DERIVATION OF AN AIR QUALITY STANDARD FOR PCDD/F'S ON THE BASIS OF INTERMEDIAL ASPECTS

Prinz, B.
Northrhine Westphalia State Environment Agency, Wallneyer Str. 6,
D-45133 Essen, Germany

Abstract

The derivation of an air quality standard for PCDD/Fs causes some problems because a complicated network of different partial path for the transfer and uptake of these components by man exist. In the following a method is described which was used for the derivation of an air quality standard for PCDD/Fs-deposition. For this method a partition of the several modes of uptake, an assumption of the tolerable daily intake and a knowledge of the transfer factors was a necessary condition.

Introduction

The air pollution strategy in Germany is historically based

- on the principles of minimization of emissions according to the best available technology and
- the control of air quality according to specific air quality standards.

An administrative and scientific board appointed by the federal and state governments, called *Länderausschuß für Immissionsschutz* (= states air quality council), is responsible to develop and to propose appropriate criteria and standards. Such a proposal exists now for polychlorinated dibenzodioxins and dibenzofurans (PCDD/Fs). In the following the basic elements in deriving the proposed air quality standards for PCDD/Fs are presented.

Basic elements for an ecological evaluation of PCDD/Fs in the environment

PCDD/Fs exist in the air primarily as vapour, which is partly ad- and absorbed in suspended or deposited particles. Therefore it can be measured alternatively as concentration or deposition. For both parameters principally air quality standards should exist.

All congeners are extremely persistent in the environment, for example with a half-life of at least one decade in soil. Therefore soil contamination is a specific problem at sites influenced by industrial emission.

Due to its lipophilic character accumulation of PCDD/Fs in cow's- and human milk is of special importance leading to an exposure of breast-fed infants which is manifold higher than with adults. Since cattle breeding is more or less concentrated to rural regions, industrial influence is as a rule no severe problem. A measure for internal exposure of man is the concentration of PCDD/Fs in blood fat. Typical values for the occurrence of PCDD/Fs in the environment are presented in the Table 1.

Table 1: Typical values for the ecological burden by PCDD/Fs

MEDIUM	URBAN AND INDUSTRIAL REGIONS	RURAL REGIONS
Air Concentration	100 ... 400 fg I-TEq m^{-3}	20 ... 100 fg I-TEq m^{-3}
Air Deposition	20 ... 100 pg I-TEq m^{-2}	5 ... 20 pg I-TEq m^{-2}
Leafy Vegetation	1 ... 10 ng I-TEq (kg dry weight)$^{-1}$	< 1 ng I-TEq (kgdry weight)$^{-1}$
Cow's Milk	-	1 ... 2.5 ng I-TEq (kg milk fat)$^{-1}$
Human Milk	-	ca. 30 ng I-TEq (kg milk fat)$^{-1}$
Blood Fat in Man	-	40 ... 50 ng I-TEq (kg blood fat)$^{-1}$
Soil	5 ... 50 I-TEq (kg dry weight)$^{-1}$	1 ... 5 ng (kg dry weight)$^{-1}$

According to the Figure 1 a manifold and complex system of different paths exist, through which PCDD/Fs transfer until they ultimately are taken up by man. Infants are a group at a specifically high risk. When protective environmental measures shall be taken the following requirements have to be met:

- It must be clear which dose of PCDD/Fs can be tolerated at maximum.
- The point within the network of the Figure 1 must be selected at which the control measures shall be effective.
- The quantitative relationships must be known which describe the transfer of PCDD/Fs from one medium to the neighbouring one.
- A system must be present which gives an unequivocal solution for the effective control in different media although innumerable interdependencies between the single partial paths exist.

The Figure 1 is principally valid for all persistent air pollutants. The quanititative relationships with regard to PCDD/Fs are presented in Figure 2.

Concerning the tolerated daily dose or intake (TDI) here the results of the meeting of the WHO-Regional Office for Europe in Bilthoven from 1990 are followed where a value of 10 pg TEq (kg body weight)$^{-1}$ d^{-1} had been derived. This value had been calculated by use of an uncertainty factor of 100 for the well-known Kociba-study, which showed that rats were not affected if fed with a dose of 1 ng 2,3,7,8-TCDD (kg body weight)$^{-1}$ d^{-1}. More precisely spoken the TDI-value is considered as a criterion for *intervention*. This means that, if this dose is expected to be exceeded for longer periods, immediate actions like withdrawal of contaminated vegetable from the market have to be undertaken.

