FINAL REPORT

THE IMPACT OF RIVER FLOODING ON FOOD PRODUCED ON FLOOD PLAINS

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A collaborative study:

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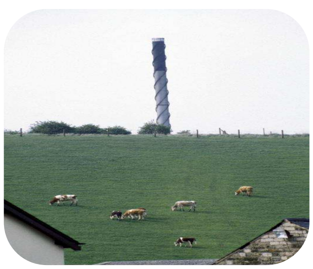
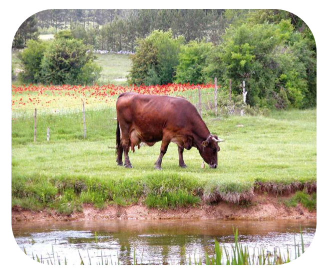
FD 12/02

The impact of river flooding on food produced on flood plains

Report to Food Standards Agency

June 2012

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Contents

Glossary

BCR	Community Bureau of Reference
CRM	Certified Reference Material
EC/EU	European Commission/ European Union
GC-HRMS	Gas chromatography - high resolution mass spectrometry
GC-LRMS	Gas chromatography - low resolution mass spectrometry
ICES	International Commission for the Exploration of the Sea
ICES 6 PCBs	Sum of ICES 6 PCB congeners
IUPAC	International Union of Pure and Applied Chemistry
MPL	Maximum permitted limit
PBDE	Polybrominated diphenylether
PCB	Polychlorinated biphenyl
non-*ortho* PCB TEQ	Sum of WHO-TEQ for individual non-*ortho* PCB congeners
ortho PCB TEQ	Sum of WHO-TEQ for individual *ortho* PCB congeners
PCDD	Polychlorinated dibenzo-*p*-dioxin
PCDF	Polychlorinated dibenzofuran
PCDD/F TEQ	Sum of WHO-TEQ for individual PCDD and PCDF congeners
PTV	Programmable temperature vaporisation
QC/QA	Quality Control/Quality Assurance
RM	Reference Material
TDS	Total diet survey
TEF	Toxic Equivalence Factor
TEQ	Toxic equivalence computed from TEF
WHO	World Health Organisation
WHO-TEQ	Sum of PCDD/F non-*ortho* PCB and *ortho* PCB TEQ using WHO assigned TEFs (1998 or 2005 as specified)

Executive Summary & Recommendations

It is known that river flooding can cause deposition of sediment on floodplains along the length of the course of a river. Where the river passes through urban and industrial areas, the sediment can contaminate flood-prone pastures with the potential to transfer contaminants to food that is produced on these areas. An earlier study (C01037) demonstrated that cows' milk produced on farms with pasture that was subject to flooding, contained higher levels of dioxins (PCDD/Fs) and PCBs than proximate, comparable and matched control farms. This study investigated whether this contaminant (dioxins, PCBs and PBDEs) exposure pathway also extended to other food raised on flood-prone farms, such as meat and offal from sheep and beef cattle, on two river systems – the Trent and the Aire/Ouse. It also revisited some of the dairy farms investigated in the previous study, to confirm the earlier findings and to update current contaminant data for milk produced there. The seasonality of contaminant concentrations which may reflect husbandry practices and environmental influences on milk production on these farms was also investigated.

In a research project of this nature and size, much depends on the availability of suitable farms and the co-operation of the farmers. These factors, coupled with project funding, can result in a study containing relatively small numbers of farms (and samples). In the statistical analyses of these data, the smaller data sets may influence outcomes, requiring very pronounced differences between flood-prone and control sets to achieve statistical significance. In this study, to overcome these limitations and to provide a more holistic overview of the data, the data from the milk, beef and sheep programmes were also examined using weights of evidence tables.

The main findings were:

- Contaminant concentrations in milk have declined significantly since the previous study, a finding that is in keeping with the trend observed for other foods in the UK and other parts of the world. Contaminant concentrations did not remain significantly higher on milk from flood-prone farms although this observation is based on a small number of farm pairs. The decline in milk contaminant concentrations from flood-prone farms was not reflected in significantly lower contamination concentrations in soil from these pastures. It may therefore follow that the decline relates more to reduction in contaminants in other inputs to dairy cows such as commercial feed, or the effect of more recent husbandry practices.

Grass concentrations mirrored those found in soils, with no evidence of a decline. The weights of evidence table analysis broadly confirmed the conventional statistical analyses.

- Statistical analysis of the data from the study on beef cattle (38 animals) did not indicate that levels of total TEQ, dioxin-like PCBs, PCDD/Fs or PBDE were significantly higher in meat or the corresponding liver from cattle on flood-prone farms. The only exception was that levels of ∑ICES6 were significantly higher in meat but not liver from flood-prone farms. The high concentrations observed on a single control farm on the River Ouse may partially influence the statistical analysis and the low number of samples (10 farm pairs) needs to be taken into account in interpreting these comparisons. The animals used in this study were sampled prior to market-readiness and would have been subjected to a 'finishing-period' before they entered the food chain. PBDE concentrations for meat were consistent with literature data, but PCDD/F and PCB WHO-TEQ$^{-}_{1998}$ concentrations (average, 2.65 ng/kg fat - River Trent and 3.87 ng/kg fat – River Aire/Ouse) were higher than reported literature values from the UK and other EU countries over the last decade. This comparative elevation was also observed for PCDD/F and PCB WHO-TEQ$_{1998}$ in the liver samples. However, the animals used in this study were not market-ready, and so meat from these animals would not be directly comparable with food products available to consumers. Commercial feed was discounted as a source of these relatively high PCDD/F and PCB levels in meat and liver as no differences between flood-prone and control sites emerged. The commercial feed data returned generally low levels of all contaminants, consistent with recently reported literature data. In contrast to the lack of statistical significance observed for the meat samples, the majority of the weights of evidence analysis, pointed to flood-prone farms having elevated levels PCDD/Fs and PCBs, but not PBDEs, in meat and liver, which suggests that cumulative river flooding events results in the transfer of PCDD/Fs and PCBs to meat and liver in beef cattle raised on the flood plains.
- Meat and the corresponding liver samples from sheep (n=22) raised on farms on two river systems – the Trent and the Aire/Ouse, did not show any significant differences in contaminant concentrations between flood-prone and control farms. The low number of kidney samples precluded a statistical anslsyis. At an average PCDD/F and PCB WHO-TEQ$_{1998}$ value of 0.9 ng/kg fat for meat, and average PBDE value of 654 ng/kg, contaminant levels were consistent with literature values reported over the last decade. The corresponding mean PCDD/F and PCB WHO-TEQ$_{1998}$ concentration in liver was considerably higher at 14.1 ng/kg fat, a level that is moderately elevated in comparison to

liver data over the last decade for the UK and Ireland. The difference between meat and liver WHO-TEQ concentration has been noted in other reported studies and has been attributed to physiology and organ functionality (kidney concentration levels are similar to meat on a fat weight basis). The weights of evidence table analysis supported the results of the conventional statistical analyses

- The study on the seasonality of contaminant concentrations in pooled milk from individual control and flood-prone farms, showed that the levels of dioxins, PCBs and PBDEs fluctuated (almost by a factor of two), over short time periods (6 weeks). The fluctuations can partly be attributed to changes in the contaminant concentrations of dietary inputs to the cattle, most notably grass and silage. It follows from this finding that the PCDD/Fs & PCBs and PBDEs concentrations observed in monitoring studies on individual farms will vary considerably depending on which part of the year the milk is sampled.

Both the conventional statistical analysis and the weights of evidence tables for the dairy and the sheep programmes fail to support the earlier reports which show that contaminant concentrations in milk produced on flood-prone pastures were significantly higher than matched controls. This may in part, be influenced by the lower numbers of samples analysed in this study (e.g. 10 milk samples were analysed in this study, compared to the larger number analysed earlier – a total of 111 when including controls). The lower concentrations across control and flood-prone farms recorded in this study may also influence this outcome as the magnitude of the differences would also be smaller. The weights of evidence analysis for the beef programme however, does provide support for the conclusion of the earlier study on milk. Relatively higher analyte concentrations were observed in the meat and liver tissues from the animals studied (n=38) in this programme.

Recommendations

The observations made in the study also highlight areas where further investigation would be beneficial in understanding contaminant pathways to food produced on floodplains, allow update of current contaminant levels and potentially allow the formulation of remedial action.

- One of the limitations of the statistical analyses in this work was the low number of data points. The analyses might be strengthened by the generation of additional data from more animals on these farms, or if the samples had been collected closer together in terms of time, just before the animals were brought indoors. However, it is likely that similar conditions may prevail on flood-prone farms in other areas of the UK, and a study targeted at other river systems that flow through urban and industrialised areas would also provide similar additional data to support the current findings, whilst further defining the extent of the issue and potentially help in the provision of advice to farmers.

- The data on WHO-TEQ$_{(1998 \text{ and } 2005)}$ concentrations in beef in this study show levels that are generally higher than recently reported retail beef samples in the UK, which may be related to the fact that the animals were not market-ready. Given the generally declining trend observed in food and environmental contaminant levels, and the fact that elevation was observed on both, flood-prone and some control farms, further investigation, into the extent and the cause of these would be helpful. The impact on contaminant concentrations through 'finishing-off' similar animals to a market-ready state should also be investigated.
- The fluctuations in milk contaminant levels that were observed during the seasonal monitoring study were observed on two farms, one flood-prone and one control. The pattern of fluctuation was different and may be the result of different dietary inputs or local differences in husbandry practices. The extent and reproducibility of these variations for other dairy farms is not known and further investigation may help identify a sampling regime that may provide more representative samples for monitoring and risk assessment purposes.

1. Introduction

Until recently, little information on the potential contamination of grazing land by PCDD/Fs and PCBs as a result of flood events was available. Even less information is available with respect to contamination by PBDEs. The earliest suggestion that flooding has such an impact revealed higher PCDD/F concentrations in cow's milk from the flood plains of the Rhine Delta (Hendriks et al 1996) as opposed to background areas. This study was however based on only 3 moderately polluted sites. Elevated levels of PCDD/Fs in cows' milk from farms near the River Rother in the UK have been associated with flood events depositing contaminated river sediment onto pasture grazed by cattle (Alcock et al 2002). However this study lacked data on concentrations of PCDD/Fs in the surface soil and was based on only two milk samples. PBDEs have similar chemical and physical properties to PCBs and PCDD/Fs and both are chemically stable, strongly lipophilic and hence widespread in the environment. It is therefore likely that contamination of grazing land by PBDEs also occurs.

Recent evidence that the concentrations of hydrophobic contaminants such as PCDD/Fs tend to be higher in suspended rather than bottom sediments (Meharg et al 2003) has served to further focus attention on the importance of such contaminant transport routes. Similar evidence has recently emerged for PBDEs (Yun et al 2008, Vane et al 2009). The ingestion of contaminated herbage together with small amounts of soil containing contaminated sediment might well be expected to result in elevated levels of PCDD/Fs, PCBs and PBDEs in produce from flood-prone land.

The first part of this project consisted of a follow-up study of PCB and PCDD/F concentrations in milk produced on farms where a portion of the pasture was subject to seasonal flooding. In previous research 38 dairy farms of which 34 were matched flood-prone and nearby non-flooding (control) farms along three UK river systems were selected. The results demonstrated that PCDD/F and PCB concentrations were significantly higher in the milk of flood-prone farms than in milk from control farms along the Trent and Doe Lea/Rother/Don river systems (FSA 2005, Lake et al 2005). Both these river systems have a history of industrialisation. Since this research the levels of PCB and PCDD/F levels in the environment have declined. The purpose of this follow-up study was to uncover whether the production of milk on flood-prone land still led to elevated PCB and PCDD/F levels in milk along river systems with a history of industrialisation. The analysis was also extended to PBDEs to examine whether levels were elevated in milk produced on farms where a portion of the pasture was subject seasonal flooding.

The second part of the project examined whether elevated levels of PCBs, PCDD/Fs and PBDEs were also evident in the tissues (meat, liver and kidney) of other livestock (sheep and cattle) reared on land where a portion of the farm was subject to seasonal flooding. Again this was focussed along river systems with a history of industrialisation. A similar case control methodology was adopted and beef and sheep samples were collected from farms at the beginning of the winter period. The animals were reared using normal husbandry techniques and conventional feeds. As part of this element it was hoped to examine PCBs, PCDD/Fs and PBDEs levels in eggs from chickens reared on flood-prone land. However, the lack of any suitable farms precluded such an analysis.

The final part of the project examined how the levels of PCBs, PCDD/Fs and PBDEs varied in milk over time. In the literature recent reports (Harrad and Mao, 2004; Motelay-Massei et al. 2005; Hovmand et al., 2007) have reported seasonal changes in atmospheric deposition fluxes in PCBs, PCDD/Fs and PBDEs. These may lead to corresponding variations in soil and grass levels which may cause temporal fluctuations in contaminant concentrations. These variations may be compounded by changes in animal husbandry practices over the year. Taken together it was hypothesised that these may lead to fluctuations in the PCDD/F, PCB and PBDE concentrations in milk over time. This was investigated by studying the changes in the concentrations of these contaminants from two farms with milk samples taken every 6 weeks. To understand any changes, potential inputs to the cattle such as soil, grass, silage, commercial feed and bedding were also included in the study.

This report is presented as a series of chapters. Chapter 2 presents the experimental methods used in the project including farm selection, sample collection and analysis. Chapter 3 is the first data chapter and presents the results from the follow-up milk study. The beef results are presented in Chapter 4 with the sheep results in Chapter 5. The analysis of variations in contaminant levels in milk over time is presented in Chapter 6. This is followed by an overall conclusion and a list of the references made throughout this report. Appendices containing all of the raw data are presented at the end of the report.

2. Experimental: Selection of River systems, farms, sample collection and analysis

Selection of river system and farms

The study initially focused on the Trent and the Doe Lea/Rother and Don river systems as these were used in the previous study completed in 1998/1999 (FSA 2005, Lake et al 2005) and would thus be useful for comparison purposes. Although suitable dairy, beef and sheep farms were found on the Trent, it soon became apparent that there were insufficient dairy, beef and sheep farms along the Doe Lea/Rother/Don system to warrant further attention. An alternative was thus required and a detailed examination of the Calder/Aire/Ouse river system was therefore carried out as this river system also has a history of industrial contamination. Owing to the hilly nature of the terrain no suitable flood-prone farms were found on the Calder. A full set of beef farms was identified on the Aire/Ouse. For sheep, only one flood-prone/control farm pair was found (on the Ouse). Thus, in summary, the river systems utilized for the various project components are as follows:

Dairy follow-up	Trent
Beef	Trent and Aire/Ouse
Sheep	Trent and Ouse
Dairy seasonal monitoring	Trent

As in previous projects, potential flood-prone farms were initially identified with the help of flood maps. Once the flood-prone farms had been identified, a letter was sent out to each of them. This letter was followed up by a telephone call, and if there was interest, this was followed up by a personal visit. At the visit, the project was explained in more detail and information was gathered in the form of a questionnaire to find out the suitability of the farms. All farmers who agreed to take part in the project were asked to complete a consent form. At the time of the visit details of herd or flock size, breed of animals, area of farm, area that floods, relevant animal husbandry details etc., were collected. For each flood-prone farm, a nearby control farm, not subject to river flooding, was needed. In choosing these farms consideration was given to industrial facilities, motorways and other potential sources of PCBs & PCDD/Fs and PBDEs in the area. As far as possible, control farms were selected that would be expected to be subject to similar levels of environmental exposure to these contaminants as the corresponding flood-prone farms.

