

# LEVELS IN THE ENVIRONMENT

## A Field Study on the Use of Sewage Sludge as Soil Amendment

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### ABSTRACT

Sewage sludge was applied at a rate of 4 tonnes every 4 years to farmland soil in southern Sweden. The sewage sludge was analyzed for PCDDs and PCDFs as well as the soil before and after the sludge application. The crop (wheat and rape) was also collected and analyzed. The study showed no increased concentrations of PCDDs and PCDFs in the crop. The major contribution to the contamination of the soil is from aerial deposition.

**Key words:** Sewage sludge, amendment, PCDDs, PCDFs, soil, crop, wheat, rape, aerial deposition.

### INTRODUCTION

A series of studies have shown that sewage sludge (biosolids) from publicly owned treatment works (POTWs) is contaminated by a series of PCDDs and PCDFs (1-3). The highest concentrations are found for octa- and hepta CDDs. A major use of sewage sludge is as a fertilizer in the agriculture. This means that there is a potential risk that PCDDs and PCDFs could enter the food chain in this way.

Unpeeled carrots and potatoes cultivated in contaminated soil show increased concentrations of PCDDs and PCDFs (4, 5). Hülster et al. (6) also found that zucchini, pumpkin and cucumber cultivated in highly contaminated soil took up both PCDDs and PCDFs from the soil. Little data can be found in the literature where the uptake of PCDDs and PCDFs from sewage sludge amended soil has been investigated. Jones and Sewart (7) claim that the contribution from sewage sludge application (when followed by tilling) to the concentrations of PCDDs and PCDFs in above ground plant structures can be ignored.

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In the present contribution we report data from a study performed in southern Sweden, where sewage sludge has been applied to farmland, where wheat and rape was grown. The wheat and rape, the fertilized soil as well as samples from unfertilized control fields have been collected and analyzed for PCDDs and PCDFs.

## EXPERIMENTAL

### Study design

From 1981 two farms in southern Sweden, Petersborg and Igelösa, have been fertilized in part with sewage sludge. The other part of the two farms has been used as the unfertilized control. The same crop, wheat or rape, has been grown on the fertilized field as well as the control field.

In the years 1981, 1985, 1989 and 1993 sewage sludge was applied in the fall at a rate of 4 tonnes per hectare corresponding to the recommended annual rate in Sweden of 1 tonne/hectare. The farm Petersborg received sludge from the POTW of Malmö, the farm Igelösa from the POTW of Lund. The sewage sludge applied in 1989 and 1993 was analyzed for PCDDs and PCDFs. The crops from 1990, 1991, 1993 and 1994 were collected and analyzed. Soil samples were also collected in 1993 before the treatment with sewage sludge and in 1994. All the analyses were performed at Umeå University.

### Analytical

The sewage sludge and oil samples were analyzed as earlier described (1, 8, 9). The crop samples were analyzed in the same way after grinding.

## RESULTS

The contamination of the sewage sludge shows a downgoing trend.

1989 Lund 51 ng TEQ/kg d.m.    Malmö 35 ng TEQ/kg d.m.

1993 Lund 14 ng TEQ/kg d.m.    Malmö 12 ng TEQ/kg d.m.

In 1990 two crop samples were collected from the fields receiving 4 tonnes/hectare the year before. The rape from Igelösa contained 0.27 ng TEQ/kg and the wheat contained 0.45 ng TEQ/kg. In 1991 two wheat samples were collected and analyzed from Igelösa, the farm that had rape the year before. From the fertilized field the contamination of the wheat was now almost ten times lower than for the rape the year before; 0.032 ng TEQ/kg.

In 1993 four samples were collected at the two farms, two soil samples and two samples of rape from Petersborg, including one control from the unfertilized plot. The two soil samples contained:

Petersborg 0.51 ng TEQ/kg d.m.    Igelösa 0.69 ng TEQ/kg d.m.

The rape sample from the fertilized plot had a little higher value than that from the control plot.

