LEVELS OF PCDD/Fs IN URBAN SURFACE SOIL AND POSSIBLE SOURCES IN TRONDHEIM, NORWAY

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Introduction

Soil has been evaluated as a good medium to estimate atmospheric deposition of dibenzo-p-dioxins and dibenzofurans (PCDD/Fs) over long periods, since it adheres strongly to organic matter in soil and therefore acts as a passive collector for atmospheric accumulation.[2] The long half-life time of PCDD and PCDF congeners in the Nordic countries adds to the suitability of soil as an indicator of long-term atmospheric pollution.[10] Concerns about the potential toxic emissions from municipal solid waste incinerators (MSWI) initiated this study where fifty samples were taken from an area that covers the most densely populated part of Trondheim.

Other studies conducted in proximity to MSWIs do not provide sufficient evidence that the MSWI is the sole source of the pollution, but additional known or unknown sources are proposed and recognised in the results.[3, 4, 5, 8] This study will demonstrate that other sources of PCDD/F emission, in addition to the MSWI plant, play an equal role as additional significant contributors to surface soil concentration levels of PCDD/Fs.

Methods

In order to determine a potential geographical pattern, and therefore potential sources, the samples were spread out over the entire densely populated part of the town. The surface soil samples were taken at a depth of 0-2 cm in undisturbed soil. All samples were collected in sealed glass jars. Figure 1 shows the localities of the samples. No specific account was taken for possible source locations or height of emission. All samples were analysed at AnalyCen laboratory, Sweden. US EPA method 1613 with accelerated solvent extractor (ASE) was used for soil analysis. The analytes were separated by a GC and detected by a high resolution ($\geq$ 10000) mass spectrometer.

Emission estimates from possible sources

Several potential point sources of PCDD/F emission exist within the town limits; (1) a MSWI, (2) a former hospital waste incineration plant, (3) a bio fuel power plant and (4) three crematoriums, of which only one is currently in active use. Only the first three have been analysed for dioxin emissions. The town was previously an industrial centre with several metal factories and metal mechanical industry. Diffuse sources, such as traffic and domestic burning of wood, may also play a significant role. Table 1 presents theoretically calculated emissions using varying emission factors for those sources where no emission analyses have been made.

Table 1. Existing possible sources in Trondheim and calculated PCDD/F emissions. The emission estimates for the MSWI, hospital and bio fuel plant derive from actual emission analyses. The others are theoretically calculated.

Possible sources	Theoretically calculated emissions (mg I-TEQ/year)
MSWI	260-880 (1994-2000), 2000-2200 (2001-2002), 102-140 (2003-2004)
Hospital waste incineration plant	74.3- 271
Bio fuel power plant	2.5- 96
Crematoriums	14.9- 425
Domestic burning	13-113 [6, 7]
Other industrial sources	36-200

The MSWI in Trondheim has, since autumn 2002, been cleaned by the injection of active carbon. Emission analyses have been made several times a year. This can clearly be seen in the emission concentration differences. Although the concentration levels differ, the congener profiles remain remarkably similar (Figure 3b).
The PCDD/F emissions from the hospital waste incinerator (Figure 3a), which only were analysed twice in 2003, are believed to be high largely due to the nature of the incinerated mass such as organic material, PVC, biological/pathological refuse and medicament wastes burnt with the aid of diesel. The incinerator lacked emission gas cleaning and was shut down in 2003.
The concentration levels of dioxin emissions from the bio fuel power plant, which were analysed six times in 2003-2004, vary due to different types of fuel and optimisation of burning procedures. Pure wood demonstrated the lowest emission factor and briquettes partly made with refuse wood the highest emission concentration levels of PCDD/Fs.
There have been three active crematoriums within the Trondheim urban area. None of the crematoriums have had any kind of gas cleaning system and no analyses of the gases emitted have been performed.
Burning of wood in domestic burning stoves, which is very common in Norway, contributes a large part of the dioxin emissions, especially when the burning of contaminated wood and paper occurs. The use of wood burning as a means of domestic heating is quite evenly distributed over the whole sampled area.[7]
Two metal smelters that refined metal or recycled scrap metal have existed in Trondheim, which both were fuelled by coal. There is no information available of other plants to be able to calculate emissions.

Results

The concentrations of dioxins and furans in the surface soil ranged from 0,16-14 ng I-TEQ kg^{-1} DW (dry weight). OCDD-, 1,2,3,4,6,7,8-HpCDD, OCDF and 1,2,3,4,6,7,8-HpCDF are the major congeners contributors in the samples. In order to pinpoint some geographical differences in congener pattern, the sampling area was divided into four parts (Figure 1). This division is based on geographical similarities of the areas and how long the area has been inhabited. Figure 1 presents the results revealing a geographical concentration pattern, where the central area of the town has the highest concentration levels of dioxins and furans. The southernmost part of town, which is the area of most recent habitation, exhibits the lowest concentration levels. The dioxin concentration pattern therefore correlates closely with the spreading of habitation, where the oldest parts of town demonstrate the highest dioxin concentration levels. No clear correlation between dioxin concentration levels and organic matter content could be found. Rather, it appears that the dioxin concentration level depends on the geographical positioning of the sample, which reflects how long and intensively the topsoil has been exposed to atmospheric deposition.

