regulation.

By the late 1980s, risk assessors further broadened their focus to include residential exposures. This reflected growing recognition that pesticide residues could also pose risks to people in and around the home, including lawn and garden applications, indoor pest control, and drift from nearby agricultural areas. These developments were an important evolution in pesticide risk assessment that expanded the scope from farm-centric concerns to a more comprehensive evaluation of how pesticide residues can affect both workers and the general public.

Another milestone in the evolution of health risk-based regulation came with the EPA's adoption of the "Red Book," the 1983 National Research Council report *Risk Assessment in the Federal Government: Managing the Process*. The report introduced a four-step risk-assessment framework, including hazard identification, dose-response assessment, exposure assessment, and risk characterization, which continues to guide the EPA's evaluation of environmental hazards today.

Public Awareness of Food Safety

In February 1989, the Natural Resources Defense Council (NRDC) issued a report *Intolerable Risk: Pesticides in our Children's Food*,[4] that looked at the hazards of 23 pesticides found in fruits and vegetables commonly consumed by children under the age of six, concluding that the pesticide regulatory system was inadequate to protect children. On the same date, the CBS documentary show 60 Minutes featured one of those chemicals –Alar, which was still being used in spite of the actions of processors and grocery stores– in a segment called "A is for Apples." [5] Its message reflected a broader concern that federal oversight had not kept pace with the increasing volume and complexity of pesticide use in agriculture.[6]

The NRDC report helped catalyze political action. At the same time, California's Food Safety Act was established (CDPR 2001). It's one of the earliest state-level efforts to strengthen pesticide oversight and establish more protective standards for food residues. It required regulators to assess dietary risks from consuming produce and processed foods treated with pesticides (Silva and Carr Jr 2010).

This period marked a turning point in the national conversation, shifting pesticide regulation further toward a public-health focus and laying the groundwork for later reforms such as the Food Quality Protection Act of 1996.

Food Quality Protection Act of 1996

On August 3, 1996, President Clinton signed the Food Quality Protection Act (FQPA)[7], a landmark bill passed unanimously by Congress and a new beginning for food safety. It amended FFDCA and FIFRA to create a more comprehensive, health-based standard for all pesticides on all foods.

During the signing ceremony, President Clinton stated:

> Today we add the cornerstone to this solid foundation with the Food Quality Protection Act. I like to think of it as the "peace of mind act", because it'll give parents the peace of mind that comes from knowing that the fruits, the vegetables, the grains that they put down in front of their children are safe.[8]

Pesticide Risk Assessment

The FQPA required EPA to develop more refined methodologies for pesticide risk assessment, especially for dietary assessment in children.[9] The agency had to determine whether a pesticide could be used with "a reasonable certainty of no harm," while also considering aggregate exposure from non-occupational sources.

> …a reasonable certainty that no harm will result from aggregate exposure to the pesticide chemical residue, including all anticipated dietary exposures and all other exposures for which there is reliable information (stat.1516).

Under the FQPA, EPA is required to:

- **consider aggregate risk from multiple exposure sources, including food, water, residential exposure, and other nonoccupational pathways;**
- **combine risk assessments for chemicals with a common mechanism of toxicity through cumulative risk assessment;** and
- **provide additional protection for infants and children.**

Tolerance of Pesticide Residues on Food

The FQPA amended the FFDCA and consolidated the U.S. EPA authority to establish, modify, or revoke pesticide tolerances under section 408 of the FFDCA. Under this authority:

> The Administrator may issue regulations establishing, modifying, or revoking a tolerance for a pesticide chemical residue in or on a food (stat.1515).

A *tolerance* is a legally enforceable maximum level—usually expressed in parts per million (ppm)—of a pesticide and/or its metabolites that may be present in or on commodities such as fresh and processed foods, animal feed, meat, milk, and eggs. These limits are based on maximum residue levels observed in field trials, using **highest number of applications**, the **maximum application rate**, and the **shortest pre-harvest interval**[10].