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Petersborg rape, fertilized 0.22 ng TEQ/kg. Petersborg rape, control 0.11 ng TEQ/kg.

In 1994 eight samples were collected and analyzed, four soil samples two samples of wheat (Petersborg) and two samples of rape (Igelösa). The fertilized soil sample had received 4 tonnes of sewage sludge per hectare the year before. The control soil had not received any sewage sludge. The two soil samples from Igelösa had the same concentrations, for Petersborg the samples show some increase in the fertilized soil

Igelösa fertilized 1.1 ng TEQ/kg d.m. Igelösa control 1.1 ng TEQ/kg d.m.  
Petersborg fertilized 0.92 ng TEQ/kg d.m. Petersborg control 0.63 ng TEQ/kg d.m.

At the farm Petersborg wheat was grown in 1994 and at Igelösa, the crop was rape. For the wheat samples the control sample had higher concentrations than the sample grown on the fertilized soil, for the rape samples the relationship was reversed

Fertilized: wheat 0.010 ng TEQ/kg rape 1.3 ng TEQ/kg  
Control: wheat 0.020 ng TEQ/kg rape 0.53 ng TEQ/kg

## DISCUSSION

The contamination of the sewage sludge shows a sharp decline between 1989 and 1993. This is in agreement with our finding of sewage sludge collected in Switzerland in 1989/90 and 1995 (10). The contamination of the 1993 sludge samples from Malmö and Lund is the same as the median of the 293 samples in the US EPA NSSS collected in 1988/89 (11).

After addition of 4 tonnes of sludge per hectare the year before the soil of Petersborg showed a slight increase, but for Igelösa the concentrations of PCDDs and PCDFs were the same for the fertilized plot and for the control. The concentrations of PCDDs and PCDFs in all soil samples are far below the German reference value of 5 ng TEQ/kg. It has been estimated that the mean soil concentration in USA for rural soil samples is 4.0 ng TEQ/kg d.m. For urban soil the value is 19.6 ng TEQ/kg d.m. (12).

2,3,7,8-Tetra CDD could not be found in any of the 1994 crop samples at a detection limit of 0.006 ng/kg or lower. The only crop sample showing any increased concentration of PCDDs and PCDFs, which might be correlated to the application of sewage sludge is the 1994 sample of rape from the farm Igelösa. The sewage sludge applied comes from the POTW in Lund. A comparison of the specific profile of the sludge, the 1993 and 1994 soil samples from Igelösa and the 1994 rape sample is given in Table 1.

An examination of Table 1 shows that there is no correlation between the profile of PCDDs and PCDFs in the sewage sludge and the concentrations in the rape and the incremental concentrations found in the soil after the application. This indicates that the main portion of the contamination in the soil and crop is due to aerial deposition.

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This conclusion is supported by the fact that the specific isomer pattern for the tetra- and penta CDFs found in the fertilized soil samples are identical to the patterns of tetra- and penta CDF found for the unfertilized soil, see Figures 1 and 2, and also the same as earlier reported for air samples (13).

Table 1. The Swedish sewage sludge land application study for farm Igelösa. PCDD/Fs in biosolid, soils and rape (ng/kg d.m.).

Homologue	Sewage sludge Lund 1993	Soil, Farm 1993	Igelösa 1994	Rape Igelösa 1994
Σ Hexa CDFs	4.7	4	7.1	0.71
Σ Hexa CDDs	100	3.5	6.5	0.57
Σ Hepta CDFs	100	4.9	8.1	1.4
Σ Hepta CDDs	1100	8.3	14	1.5
OCDF	140	4.9	18	3.5
OCDD	3800	31	85	5.2