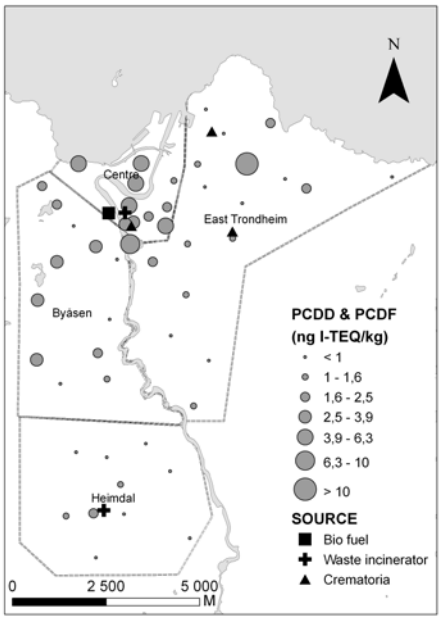

Figure 1. The concentration levels of PCDD/Fs in surface soil samples

Figures 2 a-d present the contribution of each of the 17 2,3,7,8-chlorine substituted congeners to the I-TEQ. Figures 2 a-d present the congener patterns of the soil samples in the four different parts of town. The profiles show a common profile pattern in all areas, but two of the areas exhibit to a larger degree uniform patterns (Figures 2 a and b), while the other two areas (Figures 2 c and d) present a larger degree of heterogeneity in the congener distributions. This heterogeneity probably reflects the influence of several emission sources in the area. The very similar congener profiles for the samples from the southernmost part of town indicate that the MSWI in the area probably is the sole contributor of dioxin emissions in that specific area.

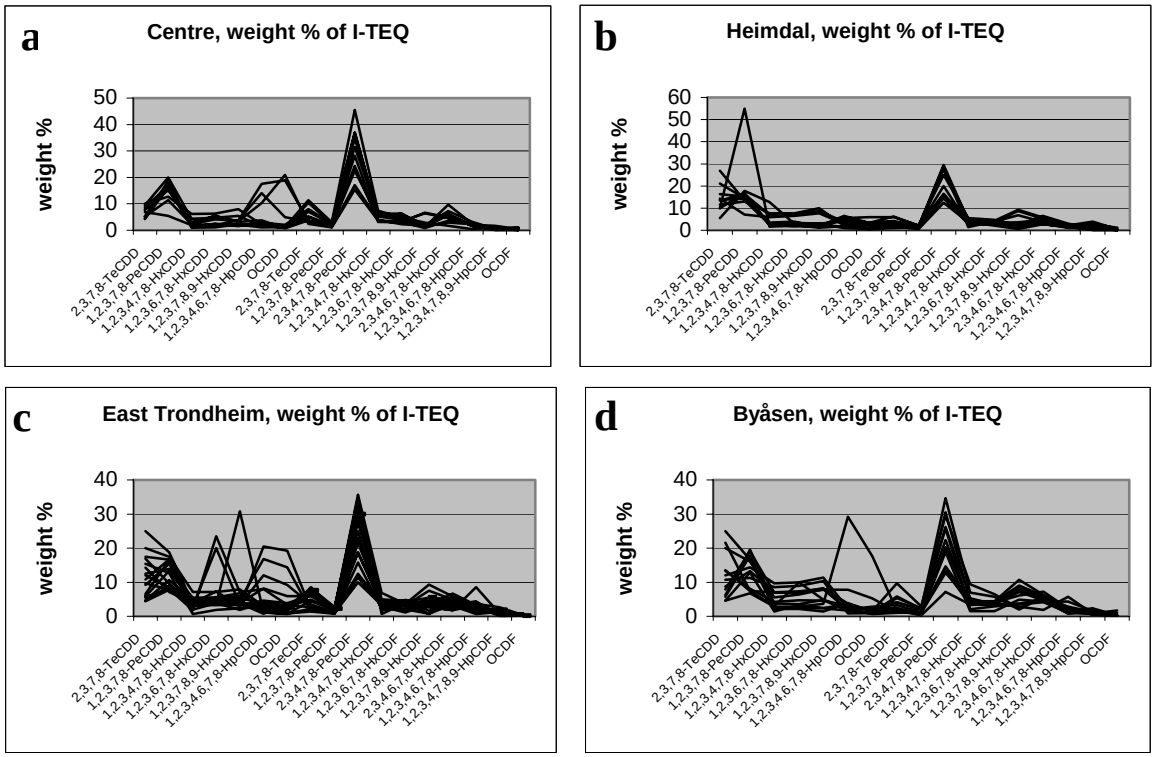

Figure 2 a, b, c, d. Congener profiles of soil samples in the four town areas

At those sources in which dioxin monitoring of the emission gases has taken place, the concentration level results display a large variation. Therefore, the calculation of accurate and representative emission factors is an impossible task. The emission estimates in Table 1 therefore are an approximation based on using a mixture of emission data from dioxin monitoring and calculations using emission factors from the literature.

