Reducing Pesticide Risks

A Half Century of Progress

EPA Alumni Association

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Preface

Former managers and staff of the U.S. Environmental Protection Agency (EPA) have formed an EPA Alumni Association (EPA AA). The Association has developed this and six other web-based environmental reports in support of our *Half Century of Progress* project. An integrated summary based on all of these reports, *Protecting the Environment: A Half Century of Progress*, is available on the Association website. The Association has developed these materials to inform high school and college students and other members of the public about the major environmental problems and issues encountered in the United States in the 1960s and 70s and the actions taken and progress made in mitigating these problems over the last half-century. We also want to highlight continuing and emerging environmental challenges we face today. We hope that, besides summarizing the history of U.S. environmental programs, these reports might inspire some students and others to consider careers in the environmental field.

A number of retired EPA program managers and subject matter experts worked together to produce the first editions of these reports in 2016. Additional experts have updated these documents in 2020 in recognition of the 50th anniversary of Earth Day and the creation of the EPA. This updated report has been reviewed by relevant members the EPA AA Board of Directors and other alumni. We welcome comments on this document, which you may provide at this EPA Alumni Association link.

The Association has also produced a *Teacher's Guide* to facilitate the use of these materials by educators interested in including the *Half Century of Progress* in high school and college curricula. The *Guide* contains data interpretation and other questions related to the report topics, with answers. It also includes activities that challenge students to learn more about environmental issues in their communities, web-based resources for additional activities, and three lesson plans related to the HCP materials. These plans were designed and tested by three AP Environmental Science Teachers. Teachers may request a copy here.

BEFORE 1970

In the beginning of the 20th century, pesticides were viewed primarily as the farmers' friend. The first law regulating pesticides, passed in 1910, was all about protecting farmers from fraudulent claims. The U.S. Department of Agriculture (USDA) was required to ensure the quality and effectiveness of products, but little or no concern was given to the potential effects on humans, wildlife, or the environment in general.

Then in World War II, soldiers were protected from disease by the "miracle" pesticide DDT, which killed insects really well. Its wartime benefits soon spread widely to virtually all aspects of civilian American life, including use on a large variety of food crops, in the home, and as a weapon against insects that carried disease. DDT was celebrated as a wonderful weapon against bugs that was harmless to people, as illustrated in this ad from TIME magazine in 1947:

That same year, Congress passed the Federal Insecticide, Fungicide and Rodenticide Act (FIFRA), which required the federal government to approve (or register) products before they entered the marketplace. Again, society at large was not focused on the potential adverse effects of the ballooning number of pesticides entering everyday life.

In the 1950s, the Food and Drug Administration (FDA) began to regulate the residues left on food resulting from the use of pesticides on growing and stored crops. FDA set "tolerances" or maximum limits on the amount of residue of a specific pesticide that could be present on a particular food commodity. FDA had a fairly narrow focus on the safety of pesticide residues.

But then! Rachael Carson, a marine biologist by training, shook up the world in 1962 with the publication of *Silent Spring*. Referring to work being done by the U.S. Fish and Wildlife Service and others, Ms. Carson described the negative effects of DDT on wildlife. She warned that continued heavy use of pesticides could someday lead to a spring without birdsong. This was a major wake-up call regarding the potential unintended effects of pesticides on living things.

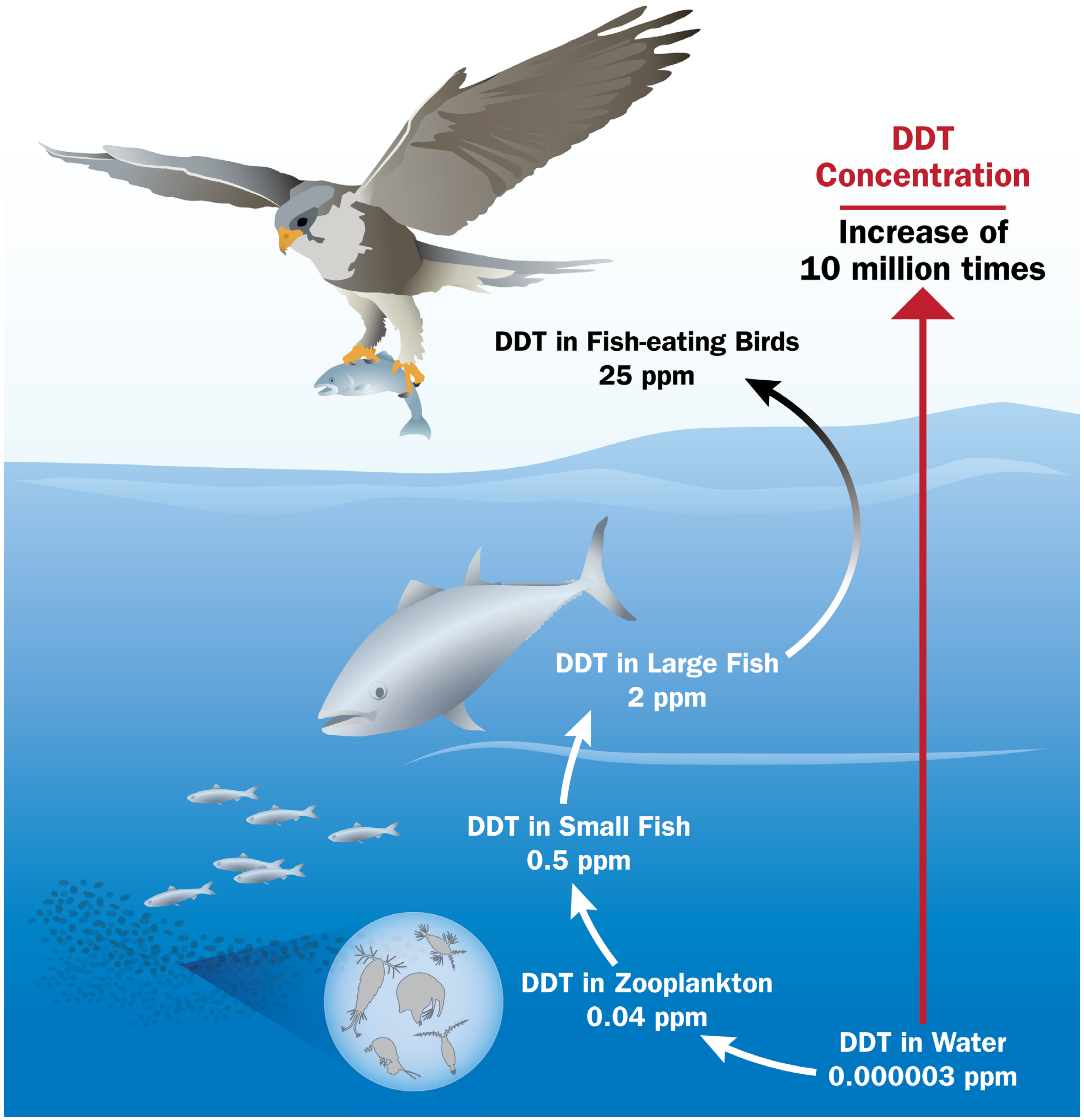
The scientific evidence began to mount. DDT and the products that DDT broke down into were found to be very long lasting in the environment. Organisms at the bottom of the food chain stored it in their tissues, and as animals higher in the food chain fed on them, the levels of DDT in their bodies concentrated and increased (a process called "biomagnification," depicted in the figure on the next page). Birds of prey in particular accumulated high levels of the pesticide, leading to thinning of eggshells and a sharp decline in the birth and survival of baby birds.