The FQPA also prevented states from establishing their own tolerance levels for pesticide residues. Additionally, it removed pesticide use from the Delaney Clause. By implementing a single standard for all foods, the act eliminates inconsistencies between allowable pesticide residues on processed foods and those on raw agricultural commodities.

From Uncertainty Factors to Safety Factors

To decide whether a pesticide is safe, regulators estimate how much of a chemical that a person can be exposed to without harmful effects. The process usually starts with a reference dose (RfD) or a population-adjusted dose (PAD), both based on the highest dose that does not cause observable harm in tests. This value is called the no-observed-adverse-effect level (NOAEL).

Because laboratory studies do not perfectly match real-life human exposure, EPA applies uncertainty factors to account for differences between species and variation among people. These typically include:

- **10× for differences between animals and humans**
- **10× for differences among humans**

By default, these factors create a **100× uncertainty factor**. In addition, the FQPA adds an extra **10× safety factor** to protect infants and children,

> … an additional tenfold margin of safety for the pesticide chemical residue and other sources of exposure shall be applied for infants and children to take into account potential pre- and postnatal toxicity and completeness of the data with respect to exposure and toxicity to infants and children. (stat. 1518)

reflecting the fact that children may be more vulnerable to chemical exposure, especially during early development.

This extra margin shows how the FQPA shifted the standard from deciding whether a chemical was safe for the average adult to asking whether it was safe for the most vulnerable groups as well.[11]

Residue Monitoring

The dietary risk assessments used by EPA and CDPR rely on residue data from several monitoring programs:

1. USDA Pesticide Data Program (PDP) [12]
2. U.S. FDA Residue Monitoring Program [13]
3. California Pesticide Residue Monitoring Program [14]

In May 1991, the USDA Agricultural Marketing Service (AMS) began designing and implementing the PDP to collect food-residue data, and Congress later strengthened the program through the FQPA.[15]

> "Requires residue data collection activities of the Department of Agriculture to provide for the improved surveillance of pesticide residues, including increased sampling of foods most likely consumed by infants and children. (TITLE III)"

The PDP is widely considered the best national source of residue data for dietary risk assessment (Pappas and Foos 2023). It samples foods sold in the U.S. market and pays special attention to products commonly eaten by infants and children. In addition to food, USDA also analyzes drinking water samples from participating utilities. Both EPA and CDPR use PDP data as a major input when estimating exposure and evaluating risk.

The California Pesticide Residue Monitoring Program and the U.S. FDA program are mainly enforcement-oriented. They focus on identifying illegal or unusual high residue levels in food, especially fruits and vegetables. California's program is designed to reduce public exposure to illegal pesticide residues and includes both domestic and imported produce.

US FDA Residue Monitoring Program

The US FDA enforces tolerances in both imported and domestic agricultural products shipped in interstate commerce, except for meat, poultry, and certain egg products for which the Food Safety and Inspection Service (FSIS) of the USDA is responsible (Liang et al. 2021).

Each year, FDA analyzes approximately 1000 to 2000 domestic samples and 4000 to 6000 imported samples. The regulatory pesticide residue monitoring program is a targeted sampling program. FDA also conducts special "focused sampling" assignments to target specific commodities for analysis. PDP data is the main source for FDA to inform selection of commodities for increased or decreased sampling. Factors considered when designing yearly sampling include

- **frequency of consumption of a particular food**,
- **dietary significance of foods to subsets of the population**,
- **history of violation for either the commodity or region producing the commodity**, and
- **pesticide usage and residue data from state, federal, or foreign partners**.

FDA also conducts the Total Diet Study (TDS), an ongoing, statistically based program that monitors levels of about 800 contaminants, pesticides, and nutrients in the average US diet.

California Pesticide Residue Monitoring Program

Federal monitoring is an essential safeguard. However, given the size and complexity of the US food system, federal monitoring alone is not sufficient. To provide additional protection, the enforcement agencies of certain individual states (e.g., California) conduct independent programs (Zhang et al. 2015).