The samples collected in this study were solely for the purposes of this scientific investigation and should not be regarded as food survey samples or informal food samples collected for regulatory purposes.

Dairy follow-up

Ten farms (five flood-prone and five control) on the Trent satisfied the various selection criteria and consented to take part in the study. Thirty six samples (10 milk, 10 soil, 10 grass and 6 feed) were analysed for PCDD/Fs & PCBs and PBDEs. These samples were collected between July and early September 2008. As far as possible the two samples of milk for each farm pair were taken on similar dates. The milk samples taken for the study had already been collected by the farmer and were destined for the food chain.

Beef

Ten farms on the River Trent (5 flood-prone/control pairs) were selected and consented to take part in the study. In the event, one of the control farms was unable to provide any animals, thus reducing the number of participating farms to 9. The farm pairs selected encompassed locations on the upper, middle and lower reaches of the river. A further 10 (5 flood-prone/control pairs) farms on the middle-lower reaches the Aire/Ouse river system also agreed to take part, making a total of 19 farms. Beef farming was not common on the upper reaches of this river system. From each of these farms, 2 beef cattle were selected from the herd and immediately transported to the abattoir for slaughter. The animals from the Trent and Aire/Ouse farms were collected during October-December 2008 and October 2010-February 2011 (poor weather extended the collection period) respectively when the beef herds would have been feeding outdoors for at least three months. From the two river systems combined, a total 148 samples (38 meat, 38 liver, 12 kidney, 19 soil, 19 grass, 12 silage and 10 feed) were analysed for PCDD/Fs & PCBs and PBDEs. The beef samples analysed were not from market ready animals, and would not normally enter the food chain at this point, and therefore were not subject to regulatory limits. These animals would normally have been subject to a finishing period (which would normally mean spending time indoors) before being sent to market. During this finishing period the animals will receive a greater proportion of commercial feed.

Sheep

Ten farms on the River Trent (5 flood-prone/control pairs) were selected and consented to take part in the study. In the event, one of the control farms was unable to provide any animals, thus reducing the number of participating farms to 9. A further 2 farms (one flood-prone/control pair) on the Ouse also agreed to take part thus making 11 farms in all. Despite an extensive search, no further flood-prone farms that reared sheep were found on the Aire/Ouse river system.

From each of these farms, two animals were selected from the flock and immediately transported to the abattoir for slaughter. The animals from the Trent and Ouse farms were collected during July-August 2009 and October 2010 respectively. From the two river systems combined, 78 samples (26 meat, 20 liver, 10 kidney, 12 soil, 9 grass and 1 feed) were analysed for PCDD/Fs & PCBs and PBDEs. All the lamb samples were collected during the period when sheep are usually sent to market and so can be considered market ready.

Dairy seasonal monitoring

Of the five pairs of farms identified for the dairy follow-up study summarised above, one pair of farms also agreed to be the subject of the seasonal monitoring study which involved a detailed investigation of the extent to which PCDD/F, PCB and PBDE concentrations in milk varied over the period of a year.

Beginning in August 2009 and at approximately six weekly intervals thereafter, a series of nine milk samples were collected from the bulk tank of each farm. Soil, grass (when the cattle were outdoors) and commercial feed samples were also collected along with the milk samples. A series of silage and bedding samples were also collected during the period when the cattle were housed indoors. In total 58 samples (18 milk, 6 soil, 10 grass, 12 commercial feed, 8 silage and 4 bedding) were analysed.

The breed of dairy cattle (Holstein-Friesian) was the same for both farms; herd sizes and annual milk yields were similar. Around 28% of the pastureland of the flood-prone farm is subject to flooding which occurs on average 3-4 times per year. No flood events were however recorded during the sampling period (18 August 2009-10 July 2010). The timing and duration of the periods that the cattle spent outdoors/indoors during the year were very similar for both farms. Home-sourced silage was provided to each herd on an ad-lib basis during the period the cattle were housed indoors. Both herds were also provided with commercial feed at a constant level throughout the year although the cattle on the flood-prone farm were given a higher protein ration during the winter months. Overall, the animal husbandry and feed patterns of the two herds were very similar.

Sampling procedures

Milk samples were taken from the bulk storage tank on each farm and each sample is an average of all cows on the farm.

Soil samples were collected using a stainless steel bulb planter. At each site, vegetation was removed prior to sampling. Before actual sample collection, several soil cores were taken and discarded to avoid cross-transfer between sites. Seven cores of 5cm depth were then taken along a letter “W” in a 10m square area. Core samples were then combined to produce a single sample of approximately 1.5 kg.

Grass samples were obtained from the 10m square area as close as possible to the soil sampling location. Care was taken to avoid contamination of the samples with soil but the samples were not washed or rinsed prior to analysis as the purpose was to identify the actual levels of PCDD/Fs & PCBs and PBDEs consumed by the animals.

Soil and grass samples were collected from locations regularly grazed by the animals. In the case of flood-prone farms, the samples were taken from locations with a known history of flooding.

Silage and feed samples were taken directly from farm stocks being fed to the animals at time of sampling.

Samples of muscle tissue, liver and kidney were taken from each animal at the abattoir. The handling of the individual carcasses was very closely scrutinized to prevent cross contamination with other animals being processed.

Analysis

Considerably more samples were collected during the period of the project than were analysed. The selection of which samples to analyse was an important aspect of the overall programme. At each stage of the research, consultation between the project team and with the FSA took place prior to making the final choice. Overall, 320 samples (milk 28, meat 64, liver 58, kidney 22, soil 47, grass 48 silage 21, commercial feed 17, feed mix 11, bedding 4) were analysed.

The method used for the preparation, extraction and analysis of samples has been reported previously (Fernandes et al 2004). In brief, samples were fortified with 13C-labelled analogues of target compounds and exhaustively extracted using mixed organic solvents. Ortho substituted PCBs and PBDEs were separated from non-ortho substituted PCBs and PCDD/Fs by fractionation on activated carbon. The two fractions were further purified using adsorption chromatography on alumina. Analytical measurement was carried out using high resolution gas chromatography/ high resolution mass spectrometry (HRGC-HRMS) for the seventeen, 2,3,7,8-Cl substituted PCDD/F congeners and non-ortho substituted PCBs (IUPAC Nos. 77, 81, 126 and 169) and the PBDEs (BDEs 17, 28, 47, 49, 66, 71, 77, 85, 99, 100, 119, 126, 138, 153, 154 and 183). High resolution gas chromatography/ unit resolution mass spectrometry

(HRGC-LRMS) was used for the measurement of the ortho substituted PCBs (IUPAC Nos. 18, 28, 31, 47, 49, 51, 52, 99, 101, 105, 114, 118, 123, 128, 138, 153, 156, 157, 167, 180 and 189).

All analyses and results were UKAS accredited to ISO 17025 standards. Accreditation for this analysis has been held for more than 10 years. Samples were analysed in sets of 12 which included a blank and a reference material such as CRM 350 or IHRM 0645 (Griepink et al, 1998, FAPAS 2010). Further quality assurance measures included the successful participation in international inter-comparison exercises such as FAPAS, Dioxins in Food-2009, Dioxins in Food-2010 and Quasimeme on dioxins, dioxin-like PCBs and PBDEs.

Data Analysis

When comparing between contaminant levels on flood-prone and control farms two statistical tests were used. These were non-parametric tests to account for the skewed nature of much of these data as well as the small sample sizes. An overall comparison, ignoring the paired structure of these data, is performed using a Mann-Whitney U test. This is followed by a Wilcoxon ranked signs test which takes into account the paired structure of these data. Statistics is generally only performed on sample sizes of at least 10. In both the beef and the sheep programme one of the control farms withdrew from the programme at the last minute. In the paired statistical analysis this was overcome by using another closely proximate control farm for that pair. This control farm is thus used twice in the paired analysis.

Spearman Rank correlation tests were used to examine the correspondence between PCDD/Fs & PCB levels and PBDEs levels in identical samples. In all cases the small numbers of samples means that very pronounced differences are required between flood-prone and control sites to achieve statistically significant results.

To overcome these limitations and to provide a more holistic overview of the data, they were also examined using a 'weights of evidence' table (Weed, 2005; Linkov et al., 2009). In this table the various strands of evidence were listed and categorised using commonly utilised causation criteria (Hill, 1965). Such integrative approaches have been used in a variety of settings including epidemiology (Swaen et al., 2009), ecology (Landis and Bryant, 2010) and sedimentology (Sanz-Lázaro, C.; Marín 2009). These data were divided into 3 categories and a number of questions asked in each:

Category 1. Strength of association between flooding and elevated contaminant levels. This was examined for the hazard (soil and grass concentrations) and outcome (milk, beef or lamb produce). The first question was (1) are average levels of contaminants higher on flood-prone farms? The second question uses the stronger evidence for the impact of flooding which emerges from the analysis of paired farms which were chosen to control for factors such as aerial deposition that could affect contaminant levels. This asks (2) the number of farm pairs where the flood-prone pair had higher average contaminant levels. For the beef and lamb sampling two animals were analysed on each farm and stronger evidence emerges from the next question (3) which examined the number of pairs where both flood-prone samples were higher than both control samples.

Category 2. Consistency of association. Internal consistency of both hazard and outcome data was assessed by the examining whether any contrasts between flood-prone and control farms were apparent on both the Trent and the Aire/Ouse river system.

Category 3. Alternative explanations. The first question (1) was whether any contrasts observed between flood-prone and control farms could have been due to supplementary feed fed to the animals. The second question (2) was whether there were logical explanations for any unusual observations observed within these data.

This weight of evidence approach was used in the milk, beef and lamb chapters to provide an overall assessment of the impact of flooding. An adapted version of this approach was used to assess whether contaminant levels had reduced in cows milk over time.

Expression of Results

The data presented in this report follow conventional reporting practice for environmental contaminants such as PCDD/Fs and PCBs. Data for food samples such as milk, meat, liver etc are given on a fat weight basis; data for animal feed are given on a whole (product) weight basis, and data for environmental matrices are given on a dry weight basis.

As all of the samples taken in this study were collected between September 2008 and February 2011, the data for dioxins and dioxin-like PCBs in this report has been presented using the WHO-1998 TEFs (Van Den Berg et al., 1998). All values are presented as upper-bound total TEQs incorporating PCDD/F, mono-ortho and non-ortho substituted PCB concentrations. This is to allow comparison with literature data which is largely reported using this system. In terms of PBDEs congeners 28, 47, 99, 100, 153, 154, and 183 were detected in most samples. As these are commonly reported by other workers, data are reported as the sum of these seven congeners (Σ7). Non-dioxin-like PCBs have been represented by the Σ ICES-6 PCB congeners (PCBS 28, 52, 101, 138, 153 and 180) reported conventionally as µg/kg of sample. All concentrations are reported as upper-bound.

In January 2012, regulatory limits were revised (European Commission, 2011, 2011B) and the new maximum limits and action limits were based on the WHO-2005 TEFs (Van Den Berg et al., 2006). For most foods, this resulted in a reduction in the regulated maximum/action levels that is generally reflected in the revised calculation of WHO-TEQ_{2005} values. However, in order to examine the effect of applying the new TEF scheme, the meat and liver data from Chapter 4 was evaluated using both, the 1998 and 2005 WHO-TEF schemes (Van Den Berg et al., 1998, Van Den Berg et al., 2006). Chapter 4 (beef programme) was selected because absolute concentrations recorded for meat and liver were relatively higher than those in the other programmes and in some recent literature, and additionally the beef programme also contains the highest number of samples.

3. Dairy Programme

This chapter focuses upon the results from the dairy sampling programme and consists of seven parts. These focus upon the milk, soil, grass and commercial feed data in turn. The final three sections conduct a weight of evidence analysis for the impact of flooding on PCDD/F & PCB levels in milk, followed by a similar analysis for PBDEs. The chapter ends with a weight of evidence analysis for the changes in PCDD/F & PCB levels in milk over time.

Milk

Overall PCDD/F & PCB and PBDE concentrations in milk and variations by type of site

As indicated earlier, 10 milk samples were analysed. Table 3.1 presents a series of descriptive statistics for the PCDD/F & PCB concentrations in these samples subdivided by type of site. Comparable data for PBDE are presented in Table 3.2.

Table 3.1: Variations in the concentrations of PCBs and PCDD/Fs in milk by type of site

Sample Group	Number of Samples	ng TEQ_{1998} /kg fat Minimum	Median	Mean	Maximum
Type of Site					
Control	5	0.59	0.94	0.96	1.37
Flood-prone	5	0.77	1.36	1.18	1.45
All Samples	10	0.59	0.97	1.07	1.45

Notes: A Mann-Whitney U test indicates no significant difference by type of site (p=0.347)

Table 3.2: Variations in the concentrations of PBDEs in milk by type of site

Sample Group	Number of Samples	$\sum_7$ ng/kg fat Minimum	Median	Mean	Maximum
Type of Site					
Control	5	200	250	2140	9520
Flood-prone	5	200	300	336	590
All Samples	10	200	280	1238	9520

Notes: A Mann-Whitney U test indicates no significant difference by type of site (p=0.843)

The data presented in Table 3.1 indicate that all the PCDD/F & PCB concentrations fell within a narrow range of between 0.59 and 1.45 (TEQ ng/kg fat). These concentrations are only a small fraction of the EU maximum levels (Council Regulation 199/2006) that were prevailent during the period of sampling. They are also below the corresponding recommended action level (Commission Recommendation (2006/88/EC). As noted in Chapter 2, from 2012, maximum and action levels have been revised to take into account the re-evaluation of TEFs (WHO-TEF_{2005} - Van den Berg et al 2006)), which resulted in a reduction in maximum/action levels that is also generally reflected in calculated WHO-TEQ_{2005} values. Thus if applied here, the relative values of the sample TEQs (if revised using WHO-TEF_{2005}) will be similarly low in relation to the revised EU levels. This is demonstrated in chapter 4 (Beef programme) where calculated TEQ values were much closer to the prevalent EU levels, and were therefore re-examined using the revised WHO-$TEFs_{2005}$ relative to the revised levels, without much difference to the outcome.

The PBDE levels in Table 3.2, demonstrate similar levels of variability (excluding one high result from Pair 4). In both cases median levels are higher on flood-prone farms but these contrasts were not statistically significant.

Comparisons between flood-prone and control sites are complicated by the relatively small sample number in each subgroup. A more sophisticated method of comparison is to examine the differences in PCDD/F & PCB and PBDE concentrations between matched pairs of flood-prone and control farms. Five such pairs were identified as part of the experimental design and the milk concentrations for these farms are presented in Table 3.3, Figure 3.1 and Figure 3.2. These demonstrate no consistent difference in concentrations between flood-prone and control farms. PCDD/F and PCB levels are higher on 3 from 5 pairs and PBDE levels are higher on 2 from 5 pairs. These contrasts are not statistically significant.

Table 3.3: Comparisons of PCDD/F & PCB and PBDE concentrations in milk by type of site for matched pairs of farms

	PCDD/F & PCB ng TEQ_{1998} /kg fat		PBDE $\sum_7$ ng/kg fat	
Comparison	Flood-prone	Control	Flood-prone	Control
Pair 1	1.36	0.59	330	250
Pair 2	1.40	0.94	260	200
Pair 3	0.77	0.91	200	230
Pair 4	1.45	1.37	590	9520
Pair 5	0.92	0.99	300	500

Notes
For PCDD/Fs and PCBs a Wilcoxon ranked sign test indicates no significant difference by type of site ($p=0.345$)
For PBDEs a Wilcoxon ranked sign test indicates no significant difference by type of site ($p=0.500$)

Within these data, pair 4 stands out as having relatively high PCDD/F & PCB and PBDE concentrations on both flood-prone and control farms. In terms of PBDE concentrations, levels are 16 times higher than any other farm sample.

