FOOD AND AGRICULTURE ORGANIZATION OF THE UNITED NATIONS
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FACT SHEET

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Dioxins in the food chain
Prevention and control of contamination

What are dioxins?

The common term dioxins is often used for a number of chemically related lipophilic compounds (*polychlorinated dibenzo-para dioxins (PCDDs)* and *polychlorinated dibenzofurans (PCDFs)*, including certain dioxin-like polychlorinated biphenyls (PCBs) with similar toxic properties. However, the denomination of **dioxin** is given to *2,3,7,8-tetrachloro-dibenzo-para-dioxin (TCDD)*. Of the identified 419 types of dioxin-related compounds, which have a dioxin-like chemical structure, only about 30 are considered to have significant toxicity, with TCDD being the most toxic. Although dioxins and dioxin-like PCBs (for convenience herein after referred to as "dioxins") show similarities in their toxicological and chemical behaviour, their sources may be different.

Dioxins are pervasive environmental pollutants. They are often referred to as persistent organic pollutants because they are resistant to both physicochemical and biological degradation decompose very slowly and remain in the environment for long periods of time because of their chemical stability. Dioxins, once entered in biological organisms including humans, accumulate in the fat tissues. For TCDD, the half-life in the body is estimated to be seven to eleven years, but other dioxins have variable half-lives. Dioxins have a highly toxic potential because they affect a number of organs and systems and bio-accumulate along the food chain.

Although formation of dioxins is local, environmental distribution is global. Dioxins are found throughout the world in practically all media. The highest levels of these compounds are found in soils, sediments and food, especially dairy products, meat, fish and shellfish. Very low levels are found in plants, water and air.

Sources of dioxin contamination

Dioxins are formed as unwanted by-products from a number of human activities including certain industrial processes (e.g., production of chemicals and combustion processes). Accidents at chemical factories have been shown to result in high emissions and contamination of local areas. Other dioxin sources include domestic heaters, agricultural and backyard burning of household wastes. Natural processes such as volcanic eruptions and forest fires can also produce dioxins. In terms of dioxins release into the environment, waste incinerators (solid waste and hospital waste) are often the worst culprits, due to incomplete burning and large amounts of waste incinerated.

Sources of dioxins in soil include deposition from atmospheric dioxins, application of contaminated sewage sludge to farm land, flooding of pastures with contaminated sludge, and prior use of contaminated pesticides and fertilizers.

Dioxins are poorly soluble in water; however, they are adsorbed onto mineral and organic particles suspended in water. The surfaces of oceans, lakes and rivers are exposed to aerial deposition of these compounds, which are consequently concentrated along the aquatic food chain. The entry of waste water or contaminated effluents from certain processes, such as chlorine bleaching of paper or pulp or metallurgical processes, can lead to contamination of water and sediment of coastal ocean areas, lakes and rivers.

Current sources of dioxins entering the food chain include new emissions and remobilisation of deposits or reservoirs in the environment. New emissions are mainly via the air route.

Routes of exposure to dioxins (humans and animals exposures)

Food of animal origin is the predominant route of **human exposure** to dioxins due to the deposition of these substances in the lipid component of animal derived foods. In lactating animals dioxins are excreted partly with milk fat, and in laying hens they are concentrated in fat content of the yolk in laid eggs.

Approximately 80-90 %, or more, of the total exposure in the human general population is via fats in fish, meat, eggs, milk and dairy products. Levels of dioxins in animal fat may be related to contamination of the local environment and to contamination of feed or, to certain production processes (e.g., artificial drying, smoking). Infants are exposed through the assumption of contaminated breast milk.

Occupational exposure is an issue for some in the chemical industry, or in agriculture sector, e.g. through application of chemicals, notably herbicides.

Due to the omnipresence of dioxins, all people have background exposure and a certain level of dioxins in the body, leading to the so-called body burden. Current normal background exposure is not expected to affect human health on average and only levels above the background levels[1] are considered when assessing occurrence of contamination. However, due to the high toxic potential of this class of compounds, efforts need to be undertaken to reduce current background exposure.

