Living in a Chemical Environment – Persistent Organic Pollutants

Rashmi Sanghi

Rashmi Sanghi is currently working as a scientist at the Facility for Ecological and Analytical Testing, IIT Kanpur. She got her PhD degree in natural products from Allahabad University in 1994 and then carried out postdoctoral work both at IIT Kanpur and at Rutgers University.

The combination of industrial development, the exponential growth of human settlements and the ever-increasing use of synthetic substances is having an adverse impact on the ecosystem and thus on human health. These chemicals find their way into soil, air, water and food. They are in the tissues of plants, animals and humans. There is very little effective national or international control of the manmade chemicals in current use.

Every person today carries approximately 250 chemicals within his/her body, chemicals that did not exist prior to 1945. World War II was a catalyst for the transformation from a carbohydrate based economy to a petrochemical based economy, as chemical substitutes began to be invented for goods restricted or made unavailable during the war. The economic boom that followed World War II supported the parallel boom in the invention and use of chemicals, which are associated with the convenience and flexibility of modern living. About 100,000 chemicals have entered into the market since 1945, and it is estimated that 75,000 of them are in commercial use. Today only about 3% (about 1200) of these chemicals have been tested for carcinogenicity. Nobody knows about the risks of cancer carried by the rest.

Persistent Organic Pollutants (POPs) are toxic substances released into the environment through a variety of human activities.

Persistent Organic Pollutants (POPs) are toxic substances released into the environment through a variety of human activities. They are very stable and long-lived chemicals that build up in the food chain and slowly poison animals and humans. POPs are lipophilic and tend to accumulate and also magnify in the fatty tissues of living beings. When they enter the body they don't leave it and are persistent. They are also semi-volatile, which means that they can stay on the ground for a number of

years and then be transported hundreds of miles away and be deposited in another place until they eventually end up in animals and humans. They are also subject to global distillation i.e. migration from warmer to colder regions called the 'grasshopper effect'. For example, a pesticide used in Asia can easily move to Europe.

Focusing on this class of poisonous chemicals (see *Box* 1), which are now targeted for elimination by ongoing international negotiation under the United Nations Environment Program (UNEP), Green Peace investigations conducted in 1998 in seven Asian countries, including Bangladesh, India, Nepal and Pakistan revealed:

1. Stocks of 5000 metric tons or more obsolete pesticides, including POP chemicals are stored in extremely hazardous conditions in some of these countries.

2. India is among the three remaining known manufacturers of DDT (10,000 mt capacity) in the world, the other two being Mexico and China.

3. India exports nearly 800,000 kg of POP pesticides including aldrin, DDT, BHC chlordane to a long list of countries where their usage is banned. Some of the pesticides such as aldrin are not permitted to be manufactured even in India.

4. In Pakistan, India, Nepal and Bangladesh, locally banned or severely restricted pesticides are freely available. Green Peace found DDT, BHC, dieldrin and heptachlor openly sold in the vegetable markets of Karachi. Hardware stores of New Delhi stock the deadly pesticide aldrin whose registration was withdrawn more than three years ago.

Hardware stores of New Delhi stock the deadly pesticide aldrin whose registration was withdrawn more than three years ago.

The pollution of the human body by POPs has occurred together with the appearance of several alarming trends in human health over the past few decades. Almost everything we eat, drink or inhale is broken down by our bodies and then expelled through the process of waste elimination. But POPs are not. As

Box 1.

POPS fall into three broad categories:

1. Pesticides like dichloro diphenyl tricholoroethane (DDT), hexachorobenzene (HCB), aldrin, etc.
2. Industrial chemical products like polychlorinated biphenyls (PCBs) and hexa bromo biphenyl.
3. Combustion by-products like dioxins and furans.

