World Health Organization

PREVENTING DISEASE THROUGH HEALTHY ENVIRONMENTS

EXPOSURE TO DIOXINS AND DIOXIN-LIKE SUBSTANCES: A MAJOR PUBLIC HEALTH CONCERN

Human exposure to dioxins and dioxin-like substances has been associated with a range of toxic effects, including immunotoxicity, developmental and neurodevelopmental effects, and changes in thyroid and steroid hormones and reproductive function. Developmental effects are the most sensitive health end-point, making children, particularly breastfed infants, the population most at risk.[1,2] Dioxins and dioxin-like substances are persistent organic pollutants (POPs) covered by the Stockholm Convention on Persistent Organic Pollutants; they can travel long distances from the emission source and can bioaccumulate in food-chains.[3] Human exposure occurs mainly through consumption of contaminated food.[1,4] Public health and regulatory actions are needed to reduce emissions of these substances, as required by the Stockholm Convention, and to reduce human exposure, particularly for children.

What are dioxins and dioxin-like substances?

The term "dioxins and dioxin-like substances" commonly refers to polychlorinated dibenzodioxins (PCDDs), polychlorinated dibenzofurans (PCDFs) and polychlorinated biphenyls (PCBs). They are two- or three-ring structures that can be chlorinated to varying degrees. PCBs can have up to 10 chlorine atoms substituting for hydrogen atoms, and PCDDs and PCDFs can have up to 8. The compounds often have similar toxicity profiles and common mechanisms of action and are generally considered together as a group to set guidelines.[1,4]

Sources of exposure to dioxins and dioxin-like substances[1,4,5]

PCDDs and PCDFs are widely present in the environment, occurring naturally and as by-products of combustion and of various industrial processes. PCDFs were major contaminants of PCBs, but neither PCDDs nor PCDFs have ever been manufactured deliberately. They have no known uses.

PCBs are not natural substances but were globally manufactured and used in the past. Although PCB manufacture is prohibited under the Stockholm Convention on Persistent Organic Pollutants, their release into the environment still occurs from the disposal of large-scale electrical equipment and waste.

Mixtures of the substances with different numbers and positions of chlorine substitution are found in the environment. The degree of chlorination of dioxin mixtures released to the environment through incineration is determined by the source material and the amount of chlorine available.

Remedial actions have led to reductions in exposure in the developed world, with a fall to around 10% of levels seen in the 1970s. Countries with rapidly expanding development are experiencing increasing exposure, particularly to PCDDs and PCDFs, but levels are still below those developed countries in the 1970s.

Industrial processes and natural events

PCDDs and PCDFs are by-products of industrial processes, including the manufacture of chlorophenols and phenoxy herbicides, chlorine bleaching of paper pulp and smelting. They can also be generated by natural events, such as volcanic eruptions and forest fires. PCBs were previously manufactured for use as dielectric fluids (with low electrical conductivity) in larger-scale electrical products such as transformers and capacitors, in heat transfer and hydraulic systems and in industrial oils and lubricants. PCDFs were common contaminants of commercial PCB mixtures.

Food, water and air

Generally, levels of PCBs, PCDDs and PCDFs in air are very low, except in the vicinity of inefficient incinerators. Concentrations of these compounds in drinking-water and surface water are also very low, because they are poorly soluble in water. Releases to air from inadequate incineration and releases from waste sites contaminate soil and aquatic sediments, leading to bioaccumulation and bioconcentration through food-chains. The higher chlorinated components and components with specific positions of chlorination persist longer in the environment and show greater bioaccumulation. The substances have high fat solubility, which may lead to higher concentrations in fatty foods, such as dairy products, some fish, meat and shellfish. Most human exposure is through ingestion of contaminated food. These compounds persist in fatty tissue, with typical half-lives in humans in excess of 7 years.

Waste disposal

Any source of organic materials in the presence of chlorine or other halogens will generate dioxins and furans during combustion. PCDDs and PCDFs are generated through the incineration of waste (domestic, industrial and hospital) at low to moderate temperatures; guidance has been developed to identify and quantify releases from various incineration processes. The use of modern incineration technology destroys dioxins and furans, whereas inadequate incineration creates them.[6]

Disposal of electrical equipment may release PCBs (and PCDF contaminants); guidance is available on equipment likely to contain PCBs.[7,8] Stockpiles of old industrial lubricants containing PCBs are also a potential source of emissions.

