The relationship between soil PCB and PCDD/DF concentrations in the vicinity of a chemical waste incinerator in south Wales, UK.

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1. Introduction

Since early 1991 the Panteg district of south Wales has been the scene of one of the most intensive investigations of environmental concentrations of PCBs and PCDD/DFs ever undertaken in the United Kingdom [1]. The survey was primarily initiated as the result of public concern over the operations of a chemical waste incinerator plant owned by Rechem International Ltd [2]. The Pontyfelin Industrial Estate, in which the incineration facility is located, occurs within a mixed industrial and residential area to the south of the town of Pontypool (see Figure 1). Parts of Lower New Inn, the nearest residential area, are within 300 metres of the plant.

Industrial activity in the Panteg district dates back to the early 18th century and has included coal mining, iron and steel production, aluminium smelting and glass manufacturing. Current industrial operations involve steel rolling, automotive engineering, pharmaceuticals, glass-fibre production and general light engineering. There are also two hospital incinerators (neither now in use) and a crematorium in the area.

The Rechem incineration plant was set up in 1972 and over the years has undergone substantial modification to comply with more rigorous emission controls. Monitoring of soil PCB concentrations in the vicinity of the incinerator has been carried out since 1984 by various agencies, chiefly Rechem itself, Torfaen Borough Council and Her Majesty's Inspectorate of Pollution. A comprehensive review of the available data undertaken by the University of East Anglia in 1991 [1,3] clearly demonstrated the existence of elevated PCB levels in soil samples from an area adjacent to, and largely downwind of, the Rechem plant. PCDD/DF concentrations in soil also appeared to be higher in this area, although the number of samples (twelve in total) limited the conclusions that could be drawn.

Following the 1991 report, a further investigation was commissioned by the Welsh Office to provide more comprehensive data on PCBs and PCDD/DFs in the valley, to determine if concentrations were in any way unusual and, if so, identify potential sources of contamination. This study has subsequently confirmed [1,4] that the Rechem plant has contributed to the

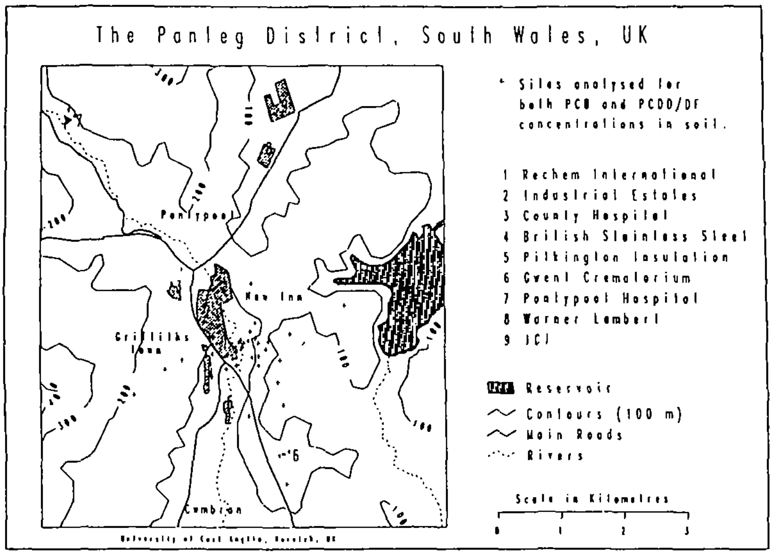

Figure 1: The Study Area and Locations of the Sampling Sites

environmental burden of both PCBs and PCDD/DFs over a strip of land some 200 metres wide around the eastern boundary of the incinerator. However, the pathways of such off-site migration are, at present, uncertain. Incomplete combustion of PCBs and similar chlorinated organics are known to result in the formation of PCDD/DFs [5]. For this reason, regulatory agencies have placed particular emphasis on the monitoring of stack gas emissions from chemical and municipal waste incinerators. Much less attention has been paid to the possibility that wastes destined for incineration that contain PCBs or similar organochlorine compounds could also include PCDD/DFs as contaminants [6,7], and that fugitive emissions from plants handling such materials might contribute to the dispersion of both types of pollutants. Indeed, it appears common for monitoring studies to measure concentrations of either PCBs or PCDD/DFs in environmental media, so evidence on the extent to which the two are correlated is distinctly limited.