One notable feature of these data is the observation that milk samples with high PCDD/F & PCB concentrations tend to have high PBDE concentrations and vice versa. This was tested statistically using a Spearman rank correlation which indicates a high correlation (Spearman's $\rho = 0.69$, $p = 0.026$) between PCDD/F & PCB and PBDE concentrations.

Figure 3.1: Mean PCDD/F and PCB concentrations in milk for matched pairs of farms

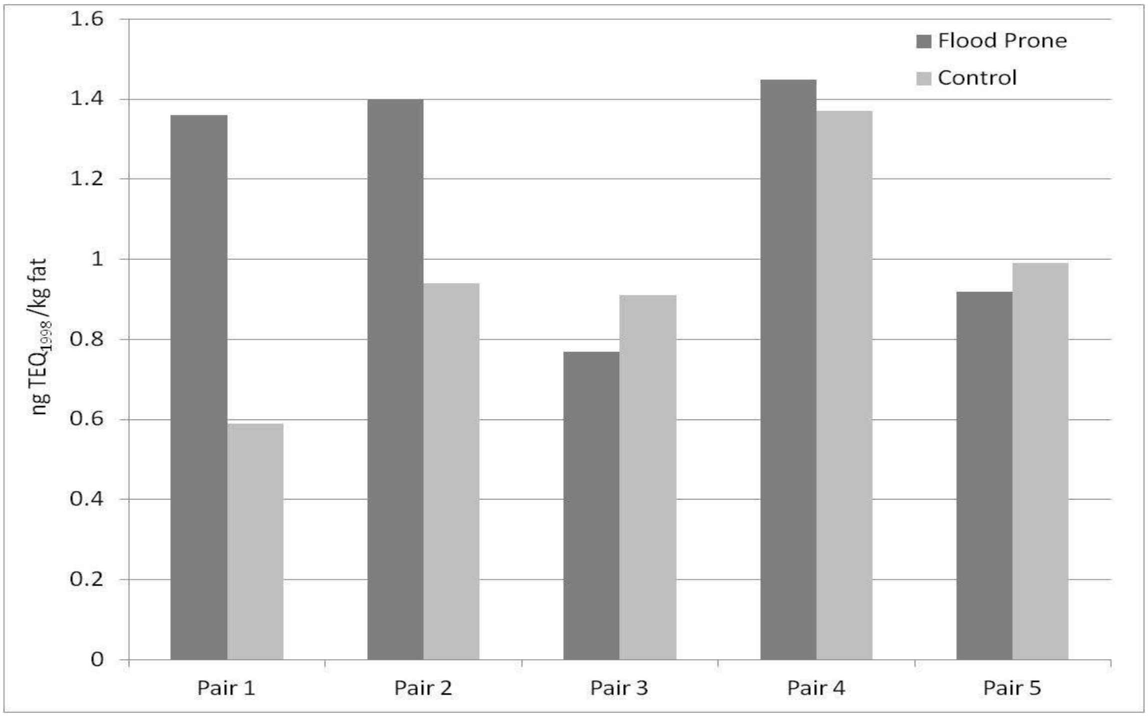
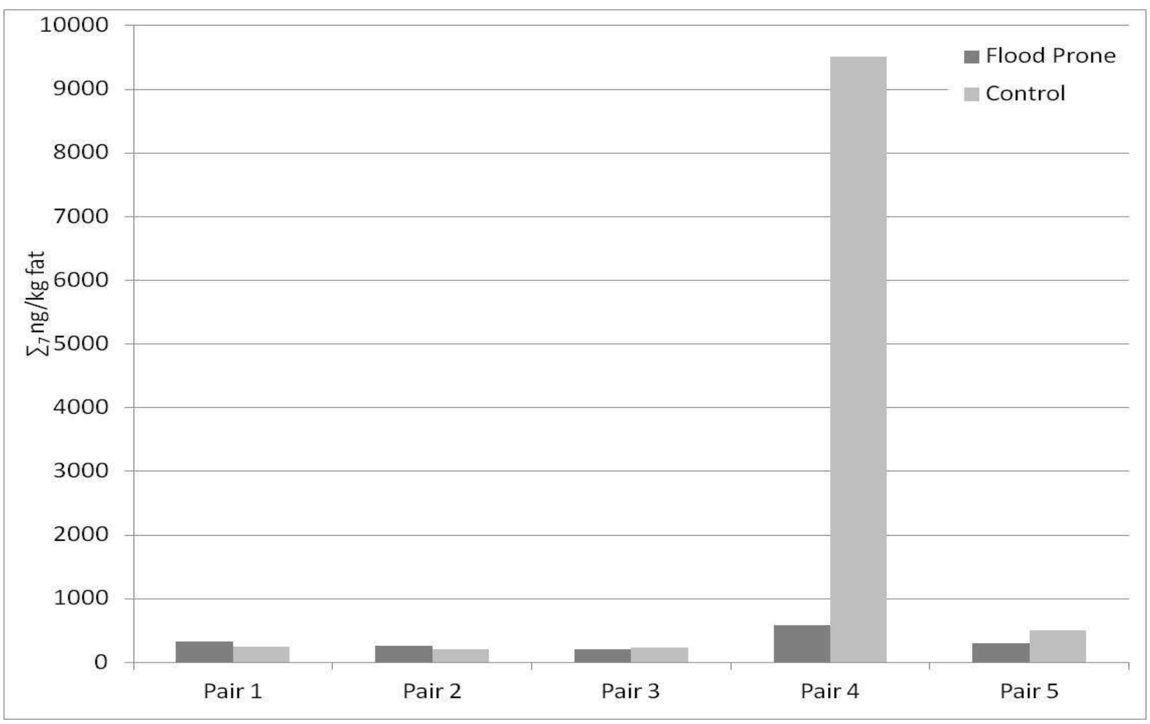


Figure 3.2: Mean PBDE concentrations in milk for matched pairs of farms



Variations in PCDD/F & PCB concentrations in milk by type of site and sampling date

The PCDD/F & PCB concentrations were compared to those in our previous research (C01037) to examine trends over time. The data are presented in Table 3.4 and indicate that the concentrations of PCDD/F & PCBs have reduced in both flood-prone and control samples since October 1998. The reduction in milk levels between August 1999 and August 2008 is statistically significant. Given the potential impact of animal husbandry upon PCDD/F and PCB levels in milk is most appropriate to compare sampling periods from identical months in the year.

Table 3.4: Variations in the median concentrations of PCDD/F & PCBs in milk by sampling date and type of site

	ng TEQ_{1998} /kg fat			
Sample Group	October 1998	March 1999	August 1999	August 2008
Type of Site				
Control	$3.02_{(8)}$	$2.47_{(8)}$	$1.49_{(8)}$	$0.94_{(5)}$
Flood-prone	$4.17_{(7)}$	$3.97_{(7)}$	$2.42_{(6)}$	$1.36_{(5)}$
Total	$3.60_{(15)}$	$2.67_{(15)}$	$1.80_{(14)}$	$0.97_{(10)}$

Notes
Figures in **(subscript)** are sample sizes
A Mann Whitney U test indicates a significant difference between milk levels in Aug 99 and Aug 08 (p = 0.003)

Additional evidence for time trends comes from farms sampled in both this and the earlier data collection phase. This applies to one control and one flood-prone farm. Their data are presented in Table 3.5. One sample was taken from the bulk tank on each farm on the specified date.

Table 3.5: Variations in PCDD/F & PCB concentrations in milk collected from one flood-prone and one control farm categorised by sampling date

	ng TEQ_{1998} /kg fat			
	October 1998	March 1999	August 1999	August 2008
Farm 1 - Flood-prone Farm	3.09	1.68	1.37	0.92
Farm 2 - Control Farm	4.85	4.30	3.68	0.94

Note
These were not a matched pair of farms

This corroborates the previous table providing strong evidence of the reduction in the concentrations of PCDD/F & PCBs over time. A more detailed comparison over time is complicated by the observation that the first two data collection phases occurred at different times of the year. However, both tables provide strong evidence for a reduction in PCDD/F & PCB concentrations between August 1999 and August 2008.

Comparison of the relative contributions of PCDD/Fs, Non-Ortho PCBs and Ortho PCBs in milk through time

In order to examine time trends in more detail the median percentage contribution of PCDD/Fs, Non-Ortho PCBs and Ortho PCBs and to total TEQ are presented in Table 3.6 subdivided by sampling period and type of site.

Table 3.6: Variations in the median percentage contribution of PCDD/Fs, Non-Ortho PCBs and Ortho PCBs to total TEQ_{1998} in milk by sampling period and type of site

	% of Total WHO-TEQ_{1998}					
	PCDD/Fs		Non-Ortho PCBs		Ortho PCBs	
Sample Group	Control	Flood	Control	Flood	Control	Flood
Sampling Period						
October 1998	$56.01_{(8)}$	$55.85_{(7)}$	$37.16_{(8)}$	$38.28_{(7)}$	$6.83_{(8)}$	$7.85_{(7)}$
March 1999	$63.54_{(8)}$	$64.69_{(7)}$	$23.76_{(8)}$	$23.62_{(7)}$	$9.88_{(8)}$	$12.80_{(7)}$
August 1999	$51.08_{(8)}$	$47.65_{(6)}$	$40.78_{(8)}$	$44.27_{(6)}$	$7.09_{(5)}$	$7.38_{(6)}$
August 2008	$51.43_{(5)}$	$50.84_{(5)}$	$41.37_{(5)}$	$41.75_{(5)}$	$7.14_{(5)}$	$6.78_{(5)}$

Notes
Figures in **(subscript)** are sample sizes

The results presented in Table 3.6 suggest few trends in the contributions of PCDD/Fs, Non-Ortho and Ortho PCBs to total TEQ on both flood-prone and control farms over time.

Comparison with previous milk data

This section of the report compares the results from the present study to previous studies of PCDD/Fs & PCBs and PBDE concentrations in milk.

The PCDD/F & PCB data for the UK studies listed in Table 3.7 show a concentration range of 0.5-1.6ng TEQ/kg fat with a mean value of 0.9 ngTEQ/kg fat. It is clear from the Table that total TEQ concentrations found during the present study for the farms on the River Trent are consistent with previously published UK data. It is also worth noting that the mean total TEQ concentration in milk from farms on the River Trent sampled during the present study has declined considerably since the earlier study on the same river. This trend is consistent with the general decline in dioxin and PCB concentrations in UK milk which is evident from the data (as summarised in Table 3.7) arising from the various studies carried out by the FSA between 1997 and 2007.

A further examination of the data in Table 3.7 reveals that for the previous UK milk surveys, the contribution of dioxin-like PCBs to the total, ranges from 35-48% (mean 42%). The corresponding figure (46%) for milk collected from farms along the River Trent during the present study agrees closely both with the UK average and that reported (41%) from the same river system in the earlier flood project.

Relatively few data on the levels of PBDEs in milk are currently available. However an examination of the ∑5 PBDE concentrations listed in Table 3.8 suggests that the data from the present study are consistent with previous UK and Irish data.

Table 3.7: Comparison of mean PCDD/F & PCB concentrations in milk with literature values.

PCDD/F (ng TEQ /kg fat)	PCB non-ortho + ortho (ng TEQ /kg fat)	Total[1] (ng TEQ /kg fat)	%PCB TEQ contribution to total TEQ[1]	Sampling date	Reference
UK					
0.8	0.7	1.6	47	1997	FSA 2000 [2]
0.5	0.4	0.9	48	2001	FSA 2003 [3]
0.5	0.4	0.9	45	2003	FSA 2004 [4]
0.4	0.2	0.6	37	2006	FSA 2006a [5]
0.3	0.2	0.5	35	2007	FSA 2007 [6]
Ireland					
0.3	0.2	0.5	43	2001	FSAI 2002 [7]
Belgium					
1.1	1.1	2.2	51	2001	Focant et al 2003 [8]
USA					
0.5	0.3	0.8	38	2000/2001	Schaum et al 2003 [9]
France					
0.3	0.6	0.9	63	2006	Durand et al 2006 [10]
Previous flood project – River Trent					
1.9	1.2	3.1	41	1998/1999	Foxall et al 2004b [11]
Present study - River Trent					
0.6	0.5	1.1	46	2008	

Notes

1. Total concentrations of dioxins and PCBs may not equal the sum of individual dioxins and PCBs values due to rounding. % PCB TEQ contributions to total TEQ are calculated before rounding of PCB TEQ and total TEQ values.
2. Retail samples collected as part of 1997 UK Total Diet Study
3. Retail samples collected as part of 2001 UK Total Diet Study
4. Retail samples collected in UK as part of EU Food Monitoring Programme 2003
5. Retail samples collected in UK as part of EU Food Monitoring Programme 2005
6. Retail samples collected in UK as part of EU Food Monitoring Programme 2006
7. Samples collected from herds in Cork harbour area and from designated control herds
8. Retail samples of long-life milk collected from January-March 2001
9. Nationwide samples from 43 dairy plants.
10. Nationwide samples from 93 dairy plants.
11. Samples collected from flood-prone and control farms along River Trent

Table 3.8: Comparison of Mean PBDE concentrations in cows' milk with literature values

	ng/kg fat BDE 47	BDE 99	BDE 100	BDE 153	BDE 154	$\sum_5$[1]	$\sum_{16}$[2]	Sampling date	Reference
Finland						100		1997-9	Kiviranta et al 2004[3]
Spain	90	64	16	8.1	5.5	184		2003-5	Gomara et al 2006[4]
	51	40	14	14	14	133		2005	Domingo et al 2008[6]
USA	87	49	7.2	4.7	6.9	155		2003-4	Schecter et al 2006[5]
Ireland							622	2005	FSAI 2005a[7]
Ireland	140	130	30	40	20	360		2006-7	Tlustos et al 2008[8]
UK	200	229	23	57	11	520		2003-4	FSA 2006b[9]
Flood-prone farms	152	112	18	22	12	316	426	2008	Present study[10]
Control farms	125	90	12	30	15	273	385	2008	Present study[11]

Notes

1. Congeners 47, 99, 100, 153 and 154
2. Congeners 17, 28, 47,49,66,71,77,85,99,100,119,126,138,153,154 and 183
3. Samples collected as part of market basket study. Figure calculated from fresh weight data using overall lipid concentration of 2% given by authors. Congener concentrations below LOD taken as LOD. Value given refers to composite of liquid milk products comprising milk 71%, sour milk 15% and yoghurt 11%. No data available for individual congeners.
4. Values calculated from fresh weight data using lipid content of 4.7% given by authors. Congener concentrations below LOD taken as LOD. Samples collected from supermarkets across Spain.
5. Concentrations calculated from fresh weight data using lipid content of 3.2% given by authors. Congener concentrations below LOD taken as 0.5 LOD value. Samples collected from national supermarkets.
6. Values calculated from fresh weight data using a lipid content of 3.5%. Congener concentrations below LOD taken as 0.5 LOD. Samples from retail outlets in twelve cities across Spain.
7. Data only available for sum of 16 congeners. Congener concentrations below LOD taken as LOD. Samples from supermarkets.
8. Samples collected from retail outlets.
9. Samples collected as part of 2003 and 2004 Total Diet Studies: Concentrations calculated from fresh weight data using lipid content of 3.5%.
10. Samples (n=5) from flood-prone farms on River Trent
11. Samples (n=4) from control farms on River Trent. One farm had BDE concentrations substantially higher than other control farms and was omitted from calculations of mean values.

