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The Panteg monitoring project: comparing PCB and dioxin concentrations in the vicinity of industrial facilities

A.A. Lovett [*], C.D. Foxall, D.J. Ball [1], C.S. Creaser [2]

School of Environmental Sciences, University of East Anglia, Norwich NR4 7TJ, UK

Abstract

This paper describes the design, implementation and outcome of a research project which investigated concentrations of PCBs and PCDD/DFs (more commonly known as dioxins and furans) in the Panteg district of Pontypool, south Wales. The project was initiated in response to public concerns regarding the operations of a chemical waste incinerator located in the area and was undertaken by a multidisciplinary team based at the University of East Anglia. Sampling was carried out around a number of industrial facilities in the Panteg district and involved a variety of environmental compartments (e.g. soil, grass, air, milk, eggs, poultry and vegetables). The results provided evidence of some unusual environmental contamination in a strip of land 200 m wide around the eastern boundary of the incineration plant. Fugitive emissions from the site appeared to be substantially responsible for this situation and exposure calculations indicated that eggs were potentially the major source of higher PCB and PCDD/DF intakes. Since the start of the project substantial alterations have been made to the incinerator and, overall, the research does seem to have resolved a number of uncertainties and helped to reduce local concerns.

Keywords: PCBs; Dioxins; Industrial sources; Waste incineration; Exposure assessment

[*] Corresponding author. Tel: +44 1603 593126; fax: +44 1603 507719; e-mail: a.lovett@uea.ac.uk

[1] Present address: School of Health, Biological & Environmental Sciences, Middlesex University, 10 Highgate Hill, London N19 5ND, UK.

[2] Present address: Department of Chemistry and Physics, Nottingham Trent University, Nottingham, NG11 8NS, UK.

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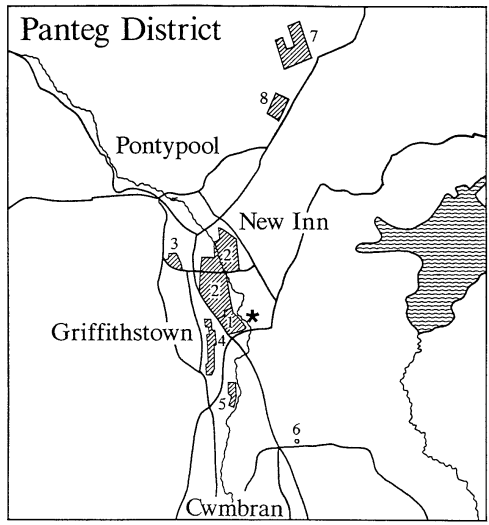
1. Introduction

Incineration has a long history as a waste management option, but has become increasingly controversial since the mid 1960s [1]. Public concerns have mainly focused on adverse health impacts, particularly from possible emissions of chlorinated dioxins (PCDDs) and furans (PCDFs) [2,3]. There is much debate regarding the toxicity of these compounds, but there is accumulating evidence that they can have carcinogenic, reproductive and developmental effects in humans [4,5].

There are a small number of specialist, high-temperature hazardous waste incinerators in the UK. One of these is located in the Panteg district to the south of the town of Pontypool in Wales and is operated by Rechem. The plant was established in 1972 and since 1979 has been licensed to incinerate polychlorinated biphenyl (PCB) contaminated waste materials. PCBs were used commercially from the 1930s onwards, particularly in electrical transformers and capacitors, but following several pollution incidents (e.g. in Japan during 1968) their use has become increasingly restricted [6]. Safe disposal of waste PCBs is difficult due to their stable and accumulative nature, with the most conventional means being incineration at temperatures in excess of 1200°C. This process requires care, however, as incomplete combustion of PCBs can readily lead to the formation of more toxic PCDD/DFs [7]. Unlike PCBs, the latter compounds have never been deliberately manufactured on any scale, and it is generally accepted that their presence in the environment is mainly due to anthropogenic combustion activities and the manufacture or use of organochlorine chemicals [8].