CDPR's CPRMP enforces the legal pesticide residue tolerances set by the USEPA to prevent "public exposure to illegal residues". CDPR focuses on sampling the following "high-risk" commodities:

- Produce highly consumed by infants and children.
- Produce treated with pesticides listed under Proposition 65[16] as carcinogens or reproductive toxins.

- Produce reflective of consumption patterns among different ethnic and socioeconomic groups.
- Produce that has a history of detected illegal pesticide residues.
- Produce originating from countries with a history of detected illegal pesticide residues.

In 1991, pesticide regulation separated from thr California Department of Food and Agriculture (CDFA). CDPR was created at the California Environmental Protection Agency (CalEPA). CDPR contracts with the CDFA Center for Analytical Chemistry for analytical services.

Between 1991 and 2011, the CDFA laboratories analyzed all samples using multi-residue screens that could detect more than 200 pesticide active ingredients and breakdown products at the parts per billion level. In 2012, the CDFA Center for Analytical Chemistry improved its capacity to detect pesticide residues. During that year, the CDFA laboratory in Sacramento replaced the “old” multi-residue screens with two new analytical techniques, LC-MS/MS (liquid chromatography—tandem mass spectrometry) and GC-MS/ MS (gas chromatography—tandem mass spectrometry).

Dietary Exposure Assessment

Pesticide residues in the diet represent the primary source of pesticide exposure for the general public.

Dietary exposure is a function of the type and amount of food consumed and the pesticide residues in or on that food. The total dietary intake of a single pesticide for any population is calculated by summing the potential pesticide intake from all food items that potentially contain its residues. The basic model for estimating dietary exposure to chemical residues in food is very simple:

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Pesticide Ingested = Residue Concentration x Foods Consumed
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There are numerous dietary exposure models ranging from single (point) exposure residue estimates to complex simulation analyses using probabilistic approaches. But all models, however complex, are based on the basic relationship: Exposure depends on the residue concentration in the food and on the amount of food consumed.

Acute and chronic exposure

Two types of dietary exposure are generally considered: **chronic** and **acute**. Chronic exposure occurs over a long period of time. It is calculated for typical exposure levels and therefore uses mean consumption and mean residue values. Acute dietary exposure is calculated using an extreme exposure scenario.

Regulators usually conduct dietary exposure assessment under the tier-based approach as,

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- Tier 1: Tolerance
- Tier 2: Max detect
- Tier 3: mean or 1/2 LOD
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Exposure depends on the residue concentration in the food and on the amount of food consumed. The final calculation is to divide the weight of each agricultural ingredient eaten by the weight of the individual. Children had higher estimated exposure if they consumed the same amount of food as an adult. For example, if a 60-kilogram adult consumes 60 grams of wheat per day, the consumption is expressed as 1 gram of wheat per kilogram of body weight:

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60 g ÷ 60 kg = 1 g/kg.
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A 20-kilogram child who eats 60 grams of wheat per day consumes approximately 3 grams of wheat per kilogram of body weight:

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60 g ÷ 20 kg = 3 g/kg.
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Food Consumption Database

Understanding how much food is consumed by different subpopulation groups is a core requirement of the FQPA.

> …shall include the collection of data on food consumption patterns of a statistically valid sample of infants and children (stat.1511).

The USDA has historically been the lead agency responsible for developing dietary data collection methods, maintaining food and nutrient databases, and overseeing data review and processing. USDA survey is designed to measure the types and amounts of foods consumed from a nationally representative sample of children and adults in the United States. Before 1999, the USDA was the primary agency collecting information on food consumption among the American public through the Continuing Survey of Food Intakes by Individuals (CSFII).

The CSFII is a critical tool for understanding U.S. dietary habits, providing detailed, nationally representative data on food and nutrient intakes. The data were collected in 1989–1991, 1994–1996, and 1998. Its rigorous methodology, including multiple-day recalls and structured questionnaires, ensures high-quality data that inform nutrition research, policy, and public health initiatives.

Since 1999, nationwide dietary intake data have been collected through the What We Eat in America (WWEIA) program. It represents the integration of CSFII with the National Health and Nutrition Examination Survey (NHANES) conducted by the U.S. Centers for Disease Control and Prevention (CDC).