Summary

The analysis presented in the above sections highlight a number of trends in the data from the milk samples. These are summarised below:

- There were no statistically significant differences in PCDD/F & PCB and PBDE levels between flood-prone and control farms
- All samples were below the relevant EU action levels and maximum permitted levels. This mirrors national trends
- There was a statistically significant reduction in PCDD/F and PCB levels in milk between August 1999 and August 2008
- One farm had PBDE levels 16 times higher than any other sample
- The levels of PBDEs in milk were closely correlated with the levels of PCDD/Fs & PCBs
- Flood-prone and control values from the present study fall within range of previous UK and Irish data

Soil

Overall PCDD/F & PCB and PBDE concentrations in soil and variations by type of site

As indicated earlier in this report, 10 soil samples were analysed. Table 3.9 presents a series of descriptive statistics for the PCDD/F & PCB concentrations in these samples subdivided by type of site. Comparable data for the PBDE concentrations are presented in Table 3.10.

Table 3.9: Variations in the concentrations of PCDD/Fs & PCBs in soil by type of site

	Number	ng TEQ_{1998} /kg dry weight			
Sample Group	of Samples	Minimum	Median	Mean	Maximum
All Samples	10	2.95	6.75	10.08	24.90
Type of Site					
Control	5	2.95	4.68	5.36	10.25
Flood-prone	5	5.64	15.83	14.80	24.90

Notes: A Mann-Whitney U test indicates significant difference between type of site (p=0.028)

The data presented in Table 3.9 indicate that the PCDD/F & PCB concentrations in soil were variable ranging from 2.95 to 24.90 (ng TEQ /kg dry weight). A similar variability occurred with PBDE concentrations (Table 3.10) ranging from 210 to 3230 ($\sum_7$ ng/kg dry weight). In terms of flood-prone vs control differences the mean and median PCDD/F and PCB levels are approximately 10 (ng TEQ /kg dry weight) or just under 300% higher on flood-prone farms. Turning our attention to PBDE concentrations, Table 3.10 indicates that the mean and median PBDE concentrations were over twice as high on flood-prone farms. Both these differences were statistically significant. The soil concentrations of PCDD/Fs & PCBs and PBDEs for the matched pairs of flood-prone and control farms are presented in Table 3.11. These data are graphed for PCDD/Fs & PCBs in Figure 3.3 and for PBDEs in Figure 3.4.

Table 3.10: Variations in the concentrations of PBDEs in soil by type of site

Sample Group	Number of Samples	Minimum	$\sum_7$ ng/kg dry weight Median	Mean	Maximum
All Samples	10	210	380	866	3230
Type of Site					
Control	5	210	280	266	300
Flood-prone	5	460	770	1466	3230

Notes: A Mann-Whitney U test indicates a significant difference between type of site (p=0.009)

Table 3.11: Comparisons of PCDD/F & PCB and PBDE concentrations in soil by type of site for matched pairs of farms

	PCDD/F & PCB ng TEQ_{1998} /kg dry weight		PBDE $\sum_7$ ng/kg dry weight	
Comparison	Flood-prone	Control	Flood-prone	Control
Pair 1	7.85	4.68	640	280
Pair 2	19.78	4.20	770	280
Pair 3	24.90	4.72	3230	300
Pair 4	15.83	10.25	2230	260
Pair 5	5.64	2.95	460	210

Notes
For PCDD/Fs and PCBs a Wilcoxon ranked sign test indicates no significant difference by type of site (p=0.043)
For PBDEs a Wilcoxon ranked sign test indicates no significant difference by type of site (p=0.043)

Figure 3.3: Mean PCDD/F & PCB concentrations in soil for matched pairs of farms

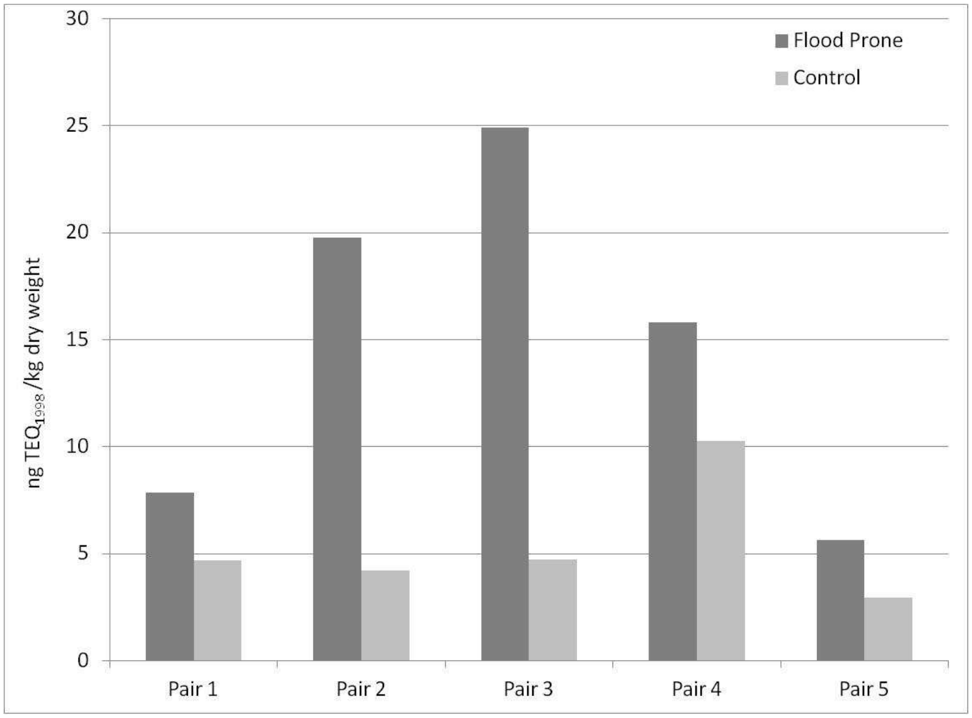


Figure 3.4: Mean PBDE concentrations in soil for matched pairs of farms

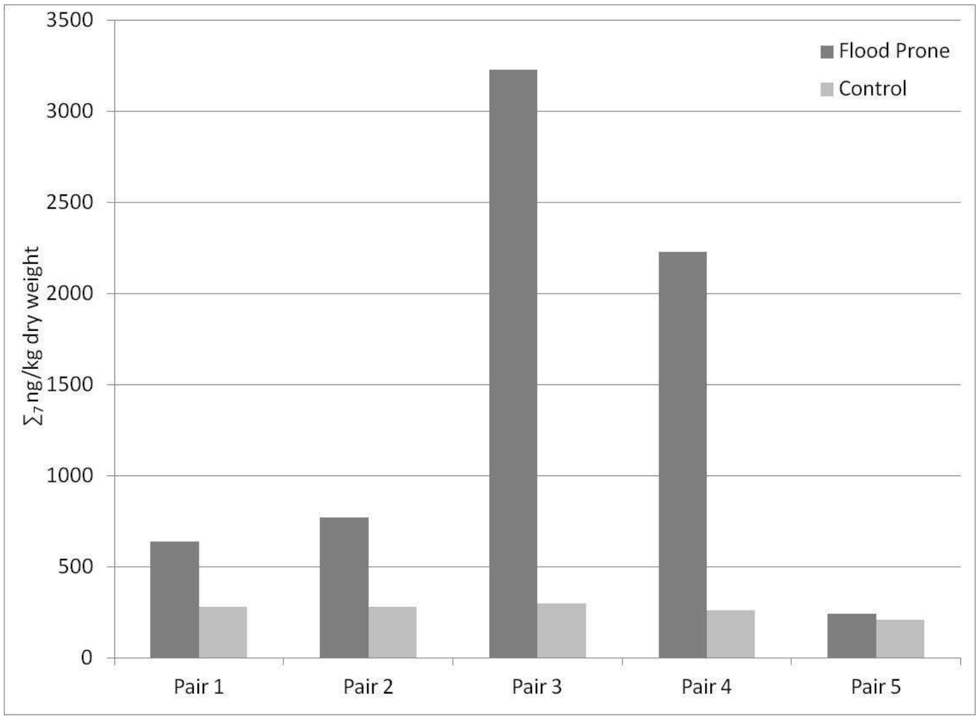


Table 3.11, Figure 3.3 and Figure 3.4 indicate concentrations of PCDD/Fs and PCBs and PBDEs in soil are higher on all flood-prone farms in comparison to their controls. These differences are statistically significant. Again a close correspondence between PCDD/F & PCB and PBDE concentrations emerges (Spearman's $\rho = 0.80$, $p = 0.005$).

Variations in PCDD/F & PCB concentrations in soil by type of site and sampling date

The PCDD/F & PCB concentrations were compared to those in our previous research (C01037) to examine trends over time. The data are presented in Table 3.12. In our view the strongest comparison is between the two sets of samples taken in August 1999 and August 2008, as these were taken at the same time of the year. These present inconclusive evidence that the concentrations of PCDD/F & PCBs on flood-prone farms have reduced between August 1999 and August 2008. The small difference in means between the control farms suggests that concentrations may have reduced between August 1999 and August 2008. In overall terms there is no significant difference between levels in soil between August 1999 and August 2008.

Table 3.12: Variations in the median concentrations of PCDD/Fs and PCBs in soil by sampling date and type of site

	ng TEQ_{1998} /kg dry weight		
Sample Group	October 1998	August 1999	August 2008
Type of Site			
Control	$4.03_{(3)}$	$5.66_{(8)}$	$4.68_{(5)}$
Flood-prone	$24.41_{(4)}$	$16.11_{(7)}$	$15.83_{(5)}$
Total	$7.80_{(7)}$	$6.99_{(15)}$	$6.75_{(10)}$

Notes
Figures in **(subscript)** are sample sizes
A Mann Whitney U test indicates no significant difference between August 99 and August 09 (p = 0.739)

Additional and stronger evidence for time trends comes from identical farms sampled in both data collection phases. This applies to 1 control and 1 flood-prone farm. Their data are presented in Table 3.13. One composite soil sample was taken from each farm on the specified date. This table indicates that on the flood-prone farm there was a small reduction in soil PCDD/Fs & PCBs between August 1999 and August 2008. A larger reduction occurred on the control farm although it is worth noting that this farm had unusually high soil levels in 1999.

Table 3.13: Variations in PCDD/F & PCB concentrations in soil collected from one flood-prone and one control farm categorised by sampling date

	ng TEQ_{1998} /kg dry weight	
	August 1999	August 2008
Farm 1 - Flood-prone Farm	5.86	5.64
Farm 2 - Control Farm	6.91	4.20

Comparison of the relative contributions of PCDD/Fs, non-ortho PCBs and ortho PCBs in soil through time

In order to examine time trends in more detail the median percentage contribution of PCDD/Fs, Non-Ortho PCBs and Ortho PCBs and to total TEQ are presented in Table 3.14 subdivided by sampling period and type of site.

Table 3.14: Variations in the median percentage contribution of PCDD/Fs, Non-Ortho PCBs and Ortho PCBs to total TEQ in soil by sampling period and type of site

	% of Total WHO-TEQ$_{1998}$					
	PCDD/Fs		Non-Ortho PCBs		Ortho PCBs	
Sample Group	Control	Flood	Control	Flood	Control	Flood
Sampling Period						
October 1998	$92.82_{(3)}$	$91.07_{(4)}$	$6.22_{(3)}$	$7.24_{(4)}$	$0.97_{(3)}$	$1.69_{(4)}$
August 1999	$92.77_{(8)}$	$92.15_{(7)}$	$6.26_{(8)}$	$7.00_{(7)}$	$0.78_{(8)}$	$0.85_{(7)}$
August 2008	$92.20_{(5)}$	$87.42_{(5)}$	$6.44_{(5)}$	$9.41_{(5)}$	$1.19_{(5)}$	$3.16_{(5)}$

Notes
Figures in **(subscript)** are sample sizes

The results presented in Table 3.14 do not indicate major shifts in the percentage contribution of Non-Ortho PCBs, Ortho PCBs and PCDD/Fs to total TEQ.

Comparison with previous soil data

This section of the report compares the results from the present study to previous surveys of PCDD/F & PCB and PBDE concentrations in soil.

The PCDD/F & PCB data for the UK studies listed in Table 3.15 have been divided into two categories - rural background and those from flood plain locations. Examination of Table 3.15 shows that the mean PCDD/F TEQ and total TEQ values from control farms are entirely consistent with the values previously reported for rural background soils in the UK.

Although the mean total TEQ concentration (14.8 ngTEQ/kg dry weight) in soils from flood-prone sites is somewhat lower than found in the previous flood project, the value agrees well with the mean concentration (10.95 ngTEQ/kg dry weight) for urban soils reported in the most recent soil survey carried out in the UK (EA 2007 – these samples may have been collected as early as 2001, so may relate better to our 1999 samples).

Table 3.15: Comparison of mean PCDD/F & PCB concentrations in rural and flood plain soils with UK literature values

PCDD/F (ng TEQ /kg dry weight)	PCB non-ortho + ortho (ng TEQ /kg dry weight)	Total[1] (ng TEQ /kg dry weight)	%PCB TEQ contribution to total TEQ[1]	Sampling date	Reference
Rural background					
5.2					Defra 2002[2]
2.8	0.15	3.0	5.1		FSA 2002[3]
2.5	0.25	2.7	9.2	2002	Foxall et al 2004a[4]
5.7	0.40	6.1	6.4	1998-9	Foxall et al 2004b[5]
5.3	0.62	5.9	10.4	2001-2	EA 2007[6]
5.0	0.35	5.4	6.5	2008	Present study[7]
Flood plains					
24.8	2.5	27.2	9.1	1998-9	Foxall et al 2004b[8]
12.2	2.6	14.8	17.8	2008	Present study[9]

Notes
1. Total concentrations of dioxins and PCBs may not equal the sum of individual dioxin and PCB values due to rounding.
2. Values quoted based on I-TEF system
3. Samples (n=2) collected from farms in Gwynedd and Cornwall during study of foot and mouth pyres.
4. Samples (n=5) collected from rural locations in Norfolk and Northumbria.
5. Samples (n=11) collected from control farms on River Trent
6. Samples (n=183) collected from rural areas in England as part of UK soil and herbage survey.
7. Samples (n=5) collected from control farms on River Trent
8. Samples (n=11) collected from flood-prone farms on River Trent
9. Samples (n=5) collected from flood-prone farms on River Trent

Examination of the data in Table 3.15 clearly suggests that both PCDD/F TEQ and total TEQ concentrations in control farm samples agree well with the values expected for rural background soils. Although the total TEQ concentration in soils from flood-prone sites is somewhat lower than that found in the previous flood project (C01037), the value (14.8 ngTEQ/dry weight) remains consistent with the levels expected in more urban soils.

For PBDEs in soils the data in Table 3.16 have been divided into two categories-rural background and those from flood plain sites. As is apparent from the Table, the ∑5 PBDE data from control farms agree well with rural background values reported previously. Likewise the corresponding data from flood-prone farms are consistent with concentrations reported for flood plains in other countries.