The operation of the Rechem incinerator has long been a subject of local controversy. Initial concerns related mainly to odour or smoke emissions, but by the mid 1980s had extended to include opposition to imports of PCB waste (from as far away as Australia) and possible risks to human or animal health [2,9]. Further difficulties arose in the late 1980s when monitoring by Rechem and the local authority responsible for the area (Torfaen Borough Council) produced conflicting estimates of PCB levels in environmental samples (soil, grass and eggs) taken simultaneously at the same sites. Particular dispute surrounded some of the results for samples collected from Pontyfelin House (the nearest residential property on the predominant downwind side of the incineration plant, see Fig. 1), but several of the reported PCB concentrations in duck eggs were such that the inhabitants were advised to no longer consume any produce from the poultry they kept [10,11].

Two other factors complicated the situation as it existed at the start of the 1990s. The first of these was the presence in the Panteg district of a number of other facilities which could conceivably be sources of PCBs or PCDD/DFs. These included a steel works, several large manufacturing plants, two (recently closed) hospital incinerators and a crematorium (see Fig. 1). A second problem was the cost of analysing a sample for PCBs (typically £80–£100) or PCDD/DFs (£800–£1000). This meant that more extensive investigations were beyond the resources of the organisations with primary regulatory responsibility for the Rechem incinerator. Reviewing the position in 1990, the Welsh Affairs Committee of the House of Commons concluded that there was a clear need for an independent and comprehensive investigation [10]. The Welsh Office accepted this recommendation and in 1991 commissioned a multi-disciplinary team



Key to Map Symbols

Principal Roads

Rivers & Llandegfedd Reservoir

1 Rechem International	5 Pilkington Insulation
2 Industrial Estates	6 Gwent Crematorium
3 County Hospital	7 ICI
4 Avesta (Sheffield)	8 Warner Lambert

* Pontyfelin House

Fig. 1. Locations within the Panteg district.

based at the University of East Anglia (UEA) to conduct a study with the following objectives:

i) to investigate the concentrations of PCBs and PCDD/DFs in the Pontypool environment;

ii) to determine if concentrations were in any way unusual and, if so, to identify as far as possible the sources of contamination;

iii) to assess, if unusual concentrations were found, their contribution to human intake.

2. Methods

The first phase of the research involved a comprehensive review of PCB and PCDD/DF concentrations measured in the vicinity of the incinerator since 1984 and design of a monitoring programme to resolve outstanding questions and uncertainties. Table 1 shows the number of samples subsequently collected for different environmental compartments. Extensive sampling of soils was undertaken at an early stage of the

Table 1
Samples collected during the Panteg Monitoring Project, 1991–1994

Sample type	Number of samples		
	PCBs	PCDD/DFs	Total
Air: hi-vol	35	23	58
Air: deposit gauge	24	12	36
Soil	140	42	182
Sediments	13	6	19
Grass	13	11	24
Milk	24	16	40
Fruit/vegetables	53	40	93
Poultry feed	10	7	17
Eggs	27	27	54
Poultry meat	8	8	16
Totals	347	192	539

fieldwork in order to assess contamination across the entire study area, while air monitoring was carried out in two main campaigns and most of the foodstuffs were collected in the later phases of the study. Some fruit, vegetable, egg and poultry meat samples had to be taken from rural areas elsewhere in Wales and England in order to assess background concentrations of PCBs and PCDD/DFs in these compartments. All the PCDD/DF analyses were based on the seventeen 2,3,7,8 substituted congeners, but for PCBs the situation varied. A minimum of seven PCB congeners (28, 52, 101, 118, 138, 153 and 180) were determined for all samples, but for fruit, vegetables and most soils the number was extended to 18, and for eggs and poultry meat it was increased to 46 to reflect recommendations regarding the assessment of PCB toxicology [12].