Because of major threats to human health, the UNEP has shortlisted twelve nasty POPs for elimination. These include

Organochlorine pesticides

1. DDT
2. Chlordane (1,2,4,5,6, 7,8,8-octachloro-3a,4,7,7a-tetrahydro-4,7-methanoindane)
3. Mirex (Hexachlorocyclopenta diene dimer)
4. HCB
5. Endrin (1,2,3,4,10,10-hexachloro-6,7-epoxy-1,4,4a,5,6,7,8,8a-octahydro-1,4-endo-endo-5,8-dimethanonapthalene)
6. Aldrin (1,2,3,4,10,10-hexachloro-1,4,4a,5,8,8a-hexahydro-exo-1,4-endo-5,8-dimethanonapthalene),
7. Dieldrin (3,4,5,6,9,9-hexachloro-1a,2,2a,3,6,6a,7,7a-octahydro-2,7:3,6-Dimethano naphth[2,3-b]oxirene)
8. Toxaphene (poly chlorinated camphene)
9. Heptachlor (1,4,5,6,7,8,8-heptachloro-3a,4,7,7a-tetrahydro-4,7-methanoindene)

Industrial chemicals

10. Cancer causing PCBs

Super-toxic chemicals (combustion by-products):

11. Dioxins
12. Furans.

we age their concentration become higher, and their potential effects on our health become more serious. People consuming excess fat are subjected to greater risk. In the United States, a recent study conducted by National Academy of Sciences estimated 20,000 cases of cancer a year, due to pesticide abuse alone.

Furthermore, there is increasing evidence of the oestrogen effect [1] of POPs. Many scientists believe that toxic agents in the environment have reduced the average sperm [2] count in men by 42% in the past 50 years, and rising percentage of sperms

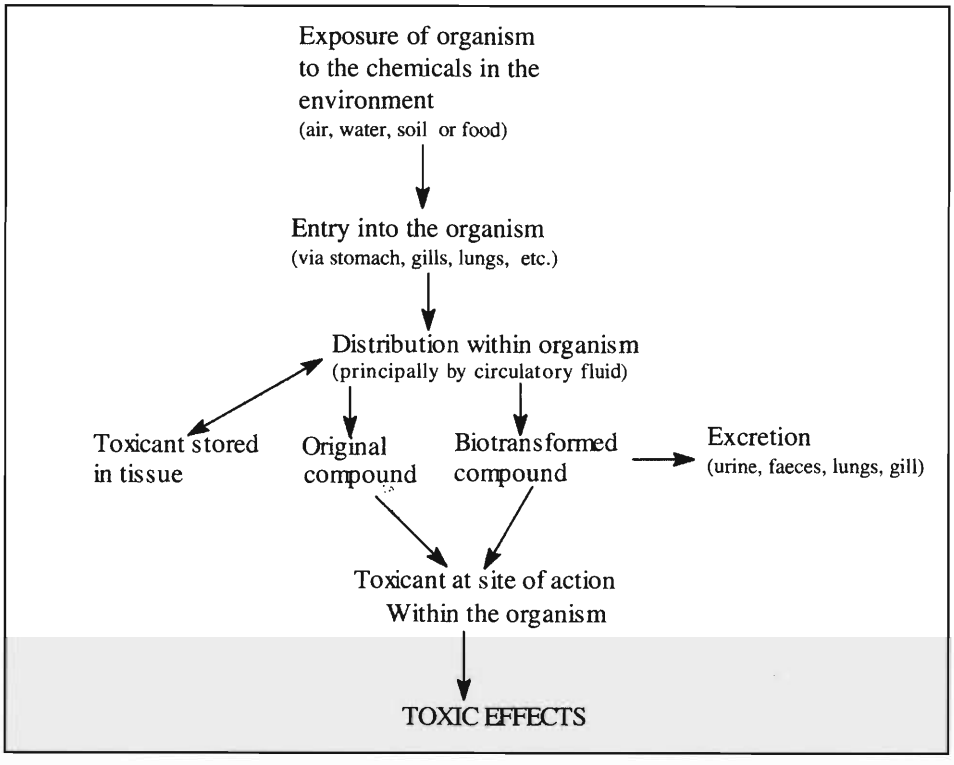


Figure 1. Generalised transfer process for a chemical from the environment to the site of toxic action.

are deformed and non-functional. Testicular cancer is on the rise, as are birth defects such as undescended testicles and menstrual disorders such as endometriosis. Toxic exposures during foetal development, infant life and childhood can have life long effects including increased susceptibility towards cancer and damage to the immune and reproductive systems. PCBs and dioxins are even suspected to contribute to learning disabilities.