Table 3.16: Comparison of Mean PBDE concentrations in soil samples with literature values

	ng/kg dry weight							
	BDE 47	BDE 99	BDE 100	BDE 153	BDE 154	$\sum_5$ BDE	Sampling date	Reference
Rural background								
UK	66	113	21	24	17	242	2003-4	Harrad et al 2006[1]
UK	61	280	36	72	22	440	1998	Hassanin et al 2004[2]
Sweden	35	50	12	1.0	2.8	101	2002	Sellstrom et al 2005[3]
UK	100	92	18	16	10	236	2008	Present study[4]
Flood plains								
Sweden	1400	2300	560	290	270	4820	2002	Sellstrom et al 2005[5]
China	629	137	28	45	29	868	2002	Zou et al 2007[6]
USA	1490	1380	290	120	130	3410	2004	Yun et al 2008[7]
UK	330	546	116	82	62	1336	2008	Present study[8]

Notes
1. Rural soils-sites 1,3,9,11. Mean of monthly samples taken over period of one year
2. Remote rural grassland soils (n=21). Median concentrations for individual congeners-mean not givenAgricultural soils (n=5). Samples from agricultural research stations (3) and private farms
3. Samples (n=5) from control farms on River Trent
4. Sample from flood-prone farm adjacent to river known to be polluted with PBDEs. River floods annually including summer immediately prior to sampling
5. Samples from vegetable growing regions of Pearl river delta
6. Floodplain soils (n=10) from Shiawassee River, Michigan
7. Samples (n=5) from flood-prone farms on River Trent

Summary

The analysis presented in the above sections highlights a number of trends in the data from the soil samples. These are summarised below:

- PCDD/F & PCB and PBDE concentrations were significantly higher in soils from flood-prone farms
- PCDD/F & PCB levels in soil had not fallen significantly since August 1999
- PCDD/F & PCB levels in soil are closely correlated
- Concentrations of PCDD/Fs & PCBs and PBDEs on control farms agree with rural background levels in soil
- Concentrations of PBDEs on flood-prone farms are consistent with levels found on other flood plains. Levels of PCDD/F & PCB are lower than previously reported on other flood plains.

Grass

As indicated earlier in this report, 10 grass samples were analysed.

Overall PCDD/F & PCB and PBDE concentrations in grass and variations by type of site

Table 3-17 presents a series of descriptive statistics for the PCDD/F & PCB concentrations in these samples subdivided by type of site. Comparable data for the PBDE concentrations are presented in Table 3-18. The median grass concentrations for the matched pairs of flood-prone and control farms are presented in Table 3-19.

Table 3.17: Variations in the concentrations of PCBs & PCDD/Fs in grass by type of site

Sample Group	Number of Samples	ng TEQ_{1998} /kg dry weight Minimum	Median	Mean	Maximum
All Samples	10	0.09	0.20	0.30	0.90
Type of Site					
Control	5	0.10	0.10	0.15	0.30
Flood-prone	5	0.09	0.27	0.44	0.90

Notes: A Mann-Whitney U test indicates no significant different by type of site (p=0.245)

Table 3.18: Variations in the concentrations of PBDEs in grass by type of site

Sample Group	Number of Samples	$\sum_7$ ng/kg dry weight Minimum	Median	Mean	Maximum
All Samples	10	90	145	168	410
Type of Site					
Control	5	90	150	146	230
Flood-prone	5	90	140	190	410

Notes: A Mann-Whitney U test indicates no significant different by type of site (p=0.883)

Table 3.19: Comparisons of PCDD/F & PCB and PBDE concentrations in grass by type of site for matched pairs of farms

	PCDD/F & PCB ng TEQ_{1998} /kg dry weight		PBDE $\sum_7$ ng/kg dry weight	
Comparison	Flood-prone	Control	Flood-prone	Control
Pair 1	0.09	0.10	90	90
Pair 2	0.70	0.10	170	150
Pair 3	0.90	0.10	410	150
Pair 4	0.27	0.30	140	230
Pair 5	0.26	0.14	140	110

Notes
For PCDD/F and PCB a Wilcoxon ranked signs test indicates no significant difference by type of site (p=0.225)
For PBDE a Wilcoxon ranked signs test indicates no significant difference by type of site (p=0.465)

The data presented in Table 3-17 indicate that the PCDD/F & PCB concentrations in grass were variable ranging from 0.09 to 0.90 (TEQ ng/kg dry weight). Table 3-17 also presents evidence that flood-prone sites have higher PCDD/F & PCB concentrations. These were not statistically significant. Table 3-18 presents some evidence that PBDE concentrations were higher on flood-prone farms. Again these were not statistically significant. In terms of the paired analysis, Table 3-19 indicates that the concentrations of PCDD/Fs and & PCBs in grass were higher on 3 of the 5 flood-prone farms in comparison to their controls. This table also indicates that PBDE levels were higher on 3 of the 5 flood-prone farms. None of these comparisons were statistically significant. A Spearman rank correlation test indicates a high correlation (Spearman's $\rho = 0.74$, $p = 0.014$) between PCDD/F & PCB and PBDE concentrations on all sites.

Variations in PCDD/F & PCB concentrations in grass by type of site and sampling date

The PCDD/F & PCB concentrations on grass were compared to those in our previous research (C01037) to examine trends over time. The data are presented in Table 3-20 and suggest that the concentrations of PCDD/F & PCBs on flood-prone farms have changed little since 1999. There is a small reduction on control sites. The differences in grass concentrations between August 1999 and August 2008 are not significant.

Table 3.20: Variations in the median concentrations of PCDD/F & PCBs in grass by sampling date and type of site

	ng TEQ_{1998} /kg dry weight		
Sample Group	October 1998	August 1999	August 2008
Type of Site			
Control	-	$0.29_{(3)}$	$0.10_{(5)}$
Flood-prone	$0.62_{(1)}$	$0.31_{(4)}$	$0.27_{(5)}$
Total	$0.62_{(1)}$	$0.29_{(7)}$	$0.20_{(10)}$

Notes
Figures in **(subscript)** are sample sizes
A Mann Whitney U test indicates no significant difference between August 99 and August 2008 (p=0.417)

Comparison of the relative contributions of PCDD/Fs, Non-Ortho PCBs and Ortho PCBs in grass through time

In order to examine time trends in more detail the median percentage contribution of PCDD/Fs, non-ortho PCBs and ortho PCBs and to total TEQ are presented in Table 3-21 subdivided by sampling period and type of site.

Table 3.21: Variations in the median percentage contribution of PCDD/Fs, non-ortho PCBs and otho PCBs to TEQ in grass by sampling period and type of site

	% of Total WHO-TEQ_{1998}					
	PCDD/Fs		non-ortho PCBs		ortho PCBs	
Sample Group	Control	Flood	Control	Flood	Control	Flood
Sampling Period						
October 1998	-	$80.65_{(1)}$	-	$14.52_{(1)}$	-	$4.84_{(1)}$
August 1999	$62.96_{(3)}$	$65.58_{(4)}$	$24.14_{(3)}$	$23.11_{(4)}$	$11.11_{(3)}$	$9.43_{(4)}$
August 2008	$60.00_{(5)}$	$69.23_{(5)}$	$21.42_{(5)}$	$19.23_{(5)}$	$20.00_{(5)}$	$11.11_{(5)}$

Notes: Figures in **(subscript)** are sample sizes

The results presented do not indicate major changes in the percentage contribution of non-ortho PCBs, ortho PCBs and PCDD/Fs to total TEQ.

Comparison with previous grass data

Table 3.22: Comparison of mean PCDD/F and PCB concentrations in grass with UK literature values

PCDD/F (ng TEQ /kg dry weight)	PCB TEQ non-ortho + ortho (ng TEQ /kg dry weight)	Total TEQ[1] (ng TEQ /kg dry weight)	%PCB TEQ contribution to total TEQ[1]	Sampling date	Reference
Rural background					
0.45	0.10	0.55	18	2001	FSA 2002[2]
0.04	0.04	0.08	53	2002	Foxall et al 2004a[3]
0.19	0.10	0.29	34	1998-9	Foxall et al 2004b[4]
2.0	0.36	2.4	15	2001-2	EA 2007[5]
0.09	0.06	0.15	38	2008	Present study[6]
Flood plains					
0.19	0.11	0.30	36	1998-9	Foxall et al 2004b[7]
0.32	0.13	0.44	28	2008	Present study[8]

Notes

1. Total concentrations of dioxins and PCBs may not equal the sum of individual dioxin and PCB values due to rounding.
2. Samples (n=2) collected from farms in Gwynedd and Cornwall during study of foot and mouth pyres.
3. Samples (n=5) collected from rural locations in Norfolk and Northumbria.
4. Samples (n=3) collected from control farms on River Trent
5. Samples (n= 42) collected from rural areas as part of UK soil and herbage pollutant survey.
6. Sample (n=5) collected from control farm on River Trent
7. Samples (n=3) collected from flood-prone farms on River Trent
8. Samples (n=5) collected from flood-prone farms on River Trent

Table 3.23: Comparison of mean PBDE concentrations in grass samples with literature values

	(ng /kg dry weight)							
	BDE 47	BDE 99	BDE 100	BDE 153	BDE 154	$\sum_5$ BDE	Sampling date	Reference
UK	74	78	14	25	<44	191	2004	Hassanin et al 2005[1]
Present study	53	57	12	12	10	144	2008	

Notes
1. Samples from agricultural research station in semi-rural location. BDE-154 concentration taken as zero in calculation of $\sum_5$ BDEs.
2. Samples (n=10; five flood-prone and five control farms) on River Trent

Table 3-22 indicates that the PCDD/F TEQ and the total TEQ values for control farms from the present study fall within the range for rural background sites previously reported. The corresponding concentrations in samples from flood-prone sites agree well with the results from the previous flood project. Few data are available for the levels of PBDEs in grass. The mean PBDE concentration from the present study agrees with values reported by an earlier UK study.

Summary

The analysis presented in the above sections, highlights a number of trends in the data from the grass samples. These are summarised below:

- Levels of PCDD/F & PCBs and PBDEs are not significantly higher on flood-prone as opposed to control sites
- The PCDD/F & PCB and PBDE levels in grass were closely correlated
- Levels of PCDD/Fs and PCBs are not significantly lower than levels observed in August 1999
- There was good agreement between PCDD/F & PCB concentrations on control farms and rural background levels

Commercial feed

Overall PCDD/F & PCB and PBDE concentrations in commercial feed and variations by type of site

As indicated earlier in this report, 4 commercial feed samples were analysed, all from flood-prone farms. Table 3-24 presents a series of descriptive statistics for the PCDD/F & PCB concentrations in these samples. Comparable data for PBDEs are presented in Table 3-25.

Table 3.24: Variations in the concentrations of PCDD/Fs & PCBs in commercial feed

	Number	ng TEQ_{1998} /kg whole weight			
Sample Group	of Samples	Minimum	Median	Mean	Maximum
Flood-prone	4	0.05	0.07	0.06	0.07

The median commercial feed concentrations for each flood-prone farm is presented in Table 3-26. Due to the high PBDE levels in milk on control farm 4, silage and feed mix samples fed to the cattle were analysed and the results are presented in Table 3-27. This farm did not use commercial feed.

Table 3.25: Variations in the concentrations of PBDEs in commercial feed

	Number	$\sum_7$ ng/kg whole weight			
Sample Group	of Samples	Minimum	Median	Mean	Maximum
Flood-prone	4	70	190	252.5	560

Table 3.26: Comparisons of PCDD/F & PCB and PBDE concentrations in commercial feed for matched pairs of farms

	PCDD/F & PCB ng TEQ_{1998} /kg whole weight		PBDE $\sum_7$ ng/kg whole weight	
Comparison	Flood-prone	Control	Flood-prone	Control
Pair 1	0.07	-	560	-
Pair 2	0.06	-	90	-
Pair 3	0.05	-	70	-
Pair 4	0.07	-	290	-
Pair 5	-	-	-	-

Table 3.27: PCDD/F & PCB and PBDE concentrations in silage and vegetable mix collected from control farm pair 4 in August 2008

	PCDD/F & PCB ng TEQ_{1998} /kg dry weight	PBDE $\sum_7$ ng/kg dry weight
Feed Mix	0.07	80
Silage	0.10	24390

The data presented in Table 3-24 indicate that the PCDD/F & PCB concentrations in commercial feed fell within a very narrow range of between 0.05 and 0.07 (TEQ ng/kg dry weight). PBDE concentrations presented in Table 3-25 were more variable ranging from 70 to 560 (ng/kg whole weight). The PCDD/F & PCB concentrations are well under the maximum level of these contaminants allowed in UK commercial feed under relevant - EU regulations (Commission Recommendation 2006/13/EC). The sampling design makes it impossible to comment upon differences between flood-prone and control farms although there is no reason why the concentrations should be different, as both types of farms use nationally distributed commercial feed. Table 3-27 presents the PCDD/F & PCB and PBDE concentrations from control farm pair 4 and indicates that high PBDE levels in silage are the most likely explanation for high values in the milk sample from this farm.

Variations in PCDD/F & PCB concentrations in commercial feed by type of site and sampling date

The PCDD/F & PCB concentrations in commercial feed were compared to those in our previous research (C01037) to examine trends over time. The data are presented in Table 3-28 and present little evidence that concentrations of PCDD/Fs & PCBs have changed since 1999.

Table 3.28: Variations in the median concentrations of PCDD/F & PCBs in commercial feed by sampling date and type of site

	ng TEQ_{1998} /kg whole weight	
Sample Group	March 1999	August 2008
Type of Site		
Control	$0.07_{(4)}$	-
Flood-prone	$0.12_{(3)}$	$0.07_{(4)}$
Total	$0.09_{(7)}$	$0.07_{(4)}$

Notes
Figures in **(subscript)** are sample sizes

Comparison of the relative contributions of PCDD/Fs, non-ortho PCBs and ortho PCBs in commercial feed through time

In order to examine time trends in more detail the median percentage contribution of PCDD/Fs, non-ortho PCBs and ortho PCBs and to total TEQ are presented in Table 3-29 subdivided by sampling period and type of site.

The results presented do not indicate major shifts in the percentage contribution of non-ortho PCBs, ortho PCBs and PCDD/Fs to total TEQ.

Table 3.29: Variations in the median percentage contribution of PCDD/Fs, non-ortho PCBs and ortho PCBs to total TEQ in commercial feed by sampling period and type of site

	% of Total WHO-TEQ_{1998}					
	PCDD/Fs		non-ortho PCBs		ortho PCBs	
Sample Group	Control	Flood	Control	Flood	Control	Flood
Sampling Period						
March 1999	$73.33_{(3)}$	$57.14_{(4)}$	$14.29_{(3)}$	$8.89_{(4)}$	$28.57_{(3)}$	$17.78_{(4)}$
August 2008	-	$58.57_{(4)}$	-	$7.14_{(4)}$	-	$30.95_{(4)}$

Notes: Figures in **(subscript)** are sample sizes

Comparison with previous commercial feed data

Table 3.30: Comparison of mean PCDD/F and PCB concentrations in commercial dairy cattle commercial feed with UK literature values.

PCDD/F (ng TEQ/kg whole weight)	PCB non-ortho + ortho (ng TEQ /kg whole weight)	Total[1] (ng TEQ/kg whole weight)	%PCB TEQ contribution to total TEQ[1]	Sampling date	Reference
0.06	0.03	0.09	33	1999	Foxall et al 2004b[2]
0.04	0.02	0.06	42	2003/4	Fernandes et al 2004[3]
0.04	0.03	0.07	46	2005/2006	Fernandes et al 2006[4]
0.04	0.03	0.07	40	2008	Present study[5]

Notes
1. Total concentrations of dioxins and PCBs may not equal the sum of individual dioxin and PCB values due to rounding.
2. Samples of commercial feed (n=6) from farms on River Trent. Mean values calculated omitting results for one farm which had elevated and apparently anomalous dioxin levels.
3. Samples of commercial cattle feed (n=9) from farms/feed mills in England, Wales and Northern Ireland. In the absence of dairy designation, samples assumed to be destined for beef cattle.
4. Samples of commercial cattle feed (n=13) from UK farms/feed mills. Not clear from report whether samples destined for dairy or beef herds.
5. Samples of commercial feed (n=4) from farms on River Trent

Few data on levels of PCDD/Fs and PCBs in commercial dairy feed have been published. However, as indicated in Table 3-30 mean PCDD/F TEQ and total TEQ concentrations from farms on the River Trent from the present study agree closely with the data arising from the previous flood project on the same river. No previous data on PBDE concentration in commercial feed are available.