Table 2
PCB and PCDD/DF concentrations in soil samples from different zones

Zone	Sum 7 PCB congeners (μg/kg)			PCDD/DF I-TEQ (ng/kg)		
	N	Median	Maximum	*N*	Median	Maximum
Pontypool Hospital	7	11.4	24.0	4	4.3	5.5
Warner Lambert and ICI	15	10.0	51.4	–	–	–
Pontypool	3	14.1	14.6	–	–	–
Griffithstown	28	6.3	23.9	6	3.4	5.4
Industrial estate	17	10.8	28.2	2	7.0	9.7
Steelworks	12	13.3	76.5	1	21.5	21.5
Rechem	12	1237.4	4620.4	4	828.5	1870.0
Pontyfelin House	33	77.6	303.2	12	47.2	250.0
New Inn	24	20.1	50.0	10	15.4	46.6
Farms and eastern rural	15	8.6	19.3	8	4.2	13.1
Pilkington and south	22	7.8	21.5	6	3.7	6.1

The sum of the number of measurements for each zone (N) is larger than the number of samples listed in Table 1 because some samples were analysed by more than one laboratory. The concentrations listed have been statistically standardised to control for systematic variations between laboratories.

Throughout the project special attention was given to matters of quality assurance and quality control. This, for instance, involved centralised preparation of samples, inter-laboratory comparisons using standards, and analyses of subsets of samples by multiple laboratories [10]. On several occasions results from individual laboratories were rejected as not meeting the necessary quality standards.

3. Results

A report on the main phase of the monitoring programme was published in 1993 [11]. This was followed by three supplementary reports, each discussing the results of additional work commissioned by the Welsh Office. The last of these report, published in 1995, also included an overall exposure assessment based on the data obtained [13]. Rather than discussing the results in strict chronological order the following summary is thematically organised. It begins with soil, then air, foodstuffs, and exposure implications.

Trends in PCB and PCDD/DF concentrations in soil across the study area were investigated by grouping the data for individual sampling sites into a series of zones.

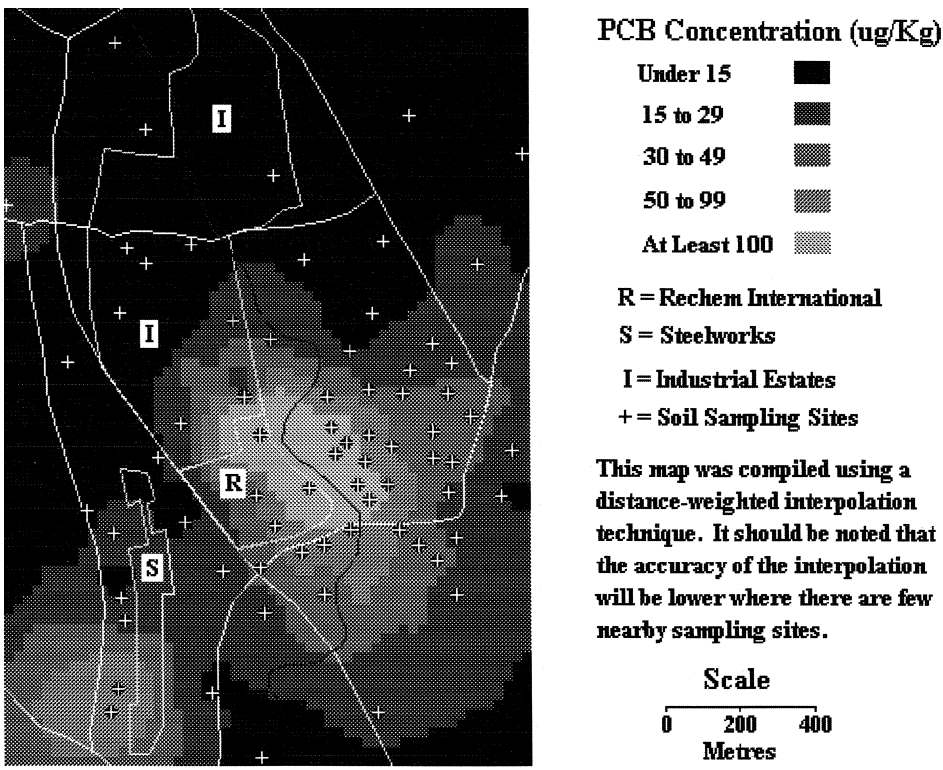


Fig. 2. Interpolated standardised sum of seven PCB congener concentrations (μg/kg).

