

WHAT ARE DIOXINS, FURANS AND PCBs



Industrial activities and combustion processes can be sources of dioxins and furans. Their actual formation and release depend on process conditions and the emission control systems in place.

When people hear about dioxins in food, they often picture a single, particularly dangerous substance. In fact, the term refers to a group of different chemical compounds, some of which share properties and toxicological mechanisms. Alongside them are furans and some polychlorinated biphenyls, commonly known as PCBs. Understanding both what these substances have in common and what distinguishes them is essential for interpreting information about food contamination correctly.

Not all molecules in these families have the same toxicity; they do not all originate from the same processes, nor are they all assessed using the same criteria. Scientific

terminology must therefore distinguish between the chemical family, the individual congener and any dioxin-like activity it may have.

DIOXINS: A FAMILY OF COMPOUNDS, NOT A SINGLE SUBSTANCE

Dioxins in the strict sense are polychlorinated dibenzo-p-dioxins, abbreviated PCDDs. Their structure consists of two aromatic rings connected by two oxygen bridges. Chlorine atoms may be attached at different positions on this structure.

The possible combinations of the number and positions of chlorine atoms give rise to 75 PCDD congeners. A congener is a specific molecular variant within the same chemical family. This is not merely a terminological distinction: the positions of the chlorine atoms can substantially alter a substance's biological behaviour.

The best known is 2,3,7,8-tetrachlorodibenzo-p-dioxin, abbreviated 2,3,7,8-TCDD. It has been extensively studied and serves as the reference compound for assessing dioxin-like toxicity. In public communications, TCDD is often referred to simply as 'dioxin', but this simplification can obscure the existence of many other molecules in the family.

PCDDs are not normally manufactured as commercial chemicals: they are formed mainly as unintentional by-products of certain thermal and industrial processes. Their origins and conditions of formation are examined in Chapter 2.

FURANS: SIMILAR, BUT NOT IDENTICAL, MOLECULES

In this context, the term furans refers to polychlorinated dibenzofurans, or PCDFs. Their structure resembles that of PCDDs, but the two aromatic rings are linked by just one oxygen bridge and a direct carbon-carbon bond. There are 135 possible PCDF congeners.

An important distinction must be made: the polychlorinated dibenzofurans discussed here are not the same as furan itself, a molecule that can also form during certain heat treatments of foods and is studied as a separate contaminant. The names are similar, but the substances and toxicological contexts are not interchangeable.

Dioxins and polychlorinated dibenzofurans are often referred to collectively as PCDD/Fs. This is a useful convention, since the two families may share environmental sources, certain properties and, for specific congeners, a common mechanism of toxic action.

PCBs: SUBSTANCES INTENTIONALLY PRODUCED IN THE PAST

Polychlorinated biphenyls, or PCBs, form a separate family. Their basic structure comprises two aromatic rings bonded directly together, to which up to ten chlorine

atoms may be attached. The number and arrangement of these substituents allow for 209 theoretically possible congeners.

Unlike dioxins and furans, PCBs were manufactured industrially in large quantities during the twentieth century, for example as insulating and dielectric fluids in transformers and capacitors, as well as for other technical uses. The characteristics that made them useful — chemical stability and resistance to degradation — also contribute to their environmental persistence. Their production and use have progressively been banned or severely restricted, but contamination from past activities can still be a source of exposure.

PCBs are not a toxicologically uniform category. A central distinction, also relevant to food safety, is that between dioxin-like and non-dioxin-like PCBs.

WHICH COMPOUNDS ARE CONSIDERED DIOXIN-LIKE?

Of the 75 PCDDs and 135 PCDFs, the group used in conventional assessments of dioxin-like toxicity consists of 17 congeners chlorinated at positions 2, 3, 7 and 8: seven PCDDs and ten PCDFs. These are joined by 12 dioxin-like PCBs (DL-PCBs). The toxic-equivalency system therefore covers 29 congeners in total.

THREE FAMILIES, DIFFERENT TOXICITY

Chemical families do not coincide with the set of congeners considered in the toxic equivalency system (TEQ)

PCDD

(polychlorinated dibenzo-p-dioxins)

- Possible congeners: 75
- Assessed in the TEQ system: 7 with TEF
- Structure: two aromatic rings linked by two oxygen atoms



Example: 2,3,7,8-TCDD
(the reference congener, TEF = 1)

PCDF

(polychlorinated dibenzofurans)

- Possible congeners: 135
- Assessed in the TEQ system: 10 with TEF
- Structure: two aromatic rings linked by one oxygen atom and a carbon-carbon bond

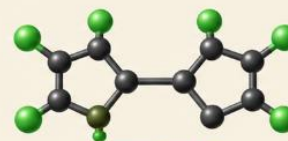


Example: 2,3,7,8-TCDF

PCB

(polychlorinated biphenyls)

- Possible congeners: 209
- Assessed in the TEQ system: 12 with TEF (DL-PCBs)
- Structure: two aromatic rings linked directly to each other



Example: PCB 126
(one of the 12 dioxin-like PCBs, TEF = 0.1)

WHAT TEQ MEANS

TEQ (Toxic Equivalents) is a measure that expresses the overall toxicity of a mixture of dioxin-like congeners.