Animal exposure to dioxin contamination by feed may originate from many different sources. Dioxins may be inherent to a product (e.g. clay minerals, recuperated copper sulphate, zinc oxide, food by-products and fish by-products such as fish meal and fish oils), can be formed during heat processing (e.g. lime in citrus pulp, directly dried bakery waste), or may arise through the use of treated wood in animal production, the grass meal or grass meal pellets produced from grass dried directly fed flue gases from (e.g. coal-fired heating plants) and pasture placed near polluting plants (e.g. coal-fired heating plants).

The uptake of dioxins by fish occurs via gills and diet. Fish accumulate dioxins in their fatty tissue and liver. Bottom dwelling/bottom feeding fish species are more exposed to contaminated sediments than pelagic fish species. However, these levels are not always higher than those in pelagic fish depending on the size, diet and physiological characteristics of the fish. In general, fish show an age-dependent accumulation of dioxins.

Effects on human and animal health

Dioxins have been showed to cause a wide variety of toxic effects and to be carcinogenic in humans and animals. Endocrine, reproductive and developmental effects are among the most sensitive to dioxin exposure. In general, toxic exposure to dioxins has been shown to cause pathology of liver, thymus and spleen, endocrine disruption, skin lesions and in extreme cases, death. The most sensitive effects, observed in multiple species, appear to be developmental, including effects on the developing immune, nervous, and reproductive systems. Health effects can be observed for years after the initial exposure. Intoxications can be acute or chronic depending on the toxic dose ingested and the time of exposure.

Differences in species sensitivity for dioxins exist and have been suggested to be a result of either different body fat compositions by species or of differences in metabolism. In spite of the differences in the amount of chemical required to elicit a toxic response, once toxicosis is induced, the toxic effects observed in different animal species are very similar.

Short-term exposure of humans to high levels of dioxins may result in skin lesions, such as chloracne and patchy darkening of the skin, and altered liver function. Long-term exposure is linked to impairment of the immune system, the developing nervous system, the endocrine system and reproductive functions. Chronic exposure of animals to dioxins has resulted in several types of cancer. TCDD was evaluated by the WHO's International Agency for Research on Cancer (IARC) in 1997. Based on animal data and on human epidemiology data, TCDD was

[1] *Background Level:* 1. The concentration of a substance in an environmental media (air, water, or soil) that occurs naturally or is not the result of human activities. 2. In exposure assessment the concentration of a substance in a defined control area, during a fixed period of time before, during, or after a data-gathering operation (US EPA Glossary)

classified by IARC as a "known human carcinogen". However, TCDD does not affect genetic material and there is a level of exposure below which cancer risk would be negligible.

Excess risks were observed for all cancers, without any specific cancer predominating. In specific cohorts, excess risks were observed for reproductive cancers (breast female, endometrium, breast male, testis) but, overall, the pattern is inconsistent. Small alterations in thyroid function have occasionally been found. Experimental data indicate that endocrine and reproductive effects should be among the most sensitive effects in both animals and humans.

Effects in animal species

In poultry, several clinical signs have been described after dioxins exposure through ingestion of contaminated feed during the Belgian dioxin crisis in 1999. The symptoms included a decrease in egg production and hatching. Furthermore, the chicken edema disease[2] was observed with symptoms of hydropericardium, edema and ascitis leading to a high mortality rate.

In cattle weight loss and emaciation, with food intake remaining at normal level, have been associated with dioxin intoxication. Furthermore, drop in milk production and pathologies in kidneys, spleen and skin can be observed. In dairy cows, hypofertility has been associated with grazing in a highly contaminated industrial area in Italy.

In experimental animals dioxins have a broad spectrum of hepaptoxic, immunotoxic, carcinogenetic, teratogenetic effects and causes developmental, reproductive and dermal toxicity. Endometritis has been linked to chronic exposure to dioxins in primates and rodents. In an incident where a horse arena became contaminated, horses showed signs of intoxication such as chronic weight loss, hair loss, skin disorders, colic, dark urine, conjunctivitis, joint stiffness, and laminitis. In dogs and cats weight loss and pathologies in liver and kidneys as well as skin lesions have been observed.