Table 2 lists some of the descriptive statistics calculated and shows a clear pattern of higher values for the zones close to the Rechem incinerator. Further assessment within this area was undertaken by producing an interpolated map of PCB levels (see Fig. 2). This revealed a general decline in concentrations away from the eastern side of the incineration plant and a small secondary peak on the disused railway line near the steelworks. Principal components analysis and classification techniques were then used

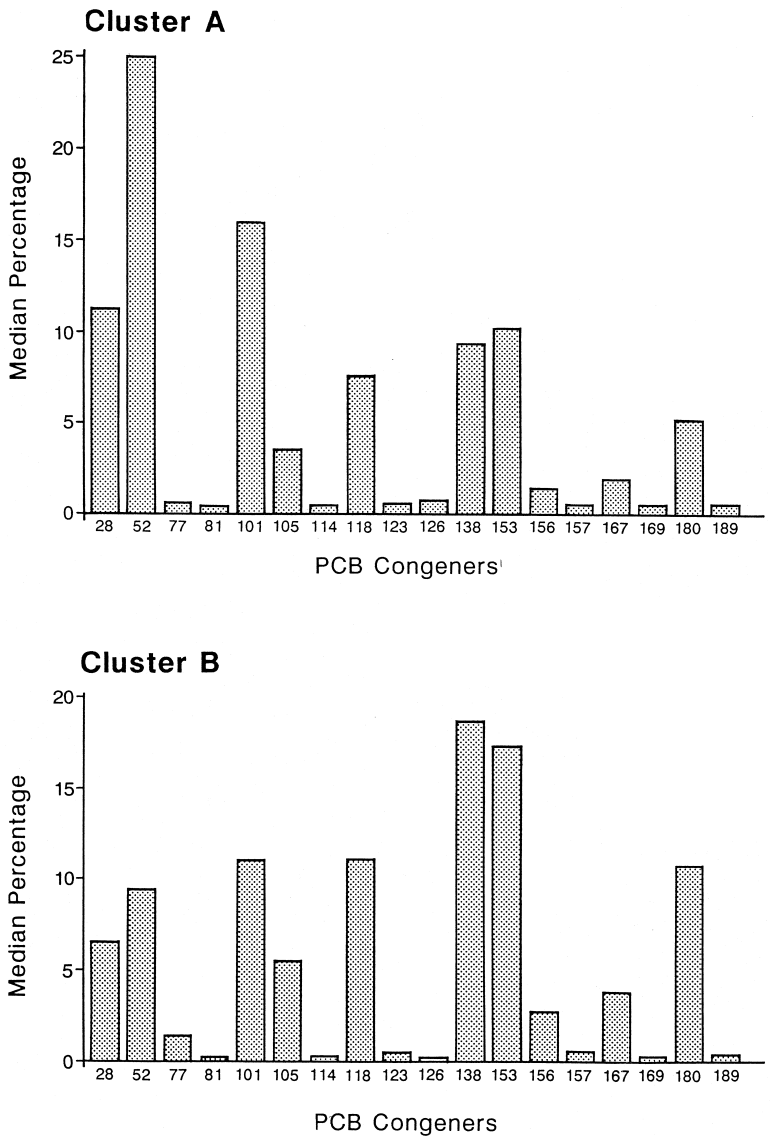


Fig. 3. PCB congener profiles for the two clusters of soil sampling sites.

to examine the composition of the soil samples in terms of different PCB congeners. Two groups of sites with contrasting profiles (see Fig. 3) were identified by these methods and when they were mapped all the sites in the more chlorinated Cluster B were found to occur either within the plant or around the eastern boundary (see Fig. 4). All the sites on the disused railway line were in the other cluster.

