WWF DETOX CAMPAIGN

Factsheet

Chain of Contamination: The Food Link

Organochlorine pesticides (OCPS)

Background

In the EU, hexachlorobenzene (HCB), dichlorodiphenyltrichloroethane (DDT), chlordane and hexachlorocyclohexane (HCH, which exists as different forms, or “isomers”, one of which, γ-HCH, is lindane) are all banned organochlorine pesticides (OCPs). They are all persistent and bioaccumulative chemicals, found widely in the environment, wildlife and humans, but, fortunately due to legislative action, levels of many are now slowly declining. DDT, chlordane and HCB are classified as POPs (persistent organic pollutants) under the Stockholm Convention of 2001 (UNEP, 2006, Ritter et al., 1995), and lindane is designated as a POP under the UNECE Protocol, and is under consideration for inclusion under the Stockholm Convention. For more details on POPs see http://www.chem.unep.ch/pops/.

HCB was widely used as a pesticide until 1965, with production ending in many countries by the late 1970s. It was also used to make fireworks, ammunition and synthetic rubber (ATSDR, 2002b). It is also an unintentional by-product in some combustion processes. HCB is one of the most persistent environmental pollutants, due to its chemical stability and resistance to biodegradation. Its persistence and tendency to bioaccumulate means HCB can travel around the globe (Ritter et al., 1995). It has been found in air, water and organisms as far away as the Arctic (Allen-Gil et al., 1997). The US Environmental Protection Agency (EPA) has classified HCB as a probable human carcinogen.

DDT is a man-made chemical developed in the 1940s which was used as an insecticide against a very wide range of insect pests (ATSDR, 2002a). Technical-grade DDT may also contain DDE (dichlorodiphenyldichloroethylene) and DDD (dichlorodiphenyldichloroethane) which are breakdown products of DDT. DDT is a long-lasting, toxic chemical which builds up in the tissues of living organisms (Braune et al., 2005). Under the Stockholm Convention it is banned worldwide for use in agriculture, but it can still be used in developing countries for disease vector control, particularly against the mosquito carrying malaria (ATSDR, 2002a).

Chlordane is not a single chemical, but a mixture of many related organochlorine chemicals such as trans-chlordane, cis-chlordane, ß-chlordene, heptachlor, and trans-nonachlor (ATSDR, 1994). Introduced in 1945, chlordane was used as a pesticide until the 1980s. It was banned for agricultural use in the EU in 1981. Chlordane is a broad-spectrum insecticide known for its toxic effects and its capacity to persist and bioaccumulate in the environment. It is stable in soil and breaks down very slowly, so can remain in soil for decades (Eitzer et al., 2003). Chlordane builds up in the fatty tissues of fish, birds and mammals (Stern et al, 2005, Ritter et al., 1995).

Hexachlorocyclohexane (HCH) is the name for a family of related man-made compounds. They differ only slightly, and have different prefixes, for example alpha (α)-HCH and beta (β)-HCH. The most important member of the family is gamma-HCH, which is more commonly known as lindane (ASTDR 2005). The information here generally refers to lindane but is applicable to the other forms of HCH.

Major uses

HCB was widely employed as a fungicide on seeds, but its marketing and use as a plant protection product has been banned in the UK since 1975 and in the EU since 1988. Although HCB is no longer manufactured or used as a commercial product, it is formed as a by-product or impurity in the manufacture of chlorinated solvents and other chlorinated compounds including several pesticides currently in use.

DDT was first used as an insecticide in 1939. It was widely employed during WWII against insects spreading malaria, typhus and other diseases. In the early 1960s, it was used widely to control agricultural pests as well as human and farm animal diseases. DDT was banned in the UK in 1986 but is still used in developing countries to control insect-borne diseases e.g. malaria.

Before it was banned, chlordane was used in the greatest quantities as a soil insecticide for controlling termites and soil-borne insects whose larvae feed on the roots of plants. Lindane was widely used as an insecticide. It is no longer used in the UK as an agricultural and domestic insecticide and in 2003 the EU agreed to ban all its agricultural uses.

How do organochlorine pesticides get into the environment and the food chain?