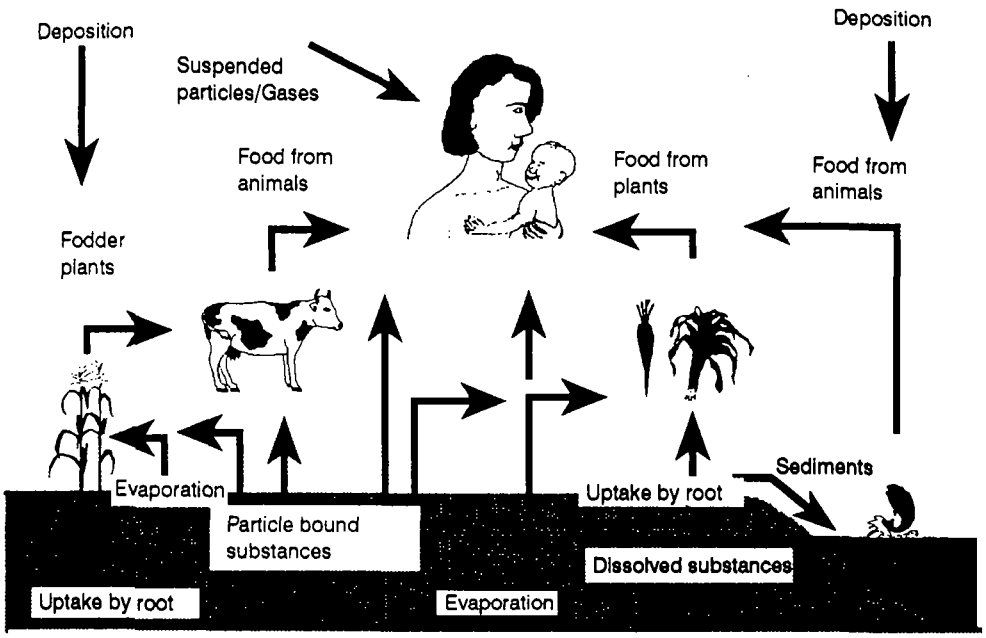


Fig.1: Paths for organic air pollutants within ecosystem

Contrary to this a second value of *precaution* has been defined with 1 pg TEq (kg body weight)$^{-1}$ d^{-1}. This value is definitely below the normal uptake of PCDD/Fs by food, contaminated on the average level. Therefore the meaning of this value is more a goal for

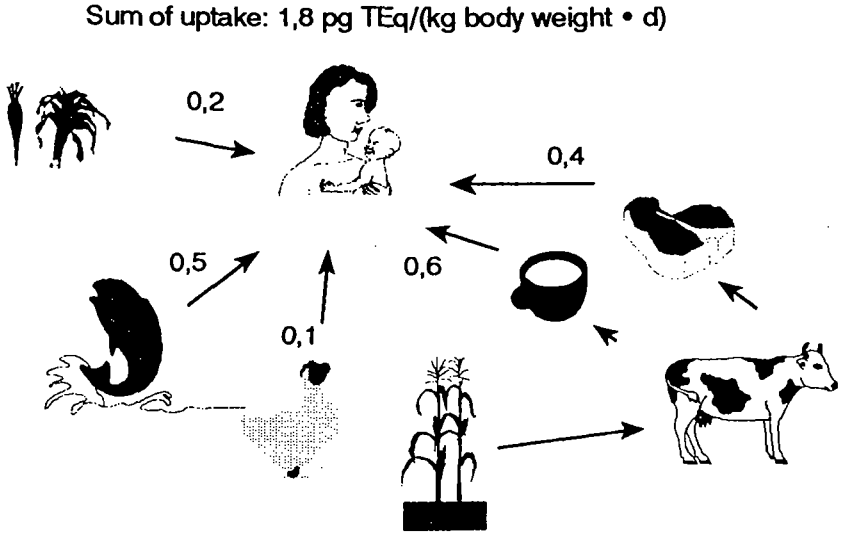


Fig. 2: Average oral uptake of PCDD/Fs by man

reaching satisfying conditions in the future than a realistic basis for present actions.