At the top of the food chain, humans were becoming exposed through their diets and the air they breathed. DDT was found to accumulate in human fat tissue—exposing developing babies before they were born—and in their mother's milk.

Moreover, evidence was building that DDT caused tumors in mice, and thus could be a potential cause of cancer in humans. The science about cancer effects was controversial, since the scientific community was just beginning to develop testing methods to identify potential human carcinogens (cancer-causing agents).

In the meantime, other pesticides chemically similar to DDT were being developed and used widely in agriculture, as well as in homes, schools, and other public buildings.

Biomagnification



THE ESTABLISHMENT OF EPA IN 1970

As other reports in this Half Century of Progress series have illustrated, by the end of the 1960s there was mounting evidence of pollution across air, land, and water, and a demand for action from the public. Public awareness and outrage led to the establishment of EPA and the passage of critical new laws to address a wide range of pollution sources. USDA's and FDA's pesticide duties were transferred to EPA when the Agency was created in 1970.

In 1972, Congress passed major amendments to FIFRA that required the newly-formed EPA to assess the potential risks of pesticides to humans, wildlife, and the environment, and to take action against pesticides whose risks were found to exceed their benefits.

In 1972, EPA banned (or "*cancelled*") virtually all uses of DDT in a landmark decision made by the first EPA Administrator, William Ruckelshaus. Then during the late 1970s, EPA began the process to ban pesticides chemically similar to DDT (called organochlorines), including aldrin, dieldrin, chlordane, heptachlor, toxaphene, and mirex. The early decisions were highly visible and controversial, with many in the agricultural community predicting dire consequences for food production. Many pesticide proponents raised alarms about potential epidemics of insect-borne diseases and questioned the practice of feeding animals high doses of chemicals to determine their cancer-causing potential.

However, alternatives to the cancelled pesticides were developed, and agricultural production has continued to thrive over the decades. Not only is there ample food to feed our own population, but also agricultural exports have steadily increased, from $40 billion in 2000 to $140 billion in 2018 according to USDA. Today, there are no organochlorine pesticides still registered.

But in 1972, when FIFRA was amended and DDT was banned, it was abundantly clear that the scientific data upon which comprehensive risk assessments could be made were woefully lacking for most pesticides. As a result, an extensive effort was begun to "call in" scientific studies. Pesticide registrants, primarily the pesticide manufacturers, were responsible for conducting the testing in accordance with Good Laboratory Practices. Informed by the new data, EPA was required by law to decide whether each pesticide sold in the United States should continue to be marketed (through a process known as "reregistration"), and whether the benefits of each use pattern exceeded the risks.

Pesticide *risk* is determined by factoring in potential *adverse effects* with potential *exposure*. This was particularly challenging as EPA scientists, with peer review from the scientific community, had to first develop the testing guidelines and protocols for a broad range of potential toxic effects. Tests needed to provide information on hazard and exposure, including acute toxicity (the extent to which the chemical caused immediate effects), birth defects, cancer, as well as what happens to the pesticide when it is released into the environment and whether it may harm nontarget animals or plants (environmental fate and effects).

At the same time, the ability to detect pesticides in food and the environment in smaller and smaller quantities was advancing. In the early days of modern agriculture, pesticides could be detected only at parts per million levels. Later, pesticide residues in the range of parts per billion could be found. Analytic methods now can detect parts per trillion or less. A part per trillion is so small it is equivalent to one bad apple in two billion barrels.

While EPA registers products on a national basis, states have significant authorities in implementing FIFRA, tribes also have authorities via cooperative agreements with EPA Regional Offices. States (and in some cases tribes) may conduct a number of activities after approval by EPA, among them:

- Deliver training and certify applicators. Some pesticides that are acutely hazardous or require special protective practices and equipment are designated “restricted use” and can be legally used only by or under the supervision of certified applicators.
- Exercise primary enforcement responsibility for violating requirements and restrictions pertaining to the use of pesticides. EPA’s Office of Enforcement and Compliance Assurance provides enforcement policy guidance and takes enforcement action where states and tribes cannot.
- Register pesticides for use in a state to meet “special local needs” for pest control.
- Issue and/or request from EPA short-term crisis/emergency exemptions for the use of pesticides at sites or on pests for which they are not registered.
- Place additional restrictions beyond the federal requirements for products used within the state.

CONCRETE AND MEASURABLE ACTIONS

There are hundreds of examples of how EPA has moved to protect the public and the environment from pesticide risks. This report illustrates two such stories: DDT and the bald eagle, and pesticide reregistration.

Bald Eagle on the Brink

Our nation's symbol, the majestic bald eagle, was on the verge of extinction because of the eggshell thinning caused by accumulation of DDT and the chemicals that resulted from its breakdown in the environment, and human activity in nesting and roosting areas. EPA's ban on DDT was critical to the recovery of the bald eagle, the brown pelican, and the peregrine falcon. Protections afforded by the Endangered Species Act, administered by the U.S. Fish and Wildlife Service, also aided in recovery.

It took years of scientific study, trial-like administrative hearings, and review by the courts before EPA could end the release of DDT and its chemical cousins to the nation's air, land, and water. Even after the ban, it took years—even decades—before residue levels declined significantly. EPA's DDT actions were aggressively challenged, with predictions of gloom and doom for crop production and disease control. The procedural and public opinion controversies swirled for years. But EPA Administrator

William Ruckelshaus stood firm, the courts backed EPA up, and the results proved the correctness of the EPA decisions.