Derivation of toxic equivalency factors (TEFs)

Some individual compounds with particular levels of chlorination and/or positions of the chlorine substitutions are much more toxic than others. Toxic equivalency factors (TEFs) have been established to compare the toxicities of individual PCDDs, PCDFs and PCBs relative to the most toxic of these compounds: 2,3,7,8-tetrachlorodibenzodioxin (TCDD), which is used as a reference and given a TEF of 1.[9,10] The common mechanism of action for these substances means that their effects are additive, and TEFs for individual compounds can be summed to establish a TEF for mixtures. This approach has proved robust as a method for establishing the relative toxicities of these compounds.

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World Health Organization (WHO) dioxin guidelines
Provisional tolerable monthly intake In 2002, the Joint Food and Agriculture Organization of the United Nations (FAO)/WHO Expert Committee on Food Additives (JECFA) established a provisional tolerable intake of 70 pg/kg body weight per month for PCDDs, PCDFs and coplanar PCBs expressed as TEFs, based on reproductive end-points.[1] The value is expressed "per month" to reflect that exposure is cumulative and chronic rather than acute.
Drinking-water No water quality guidelines have been set for these substances because of their low water solubility.
Air An air quality guideline for PCBs was not established, because direct inhalation exposures constitute only a small proportion of the total exposure, in the order of 1–2% of the daily intake from food. Although this air concentration is only a minor contributor to direct human exposure, it is a major contributor to contamination of the food-chain.[11]

Health effects

- Short-term exposure to high levels of dioxins and dioxin-like substances in occupational settings or following industrial accidents may cause skin lesions known as chloracne, which is persistent.[1]

- Longer-term environmental exposure causes a range of toxicity, including immunotoxicity, developmental and neurodevelopmental effects, and effects on thyroid and steroid hormones and reproductive function. The most sensitive life stage is considered to be the fetus or neonate. Guidance values have been based on reproductive and developmental effects.[1,4,5]

- Experimental animal studies indicate carcinogenicity in a range of species with multiple sites of tumours. Epidemiological studies in occupational settings also indicate human carcinogenicity at multiple sites. The International Agency for Research on Cancer (IARC) classified TCDD in Group 1 (*carcinogenic to humans*) and some other dioxins in Group 3 (*not classifiable as to their carcinogenicity to humans*).[12,13] PCBs as a group are classified in Group 2A (*probably carcinogenic to humans*).[14] In addition, IARC recently classified 2,3,4,7,8-pentachlorodibenzofuran and 3,3′,4,4′,5-pentachlorobiphenyl in Group 1.[13]

- These substances are not genotoxic carcinogens. It is considered that the mechanism of carcinogenesis, involving the aryl hydrocarbon receptor, means that there is a threshold for carcinogenicity. Tolerable intake guidance based on non-cancer end-points is considered protective for carcinogenicity.[1]

Risk mitigation recommendations

Inventory and reduce emissions

- Inventory emissions of dioxins and dioxin-like substances, guidance on inventory development and analysis of current inventories regionally and globally is available.[15]

Countries should develop local inventories based on guidance for the identification and quantification of dioxin and furan releases.[6]

- Reduce emissions of dioxins and dioxin-like substances as required under the Stockholm Convention on Persistent Organic Pollutants.[3]

- Incineration at high temperatures with long residence times and adequate mixing is required to reduce emissions of dioxins and dioxin-like substances. An inventory of suitable incineration facilities globally has been prepared.[16]

Disposal

- Follow global guidelines for the identification of PCBs in materials and equipment to inform local actions.[7,8]
- Clean up and safely dispose of industrial waste containing PCBs and PCDFs (or likely to generate PCDDs). Routine rehabilitation of contaminated sediments is not recommended. The necessity for environmental cleanup should be decided through risk assessment on a case-by-case basis.
- Guidance is available on the disposal of health-care waste.[17]
- Further develop international programmes for disposal to aid countries without suitable waste management facilities.

Reduce contamination in food

- Apply strategies developed by WHO/FAO to reduce contamination in food and feed. Countries should develop and implement local strategies.[2]

Monitoring

- Monitor PCDDs, PCDFs and PCBs in food items and human milk. WHO has been involved in such monitoring since 1976, and this is properly done at the international level.[18] More cost-effective bioassays should precede costly chemical analysis in individual developing countries.

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