Scientists have traced continued local extinction of the lake Ontario bald eagle from exposure to PCBs and other POPs. The beluga whales of the St. Lawrence estuary and the Alaskan Arctic are highly contaminated by a range of POPs and suffer from a high incidence of tumours and reproductive problems. Deformities and behavioural abnormalities in several species of fauna in the Great Lakes basin have also been linked to POPs. (Also see *Box* 2.)

Box 2. Some More Toxic Facts

Every year approximately 20,000 people, mostly in the third world countries die as a result of direct pesticide poisoning.

United States of America is the major producer and exporter of pesticides. 60% of herbicides used in USA are endocrine disruptors. 60 million birds are killed annually by legal pesticide use in USA.

Several studies, including one conducted by Indian Council of Medical Research in 1993, found alarmingly high levels of DDT, HCH and other extremely toxic pesticides in vegetables, fruits and milk in Delhi and other states such as Maharashtra, Punjab, Andhra Pradesh and Uttar Pradesh. The average diet of an Indian today contains 0.27 mg of DDT. Even infants are at risk. 25 Delhi women tested positive for pesticides in their breast milk and maternal serum. High levels of pesticides were found in the carrion of buffaloes, the main food of vultures which are fast disappearing. From 2000 in 1995, the vulture population of Bharatpur Keoladeo National park has reduced to just four in a span of three years.

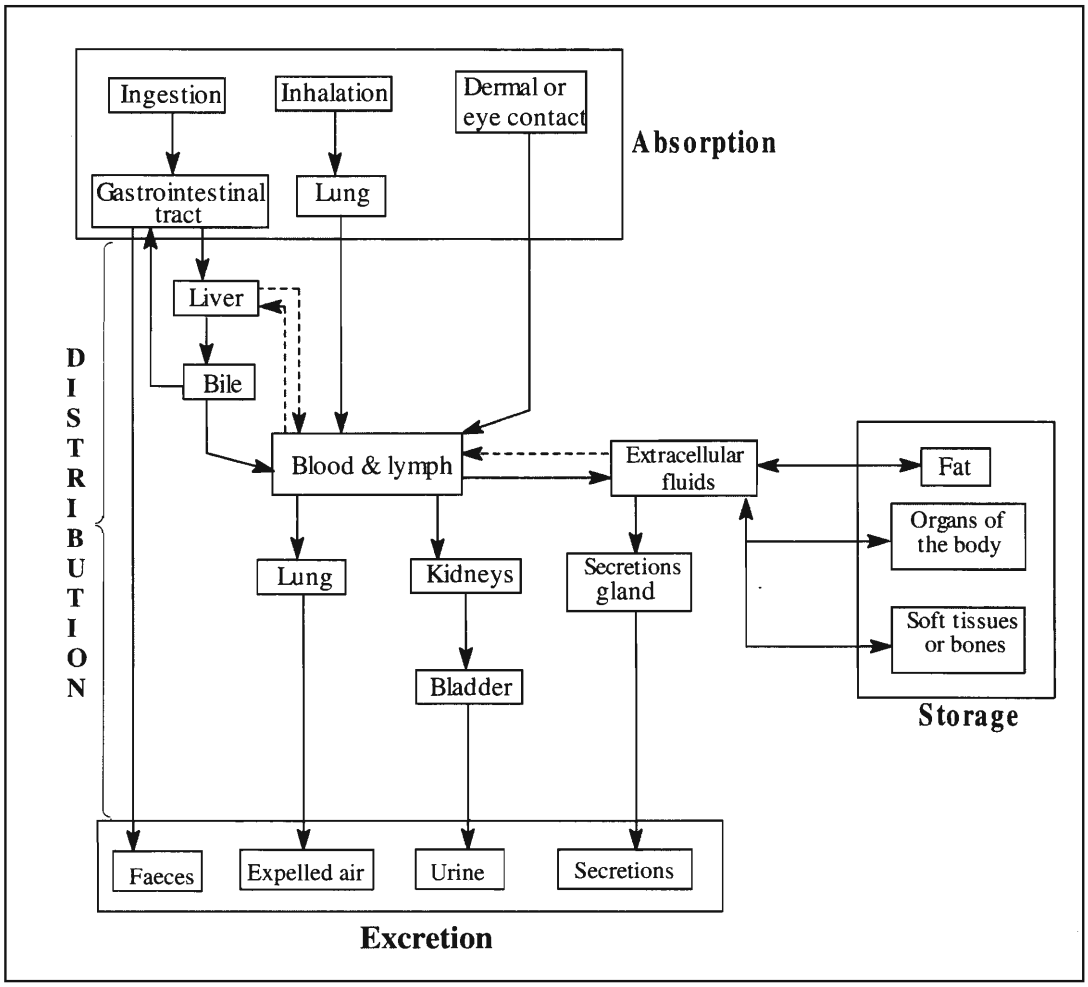
In India, pesticides continue to be used despite repeated warnings from scientists. Malathion, a chemical sprayed to create an anti-mosquito fog for example, is a known neurotoxin, particularly dangerous because it is absorbed both by the skin and through the respiratory system. Most importantly, it has an extre-mely low efficacy – only about 10% of the mosquitoes are killed by the chemical. But, India continues to use it.