Summary

The analyses presented in the above sections, highlight a number of trends in the data from the commercial feed samples. These are summarised below:

- PCDD/F & PCB concentrations in commercial feed are very similar to concentrations recorded in 1998
- PBDE levels in commercial feed are highly variable
- One farm had high PBDE levels in silage

PCDD/F & PCB Weight of Evidence Summary – Flood Prone vs Control

In the statistical analysis of the PCDD/F and PCB data, the small numbers of samples meant that very pronounced differences were required between flood-prone and control sites to achieve statistically significant results. To overcome these limitations and to provide a more holistic overview of the data (i.e. look at the milk, soil, grass and feed data together), they were also examined using a weights of evidence table as described in Chapter 2. The results are presented in Table 3.31.

Table 3.31: Weight of evidence table examining the impact of river flooding upon PCDD/F and PCB concentrations in milk

Strength of Association		
Hazard	Soil	• Higher total TEQ (median 15.83 vs. 4.68 ng TEQ_{1998} /kg dry weight) on flood-prone farms • 5/5 flood-prone pairs have higher total TEQ
	Grass	• Higher total TEQ (median 0.27 vs. 0.10 ng TEQ_{1998} /kg dry weight) on flood-prone farms • 3/5 flood-prone pairs have higher total TEQ
Outcome	Milk	• Flood-prone farms have higher total TEQ (median 1.36 vs.0.94 ng TEQ_{1998} /kg fat) • 3/5 flood-prone pairs have higher total TEQ
Consistency of Association		
Hazard	Soil	• Consistency difficult to assess as all farm pairs on the Trent
	Grass	• Consistency difficult to assess as all farm pairs on the Trent
Outcome	Milk	• Consistency difficult to assess as all farm pairs on the Trent
Alternative Explanations		• There is no reason to believe that flood-prone farms would receive different feed supplies and hence experience different total TEQ to control farms

There is very little evidence in the table above that river flooding leads to elevated total TEQ in milk. There was a clear indication that PCDD/F and PCB levels were higher in soil from flood-prone farms. These are some indications that these contrasts are transferred to grass samples. Although it was not possible to assess consistency of association due to the lack of samples on the Aire/Ouse, we conclude that a potential for elevated PCDD/F and PCB levels in milk exists due to the results presented as well as the soil and grass results from Chapter 4 and Chapter 5. The most direct evidence of the impact of flooding on PCDD/F and PCB levels emerges from the analysis of the milk samples. These suggest that this potential for elevated PCDD/F and PCB concentrations was not realised. Milk samples from flood-prone farms had higher total TEQ levels (~40%) to those from control farms. The strongest evidence to examine the impact of flooding comes from the paired analysis, but there was no clear contrasts between flood-prone and control farms in the paired analysis. Based upon all evidence presented above, in this case it is not possible to conclude that river flooding transfers PCDD/Fs and PCBs to milk from dairy cattle on the flood plains. This interpretation is strongly influenced by the small number of farm pairs.

PBDE Weight of Evidence Summary – Flood Prone vs Control

The weights of evidence table for PBDEs in this (dairy) programme is presented in Table 3.32.

Table 3.32: Weight of evidence table examining the impact of river flooding upon PBDE concentrations in milk

Strength of Association		
Hazard	Soil	• Higher PBDE (median 770 vs. 280 ng /kg dry weight) on flood-prone farms • 5/5 flood-prone pairs have higher PBDE levels
	Grass	• Similar median PBDE (median 140 vs.150 ng /kg dry weight) on both farm types • 3/5 flood-prone pairs have higher PBDE levels
Outcome	Milk	• Flood-prone farms have higher PBDE (median 300 vs. 250 ng /kg fat) • 2/5 flood-prone pairs have higher PBDE
Consistency of Association		
Hazard	Soil	• Consistency difficult to assess as all farm pairs on the Trent
	Grass	• Consistency difficult to assess as all farm pairs on the Trent
Outcome	Milk	• Consistency difficult to assess as all farm pairs on the Trent
Alternative Explanations		• No reason to believe that flood-prone farms would receive different feed supplies and hence experience different total TEQ to control farms

There is very little evidence in the table above that river flooding leads to elevated PBDE in milk. There was a clear indication that PBDE levels were higher in soil from flood-prone farms. These contrasts do not appear to be consistently transferred to the grass samples. We conclude that a potential for elevated PBDE levels in milk exists due to the results presented as well as the soil and grass results from Chapter 4 and Chapter 5. The most direct evidence of the impact of flooding on PBDE levels emerges from the analysis of the milk samples. These suggest that this potential for elevated PBDE concentrations was not realised. Milk samples from flood-prone farms had higher total TEQ levels (~20%) to those from control farms. The strongest evidence to examine the impact of flooding comes from the paired analysis, but there was no clear contrasts between flood-prone and control farms. Based upon all evidence presented above, we conclude that river flooding does not transfer PBDEs to milk from dairy cattle on the flood plains. This interpretation is strongly influenced by the small number of farm pairs.

PCDD/F & PCB Weight of Evidence Summary – Time Trends

The relevant information relating to time trends is presented as weights of evidence in Table 3.33.

Table 3.33: Weight of evidence table examining the change in concentrations of PCDD/F and PCB concentrations in milk over time

Strength of Association		
Hazard	Soil	• Total TEQ declined by a small amount (median 6.99 vs. 6.75ng TEQ_{1998} /kg dry weight) between Aug 99 and Aug 08 • On two farms sampled in both periods soil TEQ was lower (5.86 vs 5.64 and 6.91 vs 4.20) in Aug 99
	Grass	• Total TEQ has declined (median 0.29 vs. 0.20 ng TEQ_{1998} /kg dry weight) between Aug 99 and Aug 08
Outcom e	Milk	• Total TEQ has halved (median 1.80 vs. 0.97 ng TEQ1998 /kg fat) between Aug 99 and Aug 08 • On 2 farms sampled in both periods total TEQ also declined (1.37 vs 0.92 and 3.68 vs 0.94)
Consistency of Association		
Hazard	Soil	• Consistency difficult to assess as all farm pairs on the Trent
	Grass	• Consistency difficult to assess as all farm pairs on the Trent
Outcom e	Milk	• Consistency difficult to assess as all farm pairs on the Trent
Alternative Explanations		• No evidence that PCDD/F and PCB levels in feed had changed between Aug 99 and Aug 08

There is strong evidence in the table above that total TEQ has declined in milk between August 1998 and August 2008. However, there was only limited evidence of a decline in soil and grass samples which is slightly at odds with the large decline (over 50%) observed in milk. The most direct evidence of the impact of time on PCDD/F and PCB concentrations in milk emerges from the two farms where samples were taken in August 1998 and August 2008. On both these farms PCDD/F and PCB concentrations were lower. Given the small decline in total TEQ observed in environmental samples between these two periods we suggest that the reduction in total TEQ may be due to increased use of commercial feed, with its associated lower total TEQ, within dairy farming. Evidence for this change is provided elsewhere (Lake et al., 2011).

4. Beef programme

This chapter focuses upon the results from the beef sampling and consists of twelve sections. These focus upon the meat, liver, and kidney followed by the soil, grass, feed and silage data in turn. The last 3 sections cover the unusually high levels on one farm, comparing PCDD/F & PCB and PBDE concentrations in milk and beef, and a comparison between WHO-1998 and WHO-2005 TEFs. The final two sections conduct a weight of evidence analysis for the impact of flooding on PCDD/F & PCB levels in beef, followed by a similar analysis for PBDE levels in beef.

The WHO-TEQ data in this chapter has been presented using the WHO-1998 TEFs (Van den Berg et al., 1998), but as mentioned in Chapter 2, the beef data has also been evaluated using the revised WHO-TEF_{2005} scheme (Van Den Berg et al., 2006) in conjunction with the revised regulations that were introduced from January 2012 (Commission Regulation (EU) No 1259/2011 incorporating WHO_{2005}-TEFs).

Meat

Overall PCDD/F, PCB and PBDE concentrations in meat and variations by river system and type of site

As indicated earlier in this report, 38 meat samples were analysed, 20 from flood-prone farms and 18 from control farms. Table 4-1 presents a series of descriptive statistics for the PCDD/F & PCB concentrations in these samples subdivided by river system and type of site. Comparable data for the PBDE concentrations are presented in Table 4-2.

The data presented in Table 4-1 indicate that all the PCDD/F & PCB concentrations fell within a range of between 0.31 (ng TEQ/kg fat) and 8.85 (ng TEQ/kg fat). In overall terms, levels on the Aire/Ouse appear higher than on the River Trent. Table 4-1 presents some evidence that flood-prone farms have higher PCDD/F & PCB concentrations than control farms. On both river systems mean and median PCDD/F & PCB concentrations are higher on flood-prone farms but the differences observed are relatively small especially on the Trent. There was no statistically significant difference between levels on flood-prone farms in comparison to control farms.

Examination of the PBDE data presented in Table 4-2 indicates that the $\sum_7$ values range from 130 - 1790 ng/kg fat. Unlike the PCDD/F and PCB data there is little evidence of elevated values on the Aire/Ouse in comparison to the River Trent. There is also some evidence of elevated mean and median PBDE levels on flood-prone farms but again the differences are relatively small. There was no statistically significant difference between flood-prone and control farms.

Table 4-1: Variations in the concentrations of PCDD/Fs & PCBs in meat by river system and type of site

	Number	ng TEQ_{1998} /kg fat			
Sample Group	of Samples	Minimum	Median	Mean	Maximum
Trent - Type of Site					
Control	8	1.51	2.40	2.34	2.89
Flood-prone	10	1.91	2.61	2.90	4.77
All Trent Samples	18	1.51	2.58	2.65	4.77
Aire/Ouse - Type of Site					
Control	10	0.31	3.48	3.63	8.85
Flood-prone	10	2.98	3.97	4.11	5.48
All Aire/Ouse Samples	20	0.31	3.91	3.87	8.85
All Samples – Type of Site					
Control	18	0.31	2.60	3.05	8.85
Flood-prone	20	1.91	3.24	3.51	5.48
All Samples	38	0.31	2.94	3.29	8.85

Notes: A Mann-Whitney U test between the median values on each farm indicates no significant differences between type of site ($p=0.165$)

Table 4-2: Variations in the concentrations of PBDEs in meat by river system and type of site

	Number	$\sum_7$ ng/kg fat			
Sample Group	of Samples	Minimum	Median	Mean	Maximum
Trent - Type of Site					
Control	8	330	545	504	700
Flood-prone	10	210	650	568	900
All Trent Samples	18	210	585	539	900
Aire/Ouse - Type of Site					
Control	10	130	345	550	1790
Flood-prone	10	200	445	564	1180
All Aire/Ouse Samples	20	130	400	557	1790
All Samples – Type of Site					
Control	18	130	445	529	1790
Flood-prone	20	200	560	566	1180
All Samples	38	130	490	549	1790

Notes: A Mann-Whitney U test between the median values on each farm indicates no significant differences between type of site ($p=0.414$)

Comparisons between flood-prone and control sites are complicated by the relatively small sample numbers in each subgroup. A more sophisticated method of comparison is to examine the differences in PCDD/F & PCB and PBDE concentrations between matched pairs of flood-prone and control farms. Ten such pairs were identified as part of the experimental design and the meat PCDD/F & PCB concentrations for these farms are presented in Table 4-3 and Figure 4.1. The ∑ICES6 PCB concentrations are presented in Table 4-4 and Figure 4.2, and the dioxin like PCB concentrations in Table 4-5 and Figure 4.3. The PCDD/F concentrations are in Table 4-6 and Figure 4.4, and the PBDE concentrations in Table 4-7 and Figure 4.5. For the comparison the concentrations between the two animals in each pair have been averaged. As animals from pair 5 (control) on the Trent were unavailable, animals from the neighbouring pair 4 farm were used as a control.

In terms of flood-prone/control comparisons, mean PCDD/F & PCB TEQ levels from flood-prone farms were higher in 7 from 10 farm pairs. On 6 from 10 farm pairs PCDD/F & PCB TEQ levels were higher in both flood-prone samples in comparison to both control samples. Examining PCDD/F and dioxin-like

PCB TEQ separately, seven from 10 flood-prone farm pairs had higher dioxin like PCB TEQ relative to controls (For 6 of these, higher levels were observed in both animals relative to controls). 6 from 10 flood-prone pairs had higher PCDD/F TEQ (for 4 of these, higher levels were observed in both animals). ∑ICES6 PCB levels were higher on the flood-prone farm in 9 from 10 farm pairs (for 9 of these, higher levels were observed in both animals). There were no statistically significant differences between flood-prone and control farms for PCDD/F & PCB, dioxin-like PCB or PCDD/F. ∑ICES6 PCBs levels were significantly higher on flood-prone farms.

Although these samples were not market ready (See Ch 2) and would not therefore be subject to regulatory limits, it is nonetheless instructive to compare the detected concentrations against the regulatory limits that were prevalent at the time of sampling and under the new regulations. (Commission Regulation (EU) No 1259/2011 using WHO $_{2005}$- TEFs). Table 4-3 indicates that 1 of the 18 meat sample from the River Trent and 5 of the 20 from the Aire/Ouse would have been above the maximum levels for PCDD/F & PCBs (4.5 ng TEQ_{1998}/kg fat). This would also apply under the new maximum levels for PCDD/F & PCBs that came into force in 2012 (4.0 ng TEQ $_{2005}$/kg fat using TEF $_{2005}$ /2011 regulations).

The dioxin like PCB levels for these farms is presented in Table 4-5 and indicates that 33/38 samples would have been above the dioxin-like PCB action levels. Under the new action levels this falls to 13 from 38. Turning our attention to the PCDD/F data, 2 out of 38 meat samples would have been above the maximum level for PCDD/Fs (3.0 ngTEQ $_{1998}$/kg fat) in place when the sampling was conducted. This would also apply under the new maximum level for PCDD/Fs introduced in 2012 (2.5 ngTEQ $_{2005}$/kg fat). Fourteen from 38 samples would have been above the dioxin action levels or 7 from 38 using the WHO $_{2005}$- TEFs in conjunction with the 2011 regulations.