Because DDT and its "classmates" are so persistent, extensive monitoring of the environment, plants, and animals has been conducted, beginning before DDT's cancellation in 1972 and continuing to this day. Many studies show downward trends in exposure over time in many wildlife populations. For instance, in 2005 Canadian researchers[1] noted that DDT levels significantly declined in animals and organisms in the Canadian Arctic from the 1970s to the late 1990s. Today, they are generally less than half the levels of the 1970s, particularly in seabirds and ringed seals. Another study in 2005[2] measured declines of 4- to 7-fold in DDT levels in eggs from colonies of herring gulls from Lakes Ontario and Michigan between 1971 and 1982. A third study[3] that year reported a continuous decrease in DDT concentrations in penguin droppings over the past 50 years. Yet another study[4] documented the decline in DDT breakdown products by 50% or more in osprey eggs in 1998 relative to 1989, with similar reductions in the fish that the ospreys eat.

Pesticide Residues in Bald Eagle Eggs on Lake Erie 1970–1994. **Banning DDT in 1972 reduced associated pesticide residues (DDE) that had weakened bird eggs, leading to recovery of bald eagle, brown pelican, and peregrine falcon populations in the US.** *Photo: U.S. Fish and Wildlife Service.*

And what a great end to the story! In the late 1990s and early 2000s, the Fish and Wildlife Service determined that the bald eagle, brown pelican, and peregrine falcon were no longer endangered because of their rebounding populations. Other bird species have been seen to stabilize and increase their numbers as well. This turnaround wouldn't have happened without EPA's groundbreaking science and strong stand in the face of controversy. It also illustrates that environmental progress doesn't necessarily happen overnight—ecological systems may need decades to recover after a decision is made.

New Scientific Standards for Old Pesticides

As mentioned earlier, EPA had to confront a mountain of pesticide decisions that had to be updated according to modern standards. EPA went about this enormous task in a strategic way. Spurred on by amendments to FIFRA in 1988, it grouped over 1,100 active ingredients used in over 40,000 products into 613 "cases" of similar chemicals. EPA identified a sequence of review for those cases that would be of the most benefit to the public in the shortest amount of time. It assumed that pesticides used on food crops had the highest potential for widespread exposure and risk; therefore, those chemicals were reviewed first. The remaining chemicals were set for review according to other potential risks, including human risk (for example, residues in drinking water or exposure to workers in the field or in the pest control business) and risk to nontarget species (such as beneficial insects, birds, fish, and other wildlife).

Pesticides are tested more thoroughly than any kind of chemical other than drugs. A pesticide used on food requires over 100 different tests to determine, for example, its potential to cause cancer, birth defects, and acute poisoning; impacts on birds, fish, and other nontarget wildlife; damage to the nervous system; its residue levels in crops; its longevity in the environment; and its potential to reach ground and surface waters.

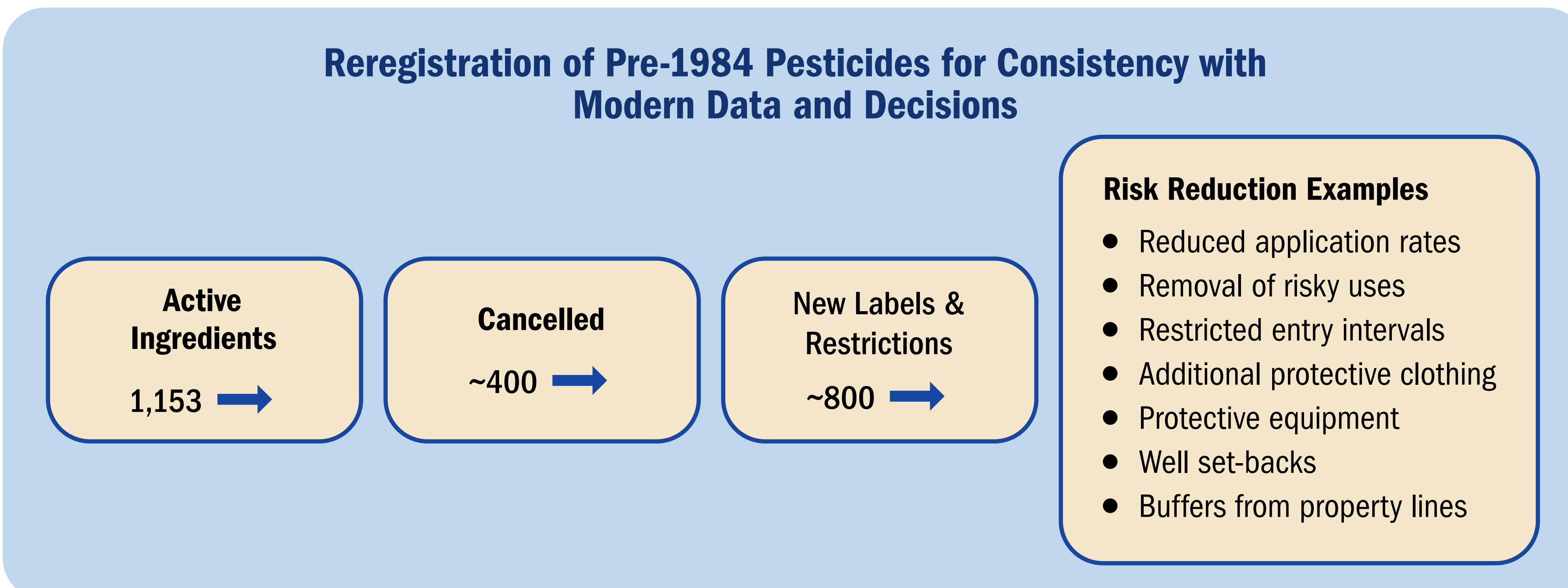
These tests are conducted by pesticide manufacturers, at costs of hundreds of thousands to millions of dollars, and evaluated by EPA scientists. The manufacturers had to decide what products they would continue to support with additional testing. As a result, almost one-third of the cases and their associated products were dropped by the industry.

And even as reregistration was moving down the track, Congress changed the requirements for review of food-use pesticides in a major way. A law passed in 1996, the Food Quality Protection Act (the "Act"), required that EPA review all existing 9,700 food tolerances over a 10-year period. A tolerance, as described earlier, is the maximum amount of a pesticide and/or its breakdown products that is allowed to remain in a food product consumed by people or animals. The Act also required that EPA add an additional safety factor to protect children, look at risks from multiple pathways of exposure (such as from eating food, drinking water, breathing air and so on), and develop a screening program to determine the effects of pesticides on hormonal systems (endocrine disruptors).

