TEF CONCEPT AND ENVIRONMENT: SCIENCE MEETS POLICY

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Abstract

The application of the TEF concept is very helpful for risk assessment to evaluate the toxicity of mixtures of dioxin-like compounds to mammalians including humans. The calculated TEQ depends on the TEF models used, bearing in mind that the TEQ for mammalians is not derived to show the real toxicity for biota, especially in conifer shoots the TEQ does not reflect the toxicity for plants. The congener pattern changes within the food chain and differs between species.

In risk management the regulations are based on different calculations of limit values. Emission and environment is mostly regulated with I-TEQ. Dioxin-like PCBs are therefore not included. Feed and food regulation in the European Union are based on WHO-TEQ (1998).

For protecting the environment, looking for sources, transfer and carry over congener specific data are necessary. Therefore all analytic results should be available on single congener base.

The TEF Concept is a useful tool for assessing and managing the risk for a group of similar acting chemicals. Therefore it is a good model for other chemical groups like estrogenic disruptors which bind on the same receptor or for phthalates, which are more and more used as a mixture.

Introduction

The use of toxic equivalency factors (TEFs) is the most plausible and feasible approach for the risk assessment of dioxin-like compounds. It has been developed for intake in mammalians including humans. It was the first time summing up a group of chemicals based on the toxic potential of each compound. Prerequisite was that dioxin-like compounds have similar chemical structure and physical chemical properties and a common toxic response. In the beginning, a lot of different factors were used. The first global adapted system was the I-TEF concept (NATO CCMS) in 1988. With increased knowledge and improved methods WHO derived TEFs, including dioxin-like PCBs in 1994, 1998, and recently in 2005. Now, the TEF concept is well established. However, TEFs are not only used for risk assessment in humans, but also for all issues regarding dioxins like emission, fate, environmental monitoring and human biomonitoring. Furthermore, they are used in policy for risk management to protect humans and the environment. There are different TEF concepts in force for regulations in the European Commission and in Germany. However there are some problems with different factors used in assessment and regulations.

What can we learn from the extensive use of the TEF concept? Is it useful for other chemical groups? Even there exist special TEFs to assess the ecotoxicological potential for fish and birds we should rise the question if the TEF concept is the “Golden Standard” for all dioxin-like issues having in mind that these chemicals also persist in the environment and bioaccumulate in fatty tissue. At what extent TEQs are sufficient and when do we need congener specific information?

Material and Methods

Analytical results of 2,3,7,8 substituted congeners (PCDD, PCDF) and dioxin-like PCBs from conifer shoots (Dübener Heide, data from 2004)[1], fish (bream muscle, Rhine, 2004)[2] and bird eggs (herring gulls from Mellum, North Sea, 2003)[3] were calculated with the WHO-TEFs derived in 1998[4] and in 2005[5] as well as with the I-TEFs from NATO-CCMS 1988[6], and with special WHO-TEFs for fish and birds. Additionally, the congener patterns of these samples and from soil were shown. The soil data are a mean value from background stations monitored by the Federal Environment Agency in 1990 and 1997[7]. All biota data stem from investigations of environmental samples archived by the German Environment Specimen Bank[8] , and are recorded by the German POP-DIOXIN DATABASE[9]. Details for methods and results are described in the papers mentioned above.

Results and Discussion

Congener patterns of dioxins and furans in conifer shoots, fish muscle and bird eggs are shown in fig. 1. The congener patterns differ strongly between species. Conifer shoots serve as a bioindicators to determine ambient air concentrations and the accumulation in plants during the time of exposure. Therefore, plants play an important role in the entry of such compounds into the terrestrial food chain. OCDD is the main congener in soil and in conifer shoots accounting for about 45 % and 28%, respectively, of the sum of PCDD/PCDF. Dominating congeners are in fish muscle 2,3,7,8 TCDF with about 38 % and in bird eggs 2,3,7,8 TCDD with about 23 %.

The difference between the samples might be due to specific physical and chemical properties of the congeners, resulting in different persistence, transfer behavior and accumulation in biota. Those environmental characteristics of single congeners are not particularly taken into account in the TEF concept. Therefore the assessment of environmental behavior has to be done on congener specific data.