The incomplete combustion of PCBs during thermal treatment processes may lead to polychlorinated dibenzofuran emissions. Chronic exposure of animals to PCBs can lead to disrupted hormone balances, reproductive failures, teratomas and carcinomas. PCBs are transferred from mother to foetus through placental transfer and later from mother to child through breast feeding. Children born of exposed mothers have lower IQs, growth retardation, premature births, diminished sensory and motor nerve conduction.

Even in trace amounts dioxins/furans have been linked to cancer and other health effects in laboratory animals. Studies of humans exposed to high levels of dioxins and furans have documented temporary adverse effects on the liver, immune system, senses and behaviour. However the most consistently observed effect was chloracne, a skin disorder.

Sources and Dispersal

POPs are found in common places. Electrical transformers contain PCBs. Dioxins, furans and other POPs are created during the manufacture of paper and vinyl plastic, which is used in making children's toys, clothing, polybags and tubing, flooring, pipes and siding. When vinyl is incinerated or burnt in a backyard trash fire, dioxin is formed again. Dioxins are also



formed during the manufacture of magnesium and other metals.

Figure 2. Distribution of toxicants within an organism.

POPs enter our bodies mainly through food. POPs accumulate (*Figure* 2) in fat and their concentration increases at each step of the food chain. For example, PCBs have been found to accumulate in the liver of sheep. Dieldrin accumulates in the wool of sheep that feed on contaminated land. Children are more vulnerable than adults to many kinds of pollution, POPs being the major one. Many POPs have been detected at significant levels in the breast milk of some women from many countries worldwide. By threatening the health and survival of our children, POPs threaten our future generations too.