Because pesticides are used worldwide, and food is traded widely between countries, EPA had a strong interest in coordinating reviews with other countries and international bodies to develop consistent assessment guidelines and regulatory decisions. Extensive efforts were made with international organizations and trading partners to harmonize U.S. approaches. This allowed for some sharing of the workload. Even more important, harmonization also works to combat the U.S. importation of foods that could be treated abroad with pesticides banned in the United States.

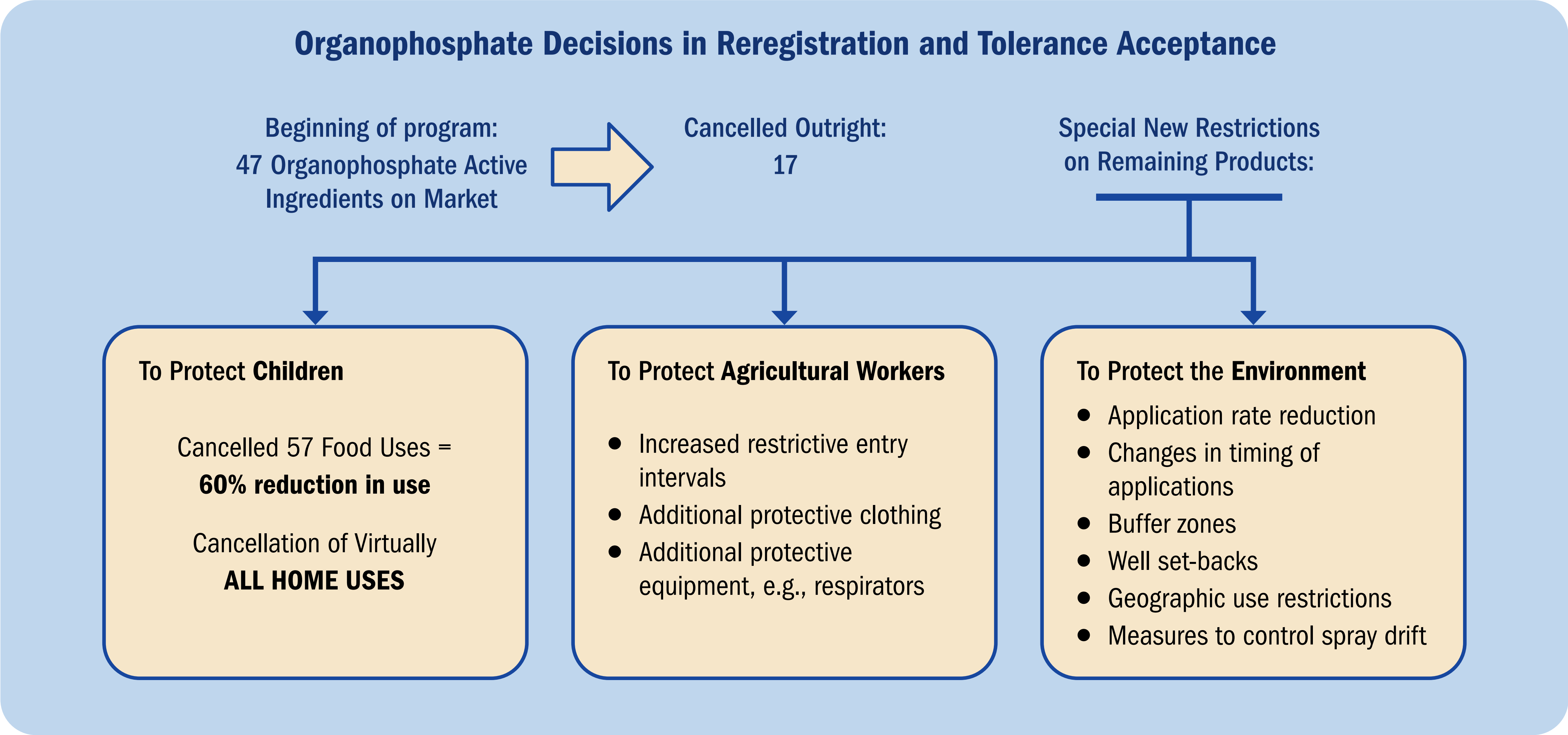
The analyses required during reregistration and tolerance review represented a monumental and complex undertaking. Thousands of new scientific studies were required, submitted, and reviewed by EPA. Reregistration ultimately resulted in the elimination of hundreds of active ingredients and products, many of which were capable of causing harmful effects in humans and other organisms, and to the environment.

The review of the almost 10,000 old food residue tolerances was completed in 2007, and the reregistration program was completed in 2008.



The history of the organophosphate pesticides in reregistration and tolerance reassessment provides a good example of how the EPA program protected public health and the environment. Organophosphates are highly toxic chemicals, and came under special scrutiny with the following results:

EPA's actions resulted in the elimination of virtually all residential uses of the organophosphates. In the case of methyl parathion, one of the more toxic organophosphates used since the 1950s, a 90% reduction of dietary risk to children was achieved. Addressing environmental justice concerns, the Agency phased out the use of the organophosphate, azinphos-methyl, due to risks to farmworkers, pesticide applicators, and aquatic ecosystems.