Direct application to land (for agriculture and public health situations), spillages and improper storage has meant that organochlorine pesticides have entered the environment and the food chain, persisting in soils, sediments in rivers and estuaries and in the marine environment (Ritter et al., 1995). From these environmental compartments they can then enter the food chain and accumulate in wildlife.

The widespread past use of HCB as a fungicide has resulted in it presence in the environment. HCB can be released into the environment due to use in agricultural products in developing countries and improper storage or disposal in developed countries. HCB is also released into the atmosphere as an accidental product from the combustion of coal, waste incineration and certain metal processes. Natural fires and volcanoes may serve as natural sources.

In countries where DDT is still in use, most release is due to its use as an insecticide. It can enter the atmosphere by evaporation and can contaminate surface water from soil run-off. It may also escape into the environment as a result of accidental discharges during use or manufacture. Because of its chemical characteristics, DDT can travel long distances through the atmosphere. This results in the wide dispersion of DDT and its metabolites throughout the world, even into remote areas such as the Arctic or Antarctic. The persistence of DDT and its breakdown products has contributed to their bioaccumulation and biomagnification (increasing concentration of a chemical in organisms higher up the food chain) in the environment. DDT and its breakdown products are ubiquitous in food and the environment (Ritter et al., 1995).

Chlordane has entered the environment mainly as a result of its use as a soil insecticide for agriculture and for domestic termite control (Eitzer et al., 2003). Lindane is released into the environment as a result of its agricultural use as an insecticide and during its manufacture, storage and transport. Lindane can be released into air from sources such as timber treatment or evaporation from treated wood (e.g. Shore et al., 1990).

How are people exposed to organochlorine pesticides?

Exposure to organochlorine pesticides can occur in several ways, such as via contaminated air, water or through the skin in countries where they are still used. However, the primary exposure route to people in developed nations (where organochlorines are no longer used) is through contaminated food. The most contaminated foods typically include oily fish and foods of animal origin such as fatty meats and dairy products. There are numerous studies on organochlorine contamination of food. Some examples can be seen below in table 1. The EU has also set maximum levels for pesticide residues (including DDTs, HCH, HCB and chlordane) in foodstuffs of animal origin - meat, meat products, offal, dairy products, eggs etc. (EU, 2006).

Food item	Reference(s)	Comments
Salmon (farmed & wild)	Hites et al (2004). Science, 303, pp226-229	Farmed salmon (US /Europe) have much higher levels of organochlorines.
Swordfish	Stefanelli et al (2004). Mar. Poll. Bull., 49, pp938-950	Swordfish caught in the Mediterranean and Azores.
Shellfish	Naso et al., (2005). Sci Total Environ., 343(1-3), pp83-95. Binelli et al., (2003). Mar Pollut Bull., 46(7), pp879-86. Yang et al., (2006) Chemosphere, 63(8), pp1342-52.	POPs in seafood from the Gulf of Naples, S. Italy. POPs in edible clams Italian/European markets PCBs and organochlorine pesticides in edible fish and shellfish from China.
Butter	Weiss et al (2005). Ambio, 34(8) pp589-597. Kalantzi et al (2001). Env. Sci. Technol., 35 (6), pp1013-1018.	Worldwide surveys of butter.
Pork	Covaci et al (2004). Chemosphere, 56, (8), pp757-766.	HCH isomers and DDTs in pork (meat, fat, liver) from Romanian farms.
Honey	Blasco et al., (2004). Jnl. Chromatogr. A., 1049 (1-2), pp155-160	Honey from Spain and Portugal.
Tomatoes	Gonzalez et al., (2003). J Agric Food Chem., 51(5), pp1353-9.	OC pesticides (incl DDT, HCH) in tomato crops from organic production.
Fruit & vegetables	Adeyeye and Osibanjo (1999). Sci Total Environ., 231(2-3), pp227-33	Organochlorine (incl. HCB, HCH & DDT) in fruits, vegetables and tubers from Nigerian markets.
Various food items (market basket surveys)	Schafer K.S. & Kegley S.E. (2002). Jnl. Epidemiol Community Health, 56 (11), pp813-817. Juhler RK et al., (1999). J AOAC Int., 82 (2), pp337-358	Analysis of fruits, vegetables, cereals, baked goods, fish and animal products (meat, butter, cheese, fat, and eggs).