One feature of the soil analyses was the strong positive correlation between the PCB and PCDD/DF concentrations in the samples [14]. The results also indicated that unusual levels of these compounds for urban residential areas were essentially confined to land within some 200 m of the incinerator plant boundary, and that samples from within this area shared a distinctive congener profile. These findings suggested that the operations of the Rechem incinerator were responsible for the contamination of nearby land. Further confirmation of this view came from ambient air monitoring data. A reanalysis of particulate phase PCB concentrations recorded by Rechem at five sites during June–October 1989 revealed a strong association with wind directions observed at the nearest Meteorological Office station (Cilfynydd). Fig. 5 shows the pattern identified and indicates that the concentrations at each site were generally higher when the wind would have blown across the waste handling area of the Rechem plant before reaching the monitoring point [11]. A similar trend was found in data collected as part of the UEA monitoring programme in 1992–1993, with PCB concentrations at Pontyfelin

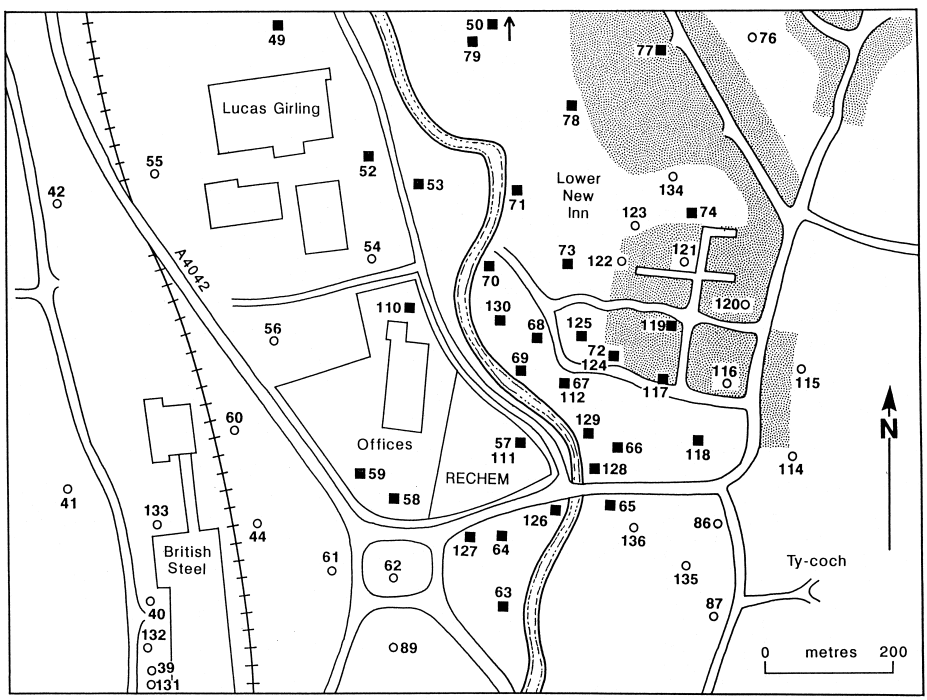


Fig. 4. Map of soil sample sites in clusters A and B in the central part of the study area.