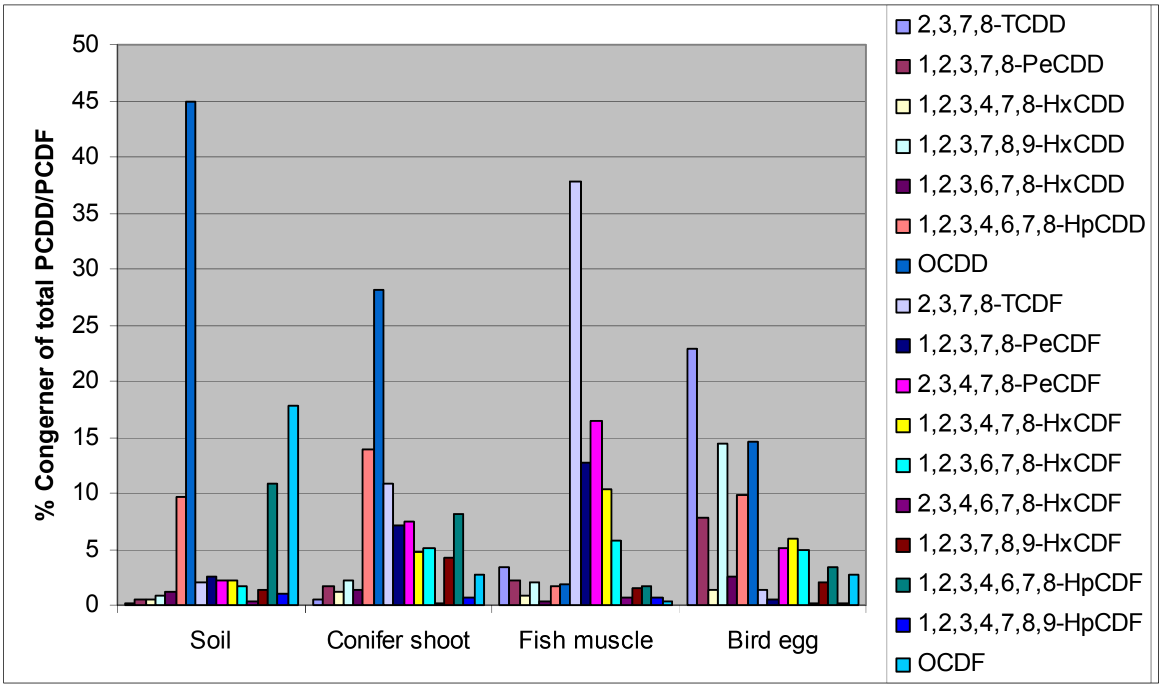

Fig. 1: Congener patterns of soil (background stations 1990 and 1997), conifer shoots (2004), bream muscles (2004) and herring gull eggs (2003) in percentage of the total sum of PCDD/PCDF concentration

In table 1 TEQs for conifer shoots, fish muscles and bird eggs calculated with different TEF approaches (I-TEQ, WHO-TEQ1998, 2005, WHO-TEQ for fish and for birds) are shown.

The I-TEQ in conifer shoots and in fish lies between the WHO-TEQ1998 and the WHO-TEQ2005, the I-TEQ for bird eggs is about 10 % lower than both WHO-TEQs. Comparing the TEQ calculated with TEFs from WHO1998 and WHO2005 for conifer shoots and fish the WHO2005 is about 17 % less, and about 3 % for bird eggs. Due to the greater change of re-evaluated WHO-TEFs the TEQs for mono-ortho PCBs decrease dramatically about 80 % for all biota samples. However, the respective TEQs for non ortho PCBs are nearly identical in conifer shoots and slightly higher in fish (7 %) and in eggs (3 %).

Table 1: Comparison of TEQs calculated with different TEF-approaches

	Conifer shoots ng/kg dry matter	Fish muscle ng/kg fresh weight	Bird egg ng/kg fresh weight
PCDD/PCDF			
I-TEQ	0.78	8.2	3.2
WHO-TEQ 1998	0.85	8.7	3.6
WHO-TEQ 2005	0.71	7.2	3.5
WHO-TEQ Fish	-	7.9	-
WHO-TEQ Bird	-	-	3.8
Non ortho PCB			
WHO-TEQ 1998	0.13	2.6	29.9
WHO-TEQ 2005	0.13	2.8	30.8
WHO-TEQ Fish	-	0.2	-
WHO-TEQ Bird	-	-	31.6
Mono-ortho PCB			
WHO-TEQ 1998	0.02	3.3	14.4
WHO-TEQ 2005	0.004	0.7	2.8
WHO-TEQ Fish	-	0.1	-
WHO-TEQ Bird	-	-	3.1

For fish and bird eggs the impact on PCDD, PCDF and dioxin-like PCB can be assessed by TEFs for human intake as food but they can also be calculated from TEFs for the fish and bird toxicity. For PCDD/PCDF the toxicity for the fish is in the same range than mammalian TEQs (2005), in bird eggs it is about 9 % higher. For non ortho PCB the TEQ in bird is only slightly higher but the toxicity for fish is more than 90 % less compared with mammalian TEQ (2005) and for mono-ortho PCB less then 83 %, respectively. The bird toxicity regarding mono-ortho PCB is about 10 % higher than the toxicity calculated for mammalians.

