Toxicological and Environmental Risk Assessment of a Highly Dioxin Contaminated Sports Field

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Abstract

High levels of polychlorinated dioxins and furans were measured on parts of a community sports field. Consequently, a comprehensive analysis scheme for the site and the surrounding area (private gardens, river sediment) was developed to uncover the horizontal and vertical distribution of PCDD/PCDF. Investigation of possible transfer routes showed that only one major transfer process, namely wind erosion, contributed to more than 90% of the total PCDD/PCDF flux from the contaminated site to the surroundings.

Based on this result and PCDD/PCDF-uptake mechanisms for humans, it was concluded that the PCDD/PCDF content of the copper slag of the sports field does not pose an acute health hazard neither to its user nor the residents living in the surroundings. However, it was recommended to remove the top layer (0-12 cm) of the most contamintated sports fields for two reasons:

1. the total amount of PCDD/PCDF in the top layer exceeds 40 000 ng I-TEQ/kg d.w. and would be a continuing source for a widespread PCDD/PCDF-contamination,
2. precautionary measures of public health and environmental protection.

Key words: Contaminated Site, Human Exposure, PCDD/PCDF, Risk Assessment, Transfer Routes

1. Introduction

At least 800,000 t of copper slag from ore mining have been brought onto the German market during the 1950s and 1960s (1). Sold as "Kieselrot" this slag was used as covering material for sports and playgrounds as well as for road construction. In 1991 it was discovered that "Kieselrot" contains polychlorinated dibenzo-*p*-dioxins, dibenzofurans (PCDD/PCDF), and other chlorinated organic compounds such as polychlorinated biphenyls (PCB) and chlorophenols in mg/kg concentrations (2). Consequently, communities and sports clubs are concerned about the potential risk of this contamination for humans as well as the environment.

2. Sampling and Chemical Analysis

A suitable sampling and analysis scheme was developed to investigate the contaminated site and the surroundings in order to locate the vertical and horizontal distribution of PCDD/PCDF. The sports field itself consists of two fields (Fields II and III, approx. 60,000 m^2 each) and one sprint-course (approx. 500 m^2).

A detailed description of the sampling and analysis scheme is given elsewhere (3). As the copper slag shows a characteristic PCDD/PCDF-homologue pattern, it is relatively easy to identify soil and sediment samples contaminated with "Kieselrot".

Results (see Table 1) demonstrated that Field II and the sprint-course were contaminated heavily with dioxins and furans due to the use of "Kieselrot". In contrast, results from Field III, from the surroundings, the drainage system and the river sediment indicated a secondary contamination with PCDD/PCDF due to transfer processes from the other sites. Levels in the drainage system and river sediment were relatively low, but the PCDD/PCDF found in these samples showed the same homologue pattern as in typical "Kieselrot" samples.

Table 1: PCDD/PCDF-concentration and TEQ of selected samples (ng/kg d.w.)

Location	Depth	Σ PCDD/PCDF	TEQ
Field II	0-5 cm	4,767,000	43,700
	5-12 cm	648,900	7,450
	12-18 cm	170,100	1,720
	18-23 cm	85,100	728
Field III	0-7 cm	6,808	85
	0-7 cm	27,960	245
	0-7 cm	22,580	181
Sprint-course	0-10 cm	289,600	2,350
	10-17 cm	516,300	3,950
Drainage System		605	7.7
River Sediment	100 m downstream	370	3.0
River Sediment	1 km downstream	143	1.3
Soil (5 samples)	surface	208-2,880	2.2-58

3. Overall Transfer of PCDD/PCDF

Summarizing the estimated transfer rates of PCDD/PCDF (data not shown) from the contaminated site to other environmental compartments via the various paths leads to the following conclusions:

- transfer via drainage system to the river sediment does not exceed 10 ng TEQ/yr,
- transfer to air due to direct evaporation does not exceed 0.65 mg TEQ/yr,
- transfer to surrounding soils due to removal with sportswear of athlets is in the range of 0.05-5 mg TEQ/yr,
- transfer to surrounding soils due to wind erosion is the most important process with transfer rates in the range of 50-500 mg TEQ/yr.

Table 2: Maximum transfer rates in (ng TEQ/yr) of PCDD/PCDF from Field II and the sprint-course to the environment

Compartment	Sediment	Air	Soil	Total
"Kieselrot"	10	625,000	500,000,000	500,625,010

For an estimated total PCDD/PCDF content of 650 g TEQ (Σ PCDD/PCDF about 6.8 kg) of the whole contaminated site this means an annual loss of about 500 mg TEQ (see Table 2) or <0.15% of the original amount.

4. Human Exposure

Epidemiological studies on residents of the town of Marsberg/North-Rhine Westfalia (where the copper slag was produced) clearly demonstrated that the bioavailability of PCDD/PCDF from "Kieselrot" is low (4). Serum dioxin levels in the Marsberg cohort which was directly exposed to "Kieselrot" particles and dust for years showed a slight increase especially of higher chlorinated PCDD/PCDF. Although the serum dioxin concentrations are within the range of PCDD/PCDF background levels in Germany (12-94 ng I-TEQ/kg, on fat basis (7)), the dioxin pattern found in these blood samples confirmed an uptake of PCDD/PCDF from the copper slag. Toxicologically this additional intake is not relevant because it is mainly limited to octachlorodibenzo-*p*-dioxin (OCDD), a congener of low biological activity. Clinical laboratory tests of Marsberg residents were not different from a control group of the town of Steinfurt, a community comparable to Marsberg, but without any "Kieselrot" contamination (4).

Dioxin exposure of humans caused by "Kieselrot" can happen via various routes. But due to the use of the contaminated site, only two main paths seem to be of importance: Dermal and intestinal absorption of "Kieselrot" particles and dust. Absorption of dioxins by skin contact is unlikely because of 1.) the strong binding of PCDD/PCDF to the copper slag, and 2.) because of the poor penetration potential of TCDD into human skin (5). Intestinal absorption of PCDD/PCDF from "Kieselrot" is estimated to about 1% with respect to I-TEQ. This value has been determined with a synthetic digestive mixture (6).

5. Conclusions

Based on a comprehensive risk assessment which included environmental and toxicological aspects, it was concluded that the dioxin burden of the contaminated sports fields does not represent an acute hazard of public health.

As a first action, the contaminated sports grounds were covered completely with plastic foil to avoid further wind erosion and infiltration of rain water. So, the main transfer paths were cut and a ongoing contamination of the surroundings can now be excluded. For precautionary reasons further remediation actions were recommended: The sports field should remain closed to the public until the contaminated material will be removed and disposed as hazardous waste.

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