Prevention and control of dioxin exposure

Source-directed measures are essential for a further reduction of dioxin contamination. These measures should be directed to reducing the formation of dioxin during thermal processes and destruction techniques; to minimizing releases from existing equipment; to preventing accidents; and to better controlling the disposal of dioxins containing oils and wastes.

As more than 90% of human exposure to dioxins in the general population is through the food supply, mainly meat and dairy products, fish and shellfish, protecting the food supply from dioxins contamination is critical. Measures to reduce dioxins contamination entering in the food chain should aim at preventing or reducing contamination of environment (air, soil and water) and animal feed (for convenience herein after, the term feed is intended to include also feed ingredients); at preventing or reducing the formation of dioxins during food and feed processing; and at applying good agricultural and hygienic practices during primary production, processing, distribution and sale of food and feed.

Contaminated animal feed above background levels should be identified and, where necessary, excluded from entering in the food chain. To reduce dioxins contamination in the environment, national authorities should prevent uncontrolled burning of wastes, including the burning of landfill sites or backyard burning, and the use of PCB treated wood for domestic heaters.

Areas with unacceptable dioxins contamination in the soil, water and air should be identified and controlled. If necessary, agricultural production should be avoided or restricted.

It is the role of national governments and producers to monitor the safety of food and feed supply and to take action to protect public and animal health. Food contamination monitoring systems must be in place to ensure that

[2] *Chicken edema disease*: a disease of broiler chickens fed on a diet containing fat contaminated by one of several toxic factors which cause hepatic necrosis.

guideline levels / maximum levels are not exceeded. When incidents of contamination are suspected, countries should have contingency plans to identify, detain and dispose of contaminated food and feed. The exposed population should be examined in terms of exposure (e.g. measuring the contaminants in blood or human milk) and effects (e.g. clinical surveillance to detect signs of ill health).

Recommended specific measures to prevent and control contamination of food and animal feed

In order to reduce the contamination of food, control measures to reduce the dioxins at the feed level should be considered. These measures may involve developing Good Agricultural Practice, Good Animal Feeding Practice and Good Manufacturing Practice.

Measures include:

- Set national guideline levels or maximum levels[3] for dioxins in soil and water and recommendation for specific agricultural use (e.g., limitation of grazing or use of appropriate agricultural techniques);
- Avoid that areas with increased dioxins contamination due to local emission, accidents or illegal disposal of contaminated materials are used for grazing or for the production of feed crops. If possible, contaminated soil should be treated and detoxified or removed and stored under environmentally sound conditions;
- Avoid spreading of sewage sludge contaminated with dioxins on pasture and grazing areas. Sewage sludge used in agriculture should be monitored for compliance with the guideline levels, as necessary for dioxins. Additionally, sewage sludge should be treated, as necessary, to render it inert or to detoxify it;
- Prevent contaminated animal derived feed from entering the food chain; animal derived feed should be monitored, as necessary, for dioxins;
- Monitor compliance with nationally-established guideline levels or maximum levels, if available, and minimize or decontaminate non-complying feed;
- Identify possibly contaminated feed and control critical feed manufacturing processes (e.g., artificial drying by direct heating);

Similar control measures, where applicable, should be considered for reducing dioxins in food.

Methods of analysis

The method of choice for the combined confirmation of dioxins is gas chromatography – high resolution mass spectrometry (GC/HR-MS) after extensive sample clean-up. This expensive and time-consuming technique is only applied by a relatively small number of laboratories. Thus, there will be a delay of several days between an incident and the results of the analysis.

Dioxin-like PCBs can also be determined by gas chromatography with other low-resolution mass spectrometry instruments. For screening purposes of mixtures of dioxins including dioxin-like PCBs, less expensive and more rapid bio-assays such as the Calux-assay are applied. Although these bio-assays are successfully applied in various laboratories, there is still a need for improvement with regards to robustness and selectivity, although knowledge of the degree toxic effects of the mixture, which is measured by the bioassay, is an important tool for risk management measures.