The examples show that the calculated TEQ depend on the TEF models used, taking into account that the TEQ for mammalians is not derived to show the real toxicity for biota anyway, especially in conifer shoots this TEQ does not reflect the toxicity for plants.

For risk management on the other hand we have the situation that regulations are based on different calculations of limit values (table 2). Emission and environment is mostly regulated with I-TEQ. Dioxin-like PCBs are therefore not included. Feed and food regulations in the European Union are based on WHO-TEQ (1998). The calculation of the daily intake is also based on WHO-TEQ but this derivation is based on toxicity for mammalians. Therefore, a change in toxic equivalent factors does not affect the tolerable daily intake.

In Germany the ordinance of the prohibition of certain chemicals (1996) does not use the TEF concept. It sets limit values for all 17 2,3,7,8 chlorinated dioxins and furans and also for 8 brominated dioxins/furans in substances, preparations and articles. These limit values are set for groups depending not only on the toxicity but also on the persistence of the congeners.

Table 2: PCDD, PCDF and dioxin-like PCB in regulations in the European Commission and in Germany

Medium	**Regulation**
Emission	**I-TEQ**, e.g. 2000/76/EG, no regulation for dioxin-like PCB
Soil, sewage sludge	**I-TEQ** German Federal Soil Protection and Contaminated Sites Ordinance (BBodSchV) dated 12 July 1999, Sewage Sludge Ordinance, (AbfKlärV),of 15 April 1992 no regulation for dioxin-like PCB
Chemicals in Substances, preparations and articles	Germany: ordinance of the prohibition of certain chemicals (1996), limit values for all seventeen 2,3,7,8 chlorinated dioxins and furans and eight brominated dioxins/ furans, **grouped depending on toxicity and persistence** of the congeners
Feed and food	**WHO-TEQ 1998** with dioxin-like PCB (e.g. EG 2375/2001; EG 2003/57)
Tolerable daily intake (TDI)	**WHO-TEQ** including all dioxin-like chemicals

It is implicated that TEFs should fit best the toxic equivalent of each congener. So, factors may change from time to time if new scientific knowledge is available. This could be a problem because results are often given only in TEQ. So it is difficult to compare the data and estimate trends.

For policy makers the TEF concept is an excellent approach to handle a group of chemicals with different toxic potency. But it could be a problem for regulation if TEFs will be updated. Limit values should be in force for a longer period and monitoring results has to be calculated in the same way as limit levels even if there are new and better fitting TEFs. Exceptions could be monitoring results far below the limit values.

Different TEFs are also derived for the assessment of the toxicity to fish and birds. However, these TEFs may not describe toxicity adequately in other environmental species. WHO pointed out that the mammalian TEFs are appropriate for environment samples and discussed the development of further TEFs for the ecotoxicity in soil and sediment.

TEFs will be updated and new TEFs and other substances like HCB, brominated compounds are under discussion to be included in the concept. The WHO plans also to derive TEFs for internal doses in mammalians. With this background it is still more important to have minimum requirements and clear standards for the documentation and publication of data. These should contain at least analytical results on a congener specific base, include limits of quantification (LOQ), and metadata specific to the kind of sample for a proper calculation and comparing of data according to the chosen objective. Furthermore, information regarding water and lipid content of samples are preferable to allow recalculations. A data base like the German POP-DIOXIN DATABASE allows such flexible assessments.

Conclusion

The application of the TEF concept is very helpful for risk assessment to evaluate the toxicity of mixtures of dioxin-like compounds to mammalians. In addition, the TEF concept is suitable to monitor the success of political measures in reducing the dioxin burden and for the screening of samples with special analytic methods like bioassays.

The TEQ is not appropriate to give information about the ecotoxicity of environmental samples. To protect the environment, looking for sources, transfer and carry over rates congener specific data are necessary. Therefore all analytical results should be available on a congener specific base with additional information described above.

Nevertheless, with the limitations discussed above the TEF concept is a very useful tool for assessing the risk for a group of similar acting chemicals. Therefore it is a good model for other chemical groups like estrogenic disruptors which bind on the same receptor or for phthalates, which are more and more used as a mixture.

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