As part of the study mentioned above, soil samples from 42 sites were analysed for both PCBs and PCDD/DFs. The resulting data set is, to our knowledge, unique in the literature. The purpose of this paper, therefore, is to examine relationships in the concentrations of these two pollutants and to assess the implications with respect to environmental pathways for dispersal of PCBs and PCDD/DFs.

2. Methods

The 42 sampling locations are shown in Figure 1. Soil was collected from 32 sites in November/December 1991 and from the remaining ten as part of a project extension in February 1993. Sample preparation was carried our centrally at the University of East Anglia and fully homogenised soils were distributed to the seven national and international laboratories involved in the analysis programme.

The performance of the individual laboratories was assessed by implementing an extensive inter-laboratory quality control programme, involving the analysis of standard solutions and soil samples. Each laboratory was also required to abide by the acceptance criteria and quality control procedures for PCDD/DFs [8] and to similar standards for PCBs [1]. Full details of the sampling, sample preparation, analysis and quality control methods have been reported elsewhere [1].

An important aspect of quality control was that samples from many sites were analysed by more than one laboratory. For PCBs there were 90 samples from the 42 locations and 54.8 % of sites were analysed by at least two laboratories. In the case of PCDD/DFs the degree of overlap was less and a total of 53 samples were processed, 21.4 % of sites being studied by multiple laboratories.

Inspection of the data produced by different laboratories revealed a satisfactory degree of consistency, mean coefficients of variation for both PCBs and PCDD/DFs being 22 % [1]. There were, however, trends for some laboratories to consistently report higher concentrations than others. In order to compensate for such variations, and to facilitate a combined assessment of the data, individual PCB and PCDD/DF concentrations were standardised for laboratory differences using an unbalanced Analysis of Variance approach [4]. Standardisation proved impracticable for some PCDD/DF samples due to the limited degree of overlap between laboratories and in these instances (13 out of 53) the original data values were retained. Once the standardisation process had been implemented, mean concentrations were calculated for each of the 42 sites with respect to the sum of seven targeted PCB congeners; total PCBs ; the I-TEQ for PCDD/DFs ; the sum of 17 targeted congeners for PCDD/DFs ; and the sum of congener group totals for PCDD/DFs. The remainder of this paper focuses on the relationships between these five variables at the 42 sites.

3. Results

There was considerable variation between sampling sites in average PCB and PCDD/DF concentrations. This can seen from the descriptive statistics in Table 1 and the contrast between the mean and median values reflects the existence of a high degree of positive skewness in each frequency distribution.

Table 1. Descriptive statistics for PCBs and PCDD/DFs at the 42 sampling sites.

Measurement	Minimum	Median	Mean	Maximum
Sum 7 PCB Congeners	4	13	139	4447
Total PCBs	14	44	475	15209
I-TEQ for PCDD/DFs	2.5	10.5	66	1745
Sum 17 Congeners for PCDD/DFs	136	1255	13843	356600
Sum Congener Group Totals for PCDD/DFs	217	1735	17155	447590

Note: PCB Concentrations are in ug/Kg. Those for PCDD/DFs are in ng/Kg.

For instance, 24 of the 42 sites (57.1 %) had average sum of seven congener concentrations for PCBs under 15 ug/Kg, but four others had values above 100 ug/Kg, the highest being in excess of 4,000 ug/Kg.

Due to the level of skewness, Spearman rank correlation coefficients were calculated to assess relationships between the different measurements of PCB and PCDD/DF concentrations. All of the results indicated statistically significant positive associations at the 99 % confidence level, the lowest correlation coefficient being +0.92. A scatterplot of one relationship is shown in Figure 2, the prominence of a single extreme observation emphasising the need to use robust statistical methods when evaluating correlations between such variables.