Discussion

The congener profiles from the emission sources (Figures 3 a, b) to a great extent resemble the soil samples analysed in this study (Figures 2 a-d), where 1,2,3,7,8-PeCDD and 2,3,4,7,8-PeCDF contribute to the largest part to the I-TEQ. Figures 3a and b demonstrate the similarity between congener profiles of the monitored emission sources. Their similarity makes it impossible to distinguish between these particular sources. A study has been conducted on emissions from secondary sources that included emissions from crematoria and emissions from domestic burning of wood and oil.[9] The emission congener profiles differ from those obtained in this study by higher weight percentage of congeners OCDD and 1,2,3,4,6,7,8-HpCDD to the I-TEQ. This particular shift in congener distribution can be seen in some soil samples in the eastern part of Trondheim and the town centre, indicating that domestic burning and emissions from the crematoria might have contributed to the dioxin levels in some of the soil samples in these areas. Calculations based on the main wind direction and wind speed indicate that the high concentration levels in the central part of Trondheim are in large part due to the hospital incinerator, the biofuel plant and the crematoria.[1] Therefore, in the case of Trondheim, the surface soil demonstrates high dioxin concentrations levels partly due to sources that are no longer active. Studies conducted in the vicinity of MSWIs also indicate that several sources must be active in order to obtain the geographical distribution and pollution levels present in the soil samples.[3,4]

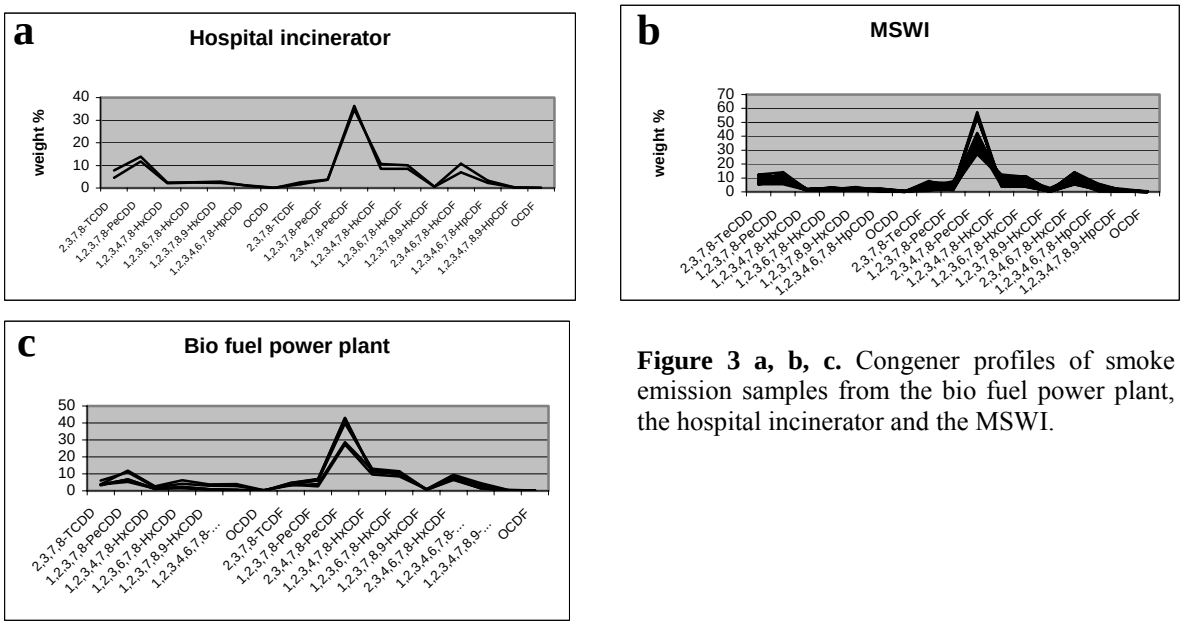

Figure 3 a, b, c. Congener profiles of smoke emission samples from the bio fuel power plant, the hospital incinerator and the MSWI.

Conclusions

- The centre of Trondheim demonstrates higher dioxin and furan concentration levels than in other parts of the town. There appears to be a strong correlation between the levels of dioxins and the age of habitation.
- The centrally situated hospital incinerator, bio fuel plant and crematorium appear to be the largest contributors to concentrations of dioxins in that area, as a pattern of high concentrations are situated in a fan shape north of these point sources. The congener profiles from these emission sources are similar, making it extremely difficult to distinguish between different sources from soil sample data.
- The soil samples from the southernmost part of town indicate that the MSWI appears to be a main and sole source of dioxins in that particular area of the town.
- Approximations of the main PCDD/F emission sources in Trondheim demonstrate that the MSWI, domestic wood burning and former metal refineries are the largest dioxin pollution sources within the area.

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