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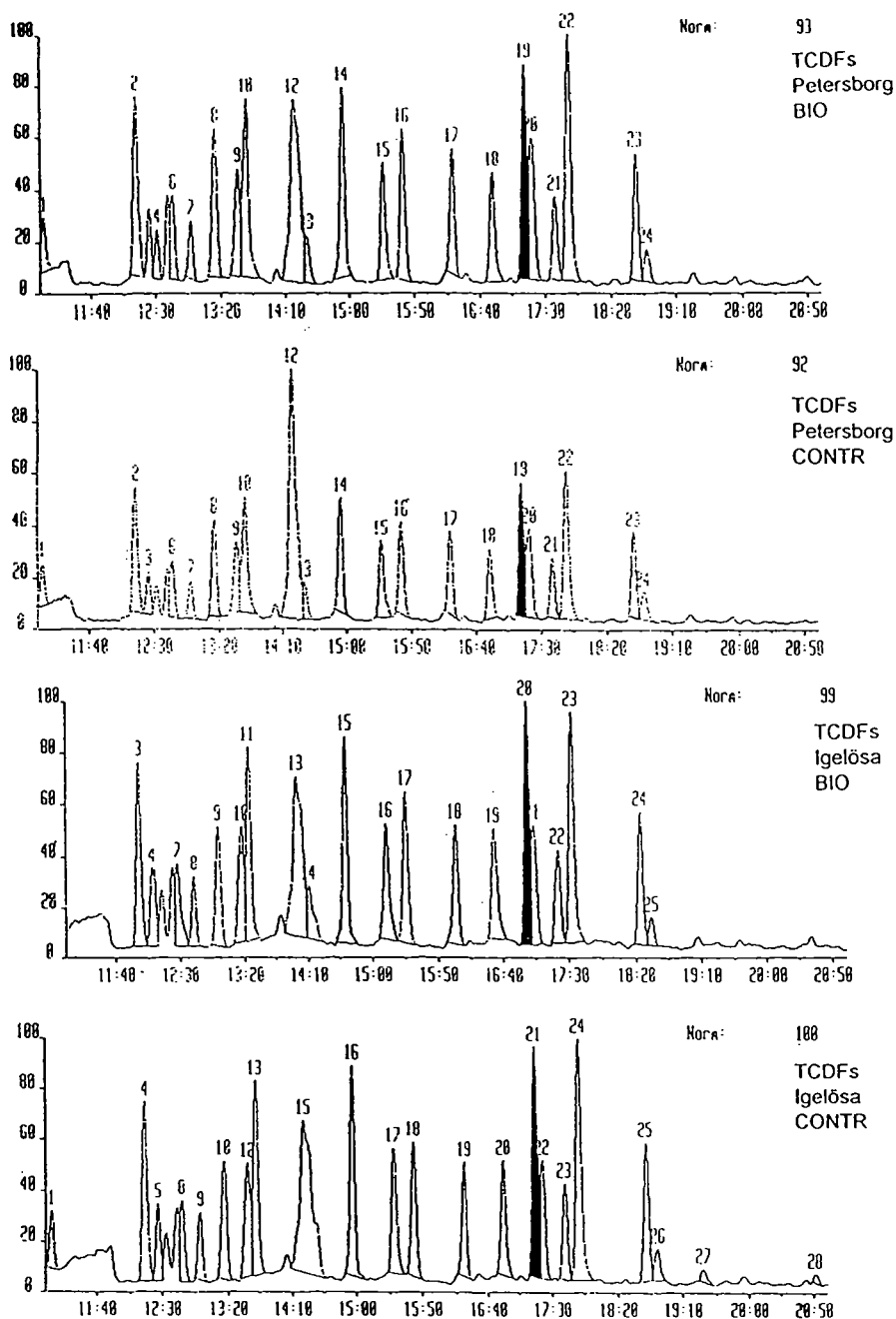


Fig. 1 TetraCDFs in soil samples at Petersburg and Igelösa.  
CONTR = control plot, BIO = plot fertilized with biosolids.