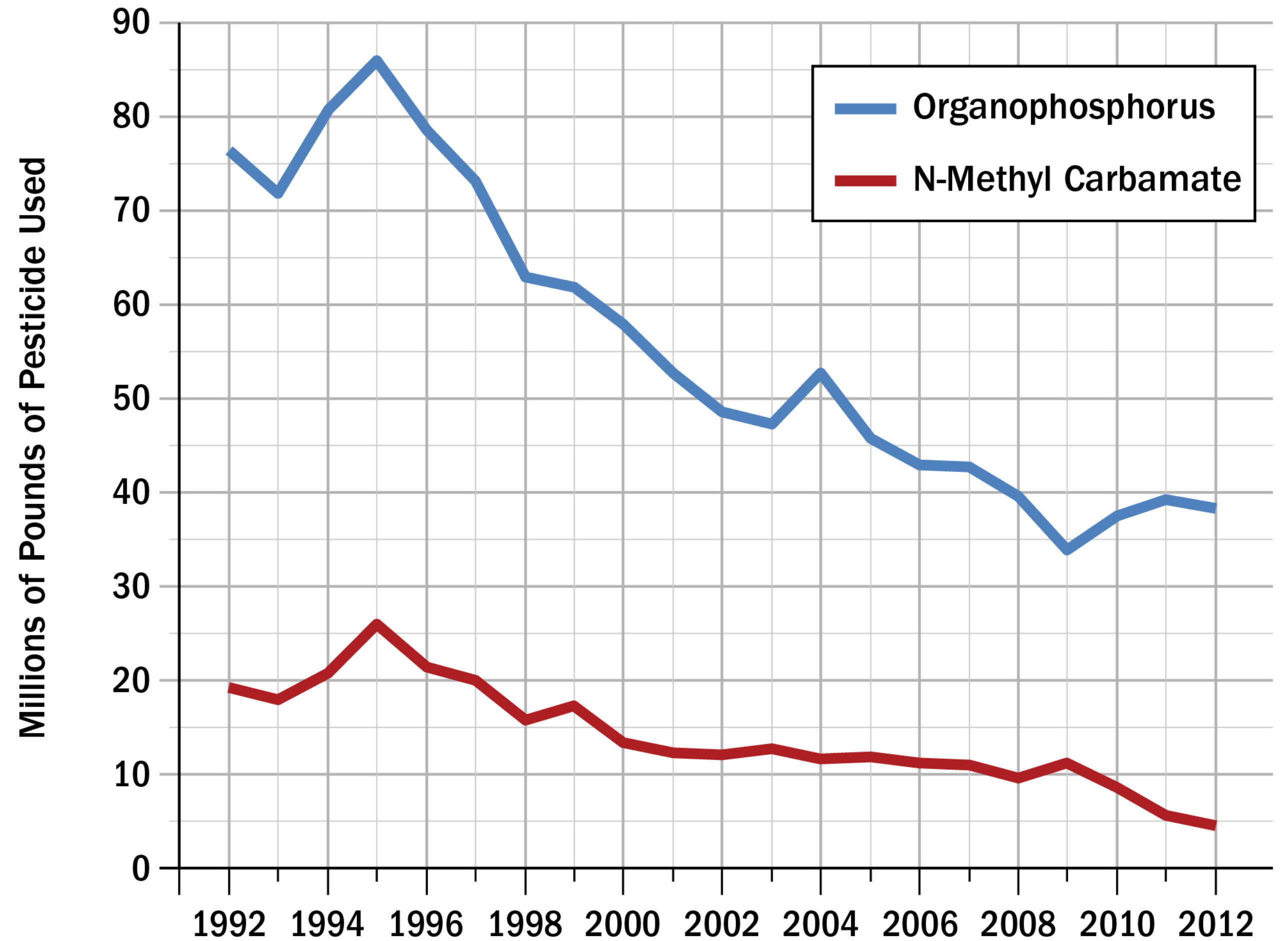
From 1994 to 2004, the amount of organophosphate pesticides used on kids' foods decreased by 57% and unintentional poisonings were reduced by 70%.

The effectiveness of the programs is also illustrated by the decrease in the use of carbamates (for example, aldicarb (Temik), carbofuran (Furadan) and carbaryl (Sevin), and organophosphates (for example, parathion, malathion, chlorpyrifos, and diazinon).

In addition, to address risks to children, in 2002 EPA and industry reached a voluntary agreement to phase out arsenic-containing wood preservatives used to construct decks, play sets, and other backyard structures.

In short, the conclusion of the reregistration and tolerance reassessment processes marked an enormous milestone in ensuring the safety of the U.S. food supply and the protection of human and ecological health.

Change in Use of Organophosphates and Carbamates in the U.S. (1992–2012)[5]



THE FUTURE

One important lesson learned over the years is that science *always* moves forward—relentlessly. EPA recognized that it had to do something to make sure that future decision makers would never have to face a big backlog of out-of-date pesticide determinations again. So, the 1996 Food Quality Protection Act included a provision that all pesticides must be reevaluated on a staggered, but regular, basis (every 15 years) in a process termed "registration review." This will ensure that, even as science moves forward, EPA never gets into the bind it confronted in 1988 when risk assessments on hundreds of active ingredients were decades out of date.

Emerging science in the realm of pesticide regulation presents some particular challenges, including:

- **Toxicity Testing.** In 2007, the National Research Council, an arm of the National Academy of Sciences, issued a report presenting a vision and a path forward for wholesale transformation of the traditional approaches to toxicity testing.[6] Historically, when determining risk, scientists relied primarily on observing harmful effects in similar groups of animals exposed to relatively high doses of chemicals. This approach is expensive, time consuming, and viewed as inhumane by many people, especially animal rights groups. Relatively few existing chemicals other than pesticides and drugs have been evaluated for risk using these methods. Important facts about how chemicals interact in the real world remain unknown. The scientific community still has little information on how chemicals produce their effects, which is critical for understanding differences between species—or between individual human beings, for that matter.

  At the core of the path forward is a shift from collecting observations in whole animals to the identification of the ways chemicals affect animal cells. This is opening the door to the use of many new tools that are providing knowledge about biologic processes and functions. EPA is working with academia, industry, other government agencies, and international organizations to develop effective alternatives to animal testing and has already found ways to refine, reduce, or replace animal with non-animal studies.

  Traditional methods are also being replaced by computer-based tools and short-term assays that require less or no animal tissue. Some short-term assays can be conducted by machines (robotics), so that many chemicals can be tested at multiple doses within hours to days, rather than weeks to years.

- **Endocrine Disruptors.** As mentioned earlier, the 1996 Food Quality Protection Act required EPA to screen pesticide chemicals for their potential to produce effects similar to those produced by the female hormones (estrogens) in humans. Endocrine systems in animals produce hormones that send "messages" to the body that affect growth, including physical, intellectual, and reproductive development. Endocrine disruptors affect how those messages are sent in animals, and some have been shown to produce effects in the offspring of exposed mothers. The law also gave EPA the authority to screen other kinds of chemicals and to include other endocrine effects. Based on recommendations from an advisory committee, EPA expanded its Endocrine Disruptor Screening Program to include male hormones (androgens) and the thyroid system, and to include effects on fish and other wildlife.

  Executing a credible and efficient endocrine testing program is a formidable challenge. New methods are being developed at a rapid pace. The endocrine testing program is being propelled by more and more data from several federal programs. So far, EPA has collected estrogen screening results for 1,800 chemicals (some of which are pesticides). Government researchers have recently developed a totally new, validated animal-free screen for estrogens, a nearly-completed equivalent for androgens, and major progress on thyroid and steroid production pathways.[7]

- **Biotechnology.** Genetic modification of crops is another controversial issue. When plants are genetically modified to resist insects or other pests, EPA considers them pesticides and regulates them as such. Many environmental and consumer advocates oppose genetic modification of plants, either on general principle or the argument that their safety has not been established adequately, even though the National Academy of Sciences has repeatedly concluded that the genetically modified plants currently in the environment are safe.

