A Small Dose of Persistent Environmental Contaminants
Or
An Introduction to the Health Effects of Persistent Environmental Contaminants

Chapter 19
A Small Dose of Toxicology - The Health Effects of Common Chemicals

ED3 – Revised October 2020

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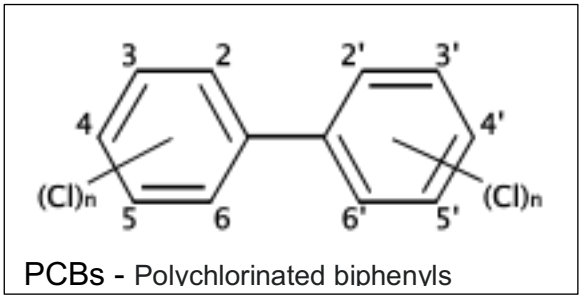
Supporting web site:
web: www.asmalldoseoftoxicology.org - "A Small Dose of Toxicology"



PCBs - Polychlorinated biphenyls

Dossier

Name: Persistent Environmental Contaminants has various names depending on agency – e.g. U.S. EPA Persistent Bioaccumulative and Toxic (PBT) or United Nations Persistent Organic Pollutant (POP) or forever chemicals
Use: varies, often restricted or banned (but still present in the environment)
Source: industry, waste sites, food chain, and environment
Recommended daily intake: none (not essential)
Absorption: varies
Sensitive individuals: fetus, children, elderly, all species accumulate PBTs
Toxicity/symptoms: range of toxic effects, developmental, learning and memory, cancer, etc ….
Regulatory facts: various local, national, and international agencies working to eliminate or greatly reduce
General facts: long history of use, bioaccumulates
Environmental: global environmental contaminants
Recommendations: avoid, work towards phaseouts

Case Studies

Lindane Dump site

From Advertisement for ORTHO Lindane – 1953

"Check These ORTHO Lindane Advantages:
High Safety Factor – Authorities have approved Lindane for lice and mange control on dairy cattle. Shows no contamination in milk when properly applied. …. Even used by dermatologists for human itch, lice and scabies. Not cumulative and practically odorless. Any taken in by a warm-blooded animal is eliminated."

Entoma – A Directory of Insect and Plant Control, George S. Langford (ed), published by The entomological Society of America. – 10th edition 1953-1954, page – 165.

Lindane (gamma-hexachlorocyclohexane) is one of the last of the old-style organochlorine pesticides still in use. Use of organochlorines such as DDT, aldrin, dieldrin, heptachlor and toxaphene is restricted or banned in many countries because of their persistence in the environmentand their bioaccumulation and toxicity. Lindane was first isolated in 1825 along with other similar compounds, but its deadly effects on insects were not recognized until the 1940s.

Lindane was widely used because it killed a broad range of insects from fleas and tics to worms that damaged crops. For a time it was even used to kill rodents. Lindane attacks the nervous system causing trembling, loss of coordination, paralysis, and ultimately death. Lindane was often applied as a spray on crops, where it would be either ingested or inhaled. Initially its environmental persistence was considered an asset, but eventually that was seen as a liability and lead to restrictions in it use. Lindane is stable in water and has an average half-life of 15 months in soil. It is also highly toxic to fish; trout are affected at levels as low as 1.7 ug of lindane per liter of water. The US EPA restricted its use in 1983, as have most European countries and in 2006 its registration as a pesticide was cancelled. However, it continues to be used in products to control head lice and scabies, under the jurisdiction of the US FDA in the United States, but even these uses are controversial and are being cancelled in some countries. The primary concern is not only lindane's toxicity, but also its persistence and environmental transport.

The U.S. EPA set a drinking water limit of 0.2 parts per billion (ppb) of lindane. Industrial dumpsites such as the one in Allegheny County, Pennsylvania contain an estimated 400 tons of lindane waste and other waste dumped over a 50-year period on 30 acres of land. The runoffs from this site as well as others have the potential to contaminate drinking water with lindane. Lindane is regularly detected in surface water in the United States (see U.S. Geological Survey monitoring studies).

Introduction and History

During the 1950s and 1960s there was an enormous increase in the use of chemicals in agriculture, industrial manufacturing, and around the home. We powdered our bodies with DDT to remove lice and spread DDT far and wide to control mosquitoes. We used other pesticides to kill insects and control weeds to improve crop yields. Lead was added to gasoline to make cars run better and added to house paint to make it last longer. At the same time we took advantage of the more sinister qualities of lead when we combined it with arsenic to spray on fruit trees to control pests. Pulp and paper mills used mercury to control fungi and molds to ensure that our paper remained white. Seeds were coated with mercury to stop soil fungi. Thermometers, thermostats, and switches brought mercury into everyone's home and school. Many will remember playing with a small silver ball of liquid mercury. Expansion of the electrical power system required chemicals that could withstand heat. For this purpose PCBs seemed to be the answer. All these chemicals appeared to be safe. A small dose did not seem harmful.