As it is discussed further below a third value with 2.1 pg TEq (kg body weight)$^{-1}$ d^{-1} for *prevention* has been defined, which is used for deriving the air quality standard for PCDD/Fs, which is applied in licensing procedures for new PCDD/Fs-emitting plants.

A difficulty of special kind is the handling of competing and interdepending partial paths. To cope with this problem the following solutions principally exist:

- Within the *proportional* model first the relations between the uptake by different partial paths for "normal conditions" are calculated. Afterwards all partial uptakes are proportionally raised so that as a sum the defined TDI-value is just not exceeded.
- Within the *constant* model certain partial paths are considered as constant, since they can not be influenced by the environmental management system, others as variable. So for example the uptake of PCDD/Fs by ingestion of sea fruits is a result of long lasting contamination of the ocean, which by no means can be changed to a better within a short time.
- Within the *dominant* model one partial path is considered as dominant and the others as irrelevant so that they can be neglected. An irrelevant partial path exists for example for the uptake of PCDD/Fs by inhalation in a normal case.

In reality mixtures of these different models are applied.

Derivation of a limiting value for PCDD/Fs-deposition by the Länderausschuß für Immissionsschutz (LAI)

As already mentioned and according to the Figure 3 a TDI-value of 2.1 pg TEq (kg body weight)$^{-1}$ d^{-1} was conventionally defined as a basis for deriving the air quality standard.The philosophy was that the above cited value of 1 pg TEq (kg body weight)$^{-1}$ d^{-1} is unrealistically low, since exceeded by normal ingestion, and the value of 10 pg TEq (kg body weight)$^{-1}$ d^{-1} is too high, since the goal of an air quality standard should be to reach a situation, where measures of intervention are with high probability unnecessary.

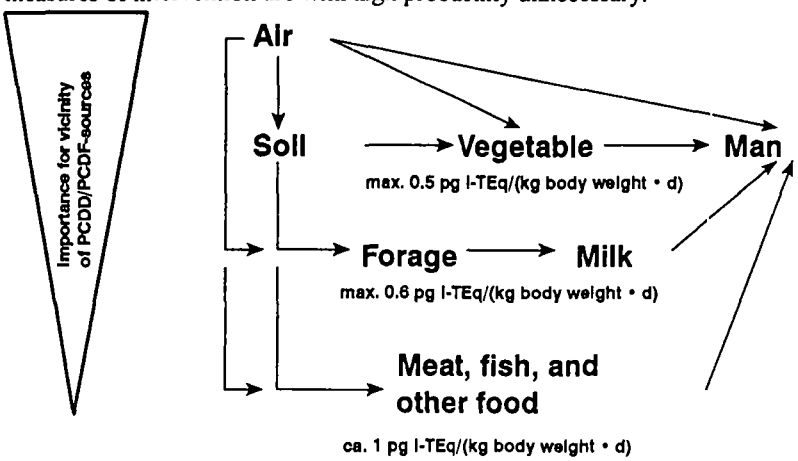


Fig. 3: Partial paths for uptake of PCDD/Fs by man

Since the uptake of statistically 1 pg TEq (kg body weight)$^{-1}$ d^{-1} by mainly meat and fish cannot be influenced by an air quality management system and the uptake of statistically 0.6 pg TEq (kg body weight)$^{-1}$ d^{-1} by cow's-milk is, due to typical sites of cattle breeding in rural areas, also irrelevant for a licensing system, the uptake of PCDD/Fs by vegetable remains the really relevant path for deriving an air quality standard. For this path an upper limit of 0.5 pg TEq (kg body weight)$^{-1}$ d^{-1} is set. For this limit the worst case was constructed that a neighbour in the vicinity of a PCDD/Fs-source extensively uses his garden for his personal supply with vegetables. Correspondingly a daily uptake of leafy vegetables of 250 g fresh weight or 25 g dry weight for a person with 75 kg body weight was assumed. This leads to a maximum tolerable concentration of 1.5 ng TEq (kg plant dry weight)$^{-1}$. With a daily consumption of 25 g milk fat the milk path of 0.6 pg TEq (kg body weight)$^{-1}$ d^{-1}, presented in the Figure 3, corresponds to a maximum tolerable and in reality also typical concentration of PCCD/F's in milk of 1.8 ng TEq (kg milk fat)$^{-1}$.