  Others see plant biotechnology as a safer way to address pest control problems and a major step forward in improving nutrition and feeding the world's population. There remains strong disagreement on whether the yields of genetically modified crops grown by traditional farming can or will exceed those of conventional crops grown according to the principles of sustainable agriculture. Sustainable agriculture takes into account an understanding of whole ecosystems to integrate knowledge of many natural and biological processes, and moves away from the one-crop-at-a-time approach.

Some countries do not allow imports of genetically modified corn or other commodities, and in the United States the term "organic" may not be applied to genetically modified produce.

Government regulators have already approved or are reviewing genetic engineering of many agricultural crops, such as corn, soybean, canola, sugar beets, potato, papaya, squash, radicchio, flax, tomato, and plums. Genetic engineering is an area that will continue to grow as new methods of manipulating the genetic composition of plants are developed, and the newly engineered organisms will continue to need government scrutiny and review.

- **Decline in number and populations of species.** The World Wildlife Fund International issues a Living Planet Index, which measures more than 10,000 representative populations of mammals, birds, reptiles, amphibians, and fish. Its 2018 report notes that the total number of animals in all of these species has declined by 60 percent between 1970 and 2014. Most of that change can be attributed to human activities that take more from our ecosystems than can be renewed.

Use of pesticides is implicated in being and, in some cases has been demonstrated to be, a contributing factor to this decline in species. Decline in the numbers of monarch butterflies, honeybees, and frogs represent just *three* examples for which pesticide use does or may play a role.


Common Milkweed.

Monarch butterfly: The monarch and other butterflies are important pollinators of flowers. Milkweed is the only plant on which monarch butterflies will lay their eggs. It is the primary food source for monarch caterpillars. Between 1995 and 2013, milkweed decreased by 21 percent in the United States.[8] An estimated 550 million monarchs completed the winter migration to Mexico in 2004, but only 33 million arrived in 2013.[9] Contributing factors to the decline include large-scale use of herbicides, increased planting of corn, loss of old forests in Mexico, adverse weather conditions, and illegal logging.[10] In the United States, milkweed is destroyed along roadsides for aesthetic reasons and within or along the edges of crop fields, either purposefully or as a consequence of pesticides drifting away from sprayed fields. EPA and other government agencies are working together at home and also with Mexico and Canada to shed more light on these problems and to find new solutions.

EPA has identified measures that can be taken when applying pesticides that are toxic to plants to minimize exposure and risk to the habitats of pollinators, including the monarch butterfly and bees. Labels on pesticides are being updated to minimize spray drift and to raise awareness. This is being done for new products and for already-registered pesticides as they go through EPA's registration review process.

Honeybees: Honeybees are critical players in the pollination of agricultural crops. They are used to pollinate billions of dollars' worth of the nation's agricultural produce each year. Well over 125 fruits and vegetables are cross-pollinated by honeybees. Many of these crops are not self-pollinating. Commercial and wild bees are responsible for the pollination of an estimated 80% of all food crops in the United States.

But honeybee populations have been dying off at extraordinary rates in recent years, sometimes greater than 50% over a winter season. The prevailing theory among scientists in EPA, USDA, and the global scientific community is that the general declining health of honeybees is related to complex interactions among multiple factors[11], including:

- Pests (for example, the varroa mite), pathogens (for example, the bacterial disease American foulbrood), and viruses;
- Poor nutrition (for example, from loss of foraging habitat and increased reliance on supplemental diets);
- Bee management practices (for example, long migratory routes to support pollination);
- Lack of genetic diversity; and
- Pesticide exposure.

A class of pesticides chemically related to nicotine called neonicotinoids or "neonics" affects insects' nervous systems. In 2018, the European Union banned all outdoor use of three, out of five, of the most widely used neonics to protect bees. While EPA has not proposed any cancellations or bans for the use of the neonics because of risks to bees, it has implemented label measures to reduce exposures, particularly when bees are present. States and tribes have also been asked to develop pollinator protection plans and best management practices. EPA continues to require and evaluate data from the manufacturers to better understand the toxicity and the extent of exposure, and to refine the ways in which it assesses risks to bees through its collaboration with California and Canada. While research is ongoing and some modest steps have been taken in this country, much remains to be done.

Frogs: Frogs and other amphibians (greater than 7,000 known species) are threatened worldwide.[12] A recent assessment of the entire group[13] found that nearly one-third (32%) of the world's amphibian species are threatened, representing 1,856 species. In just the last two decades, about 168 species are believed to have gone extinct, and at least 2,469 (43%) more have populations that are declining.

As with the honeybee, interactions of many factors are thought to be responsible for the declines. Likely and confirmed factors include:

- Habitat destruction;
- Introduced species;
- Climate change;
- Ultraviolet-B radiation;
- Disease; and …
- Chemical Contaminants: Chemical stressors (for example, **pesticides**, heavy metals, acidification, and nitrogen-based fertilizers) can harm amphibians. The effects may include death, decreased growth rates, developmental and behavioral abnormalities, decreased reproductive success, weakened immune systems, and/or gender changes. A substantial body of peer-reviewed studies in the scientific literature supports these findings. A particularly useful resource is the analysis performed to provide the European Food Safety Agency with information relating to assessment of risk to European species of aquatic and terrestrial amphibians posed by pesticide exposure.[14] It is likely that risks in the U.S. setting would be comparable.

No amphibian-specific testing requirements exist to support the U.S. registration of pesticides. In general, EPA uses bird toxicity data as a surrogate for land-based reptiles and amphibians, and the required fish toxicity data as a surrogate for aquatic-phase amphibians. At present, no EPA research projects are directed at issues related specifically to amphibians—again, more work for the future.