During the 1970s we began to appreciate that a small dose can harm sensitive individuals. Thirty years ago in *Silent Spring*, Rachael Carson, sounded one of the first alarms about the effects of environmental contaminants. Toxicity does come in small doses to sensitive individuals (including animals). Evidence accumulated that a pesticide like DDT can cause very unexpected effects. The first and most obvious was the thinning of birds' eggshells, causing a sharp decline in predator bird populations. Predatory birds are at the top of the food chain, where they accumulate and concentrate DDT. Next we became aware of the potential of low-level exposures to these agents to cause diseases like cancer that appears only after many years. Humans at the top of the food chain accumulate DDT in fat. Fat is mobilized during lactation, and breast-feed mothers pass along the DDT to their infant. The small infant actually receives a large dose because of their low weight. We also learned that mercury and lead cause developmental effects, harming the developing nervous system for a lifetime.

It turns out that most of these substances have similar characteristics that contribute to their toxicity to both humans and other species of plants and animals. First, the substances are environmentally persistent. Many of the early pesticides, and certainly the metals, do not break down in the environment or do so only very slowly. If persistent chemicals are released continually to the environment, the levels tend to rise ever higher. This means they are available to cause harm to other organisms, often not even the target

of the pesticide. Second, the early pesticides were broadly acting and toxic to many species, not just the target species. These poisons often killed beneficial insects or plants. Third, many of these compounds would bioaccumulate or concentrate in species as they moved up the food chain. The chlorinated pesticides accumulate in the fat of animals. Animals that consumed other animals would accumulate more and more of these pesticides. Most species could not metabolize or break down the compounds. Lead accumulates in bone and methylmercury in muscle. And finally, because of their persistence in the environment and accumulation in various species, the persistent toxicants spread around the world even to places that never used them. Animals at the top of the food chain, such as polar bears and beluga whales, routinely have fat PCB levels greater than 6 ppm even though these animals live far from where PCBs were used or produced.

To address the public and environmental health concerns caused by these and other compounds, government agencies have initiated various programs and regulations to control or restrict the use of the offending substances. Laws were passed to ensure more rigorous testing of compounds before widespread use, although this was not entirely effective. For example, the US Toxic Substance Control Act (TSCA) was passed in 1976 but has been largely ineffective for chemical management. The US Food Quality Protection Act (FQPA) of 1996 was more effective in implementing pesticide testing requirements. Researchers worked to develop new pesticides and other agents that were more specific in their toxicity and much less persistent. The use of many of the persistent chemical pesticides was restricted or even banned in some places. Individual countries are responsible for regulations, so there are some countries that still use pesticides that are banned elsewhere.

Lists of persistent chemical pollutants are created to help prioritize efforts to reduce exposure. There are many lists, and even lists of lists of persistent chemicals, which are often, revised as new data become available. The United Nations Environment Programme (UNEP) created a list called Persistent Organic Pollutants (POPs) that focuses on “chemical substances that persist in the environment, bioaccumulate through the food web, and pose a risk of causing adverse effects to human health and the environment.” The UNEP also created a list of Persistent Toxic Substances. The U.S. EPA crated a list of agents called Persistent Bioaccumulative and Toxic (PBT). Both these lists included organic chemicals and metals. Regional groups are also beginning to create lists of persistent chemical pollutants to emphasize and prioritize local issues. For example, Washington State Department of Ecology, in the United States, has created a list of Persistent, Bioaccumulative Toxins (PBTs), with 27 chemicals to be phased out in the state. It is instructive to look at the overlap of these lists. The table below compares the lists of persistent chemical pollutants from these agencies. Overall there is considerable agreement as what chemicals are considered a priority. It is also obvious that pesticides are a major class of persistent chemicals, as are flame retardants (Table 14.1).