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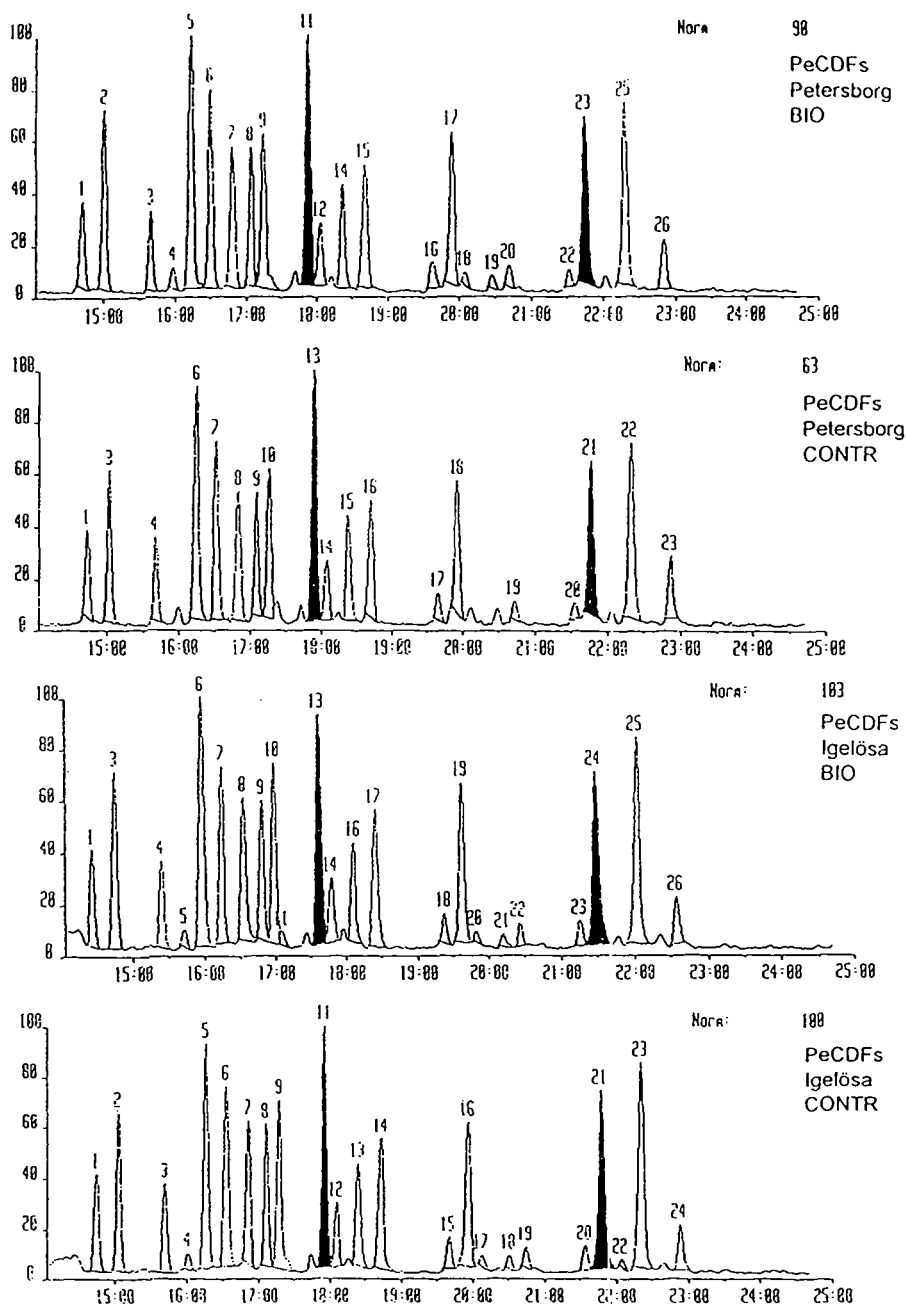


Fig. 2 PentaCDFs in soil samples at Petersborg and Igelösa.  
CONTR = control plot, BIO = plot fertilized with biosolids.