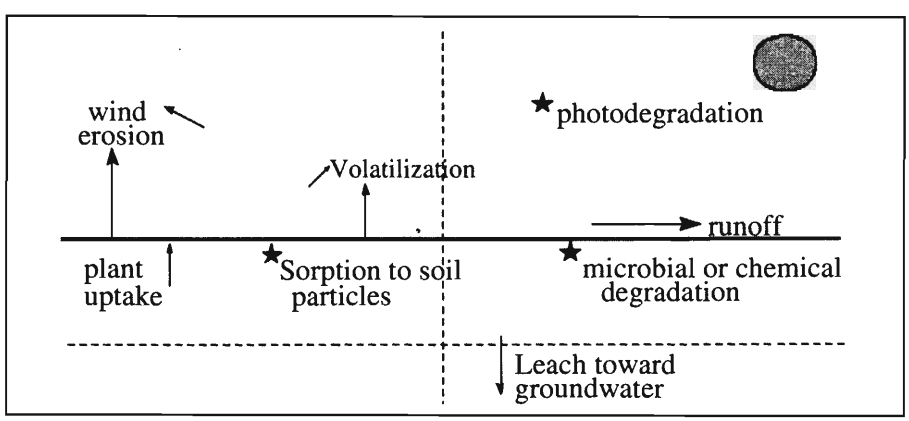
Pesticides

Use of pesticides in agriculture and horticulture are widely accepted as necessary in the production and conservation of food resources. Chemical pest control has won a central place in modern agriculture, contributing to the dramatic increase in crop yields achieved in recent decades for major field, fruit and vegetable crops. On the other hand this usage has resulted in the presence of pesticide residues in our food when it is consumed. By their very design, most pesticides are highly toxic.

Initially, pesticides were heralded as a 'cure-all' that would result in the total elimination of pest species but instead have steadily declined in effectiveness as pest species have become resistant to them. The three basic kinds of synthetic organic pesticides are organophosphates, carbamates and chlorinated hydrocarbons like aldrin, chlordane, dieldrin, DDD, DDT and lindane. Organophosphates and carbamates, though more expensive and toxic, are less persistent lasting only for days, weeks or months in the environment, while chlorinated hydrocarbons have high persistence and tend to get concentrated in tissues. But, organochlorines are the cheapest group of pesticides causing long term harm to biological communities as they are easily bioconcentrated in the food pyramid.

Figure 3. Pesticide fate processes.

Following the release of pesticides into the environment, they may have different fates (*Figure* 3). Pesticides which are sprayed



can move in air and eventually end up in other parts of the environment, such as in soil or water. Pesticides that are applied directly to the soil may be washed off the soil into nearby bodies of surface water or may percolate through the soil to lower soil layers and ground water. Pesticides that are injected into the soil may also be subjected to the latter two fates. The application of pesticides directly to bodies of water for weed control, or indirectly as a result of leaching from boat paint, runoff from soil or other routes, may not only lead to build up of pesticide concentration in water, but also may contribute to their build up in air through evaporation.

Industrial Chemicals: PCBs are typical industrial contaminants and can be found everywhere in the environment, (in air 0.002-15 ng/m^3, around industrial plants in rainfall 1-250 ng/l, in the ocean 0.05-06 ng/l). In the nutrition chain there is a significant cumulation and in breast milk 0.5-1mg/kg and in human fat 1-5 mg/kg can be found. PCBs, also referred to by trade names Aroclor, Phenoclor and Kanechlor, encompass a class of chlorinated compounds that include upto 209 variations or congeners with different physical and chemical characteristics. Most of the PCBs are oily liquids whose colour darkens and viscosity increases with rising chlorine content. PCBs with fewer chlorine atoms are more soluble, more amenable to chemical and biological degradation, and less persistent in the environment than those with more chlorine atoms.

PCBs are very persistent, hydrophobic, and generally do not migrate. However, the mobility of PCBs is dependent on soil or sediment characteristics like soil density, particle size distribution, moisture content and permeability. Additionally, meteorological and chemical characteristics such as amount of precipitation, organic carbon content and the presence of organic colloids also affect PCB mobility. Because of their stability many exposure routes of PCB are possible; dermal exposure, ingestion of PCBs contaminated soil, water and food, and inhalation of ambient air contaminated with PCBs.

Most of the PCBs are oily liquids whose colour darkens and viscosity increases with rising chlorine content.