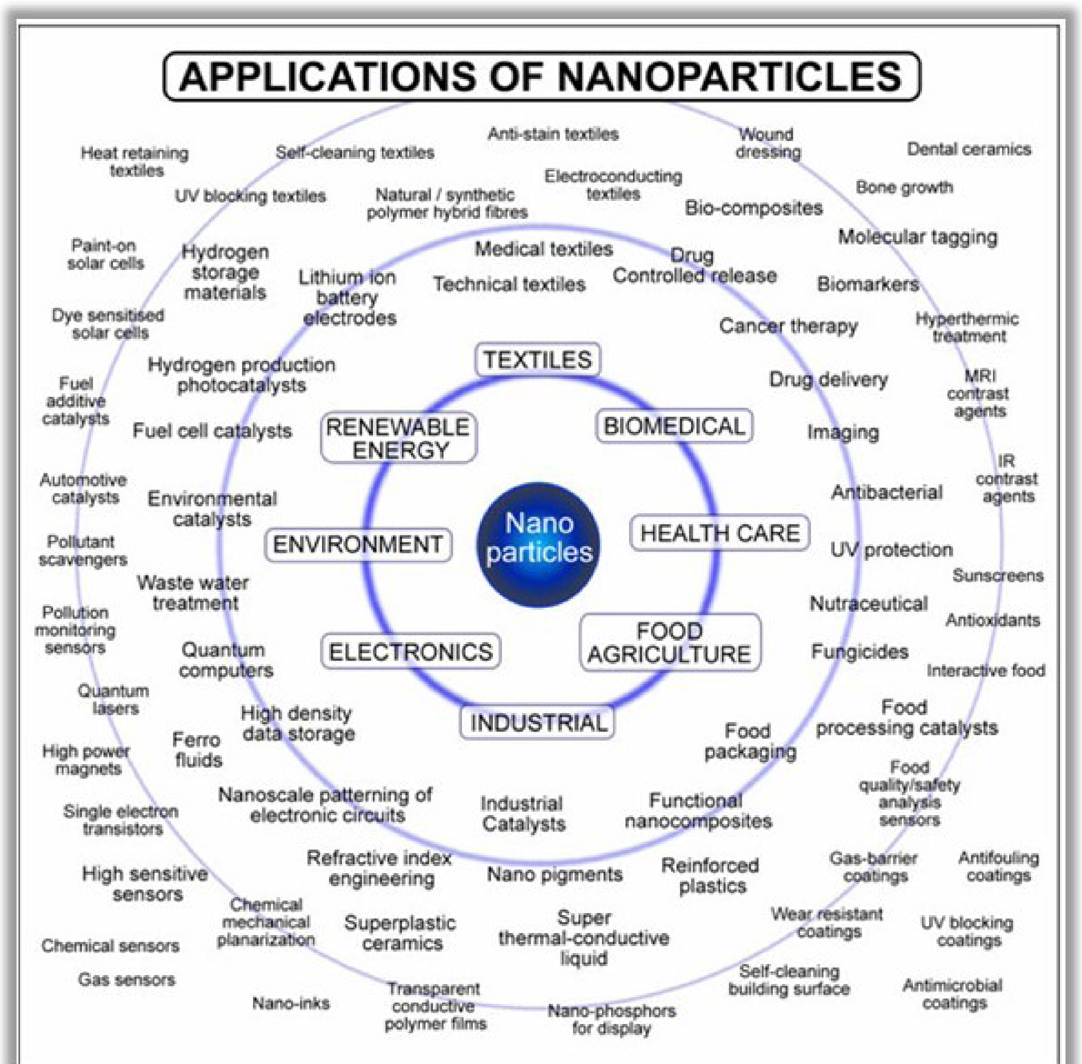
- **Improved pest control techniques and expansion of biopesticides.** The future of protection of pollinators and amphibians—and in fact the environment and public health at large—can be achieved by smarter pest control. Since the late 1990s, EPA has encouraged companies to develop new, lower risk products that control pests by non-toxic means. For example, pheromone lures can attract destructive insect pests to traps without harming people or any nontarget wildlife. The market for such biologically-based pesticides has grown significantly in the last decade with EPA's approval of far more new pesticide active ingredients of this type than new conventional chemical pesticides. A recent report indicates that the international biopesticides market was valued at $2.9 billion in 2018 and is expected to reach $6.5 billion by 2027.[15]

  By the 2010s, the agricultural sector adapted new technologies to improve pest control. "Precision farming" uses GPS-locators to ensure that pesticides are applied only where needed and to prevent wasteful, off-target applications. In addition, aerial unmanned vehicles (drones) are being adapted to apply pesticides in hard-to-reach landscapes like swamps and steep cliffs unreachable by conventional equipment.

  Use of "smart technology" and safer products are therefore critical to the future improvements in pesticide usage and protection of people, beneficial species, and animals.

- **Better protection for farmworkers.** In 2015, EPA also strengthened the protections for agricultural workers who may be exposed to pesticides. People who mix, load, and apply pesticides or who enter fields or orchards that have been sprayed with pesticides receive some of the highest exposures to pesticides of any population group. Because many farmworkers have limited education and English skills, they are particularly at risk. EPA's new protections include requirements for annual training on pesticide safety practices; providing employees access to soap and water to wash off pesticides after working and immediate access to medical treatment in case of accidental poisoning.

- **Nanotechnology.** Nano-sized materials (1 to 100 billionths of a meter) can, and often do, have physical properties fundamentally different from those of their larger counterparts. Therefore, they may also possess very different toxicity characteristics and potential risks. Many different categories of products use nanoscale materials, including household appliances, automobiles, coatings, electronics and computers, food and beverages, medical devices and drugs, clothing, and personal care products.



Many of these products were introduced into commerce without any prior evaluation of the potential for risk to human or environmental health.

When EPA began considering pesticide products containing nano materials, it wanted to move ahead in a way that encouraged the new technology while still protecting public health and the environment. Therefore, after several years of careful review, EPA conditionally registered two nanomaterial pesticide products as new active ingredients, each for a period of four years during which the manufacturers needed to develop additional safety data.

The major challenges facing the scientific community now are the relative meager body of data characterizing the toxicity of these materials compared with their larger-sized counterparts. Validated testing protocols are lacking and need to be developed. The Toxic Substances Control Act will address chemicals that are not pesticides, food or drugs. Please refer to that report for more information.

CONCLUSION

The first 50 years of EPA's work has continually improved the safety of pesticide products available to meet evolving pest control needs. But the job is never done! EPA needs to continue to lead the way in developing measures of risk of pesticides, and in determining ways to protect the public and environment from adverse effects. As science marches on, so must the practices of regulators who guard the future of our children, wildlife, and environment.