Table 14.1 Classification of Persistent Chemicals

Chemical	EPA	WA State	UN (POPs)	UN (PTSs)	Class
Aldrin/Dieldrin	X	X	X	X	Pesticide
Benzo(a)pyrene	X	X			A PAH (See below)
Cadmium		x			Metal
Chlordane	X	X	X	X	Pesticide
Chlordecone		X	X		Pesticide
DDT, DDD, DDE	X	X	X	X	Pesticide
Dicofol		X			Pesticide
Dioxins (TCDD) & Furans	X	X	X		Combustion by products
Endrin		X	X	X	Pesticide
Endosulfan		X			Pesticide
Hexachlorobenzene	X	X	X	X	Pesticide
Alpha- and beta-hexachlorocyclohexane			X		Pesticide
Heptachlor		X		X	Pesticide
Hexabromobiphenyl		X	X		Flame retardant
Hexabromodiphenyl ether			X		Flame retardant
alkyl-lead	X	X	X		Metal
Lindane		X	X	X	Pesticide
Mercury (methyl mercury)	X	X		X	Metal
Methoxychlor		X			Pesticide
Mirex	X	X	X	X	Pesticide
Octachlorostyrene	X				By product
Polychlorinated biophenyl's (PCBs)	X	X	X	X	Heat resistant
Pendimethalin		X			Pesticide
Pentabromo diphenyl ether (PBDEs)		X			Former Flame retardant
Pentachlorobenzene			X		Fungicide, flame retardant
Pentachloronitrobenzene		X			Pesticide
Perfluorooctane sulfonic acid,		X	X		Widely used in many products
Polybrominated Hydrocarbons (PBDEs)		X		X	Contaminate

Polycyclic aromatic hydrocarbons (PAHs)		X		X	Combustion by products
Tetrabromodiphenyl ether		X	X		Flame retardant
Tin (organotins)				X	Metal
Toxaphene	X	X	X	X	Pesticide
Trifluralin		X			Pesticide
1,2,4,5-tetrachlorobenzene		X			Pesticide

Health Effects

Table 14.2 provides a very brief description of the chemicals and associated toxicity. Additional information on individual agents can be found elsewhere in this book as well as in many other sources.

Table 14.2 Chemicals and Toxicity

Chemical	Comment
Aldrin/Dieldrin	Pesticide – Organochlorine – Bioaccumulates – Used to control mosquitoes and termites Importation and manufacture prohibited in the U.S. in 1987.
Benzo(a)pyrene	A PAH (see below under PAH)
Cadmium	Metal – naturally occurring – used in steel and plastics, batteries, cigarette smoke – lung carcinogen
Chlordane	Pesticide – Organochlorine – Bioaccumulates – Used to control mosquitoes and termites Importation and manufacture prohibited in the U.S., use banned in 1988.
DDT, DDD, DDE	Pesticide (DDT), breakdown product (DDD, DDE) – Organochlorine – Bioaccumulates – Used to control mosquitoes - Importation and manufacture prohibited in the U.S. in 1972. Affects wildlife – found in breast milk and fat
Dicofol	Pesticide – Organochlorine – Bioaccumulates – Insecticide on fruits – Analog of DDT – degrades but very toxic to aquatic wildlife including fish
Dioxins (TCDD) & Furans	Byproduct of combustion Bioaccumulates – municipal and medical waste incinerators – human carcinogen
Endrin	Pesticide – Organochlorine – Bioaccumulates – Insecticide used on many crops – Most use canceled in 1980
Endosulfan	Pesticide – Organochlorine – Bioaccumulates – Currently used as an insecticide

Heptachlor epoxide	Pesticide – Organochlorine – Bioaccumulates – Heptachlor epoxide is a breakdown product of heptachlor, an Insecticide from 1953 to 1974 in U.S. on wide range of insects. Most use canceled in 1974 and importation and manufacture prohibited in the U.S., use banned in 1988.
Hexachlorobenzene	Pesticide – Organochlorine – Bioaccumulates – Fungicide used in seeds, most use ended in 1965 but is a by-product in solvent manufacture
Lead	Metal – Widely distributed in environment when used as a gasoline additive and in paint. Now banned from use in gasoline and paint. Potent child neurotoxicant.
Lindane	Pesticide – Organochlorine – Bioaccumulates – Insecticide widely used prior to 1983. Regulated as drinking water contaminant by U.S.EPA
Mercury	Metal – Persistent – Bioaccumulates – Contaminates many species of fish. Widely used in industrial processes. Cause developmental neurotoxicity – children most susceptible.
Methoxychlor	Pesticide – Organochlorine – Bioaccumulates – Used as a replacement for DDT. In the U.S., 3.7 million pounds manufactured in 1978. Use has declined significantly – regulated as a water contaminant.
Mirex	Pesticide – Organochlorine – Bioaccumulates – Extensively used in U.S. from 1962-1978 to control fire ants. All use canceled in U.S. in 1978.
Octachlorostyrene	By product of electrolytic production of magnesium. List by U.S. EPA as persistent and Bioaccumulative.
Pendimethalin	Pesticide – Herbicide used to control grasses and broadleaf weeds in crop fields and turf
Pentabromo diphenyl ether	Formerly used as flame retardant
Pentachlorobenzene	Pesticide – Fungicide used for treatment of seeds and soil
Polybrominated Hydrocarbons	Used in the manufacture of plastic products. Bioaccumulate and are highly persistent in the environment.
Polychlorinated biophenyl's (PCBs)	Heat and fire resistant – extensively used from 1929 and 1977 in electrical transformers – all manufacture banned – extensively regulated – very widespread global contaminant.
Polycyclic aromatic hydrocarbons (PAHs)	Combustion byproducts – class of 100 chemicals – combustionby products from oil to tobacco. Some of the first known carcinogens.
Tin (organotins)	Organotins are used in a number of consumer products including paint as a pesticide. Bioaccumulates and persistent, affects nervous system.