As analyses for dioxins by GCMS are quite expensive in comparison to determination of other chemical contaminants, periodic tests should be performed to the extent feasible at least by industrial feed and food manufacturers including both incoming raw materials and final products and data should be kept. The frequency of sampling should consider results from previous analysis (by individual companies and/or via a pool of industry results within the same sector).

[3] *Codex maximum level for a contaminant in a food or feed commodity* is the maximum concentration of that substance recommended by the Codex Alimentarius Commission to be legally permitted in that commodity (Codex Procedural Manual). *Codex guideline level* is the maximum level of a substance in a food or feed commodity which is recommended by the Codex Alimentarius Commission to be acceptable for commodities moving in international trade. When the GL is exceeded, governments should decide whether and under what circumstances the food should be distributed within their territory or jurisdiction (Codex General Standards for Contaminants and Toxins in Foods, CODEX STAN 193-1995).

FAO activities related to dioxins

Reducing dioxin exposure is an important public and animal health goal and has also positive economic repercussion in the agriculture sector.

FAO jointly with WHO develop scientific information and guidance related to dioxins through programmes such as the joint FAO/WHO Expert Committee on Food Additives (JECFA), ad hoc experts meeting and consultations, and joint FAO/WHO Codex Alimentarius Commission. FAO gathers and disseminates scientific and technical information, compiles sets of technical measures to prevent and control dioxins contamination and supports its member countries with capacity building activities.

Joint FAO/WHO Expert Committee on Food Additives (JECFA)

The 57th meeting of JECFA (2001) performed an updated comprehensive risk assessment of PCDDs, PCDFs, and "dioxin-like" PCBs. The experts concluded that a tolerable intake could be established for dioxins on the basis of the assumption that there is a threshold for all effects, including cancer. The long half-lives of PCDDs, PCDFs and "dioxin-like" PCBs mean that each daily ingestion has a small or even a negligible effect on overall intake. In order to assess long- or short-term risks to health due to these substances, total or average intake should be assessed over months, and the tolerable intake should be assessed over a period of at least one month. The experts established a provisional tolerable monthly intake (PTMI) of 70 picogram/kg per month. This level is the amount of dioxins that can be ingested over lifetime without detectable health effects.

Codex Alimentarius Commission

The Codex Alimentarius Commission has not set any numerical standards for dioxins, i.e. no maximum levels for dioxin have been included in the *General Standard for Contaminants and Toxins in Foods* (CAC/RCP 193-1995)[4] or in commodity standards. Under these circumstances, countries may choose to establish national maximum levels or guideline levels based on their risk assessment, and preferably based on JECFA assessments from 2001.

Specific guidance for the prevention and reduction of dioxin is contained in the Codex *Code of Practice for the Prevention and Reduction of Dioxin and Dioxin-like PCB Contamination in Food and Feed* (CAC/RCP 62-2006)[5].

Other relevant Codex texts include: *Code of Practice for Source-Directed Measures to Reduce Contamination of Food with Chemicals* (CAC/RCP 49-2001)[6]; and *Code of Practice on Good Animal Feeding* (CAC/RCP 54-2004)[7]. Work in ongoing in the Codex Committee on Methods of Analysis and Sampling (CCMAS) where discussion has started on methods of analysis for dioxin and dioxin-like PCB, despite no MLs exist in Codex, as the methods are essential to monitor the levels of contamination at national the level.

Related links

Codex Alimentarius: http://www.codexalimentarius.net

JECFA: (FAO): http://www.fao.org/ag/agn/agns/jecfa_index_en.asp

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[4] http://www.codexalimentarius.net/download/standards/17/CXS_193e.pdf
[5] http://www.codexalimentarius.net/download/standards/10693/CXP_062e.pdf
[6] http://www.codexalimentarius.net/download/standards/373/CXP_049e.pdf
[7] http://www.codexalimentarius.net/download/standards/10080/CXC_054_2004e.pdf