Dioxins and furans have never been manufactured deliberately, except in small amounts for research purposes.

Dioxins and Furans

Polychlorinated dibenzodioxins and dibenzofurans constitute a group of chemical compounds that exhibit similar chemical, physical and toxicological properties. They are created by the chemical interaction of chlorinated compounds with organic matter. They feature the same basic chemical skeleton on which one to eight chlorine atoms attach themselves in various positions to produce 75 dioxin isomers and 135 furan isomers. Of the numerous forms of these compounds, 17 are toxic. TCDD (2,3,7, 8-tetra chloro dibenzo-*p*-dioxin), commonly called dioxin, is the most toxic and is considered by the Environmental Protection Agency (EPA) to be a probable human carcinogen. A less toxic form 2,3,7,8-tetrachlorodibenzofuran, has also been found in fish flesh.

Dioxins and furans have never been manufactured deliberately, except in small amounts for research purposes. They are unintentionally created in two major ways – 1) by the process used to manufacture some products like pesticides, preservatives, disinfectants and paper products. 2) when materials are burnt at low temperatures, for example, certain chemical products, leaded gasoline, plastic, paper and wood. Dioxins can be inadvertently formed during the manufacture of a group of chemicals called chlorophenols, used to preserve wood, hides, textiles, paints, glues, etc.

Open burning of household waste in barrels is potentially one of the largest sources of airborne dioxin and furan emissions [4]. Dioxins/furans are widespread in the environment and persist over long periods of time. Although they are most often associated with industrial activities, some natural occurrences such as forest fires are also believed to make a small contribution to their presence in the environment. These compounds have been measured in air, soil, sediments, meat, milk, fish, vegetables and human biological samples [5].

Conclusion

The problem of a variety of toxic chemical pollutants has been well-known for many years and that is why DDT was banned a long time ago in many countries. According to Nityanand Jayaram, a Green Peace campaigner, Asia faces a frightening scenario of historic, current and potential poisoning by the most dangerous variety of persistent pollutants. It is unfortunate that while governments are still grappling for ways to dispose of their stockpiles of obsolete imported pesticides, the continuing production and trade of these chemicals goes on unabated.

Suggested Reading

[1] Theo Colburn, S Von Soal Frederick and M Soto Ana, Developmental effects of endocrine disrupting chemicals in wildlife and humans, *Environmental Health Perspectives*, Vol. 101, No. 5, pp. 378-384, 1993.

[2] Gray Jr and Leon, Chemical induced alterations of several differentation- a re view of effects in Humans and Rodents, M A Mehlman (ed), *Advances in modern Environmental Toxicology*, Princeton, NJ, Princeton Scientific Publishing Co.Inc., pp.203-230, 1993.

[3] A Nair, R Mandapati, P Dureja, M K K Pillai, DDT and HCH load in mothers and their infants in Delhi, India, *Bull. Environ. Contam. Toxicol.*, Vol.56, pp.58-64, 1996.

[4] World Health Organization, Executive Summary, Assessment of the health risk of dioxins: re-evaluation of the Tolerable Daily Intake (TDI). http://www.who.int/pcspubs/dioxin-exec-sum/exe-sum-final.html, 1998.

[5] P H Howard (Ed.), *Handbook of Environmental Fate and Exposure data for Organic Chemicals. Pesticides*, Lewis Publishers, Chelsea, MI, pp.6-13, 1991.

Address for Correspondence
Rashmi Sanghi
302 Southern Labs
Facility for Ecological and Analytical Testing (FEAT)
Indian Institute of Technology
Kanpur 208016, India.
Email: rsanghi@iitk.ac.in

Einstein examined the photoelectric effect, which is now so well understood that it is used to open the doors of supermarkets and elevators when you step through a beam of light. In 1905 it was still a mystery.

Sheldon L Glashow
Higgins Professor of Physics, Harvard University
Interactions
Warner Books
New York, 1988, p.52