Toxaphene	Pesticide – Organochlorine – Bioaccumulates – Extensively used on U.S. cotton crops from 1947 to 1980. Manufacture and use prohibited in the U.S.
Trifluralin	Pesticide – Herbicide used to prevent emergence of weeds in crop fields and landscapes
1,2,4,5-tetrachlorobenzene	Pesticide – insecticide and intermediate in herbicide production – related to Dioxin (TCDD)

Reducing Exposure

Exposure depends on region of the world, diet, housing, occupation, socioeconomic issues, and other factors. For example, methylmercury bioaccumulates in certain fish and is particularly toxic to the developing fetus. Many government agencies advise that women of childbearing age or children reduce their consumption of certain species of fish known to bioaccumulate methylmercury, but this may be difficult for those dependent on high fish diets. Reducing exposure to persistent chemical pollutants is difficult because they are so pervasive and continue to build up over time. While individuals can sometimes reduce exposure to particular PBTs, such as mercury, by regulating their diet, in general government agencies have found that the most effective way of reducing exposure is by phasing out the uses of the products or processes that create these chemicals.

Many of the chemicals identified as persistent chemical pollutants are pesticides. Integrated Pest Management (IPM, see definition below) is an approach to pest control that can significantly reduce pesticide use while still providing adequate or even improved results. IPM programs are used in agriculture, landscaping, and indoor pest control. Typically, IPM programs maximize prevention of pest problems through non-chemical methods, and chemicals, when used, are selected for minimum risk to non-targeted species. Many institutions, such as schools, are adapting IPM protocols for pest management.

> "Integrated Pest Management (IPM) is a sustainable approach to managing pests by combining biological, cultural, physical and chemical tools in a way that minimizes economic, health and environmental risks."
>
> From: Anonymous. Integrated Pest Management Practices on 1991 Fruits and Nuts, RTD Updates: Pest Management, 1994, USDA-ERS, 8pp)

More Information and References

Slide Presentation

- A Small Dose of Persistent Environmental Contaminants presentation material and references online: www.asmalldoseoftoxicology.org .
  Web site contains presentation material on the health effects of Persistent Environmental Contaminants.

European, Asian, and International Agencies

- European Commission on the Environment -). Online: < https://ec.europa.eu/environment/index_en > (accessed: 8 October 2020).
  REACH is a new European Community Regulation on chemicals and their safe use (EC 1907/2006). It deals with the Registration, Evaluation, Authorization and Restriction of Chemical substances. The new law entered into force on 1 June 2007.

- United Nations Environment Programme (UNEP) – Persistent Organic Pollutants (POP). Online: < http://www.chem.unep.ch/pops/ > (accessed: 8 October 2020)
  UNEP is the global champion for the environment with programs focusing on sustainable development, climate, biodiversity and more.

- Stockholm Convention on Persistent Organic Pollutants (POP). Online: < http://chm.pops.int/ > (accessed: 8 October 2020).
  "The Stockholm Convention on Persistent Organic Pollutants is a global treaty to protect human health and the environment from chemicals that remain intact in the environment for long periods, become widely distributed geographically and accumulate in the fatty tissue of humans and wildlife."

North American Agencies

- Health Canada - Chemical Substances Online: < https://www.canada.ca/en/health-canada/topics/chemicals-your-health.html> (accessed: 9 October 2020).
- Health Canada provides information on the health effects and environmental distribution of chemical substances in Canada.

- US Centers for Disease Control and Prevention (CDC). Environmental Health Laboratory, National Biomonitoring Program (NBP). Available: http://www.cdc.gov/biomonitoring/. (accessed: 9 October 2020).
  CDC's Division of Laboratory Sciences coordinates the National Biomonitoring Program (NBP) which offers an assessment of nutritional status and the exposure of the U.S. population to environmental chemicals and toxic substances.