Table 1: Organochlorine pesticide residues – including HCB, DDTs (DDT, DDD and DDE), chlordane and HCH (lindane) – in food items.

HCB residues have been found in shellfish, fish and certain vegetables (see table 1). Exposure to HCB can also occur by consuming milk, other dairy products, meat and poultry, if the animals from which these products were obtained have been exposed to it through their feed or other sources of contamination.

The main dietary route of exposure to DDT (and its breakdown products DDE and DDD) is consumption of food such as fish, meat, poultry and dairy products (see table 1). Leafy vegetables generally contain more DDT than other vegetables (ATSDR, 2002a), possibly because DDT in the air is deposited on the leaves. The amount of DDT in food has greatly decreased since the insecticide was banned in the 1970s and subsequent human exposure is therefore slowly declining (e.g. Smith, 1999).

Exposure to chlordane may occur through consumption of contaminated meat, fish, shellfish, root crops and other foods. However, over the last few years it has not been detected in pesticide residue surveys of typical foodstuffs in the UK. A recent survey of cow's milk carried out by the UK-MAFF Working Party on Pesticide Residues (WPPR) revealed detectable levels of lindane in all samples taken (MAFF, 1997). The lindane detected was most likely to have originated from imported animal feed contaminated with lindane.

Once in the body, organochlorines tend to accumulate in fatty tissues and can remain there for years (Covaci et al., 2002a, Alawi et al., 1999). Organochlorines can also circulate in the lipid (fat) portion of the blood serum (Thomas et al., 2006). During pregnancy, organochlorine residues can be transferred in utero to the developing foetus via the placental blood supply (Sala et al., 2001). For example, organochlorine pesticides have been found in amniotic fluid, human placentas, foetuses, and maternal and umbilical cord blood (Jaraczewska et al., 2006, Covaci et al., 2002b, Foster et al., 2000, Kanja et al., 1992). A proportion of a mother's organochlorine burden can also be mobilised from fat stores during lactation/breast feeding and transferred to her baby via breast milk. Organochlorines such as DDT, for example, have been measured in human milk (Chao et al., 2006, Kalantzi et al., 2004), but it is believed that the benefits of breast-feeding outweigh any risks from exposure to these compounds in the mother's milk.

What health effects are associated with exposure to organochlorine pesticides?
Long term studies in animals have shown that HCB can harm the liver, endocrine (including thyroid), immune and nervous systems and can damage bones, kidneys, and blood (ASTDR, 2000b). Levels of exposure from the diet are however, likely to be lower than those responsible for such effects, but unborn and young children may be more sensitive to these effects than adults. Young animals exposed to HCB before and soon after birth are especially sensitive to HCB. Effects on the liver, nervous system and immune function occurred at lower doses in young developing animals than in adults. Animal studies show that HCB affects various endocrine (hormone) organs, including the thyroid gland, parathyroid gland, adrenal gland and ovaries (ATSDR, 2002b). These tissues produce hormones that are important to normal growth and development. The US EPA has determined that hexachlorobenzene is a probable human carcinogen and the International Agency for Research on Cancer (IARC) has determined that HCB is possibly carcinogenic to humans (ASTDR, 2002b).

The health effects of DDT are still under scrutiny. It is difficult to get absolute proof that a particular chemical causes effects in humans exposed at typical levels (for example, at levels encountered via the dietary exposure route), but more and more studies are now providing evidence to show that DDT may be linked with effects on reproduction, brain development, diabetes, and immune system function. For example, a study has shown that increased concentrations of p,p'-DDE in human breast milk were associated with reductions in the duration of lactation (Gladen and Rogan, 1995, Rogan et al., 1987). Furthermore, other epidemiological studies have found that as the DDE levels in the blood of pregnant women increased, the chances of having a pre-term baby also increased, and this might also be linked with increased infant mortality (Torres-Arreola et al., 2003, Longnecker et al., 2001). The impacts of DDTs on neurodevelopment have also been investigated. For example, a study on the children of Mexican farm workers in California has shown that prenatal exposure to DDT, and to a lesser extent DDE (determined by measuring levels of these compounds in maternal blood), is associated with delays in neurodevelopment during early childhood (Eskenazi et al., 2006).