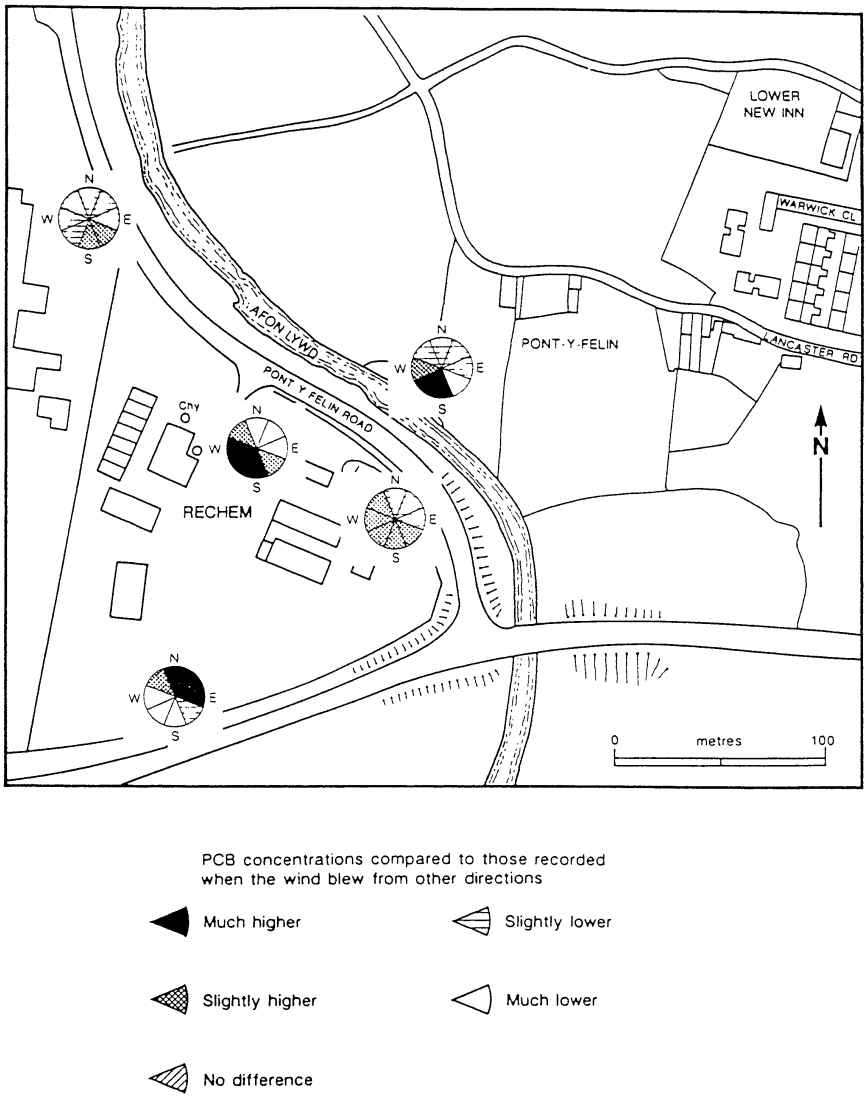


Fig. 5. The relationship between PCB concentrations in air and wind directions.

House and Warwick Close (New Inn) being positively associated with the proportion of prevailing winds from the south west or west during each survey period. Levels at Pontyfelin House were always greater than those at Warwick Close (appreciably so when the wind was predominantly from the south west or west) and, taken together, these trends implied that fugitive (rather than stack gas) emissions from the facility were the most likely means of contaminant dispersal beyond the incineration plant boundary [11,15].

Table 3
Total PCB concentrations in samples from different locations

Sample type	Median concentration		
	Pontyfelin House	Panteg district	Background
Milk	–		
Duck eggs	232.0	14.0	5.3
Bantam eggs	428.0	–	16.0
Chicken eggs	–	6.7	6.6
Duck meat	20.0	–	13.0
Apples	14.3	2.6	1.8
Lettuce	–	1.5	2.3
Potatoes	–	2.2	1.3
Air	5.1	1.0	0.5
Soil	330.0	100.0	20.0

The units are: food, μg/kg fresh mass; air, ng/m^3; soil, μg/kg dry mass.