For each congener, the measured concentration is multiplied by its **toxic equivalency factor (TEF)**, which indicates its relative potency compared with the reference congener (2,3,7,8-TCDD, with TEF = 1).

The sum of these contributions gives the TEQ value of the sample.

The TEQ system considers 29 congeners: 7 PCDDs, 10 PCDFs and 12 dioxin-like PCBs (DL-PCBs).

EXAMPLE OF TEQ CALCULATION

Congener	Measured concentration (pg/g)	TEF (relative potency)	Contribution to TEQ (pg TEQ/g)
Congener A	2.0	0.1	0.20
Congener B	1.0	0.01	0.01
Congener C	0.5	0.01	0.005
Total TEQ (of the sample)			0.215

The 12 DL-PCBs have structural characteristics that allow molecular configurations favourable to biological activity similar to that of TCDD. They include four non-ortho-substituted and eight mono-ortho-substituted PCBs. 'Ortho' describes positions of chlorine atoms adjacent to the bond between the biphenyl rings: this arrangement influences molecular geometry.

This classification does not mean that other congeners necessarily have no health effects. Rather, non-dioxin-like PCBs (NDL-PCBs) are not grouped with dioxins under the same toxic-equivalency system. They require separate assessments that consider other possible mechanisms and effects.

WHY CHEMICAL STRUCTURE MATTERS

Two molecules with the same number of chlorine atoms can behave differently if those atoms occupy different positions. Certain congeners interact to different extents with the cellular aryl hydrocarbon receptor (AhR), which is involved in the mechanism of action of dioxin-like substances. Structural differences also affect physicochemical properties and biological processes.

To avoid adding together substances of very different toxic potencies as though they were equivalent, scientific bodies use toxic equivalency factors (TEFs). Each congener included in the system is assigned a factor expressing its relative potency compared with 2,3,7,8-TCDD, which is conventionally assigned a value of 1.

The concentration of each congener is multiplied by its TEF and the contributions are added together to obtain a concentration expressed as toxic equivalents, or TEQ. TEQ is therefore a potency-weighted index of the mixture's dioxin-like toxicity, rather than simply the sum of the masses of the substances present.

TEF values are re-evaluated as new knowledge emerges. The World Health Organization updated them in 2022, and the EFSA assessment published in June 2026 uses that update. The method and its implications for interpreting laboratory reports are explained in Chapter 7.

SHARED PROPERTIES: PERSISTENCE AND AFFINITY FOR FATS

Many of these substances exhibit considerable chemical stability, limited water solubility and a strong affinity for lipids. These properties promote persistence in the environment and, for several congeners, accumulation in living organisms. Actual behaviour nevertheless depends on the specific molecule, the environmental matrix and exposure conditions.

PCDDs, PCDFs and PCBs are among the classes of persistent organic pollutants covered by international agreements, including the Stockholm Convention. Their

presence does not necessarily indicate recent contamination: residues from past activities can remain in the environment and enter the food chain long after the original source has ceased operating.

Lipophilicity helps explain why monitoring these compounds is particularly important in certain animal-derived foods. It would nevertheless be wrong to assume that all fatty foods contain similar concentrations, or that low-fat foods are always free of contamination: actual levels also depend on environmental sources, animal diets and numerous other factors.

PRESENCE, AMOUNT AND RISK: THREE DIFFERENT QUESTIONS

Knowing that a dioxin or PCB has been identified in a food provides information, first and foremost, about the presence of the substance. Interpretation also requires at least the measured concentration, the identity of the congeners, the performance of the analytical method and the consumption context. A result expressed as a sum of PCBs cannot automatically be compared with a result expressed in TEQ.

The presence of a contaminant does not, by itself, demonstrate harm to health. Risk depends on exposure and the toxicological characteristics of the substances involved. Conversely, the persistence of these compounds means that assessments must not be confined to a single eating occasion: exposure over time is relevant to many effects.

The 2026 EFSA assessment confirms the public-health importance of dietary exposure to PCDD/Fs and DL-PCBs in the European population. This is not, however, a blanket judgement on every food containing a measurable quantity of these substances. Health effects and the meaning of reference values are examined separately in subsequent chapters.

A USEFUL DISTINCTION TO REMEMBER

In summary, dioxins (PCDDs) and polychlorinated dibenzofurans (PCDFs) are two closely related families arising mainly as unwanted by-products. PCBs constitute a third family, intentionally manufactured in the past. Only some PCBs have dioxin-like activity and are assessed alongside particular PCDDs and PCDFs using the TEF/TEQ system.

These differences are not just matters for specialists. They are the key to understanding what laboratories actually measure, why regulations distinguish different parameters and why accurate communication about food safety cannot rely solely on the general term 'dioxins'.

SCIENTIFIC AND REGULATORY REFERENCES

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