A study on Swedish fisherman (and their wives) consuming fish from the highly contaminated Baltic Sea has shown an association between levels of DDE and PCBs (another class of organochlorine chemicals) in their serum and prevalence of type II diabetes in this population (Rylander et al., 2005). The authors of this paper conclude that these results suggest POPs such as DDE and PCBs might contribute to type II diabetes.

Organochlorines have also been shown to be immunotoxic (toxic to the immune system). For example, a study of Inuit infants in Nunavik, Canada revealed an association between exposure to DDE and PCBs during pregnancy and incidence of acute infections such as those of the upper and lower respiratory tract, middle ear (otitis media) and gastrointestinal tract (Dallaire et al., 2004). This population is exposed to organochlorines principally through their traditional diet of fish and marine mammal fat.

Results from wildlife studies suggest that organochlorines such as DDT and its breakdown products have the potential for disrupting hormone processes in the body i.e. they can be endocrine (hormone) disrupting chemicals (e.g. Tanabe, 2002, Mills et al., 2001, Guillette, 2000, Guillette et al.,1996). This is important given that low levels of endocrine-disrupting chemicals have the potential to affect the development of the reproductive organs and the brain in utero.

The possible association between exposure to DDT and various types of cancers in humans, particularly breast cancer, has been studied extensively (Snedeker, 2001). Controversy still exists, but as yet there appears to be no conclusive evidence linking DDT and related compounds to breast cancer in humans (e.g. Beard, 2006, Siddiqui et al., 2005, Calle et al, 2002). However, DDE is known to be oestrogenic (oestrogen mimicking) properties, and increased oestrogen exposure is a risk factor for breast cancer (Kortenkamp, 2006).

Chlordane has been linked to liver and blood disorders, severe neurological effects, and damage to the endocrine and reproductive systems. Effects on the kidneys and on the cardiovascular, respiratory and gastrointestinal systems have also been observed (ATSDR, 1994). These effects were seen mostly in people who swallowed chlordane mixtures and not those exposed to low levels in the diet. It is not known whether chlordane will cause cancer in humans after long-term exposure, but previous studies have led chlordane to be designated a possible human carcinogen by the IARC, and a probable human carcinogen by the US EPA.

Exposure to lindane (γ-HCH) in occupational settings has been associated with had blood disorders, dizziness, headaches, and changes in the levels of sex hormones. All HCH isomers can produce liver and kidney effects. Animal studies have shown that exposure to γ-HCH can reduce the ability to fight infection and damage the ovaries and testes (ATSDR 2000a), although exposure to levels found in everyday foods has not been associated with these effects. Lindane is classified by the EU as a possible human carcinogen. IARC has classified HCH (all isomers) as possibly carcinogenic to humans.

How can exposure to organochlorine pesticides be reduced?

Since the predominant exposure route for organochlorines is through oily fish and fatty foods of animal origin (meat, dairy products), eating less of these foods can help to reduce exposure, although a certain amount is considered beneficial for the heart. For oily fish and other fish/seafood it is advisable to follow the UK Food Standards Agency's (FSA) consumption guidelines, particularly if you are pregnant, planning to have children or are breast feeding. Details of FSA analyses of fish and other foods for organochlorines can be found here http://www.food.gov.uk/science/surveillance/. DDT is still used in some countries for disease vector control, and so washing imported fruit and vegetables before eating them is good practice. Cooking can also reduce the levels of organochlorines in fish (Bayen et al., 2005). UK food surveys suggest levels of chlordane have decreased significantly, so exposure already appears to be minimal.

Further information:

Pesticides Residue Committee (PRC) http://www.pesticides.gov.uk/prc.asp?id=974
Pesticide Action Network (see "active ingredient" factsheets on the Publications page) www.pan-uk.org
Agency for Toxic Substances and Disease Registry www.atsdr.cdc.gov/ToxProfiles/

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