Endnotes

1. Braune et al. (2005)
2. Norstrom and Herbert (2005)
3. Sun et al. (2005)
4. Clark et al. (2001)
5. Kegley (2019)
6. NRC (2007)
7. U.S. EPA, 2019b
8. Smith (2014)
9. Rendon-Salinas, E ., and Tavera-Alonso, G. (2014)
10. Flockhart et al. (2014)
11. U.S. EPA, 2014a
12. AmphibiaWeb.org (2014)
13. iucnredlist.org/amphibians
14. Fryday and Thompson (2012)
15. Forex Tribune Biopesticides Market Outlook (2019)

References

AmphibiaWeb.org. 2014. Worldwide Amphibian Declines: How big is the problem, what are the causes and what can be done? (available at http://amphibiaweb.org/declines/declines.html) (Note: AmphibiaWeb was created in conjunction with the Digital Library Project at the University of California, Berkeley).

Braune BM et al. (2005). Persistent organic pollutants and mercury in marine biota of the Canadian Arctic: an overview of spatial and temporal trends. Sci Total Environ. 351-352:4-56.

Bruhl C. et al (2014). Terrestrial pesticide exposure of amphibians: An underestimated cause of global decline? Scientific Reports 3:1135 (available at http://www.nature.com/srep/2013/130124/srep01135/full/srep01135.html).

Clark KE, et al. (2001). Changes in contaminant levels in New Jersey osprey eggs and prey, 1989 to 1998. Arch Environ Contam Toxicol. 40(2):277-84.

Federal Register, Vol. 37, No. 131, Friday, July 7, 1972: June 30, 1972 Opinion and Order of Administrator Ruckelshaus Concerning the Registrations of Products Concerning DDT.

Flockhart et al. (2014). Unravelling the annual cycle in a migratory animal: breeding-season habitat loss drives population declines of monarch butterflies Journal of Animal Ecology (Published online June 25, 2014).

Forex Tribune. 2019, Biopesticides Market Outlook. Biopesticides Market Evolution By Recent Trends, Regional Growth, Revenue and Opportunities Till 2026. https://forextribune.com/tag/biopesticides-market-outlook/

Fryday, S. and Thompson, H. (2012). Toxicity of pesticides to aquatic and terrestrial life stages of amphibians and occurrence, habitat use and exposure of amphibian species in agricultural environments. Supporting Publications 2012:EN-343. [348 pp.]. Available online: www.efsa.europa.eu/publications.

Kegley, Susan, PhD, Principal and CEO, Pesticide Research Institute, Inc., Santa Rosa, CA. Data originally published in *An assessment of acute insecticide toxicity loading (AITL) of chemical pesticides used on agricultural land in the United States*. DiBartolomeis M, Kegley S, Mineau P, Radford R, Klein K (2019) PLoS ONE 14(8): e0220029. https://doi.org/10.1371/journal.pone.0220029

Norstrom RJ, and Hebert CE. (2006). Comprehensive re-analysis of archived herring gull eggs reconstructs historical temporal trends in chlorinated hydrocarbon contamination in Lake Ontario and Green Bay, Lake Michigan, 1971-1982. J Environ Monit. 8(8):835-47.

NRC. (2007). National Research Council. Toxicity Testing in the Twenty-first Century: A Vision and A Strategy. National Academy Press, Washington, DC.

Perera FP, et al (2003). Effects of transplacental exposure to environmental pollutants on birth outcomes in a multiethnic population. Environ Health Perspect. 111(2):201-5.

Rauh VA, et al (2006). Impact of prenatal chlorpyrifos exposure on neurodevelopment in the first 3 years of life among inner-city children. Pediatrics. 118(6):e1845-59.

Rauh V, et al (2011). Seven-year neurodevelopmental scores and prenatal exposure to chlorpyrifos, a common agricultural pesticide. Environ Health Perspect. 119(8):1196-2.

Rendon-Salinas, E .and Tavera-Alonso, G. (2014). Forest Surface Occupied by Monarch Butterfly Hibernation Colonies in December 2013. World Wildlife Fund (available at http://www.worldwildlife.org/stories/monarch-population-hits-lowest-point-in-more-than-20-years).

Smith, LN. (2014). Monarch Butterfly's Reign Threatened by Milkweed Decline. Use of herbicides in the U.S. is causing a decline in plants essential for the golden icon. National Geographic magazine. Published online August 29, 2014 (available at http://news.nationalgeographic.com/news/2014/08/140819-monarch-butterfly-milkweed-environment-ecology-science/).

Sun LG, Yin XB, Pan CP, Wang YH. (2005). A 50-years record of dichloro-diphenyl-trichloroethanes and hexachlorocyclohexanes in lake sediments and penguin droppings on King George Island, Maritime Antarctic. J Environ Sci (China). 17(6):899-905.

USDA, Release No. 0215.B, Statement from Agriculture Secretary Tom Vilsack on U.S. Agricultural Exports in 2013, November 14, 2013.

US EPA. 2014a. US Environmental Protection Agency. Pollinator Health Concerns (available at http://www2.epa.gov/pollinator-protection/pollinator-health-concerns).

US EPA. 2014b. US Environmental Protection Agency. EPA Actions to Protect Pollinators (http://www2.epa.gov/pollinator-protection/schedule-review-neonicotinoid-pesticides).

US EPA. 2019a. DDT – A Brief History and Status (https://www.epa.gov/ingredients-used-pesticide-products/ddt-brief-history-and-status)

US EPA. 2019. Use of High Throughput Assays and Computational Tools in the Endocrine Disruptor Screening Program. (https://www.epa.gov/endocrine-disruption/use-high-throughput-assays-and-computational-tools-endocrine-disruptor#advancements)

US EPA. 2019c. Protecting Monarch Butterflies from Pesticides (https://www.epa.gov/pollinator-protection/protecting-monarch-butterflies-pesticides)

US EPA. 2019e. Food and Pesticides https://www.epa.gov/safepestcontrol/food-and-pesticides

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p.15, non-GMO corn photo, in article entitled "France Bans Monsanto GMO Corn." No changes made. Available at: http://healthimpactnews.com/2014/france-bans-monsanto-gmo-corn/.

p.17, Monarch butterfly, photo by Mark Musselman, National Audubon Society, USFWS National Digital Library. Available at: http://digitalmedia.fws.gov/cdm/singleitem/collection/natdiglib/id/14197/rec/2

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p.20, Squash harvest in Virginia, photo by Lance Cheung, USDA

p.21, Nanotechnology figure, in article entitled "Nanotechnology Applications" available at: http://www.nanowerk.com/nanotechnology-applications.php. Source: Tsuzuki, T. 2009. Commercial scale production of inorganic nanoparticles. International Journal of Nanotechnology (IJNT), Vol. 6(5/6): 567-578. No changes made.

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