

HOW DIOXINS AND PCBs ARE MEASURED IN FOOD

Dioxins, furans and polychlorinated biphenyls (PCBs) are contaminants that may be present in food in extremely small quantities. Measuring them involves more than establishing their presence: individual molecules must be identified, reliably quantified and, for dioxin-like compounds, the findings must be translated into a measure of the mixture's relative toxicity. This distinction is essential for interpreting a laboratory test report correctly.

WHAT THE LABORATORY LOOKS FOR

Targeted testing covers the 17 dioxin and furan congeners chlorinated at the 2,3,7,8 positions and the 12 dioxin-like PCBs (DL-PCBs) for which toxic equivalency factors are available. These 29 compounds do not have identical toxicity and are not present in fixed proportions. For non-dioxin-like PCBs (NDL-PCBs), European rules also use the sum of six indicator congeners: PCB 28, 52, 101, 138, 153 and 180, frequently called 'PCB6'. The PCB6 result, expressed as mass, must not be added directly to the dioxin-like result expressed as toxic equivalents.

FROM SAMPLE TO RESULT

Analysis begins before the instrument is used: samples must be collected according to suitable criteria, identified and stored without loss or contamination. Preparation varies with the matrix, such as fish, milk, eggs or oils. It generally includes extraction, clean-up and removal of interfering substances, with particular attention to the lipid fraction. Internal standards, often isotopically labelled, enable checks on recovery and measurement precision. The quality of the result depends as much on sample representativeness as on instrument sensitivity.

INSTRUMENTAL TECHNIQUES AND SCREENING METHODS

For confirmatory determination of dioxins, furans and DL-PCBs, Regulation (EU) 2017/644 provides for gas chromatography coupled with high-resolution mass spectrometry (GC-HRMS) or tandem mass spectrometry (GC-MS/MS), subject to specified performance requirements. Gas chromatography separates compounds; mass spectrometry identifies and quantifies them with high selectivity. Other suitable analytical configurations are also permitted for non-dioxin-like PCBs, provided they meet the regulatory requirements.

Screening methods, including certain bioassays, identify potentially problematic samples and select those requiring confirmation. A biological assay may produce a

response expressed as bioanalytical equivalents (BEQ), but does not necessarily identify the individual congeners. A BEQ value must not automatically be treated as equivalent to a TEQ result from confirmatory chemical analysis.

FROM SAMPLE TO TEST REPORT

A valid method starts with representative sampling



Data quality depends on the entire procedure

Traceability · internal standards · recovery · LOQ · uncertainty

FROM CONCENTRATIONS TO TEF VALUES

For the 29 dioxin-like congeners, the concentration of each substance is multiplied by its toxic equivalency factor (TEF). The conventional reference is 2,3,7,8-TCDD, assigned a TEF of 1. Within the assumptions of the method, a TEF expresses the congener's toxic potency relative to that reference. The sum of the weighted contributions is called TEQ (toxic equivalents): $TEQ = \sum (\text{congener concentration} \times \text{congener TEF})$.

As a purely illustrative example, a sample containing 2 pg/g of a congener with TEF 0.1 and 1 pg/g of another with TEF 0.01 would, considering only those two compounds, yield 0.21 pg TEQ/g. The sum of their mass concentrations would instead be 3 pg/g: these are different, non-interchangeable measures. The complete calculation requires all prescribed congeners and correct handling of results below the limit of quantification.

2005 TEFs, 2022 TEFs AND COMPARABILITY

The WHO reassessed TEFs in 2022 and published the findings subsequently. EFSA's 2026 assessment uses WHO 2022 TEFs to update exposure and risk estimates. However, as EFSA itself described in 2026, the maximum levels laid down in European

legislation were expressed using the WHO 2005 TEFs. A laboratory or reader should therefore not compare a result calculated with 2022 TEFs against a limit expressed with 2005 TEFs without recalculating according to the prescribed system. The TEF version is substantive information, not merely a label.

LIMITS OF DETECTION AND QUANTIFICATION, AND RESULTS BELOW THE LOQ

The limit of detection (LOD) concerns the ability to distinguish a signal from analytical background; the limit of quantification (LOQ) is the level at which a substance can be quantified with adequate analytical performance. A result 'below LOQ' does not necessarily mean that the substance is absent: it means that the method cannot assign a sufficiently reliable quantitative concentration below that level.

Where some congeners cannot be quantified, TEQ can be reported under three conventions: lower bound, assigning zero to values below LOQ; middle bound, assigning half the LOQ; and upper bound, assigning the full LOQ. These are calculation assumptions, not three distinct measurements of the same substance. For checking compliance with the European maximum levels concerned, legislation requires the upper-bound convention. An excessively high LOQ may influence the upper-bound result and limit its interpretability.

UNITS AND EXPRESSION BASIS

Concentrations may be reported in picograms (pg, one trillionth of a gram) or nanograms (ng). The denominator must be checked: pg WHO-TEQ/g of fat, pg WHO-TEQ/g of fresh product and other reporting bases are not equivalent. For many food categories legal limits are expressed on a fat basis; for others, including certain fishery products, different criteria apply. The matrix's fat content and the reporting basis must therefore be stated before any comparison.

WHAT A TEST REPORT CAN AND CANNOT TELL US

A useful analytical report specifies at least the sample matrix and identification, substances tested, units, reporting basis, method, LOQ, calculation convention, TEF version and, where relevant, measurement uncertainty. A result from one sample does not prove that every specimen or batch of that food has the same concentration. Compliance with a legal limit does not mean zero exposure, and a single measurement cannot, by itself, calculate an individual's health risk.

In conclusion, correct interpretation involves two distinct stages: first, evaluating the reliability of the analytical result and then interpreting it in the context of legislation and

dietary exposure. Legal limits and official controls are discussed in the following chapter.

SCIENTIFIC AND REGULATORY REFERENCES

- [1. European Commission \(2017\). Regulation \(EU\) 2017/644: sampling and analysis methods for dioxins and PCBs in food.](#)
- [2. European Commission \(2023\). Regulation \(EU\) 2023/915: maximum levels for certain contaminants in food.](#)
- [3. EFSA CONTAM Panel \(2026\). Update of the risk assessment on dioxins and dioxin-like PCBs in feed and food. EFSA Journal 24\(6\), e10103.](#)
- [4. World Health Organization \(2024\). WHO expert consultation on updating the 2005 toxic equivalency factors for dioxin-like compounds.](#)
- [5. World Health Organization. Dioxins and their effects on human health.](#)