Due to these conclusions the latter stages of the research project focused on possible contamination of local foodstuffs (consumption of these would be the main pathway for human exposure [4]). Particular attention was given to the Pontyfelin House area and how PCB and PCDD/DF concentrations found in this vicinity compared with those found elsewhere in the Panteg district or at rural background locations. Table 3 summarises the data generated for PCBs and Table 4 does the same for PCDD/DFs. Both tables highlight distinct environmental gradients, the concentrations in eggs from Pontyfelin House being particularly prominent [13,16].

Using mean daily consumption rates for the various foodstuffs [11], inhalation and soil ingestion rates of 20 m^3/day and 100 mg/day respectively, and the median concentrations from Tables 3 and 4, estimated intakes of PCBs (μg/day) and PCDD/DFs (pg TEQ/day) were calculated. Details of the results for PCDD/DFs are presented in Table 5. Overall, these assessments demonstrated that the residents of the

Table 4
PCDD/DF (I-TEQ) concentrations in samples from different locations

Sample type	Median concentration		
	Pontyfelin House	Panteg district	Background
Milk	–		
Duck eggs	3.8	1.0	0.8
Bantam eggs	12.0	–	0.6
Chicken eggs	–	1.0	1.2
Duck meat	1.0	–	0.4
Apples	0.7	0.4	0.3
Lettuce	–	0.3	0.3
Potatoes	–	0.4	0.3
Air	0.8	0.2	0.2
Soil	112.0	19.0	6.3

The units are: food, ng TEQ/kg fresh mass; air, pg TEQ/m^3; soil, ng TEQ/kg dry mass.

Table 5
Estimated intakes of PCDD/DFs (pg/TEQ/day) at different locations

Sample type	Consumption (kg/person/day)	Estimated intake (pg/TEQ/day)		
		Pontyfelin House	Panteg district	Background
Milk	0.303	–	36	15
Duck eggs	0.027	103	26	22
Bantam eggs	0.017	204	–	10
Chicken eggs	0.027	–	27	32
Duck meat	0.017	17	–	7
Apples	0.032	22	13	10
Lettuce	0.0058	–	2	2
Potatoes	0.151	–	60	45
Air	20 m^3/day	12	2	3
Soil	100 mg/day	11	2	1

Panteg district (excluding Pontyfelin House) were not subject to PCB and PCDD/DF concentrations obviously different from background levels. Estimated intakes of both PCBs and PCDD/DFs at Pontyfelin House were, however, substantially above background levels [17]. As illustrated in Table 5, the major contribution to these elevated intakes came from egg consumption. Calculated on a body mass of 60 kg, these egg intakes (estimated at 3.4 and 1.7 pg TEQ/kg body mass/day for bantam and duck eggs respectively) would in themselves represent 34% and 17% of the WHO TDI value of 10 pg TEQ/kg body mass [18]. The corresponding PCB intakes of 7.3 and 6.3 μg/day would constitute 73% and 63% respectively of an average dietary intake (10 μg/day) of this contaminant [19]. In view of these figures, the owners of Pontyfelin House have been advised by the Welsh Office that they should continue to refrain from eating any eggs produced by their poultry.

4. Conclusions

Considerable improvements have been made to the Rechem plant since the start of the Panteg Monitoring Project. Rechem have invested approximately £13 million in new facilities during this time, including the installation of a rotary kiln, a computerised control system and improvements to the gas cleaning plant. Routine environmental monitoring on and around the site is now being carried out under the supervision of the Environment Agency. The Panteg Monitoring Project itself was completed in 1995. Undertaking the investigation was certainly challenging, involving an issue of considerable local sensitivity and requiring considerable care in issues of environmental sampling, quality control in analytical chemistry and use of statistical methods. The project cost over £650 000 but does appear to have to have successfully resolved a number of uncertainties and met the original objectives set. A legal action between the residents of Pontyfelin House and Rechem is still outstanding, but more generally the research does seem to have helped reduce local concerns regarding the operations of the incinerator.

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