Table 4-3: Comparisons of PCDD/F & PCB concentrations in meat[1] by river system and type of site for matched pairs of farms

	ng TEQ_{1998} /kg fat			
	Flood-prone		Control	
Sample	Sample 1, Sample 2	Mean	Sample 1, Sample 2	Mean
Trent				
Pair 1	4.40, 2.58	3.49	2.89, 2.62	2.76
Pair 2	2.21, 1.91	2.06	2.22, 2.57	2.40
Pair 3	2.76, 3.04	2.90	2.65, 2.23	2.44
Pair 4	2.38, 2.35	2.37	1.51, 2.00	1.76
Pair 5	[+]4.77, 2.64	3.71	1.51, 2.00[&]	1.76[&]
Aire/Ouse				
Pair 1	3.43, 4.01	3.72	[+]8.85, [+]7.61	8.23
Pair 2	[+]4.76, 4.50	4.63	4.00, 3.36	3.68
Pair 3	2.98, 3.89	3.44	3.60, 3.93	3.77
Pair 4	[+]5.48, 3.92	4.70	1.73, 2.00	1.87
Pair 5	[+]5.15, 2.99	4.07	0.90, 0.31	0.61

Notes
[1]These animals were not market ready as described in Ch 2.
[&] Control farm same as pair 4 due to its close proximity to the flood-prone farm in pair 5
[+] Samples exceeding Total TEQ maximum levels (4.5 ng TEQ/kg fat) prevalent at time of sampling
A Wilcoxon ranked signs test indicates no significant differences between type of site (p=0.139)

Figure 4.1: Mean and range of PCDD/F & PCB levels in meat in matched pairs of farms

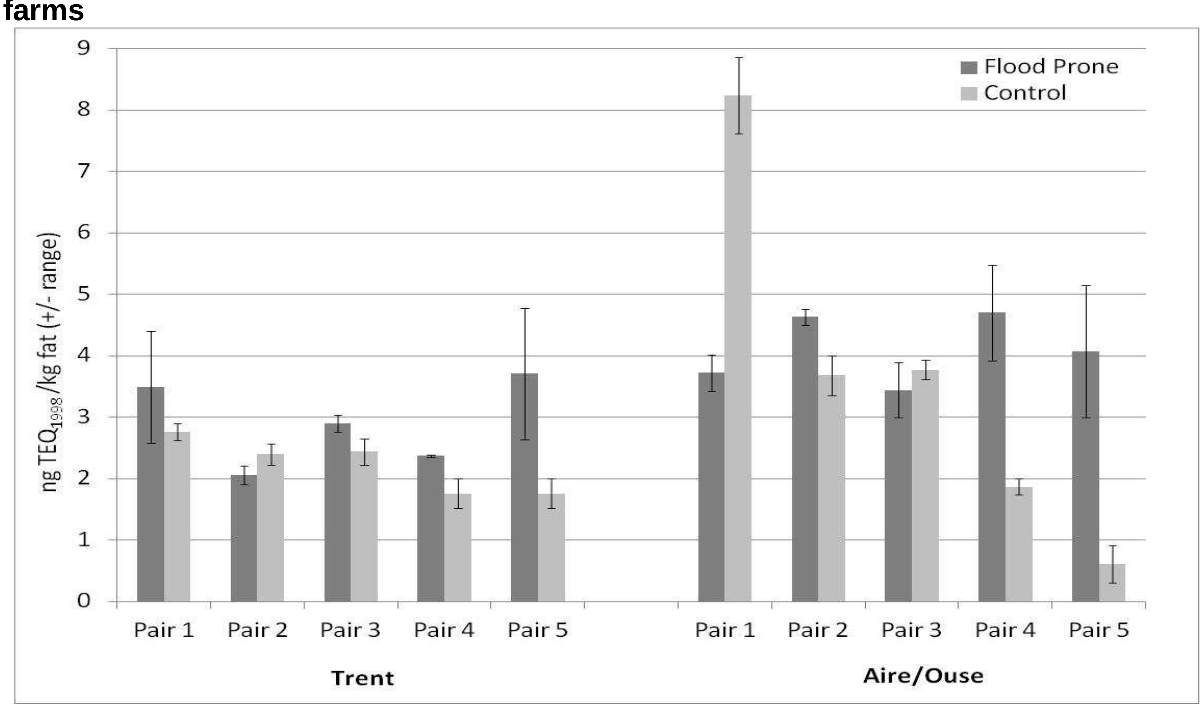


Figure 4.2: Mean and range of ∑ICES6 concentrations in meat in matched pairs of farms

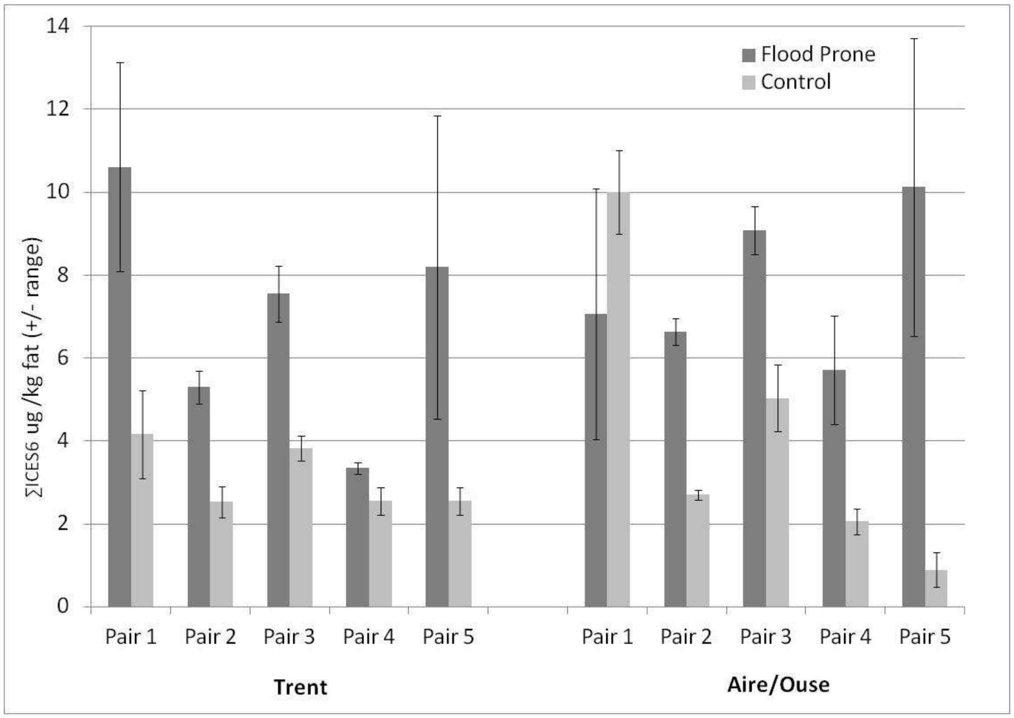


Table 4-4: Comparisons of ∑ICES6 concentrations in meat by river system and type of site for matched pairs of farms

	µg/ kg fat			
	Flood-prone		Control	
Sample	Sample 1, Sample 2	Mean	Sample 1, Sample 2	Mean
Trent				
Pair 1	13.13, 8.09	10.61	5.22, 3.10	4.16
Pair 2	5.70, 4.90	5.30	2.14, 2.91	2.53
Pair 3	6.87, 8.22	7.55	4.12, 3.52	3.82
Pair 4	3.49, 3.21	3.35	2.21, 2.88	2.55
Pair 5	11.84,4.53	8.19	2.21, 2.88[&]	2.55[&]
Aire/Ouse				
Pair 1	4.04, 10.08	7.06	9.00, 11.02	10.01
Pair 2	6.96, 6.32	6.64	2.82, 2.58	2.70
Pair 3	8.49, 9.65	9.07	5.82, 4.23	5.03
Pair 4	7.01, 4.40	5.71	1.74, 2.37	2.06
Pair 5	13.71, 6.53	10.12	1.31, 0.47	0.89

Notes
[&] Control farm same as used in pair 4 due to its close proximity to the flood-prone site in pair 5
A Wilcoxon ranked signs test indicates a statistically significant difference between type of site ($p=0.013$)

Table 4-5: Comparisons of dioxin like PCB concentrations in meat[1] by river system and type of site for matched pairs of farms

	ng TEQ_{1998} /kg fat			
	Flood-prone		Control	
Sample	Sample 1, Sample 2	Mean	Sample 1, Sample 2	Mean
Trent				
Pair 1	†2.33, †1.43	1.88	†5.22, †1.29	3.26
Pair 2	†1.32, †1.19	1.26	0.93, †1.24	1.09
Pair 3	†1.73, †1.86	1.80	†1.56, †1.30	1.43
Pair 4	†1.27, †1.22	1.25	0.77, †1.07	0.92
Pair 5	†2.63, †1.39	2.01	0.77, †1.07&	0.92&
Aire/Ouse				
Pair 1	†1.94, †2.32	2.13	+†4.21, +†3.69	3.95
Pair 2	†2.80, †2.56	2.68	†1.61, †1.28	1.45
Pair 3	†1.87, †2.03	1.95	†2.17, †2.24	2.21
Pair 4	†2.79, †1.84	2.32	0.91, †1.20	1.06
Pair 5	†2.75, †1.80	2.28	0.49, 0.14	0.32

Notes
[1]These samples were not market ready as described in Ch 2
[&] Control farm same as used in pair 4 due to its close proximity to the flood-prone site in pair 5
†Samples exceeding dioxin-like PCB action levels (1 ngTEQ/kg fat) prevailing at time of sampling
A Wilcoxon ranked signs test indicates no significant difference between type of site (p=0.386)

Figure 4.3: Mean and range of dioxin like PCB concentrations in meat by river system and type of site for matched pairs of farms

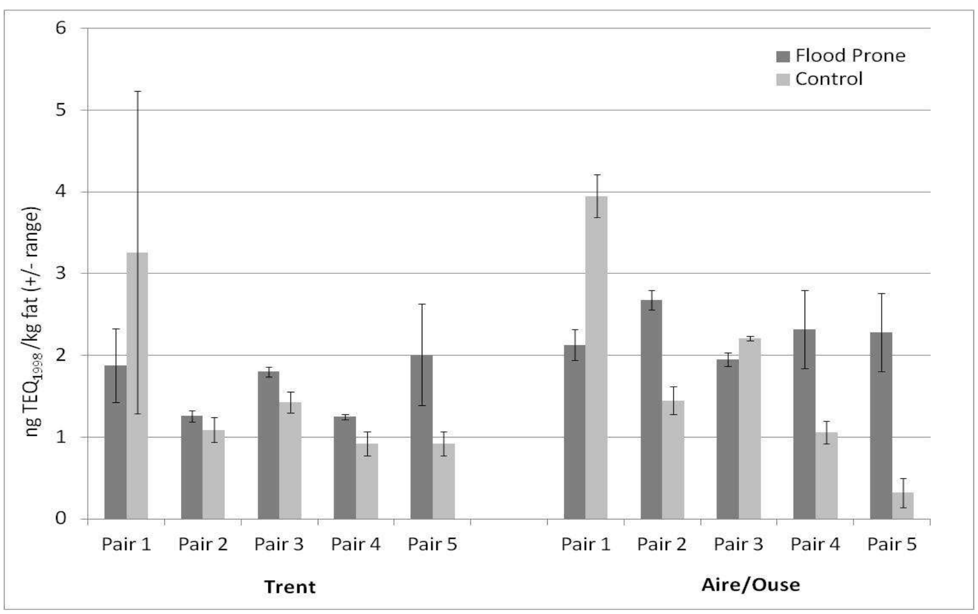
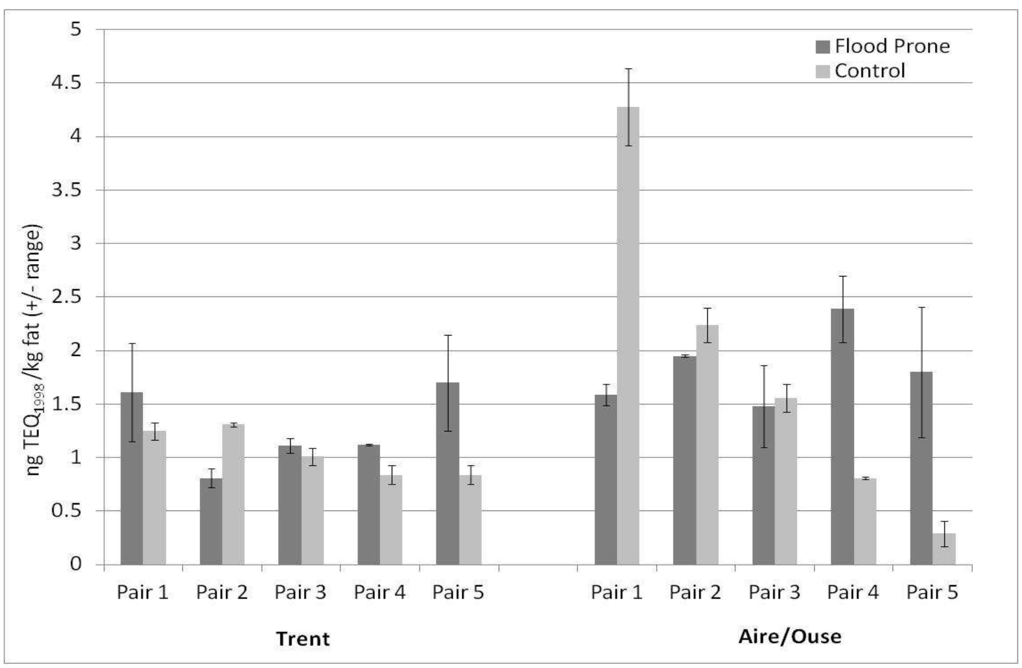


Table 4-6: Comparisons of PCDD/F concentrations in meat[1] by river system and type of site for matched pairs of farms

	ng TEQ_{1998}/kg fat			
	Flood-prone		Control	
Sample	Sample 1, Sample 2	Mean	Sample 1, Sample 2	Mean
Trent				
Pair 1	‡2.07, 1.15	1.61	1.17, 1.33	1.25
Pair 2	0.89, 0.72	0.81	1.29, 1.33	1.31
Pair 3	1.03, 1.18	1.11	1.09, 0.93	1.01
Pair 4	1.11, 1.13	1.12	0.74, 0.93	0.84
Pair 5	‡2.14, 1.25	1.70	0.74, 0.93[&]	0.84[&]
Aire/Ouse				
Pair 1	1.49, ‡1.69	1.59	*‡4.64, *‡3.92	4.28
Pair 2	‡1.96, ‡1.94	1.95	‡2.39, ‡2.08	2.24
Pair 3	1.11, ‡1.86	1.48	1.43, ‡1.69	1.56
Pair 4	‡2.69, ‡2.08	2.39	0.82, 0.80	0.81
Pair 5	‡2.40, 1.19	1.80	0.41, 0.17	0.29

Notes
[1]These samples were not market ready as described in Ch 2
[&] Control farm same as used in pair 4 due to its close proximity to the flood-prone site in pair 5
[*] Samples exceeding dioxin maximum levels (3 ng TEQ/kg fat) in place at time of sampling.
‡Samples exceeding dioxin action levels (1.5 ngTEQ/kg fat) in place at time of sampling.
A Wilcoxon ranked signs test indicates no significant difference between type of site. (p=0.508)

Figure 4.4: Mean and range of PCDD/F concentrations in meat for matched pairs of farms



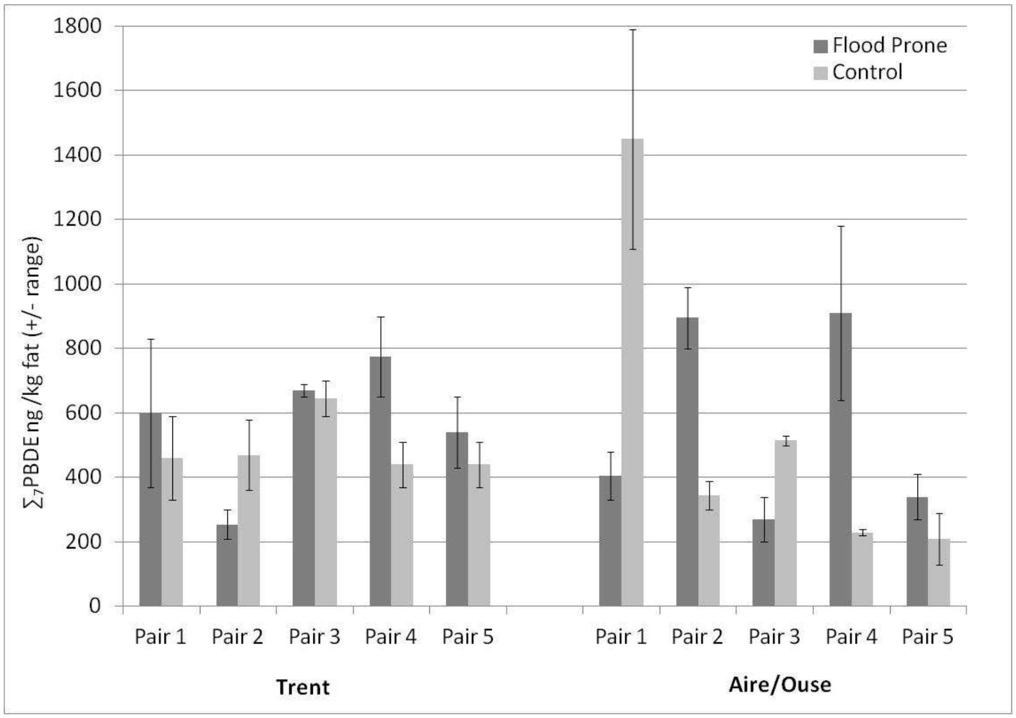
The corresponding PBDE data for the same 10 farm pairs are presented in Table 4-7 and Figure 4.5. The results show very similar patterns to those evident in the PCDD/F and PCB data. Mean PBDE concentrations in beef from flood-prone were higher in the same 7 flood-prone / control farm pairs as those pairs found to have elevated PCDD/F & PCB levels. This difference was not statistically significant. On 3 from 10 farm pairs PBDE levels were higher in both flood-prone samples in comparison to both control samples.