EPA/Office of Pesticide Programs' (OPP) dietary exposure assessment methods, including the development of the Food Commodity Intake Database (FCID) [17], were originally based on CSFII (1994-96/1998). Beginning in 1999, the CSFII was integrated into the NHANES survey and was renamed the WWEIA component. FCID is a translated version of CSFII and later NHANES data that express food intake in terms of food commodities.

Exposure Models

Residue concentration and food consumption are the only two inputs the basic model requires, but exposure models differ substantially in how they combine them. The differences that matter are whether a single point estimate or a full distribution is carried through the calculation, whether exposure is tracked for a population average or for simulated individuals, whether pathways other than food are included, and—most importantly—what regulatory question the output is meant to answer.

Two model families illustrate the range: EPA/OPP's Dietary Exposure Evaluation Model (DEEM), which supports tolerance decisions, and EPA/ORD's Stochastic Human Exposure and Dose Simulation (SHEDS), which was built for research and prioritization.

DEEM-FCID and Calendex

DEEM-FCID is the regulatory workhorse for dietary assessment[18]. The model pairs residue values with the Food Commodity Intake Database, so that every food reported in WWEIA is decomposed through recipe translation into the raw agricultural commodities for which tolerances actually exist. DEEM supports both the deterministic tiers described above and probabilistic acute analyses. Chronic exposure is estimated from mean consumption and mean residues; acute exposure is estimated from the upper tail of the eating-occasion distribution. Because the underlying consumption data are periodically refreshed, the model version matters: DEEM/FCID v4.02 is based on the 2005–2010 NHANES/WWEIA survey, replacing the 2003–2008 data OPP had previously used [19].

The companion module, Calendex-FCID, adds a calendar dimension, allowing food, drinking water, and residential exposures to be combined on the days they plausibly co-occur—the operational answer to the FQPA's aggregate exposure requirement. DEEM is used not only by EPA/OPP but also by CDPR, which makes it the common language for federal and state dietary assessments.

SHEDS and SHEDS-HT

SHEDS came from a different starting point[20]. The original model was developed by EPA/ORD's National Exposure Research Laboratory to estimate children's residential exposure and dose to chlorpyrifos via dermal contact and nondietary ingestion (Zartarian et al. 2000). It simulates a population of individuals, each assigned activity patterns, body weights, and food diaries drawn from survey data, so the output is a distribution across simulated people rather than a single population value. SHEDS-Multimedia was later applied to children's aggregate dietary and residential exposure to permethrin (Zartarian et al. 2012), linked to a pharmacokinetic model so that predicted intakes could be evaluated against NHANES urinary biomarker data (Tornero-Velez et al. 2012), and extended to the cumulative exposure of seven pyrethroids (Xue et al. 2014).

Because running many chemicals through the full model is computationally expensive, the high-throughput version SHEDS-HT was developed to screen large numbers of chemicals with relatively few inputs (Isaacs et al. 2014).

Choosing a Model

In practice, regulatory agencies such as the U.S. EPA and CDPR rely on a deterministic approach to assess acute and chronic dietary exposure. A stochastic model built on measured residues serves a different purpose: it describes the exposure distribution as observed in the monitoring data, including the influence of individual high-residue samples, and it can be evaluated against biomonitoring data. Neither approach is more correct in the abstract; the tiered framework exists precisely so that the level of refinement matches the decision at hand.

Conclusion: Thirty Years of Science-Based Food Safety

As the United States marks the 30th anniversary of the Food Quality Protection Act in 2026, it is clear that the FQPA fundamentally transformed pesticide regulation from a fragmented, chemical-by-chemical approach into a unified, health-centric framework. The regulatory system described here—with its exposure monitoring/modeling, cumulative risk assessments, and additional protective factors for children—represents decades of institutional learning.

While no regulatory system is perfect, the FQPA's emphasis on aggregate exposure, cumulative risk, and child protection represents a significant advance in food safety science. The continued evolution of techniques, such as analytical chemistry and computational modeling, demonstrates that this system adapts as science advances.

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