As a further step quantitative transfer-relationships have to be defined for the paths soil ⇒ plant, air ⇒ plant, plant ⇒ cow's milk, air ⇒ soil, and fodder plants ⇒ cow's milk.

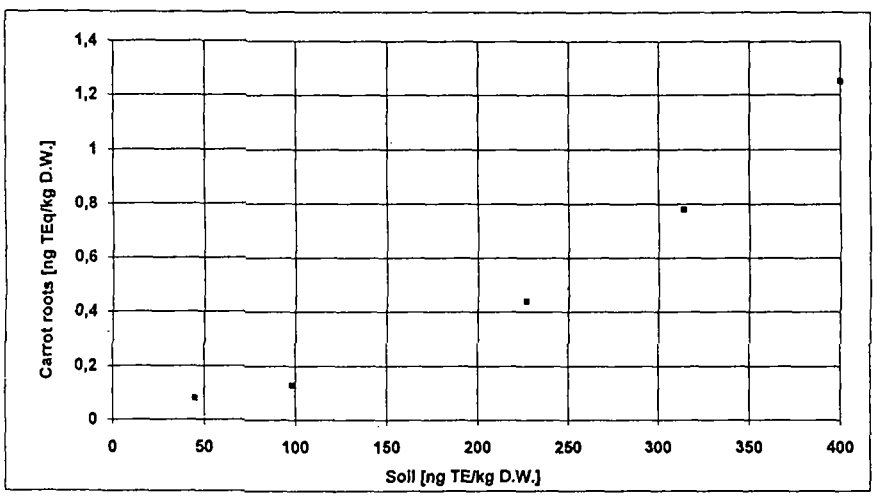


Fig. 4: Uptake of PCDD/Fs in carrot roots from field exposure

The uptake of PCDD/Fs from soil into plants via roots has been largely overestimated in the past. It is highest into the roots, for which an example is presented in the Figure 4, in which the concentration of PCDD/Fs in carrot roots, grown in different distances from a former copper smelter is compared to the concentration in the soil. The transfer is by a factor of roughly 10 lower into the shoot by transport within the xyleme. As a rather conservative estimation a transfer factor for the uptake from soil of

0.01 ng I-TEq (kg plant dry weight)$^{-1}$/1 ng I-TEq (kg soil dry weight)$^{-1}$

transfer factors show great differences for the different congeners. Therefore the choice of toxic equivalency factors - definition by the Federal Health Office (FHO) or NATO/CCMS - is of outstanding importance for the height of the value. A best possible estimation of the transfer factor for uptake from fodder plants to cow's milk, based on NATO/CCMS, is

2 ng I-TEq (kg milk fat)$^{-1}$/1 ng TEq (kg plant D.M.)$^{-1}$

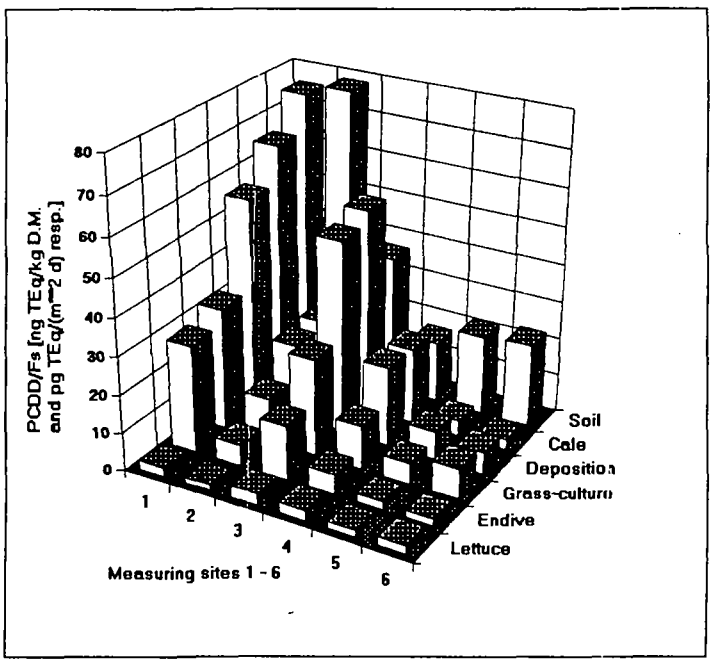


Fig. 6: Deposition of PCDD/Fs and content of PCDD/Fs in different media at sites in Duisburg area