- US Environmental Protection Agency Persistent Organic Pollutants: A Global Issue, A Global Response Online: https://www.epa.gov/international-cooperation/persistent-organic-pollutants-global-issue-global-response. (accessed: 8 October 2020).
  A global effort.

- US Environmental Protection Agency – Persistent Bioaccumulative Toxic (PBT) Chemicals Rules Under the TRI Program. Online: < https://www.epa.gov/toxics-release-inventory-tri-program/persistent-bioaccumulative-toxic-pbt-chemicals-rules-under-tri> (accessed: 9 October 2020).
  Information of the efforts of U.S. EPA to reduce PBT chemicals.

- US Geological Survey. Online: < https://www.usgs.gov/science-explorer-results?es=chemicals> (accessed: 9 October 2020).
  This site contains information and maps on the use of chemicals across the US both as contaminants, use, and distribution.

- Washington State Department of Ecology – Addressing priority toxic chemicalsPersistent, Bioaccumulative Toxins. Online: < https://ecology.wa.gov/Waste-Toxics/Reducing-toxic-chemicals/Addressing-priority-toxic-chemicals> (accessed: 9 October 2020).
  Information on Washington's approach to persistent, bioaccumulative toxins, and includes several chemical action plans.

- US Department of Agriculture – Integrated Pest Management (IPM). Online: <https://www.ers.usda.gov/topics/farm-practices-management/fertilizers-pesticides/ > (accessed: 9 October 2020).
  Site provides information and other links on pest management.

Non-Government Organizations

- Pesticide Action Network UK. Online: < http://www.pan-uk.org/ > (accessed: 08 October 2020).
  PAN-UK works to eliminate the dangers of toxic pesticides, exposure to them, and their presence in the environment in Europe.

- Pesticide Action Network North America (PANNA). Online: <http://www.panna.org> (accessed: 08 October 2020).
  "PANNA works to replace pesticide use with ecologically sound and socially just alternatives."

- Toxic Free Futures (TFF). Online: <https://toxicfreefuture.org> (accessed: 08 October 2020).

Our mission: Toxic-Free Future advocates for the use of safer products, chemicals, and practices through advanced research, advocacy, grassroots organizing, and consumer engagement to ensure a healthier tomorrow.

- Beyond Pesticides. Online: <http://www.beyondpesticides.org/> (accessed: 08 October 2020).
  "Beyond Pesticides is a national network committed to pesticide safety and the adoption of alternative pest management strategies which reduce or eliminate a dependency on toxic chemicals."

- Northwest Coalition for Alternatives to Pesticides (NCAP). Online: <http://www.pesticide.org/> (accessed: 08 October 2020).
  "NCAP works to protect people and the environment by advancing healthy solutions to pest problems."

- University of California Statewide Integrated Pest Management Program (UC IPM). Online: <http://www.ipm.ucdavis.edu/> (accessed: 08 October 2020).
  "UC - IPM develops and promotes the use of integrated, ecologically sound pest management programs in California."

- Environmental Working Group – Developed a list of Fruits and vegetables "dirty dozen" with the most toxic chemicals Online: https://www.ewg.org/foodnews/dirty-dozen.php (accessed: 08 October 2020).

Wikipedia

- Registration, Evaluation, Authorisation and Restriction of Chemicals (REACH). Online: https://en.wikipedia.org/wiki/Registration,_Evaluation,_Authorisation_and_Restriction_of_Chemicals . (accessed: 8 October 2020).

- United Nations Environment Programme. Online: https://en.wikipedia.org/wiki/United_Nations_Environment_Programme . (accessed: 8 October 2020).
- The United Nations Environment Programme (UNEP or UN Environment[1]) is responsible for coordinating the UN's environmental activities and assisting developing countries in implementing environmentally sound policies and practices.

- Persistent organic pollutant (POPs). Online: https://en.wikipedia.org/wiki/Persistent_organic_pollutant - (accessed: 8 October 2020).

- Stockholm Convention on Persistent Organic Pollutants. Online: https://en.wikipedia.org/wiki/Stockholm_Convention_on_Persistent_Organic_Pollutants - (accessed: 8 October 2020).

- Persistent, bioaccumulative and toxic substances. Online: https://en.wikipedia.org/wiki/Persistent,_bioaccumulative_and_toxic_substances . (accessed: 8 October 2020).

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National Research Council (2006). Human Biomonitoring for Environmental Chemicals - Committee on Human Biomonitoring for Environmental Toxicants, National Academy Press Available: http://www.nap.edu/catalog.php?record_id=11700 (accessed: 8 October 2020).