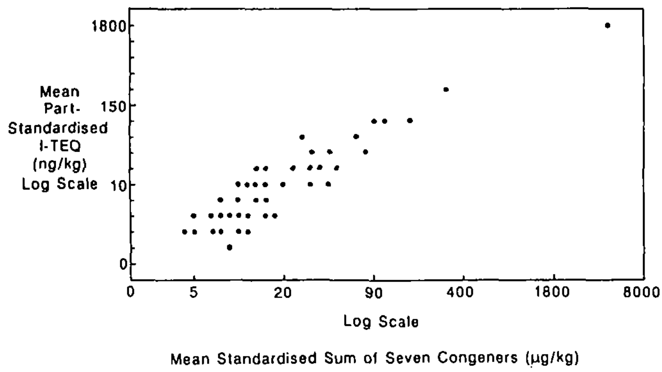

Figure 2: The Relationship between sum of 7 Congener Concentrations for PCBs and I-TEQ Values for PCDD/DFs at 42 Sites

An assessment was also made of the relative mass of PCBs and PCDD/DFs at each site. The sum of the congener group totals for PCDD/DFs was first converted to ug/Kg and then divided by the concentration for total PCBs. These calculated ratios ranged from 0.0078 to 0.0941, there being a strong tendency for the values to rise with the absolute PCB or PCDD/DF concentration. An illustration of this point is provided by Table 2 and an Analysis of Variance on the ratios revealed a highly statistically significant difference (greater than 99 % confidence) between the total PCB concentration categories.

Table 2. Relationship between total PCB concentrations and the mass of PCDD/DFs relative to PCBs.

	Sum of Congener Group Totals for PCDD/DFs as a Ratio of Total PCBs			
Total PCB Concentration (ug/Kg)	Number of Sites	Median	Mean	St Deviation
0-29.9	10	0.0157	0.0178	0.0071
30-59.9	15	0.0220	0.0289	0.0176
60-199.9	10	0.0443	0.0474	0.0178
> = 200	7	0.0590	0.0603	0.0204

4. Discussion

The above results imply that, PCB and PCDD/DF contamination in the Panteg district has originated from one or more common sources. It also appears unlikely that stack gases from the Rechem incinerator are responsible, since both plume modelling and studies of deposition patterns suggest that these emissions typically do not reach the ground within a 300 metre radius of the plant [1]. This contrasts sharply with the levels of PCBs and PCDD/DFs found in soils and high-volume air samples, the greatest off-site concentrations occurring inside 200 metres from the eastern boundary of the plant [4].

In the entire investigation, the highest concentrations in soil for PCBs (15,200 ug/Kg total PCB) and PCDD/DFs (1740 ng TEQ/Kg) were found at a site within the Rechem plant. There was also evidence that PCB concentrations in air were generally greater at locations immediately downwind of the waste handling facilities and lower at upwind monitoring sites [1]. Given that winds in the study area blow predominantly from the west and south-west, there is a strong case that fugitive emissions from the plant have been substantially responsible for the elevated levels of PCBs and PCDD/DFs detected at sites close to the eastern boundary. Possible sources for such emissions could have included the waste storage areas, the transformer handling facility, the incinerator loading bay and ash disposal operations. In addition, it should be recognised that volatilisation of PCBs [5] and re-mobilisation of PCDD/DFs [9] from contaminated surfaces around the plant may have made a significant contribution.

5. Conclusion

Extensive alterations and improvements have been made to the Rechem plant in recent years and several potential sources of fugitive emissions have been eliminated. It is also necessary to be cautious about generalising from the situation in the Panteg district to locations where other chemical waste incinerators occur, but the results presented here certainly indicate that geographical patterns of PCB and PCDD/DF concentrations may be strongly correlated. Overall, this study suggests that the possibility of organochlorine wastes being contaminated with PCDD/DFs deserves serious attention ; that analyses which focus only on PCBs or PCDD/DFs may underestimate the scale of environmental contamination ; and, finally, that fugitive emissions should be given much more consideration in the monitoring of incineration plants than has previously tended to be the case.

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