All these transfer factors in combination with the partitioning of the different paths according to the above diagram leads to an

air quality standard of 15 pg TEq m^{-2} d^{-1}

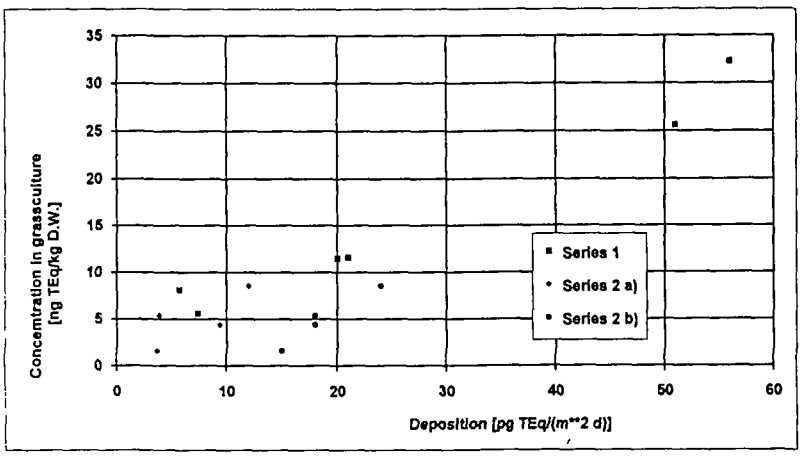
which is quite reasonable also under the aspects of the existing air pollution situations. As an example deposition values for different sites in the heavily industrialized area of Duisburg, but in different distances from specific PCDD/Fs-sources, are presented in the left Figure. Again the correlation to the content of PCDD/Fs in vegetation besides lettuce with an extremely short cultivation time is quite obvious. The hig PCDD/Ds content in the soil at site 2 is due to the emission in former times, but no longer present. The recent status of discussion is that the proposed standard for deposition, presented above, shall at the nearest time officially be introduced into the *Technische Anleitung zur Reinhaltung der Luft* (= Technical Regulation for Air Quality Management) so that then this standard has the same character of enforcement

is used for plant parts above ground and a transfer factor of

0.1 ng I-TEq (kg plant dry weight)$^{-1}$/1 ng I-TEq (kg soil dry weight)$^{-1}$

for plant parts below ground.

Most of the PCDD/Fs in plants is taken up from the air in form of deposition. As an example in the Figure 5 the uptake of PCDD/Fs into standardized grass-cultures from a field experiment is presented.



Fit. 5: Uptake of PCDD/Fs in standardized grass cultures from deposition. In series 1 (Dortmund area) and series 2a) (different sites in Northrhine-Westphalia) values below detection limit were taken as measured, in series 2b) set to 1/2 detection limit

As a consequence and together with other slightly differing results the transfer factor for leafy plants by uptake from air was estimated as

0.2 ng TEq (kg plant D.W.)$^{-1}$ pg TEq m^{-2} d^{-1}

For curly cale this transfer factor is double and for non-leafy plants much lower.

For the transfer of PCDD/Fs from air to soil the following factor as a rather conservative estimation has been defined

1 ng TEq (kg soil D.W.)$^{-1}$/1 pg TEq m^{-2} d^{-1}

The uptake of PCDD/Fs from fodder plants to cow's milk is not as unequivocal as with the paths discussed above. Of special interest is the circumstance that contrary to other media the

like the other official standards in this regulation. But before the conference of the environment ministers has still to decide on this matter, which has not yet taken place.

REFERENCES

1. Prinz, B., Krause, G.H.M. and Radermacher, L. (1993): Standards and Guidelines for PCDD/PCDF - An Integrated Approach with special Respect to the Control of Ambient Air Pollution. Chemosphere Vol. 27, pp 491 - 500
2. Immissionswerte für die Luftschadstoffe PCDD und PCDF. Internal report of the sub-committee "Effects" of the Länderausschuß für Immissionsschutz 1994