Table 4-7: Comparisons of PBDE concentrations in meat[1] by river system and type of site for matched pairs of farms

	ng/kg fat			
	Flood-prone		Control	
Sample	Sample 1, Sample 2	Mean	Sample 1, Sample 2	Mean
Trent				
Pair 1	830, 370	600	330, 590	460
Pair 2	300, 210	255	360, 580	470
Pair 3	690, 650	670	700, 590	645
Pair 4	650, 900	775	370, 510	440
Pair 5	650, 430	540	370, 510[&]	440[&]
Aire/Ouse				
Pair 1	330, 480	405	1790, 1110	1450
Pair 2	990, 800	895	300, 390	345
Pair 3	200, 340	270	530, 500	515
Pair 4	1180, 640	910	220, 240	230
Pair 5	410, 270	340	290, 130	210

Notes
[1]These samples were not market ready as described in Ch 2.
[&] Control farm same as used in pair 4 due to its close proximity to the flood-prone site in pair 5
A Wilcoxon ranked signs test indicates no significant difference between type of site (p=0.508)

Figure 4.5: Mean and range of PBDE concentrations in meat for matched pairs of farms



One notable feature of these data is the observation that meat samples with high PCDD/F & PCB concentrations tend to have high PBDE concentrations and vice versa. This was tested statistically using a spearman rank correlation which indicates a moderate correlation (Spearman's $\rho = 0.540$ $p < 0.017$) between PCDD/F & PCB and PBDE concentrations.

Comparison of the relative contributions of PCDD/Fs, Non-Ortho PCBs and Ortho PCBs in meat

The median percentage contribution of PCDD/Fs, Non-Ortho PCBs and Ortho PCBs to total TEQ are presented in Table 4-8 subdivided by river system and type of site. The results indicate few differences between flood-prone and control farms or by river system.

Table 4-8: Variations in the median percentage contribution of PCDD/Fs, Non-Ortho PCBs and Ortho PCBs to total TEQ in beef by river system and type of site

	% of Total WHO-TEQ_{1998}					
	PCDD/Fs		Non-Ortho PCBs		Ortho PCBs	
Sample Group	Control	Flood	Control	Flood	Control	Flood
Trent	$47.75_{\mathbf{(8)}}$	$44.72_{\mathbf{(10)}}$	$44.85_{\mathbf{(8)}}$	$46.35_{\mathbf{(10)}}$	$7.39_{\mathbf{(8)}}$	$9.35_{\mathbf{(10)}}$
Aire/Ouse	$49.46_{\mathbf{(10)}}$	$43.28_{\mathbf{(10)}}$	$44.77_{\mathbf{(10)}}$	$46.16_{\mathbf{(10)}}$	$6.01_{\mathbf{(10)}}$	$9.39_{\mathbf{(10)}}$

Notes: Numbers in **(subscript)** represent number of samples

Comparison with previous meat data

This section of the report compares the results from the present study to previous surveys of PCDD/F, PCB and PBDE concentrations in meat. The results for PCDD/F & PCB concentrations are presented in Table 4-9 and those for PBDEs in Table 4-10.

Table 4-9: Comparison of mean PCDD/F and PCB concentrations (ngTEQ/kg fat) in carcase meat from beef cattle with literature values.

PCDD/F TEQ	PCB TEQ non-ortho + ortho	Total TEQ[1]	%PCB TEQ contribution to total TEQ[1]	Sampling date	Reference
USA					
0.6	0.1	0.7	14	2001	Huwe et al 2005[2]
Belgium					
1.56	3.34	4.90	68	2000-2001	Focant et al 2002[3]
Finland					
0.29	0.31	0.60	52	1998-2000	Kiviranta et al 2001[4]
Ireland					
0.43	0.45	0.88	51	2003	FSAI 2005b[5]
UK					
0.43	0.45	0.88	51	2003	FSA 2004[6]
0.42	0.47	0.89	53	2005	FSA 2006a[7]
Present study - Trent					
1.19	1.46	2.65	55	2008	
Present study - Aire/Ouse					
1.84	2.03	3.87	53	2010	

Notes
1. Total concentrations of dioxins and PCBs may not equal the sum of individual dioxins and PCBs values due to rounding. % PCB TEQ contributions to total TEQ are calculated before rounding of PCB TEQ and total TEQ values.
2. Steak (n=10) from supermarkets across USA. PCB TEQ concentration is total for non-ortho congeners 77, 126 and 169 only.
3. Meat samples (n=25) from slaughter houses or retail outlets. PCB total includes non-ortho (77, 81, 126, 169) congeners only.
4. Tenderloin samples (n=5) from slaughter houses. TEQs calculated using I-TEFs.
5. Samples of carcass fat (n=10) from slaughter houses.
6. Samples of minced beef (n=3) from retail outlets.
7. Various beef joints (n=7) from supermarkets.

An examination of the data in Table 4-9 indicate that PCDD/F TEQ and total TEQ concentrations in beef from the present study are higher than those previously reported for the UK and for other countries. This is an interesting observation given that PCB & PCDD/F levels in many industrialised countries have been falling over the past few years. One factor that may influence these results is the fact that, although these animals were destined for market, our samples were taken close to the time when the animals moved indoors. The animals would then have spent time indoors before being sent to market. It is unknown how levels of PCDD/F, PCB and PBDEs would alter during this gap. The % contribution of PCBs to the total TEQ is however generally consistent with literature values.

Table 4-10: Comparison of PBDE Concentrations (ng/kg fat) in carcase meat from beef cattle with literature values

	BDE 47	BDE 99	BDE 100	BDE 153	BDE 154	$\sum_5$ BDE	Sampling date	Reference
USA	256	294	50	36	27	663	2003-4	Schecter et al 2006[1]
USA	70	110	20	19	11	230	2001	Huwe et al 2005[2]
USA						420	2003	Schecter et al 2004[3]
Ireland	110	130	60	60	60	420	2004	FSAI 2005b[4]
Present study – Trent	233	167	31	54	29	515	2008	
Present study – Aire/Ouse	192	181	37	77	36	523	2010	

Notes
1. Concentrations calculated from fresh weight data using lipid content for beef tenderloin of 13.7% given by authors. Congener concentrations <LOD = 0.5LOD. Samples collected from national supermarket chains.
2. Sirloin steak samples (n=10) collected from supermarkets across USA.
3. Concentrations calculated from fresh weight data using lipid content given by authors of 13.6%. Congener concentrations <LOD=LOD. Samples collected from supermarkets in Dallas, Texas.
4. Samples (n= 10) collected directly from slaughter houses. Congener concentrations <LOD

Relatively few data on PBDEs in beef have been published. Table 4-10 suggest that the PBDE concentrations for the present study are comparable with samples from the USA and Ireland.

Summary

The analysis presented highlights a number of trends in the data from the meat samples. These are summarised below:

- There were no statistically significant difference between flood-prone and control sites farms for PCDD/F & PCB, dioxin-like PCB, PCDD/F or PBDE levels in meat.
- ∑ICES6 levels were significantly higher in meat from flood-prone farms.
- The animals used in this study were not market-ready and as such would not enter the food chain at this stage, or be subject to EU regulatory limits on dioxins and PCBs. They would have received a "finishing period" during which the animals would have received a greater proportion of commercial feed as opposed to silage and grass.

- Although these samples were not market ready under the regulations in place at the time of sampling 6 from 38 samples would have been above the maximum permitted level for PCDD/Fs and PCBs, 33 from 38 samples would have been above the dioxin-like PCB action level, 2 out of 38 samples would have exceeded the PCDD/F maximum level and 14 out of 38 meat samples would have been above the PCDD/F action level.
- Although these samples were not market ready, under the new 2011 regulations 6 from 38 samples would have been above the maximum permitted level for PCDD/Fs and PCBs, 13 from 38 samples would have been above the dioxin-like PCB action level, 2 out of 38 samples would have exceeded the PCDD/F maximum levels and 7 from 38 meat samples would have been above the PCDD action level.
- With respect to the revised 2011 regulations (Commission Regulation (EU) No 1259/2011 using WHO_{2005}- TEFs) for beef, it is clear that the number of samples that would have exceeded the MPLs remain unchanged irrespective of which regulation is used, but fewer samples would exceed the new recommended action levels.
- All of the samples were below the new maximum levels set for non dioxin-like (∑ICES6) PCBs (40ng/kg fat)
- PCDD/F and PCB TEQ levels were substantially higher than previously reported concentrations.
- PBDE concentrations were broadly comparable with previously published values.

Liver

Overall PCDD/F, PCB & PBDE concentrations in liver and variations by river system and type of site

As indicated earlier in this report, 38 liver samples were analysed. Table 4-11 presents a series of descriptive statistics for the PCDD/F & PCB concentrations in these samples subdivided by river system and type of site. Comparable data for the PBDE concentrations are presented in Table 4-12.

Table 4-11: Variations in the concentrations of PCDD/Fs & PCBs in liver by river system and type of site

Sample Group	Number of Samples	ng TEQ_{1998} /kg fat Minimum	Median	Mean	Maximum
Trent-Type of Site					
Control	8	4.59	6.74	7.62	12.45
Flood-prone	10	6.84	9.27	9.19	13.12
All Trent Samples	18	4.59	7.82	8.49	13.12
Aire/Ouse - Type of Site					
Control	10	1.34	8.22	15.03	52.62
Flood-prone	10	5.11	8.46	9.66	16.60
All Aire/Ouse Samples	20	1.34	8.44	12.35	52.62
All Samples – Type of Site					
Control	18	1.34	7.21	11.74	52.62
Flood-Prone	20	5.11	8.97	9.42	16.60
All Samples	38	1.34	8.02	10.52	52.62

Notes
A Mann-Whitney U test between the median values on each farm indicates no significant differences between type of site (p=0.327)

Table 4-12: Variations in the concentrations of PBDEs in liver by river system and type of site

Sample Group	Number of Samples	$\sum_7$ ng/kg fat Minimum	Median	Mean	Maximum
Trent-Type of Site					
Control	8	360	520	513	660
Flood-prone	10	370	520	564	910
All Trent Samples	18	360	520	541	910
Aire/Ouse - Type of Site					
Control	10	280	495	792	2080
Flood-prone	10	360	545	639	1240
All Aire/Ouse Samples	20	280	530	716	2080
All Samples – Type of Site					
Control	18	280	515	668	2080
Flood-Prone	20	360	530	602	1240
All Samples	38	280	530	633	2080

Notes
A Mann-Whitney U test between the median values on each farm indicates no significant differences between type of site (p=0.391)

The data presented in Table 4-11 indicate that all the PCDD/F & PCB concentrations fell within a range of between 1.34 and 52.62 (ngTEQ/kg fat). Levels on the Aire/Ouse appear higher the Trent. Table 4-11 presents mixed evidence that flood-prone farms have higher PCDD/F & PCB concentrations than control farms. Mean and median PCDD/F & PCB concentrations are higher on flood-prone farms on the Trent but this is less clear on the Aire/Ouse. The difference between flood-prone and control sites farms was not statistically significant.

Examination of the PBDE data presented in Table 4-12 indicates that the $\sum_7$ values range from 280 - 2080 ng/kg fat. Concentrations were similar on the Aire/Ouse in comparison to the River Trent. PBDE levels on flood-prone farms were similar to those on control farms. The differences between flood-prone and control farms was not statistically significant.

Comparisons between flood-prone and control farms are complicated by the small sample numbers in each subgroup. A more sophisticated method of comparison is to examine the differences in PCDD/F & PCB and PBDE concentrations between matched pairs of flood-prone and control farms. The liver PCDD/F & PCB concentrations for these farm pairs are presented in Table 4-13 and Figure 4.6, and the ∑ICES6 PCB concentrations in Table 4-14 and Figure 4.7. The dioxin like PCB concentrations are presented in Table 4-15 and Figure 4.8, the PCDD/F concentrations in Table 4-16 and Figure 4.9, and the PBDE concentrations in Table 4-17 and Figure 4.10. For the comparison concentrations between the two animals in each pair have been averaged.

In terms of flood-prone control comparisons mean PCDD/F & PCB levels and dioxin like PCB levels were higher in 7 from 10 farm pairs. In 6 from 10 farm pairs PCDD/F & PCB levels were higher in both flood-prone samples in comparison to the two control farm samples. In 7 from 10 farm pairs dioxin like PCB levels were higher in both flood-prone samples in comparison to the two control farm samples.

In 8 out of 10 flood-prone farm pairs, median ∑ICES6 PCB levels (Table 4-14 and Figure 4.7) were higher relative to their controls (for 8 of these, higher levels were observed in both animals). PCDD/F concentrations were higher in 7 from 10 pairs (For 6 of these, higher levels were observed in both animals relative to the two control farm samples). PBDE concentrations were higher in 8 from 10 pairs. In 3 from 10 farm pairs PBDE levels were higher in both flood-prone samples in comparison to the two control farm samples. For liver none of these differences between median levels on pairs of flood-prone and control farms for PCDD/F & PCBs, dioxin like PCBs, ∑ICES6, PCDD/Fs or PBDEs were statistically significant.

Table 4-13: Comparisons of PCDD/F & PCB concentrations in liver[1] by river system and type of site for matched pairs of farms

	ng TEQ_{1998} /kg fat			
	Flood-prone		Control	
Sample	Sample 1 , Sample 2	Mean	Sample 1 , Sample 2	Mean
Trent				
Pair 1	+13.12, 7.92	10.52	6.80, 6.68	6.74
Pair 2	6.84, 7.06	6.95	+12.45, 11.31	11.88
Pair 3	9.38, 11.74	10.56	5.52, 4.59	5.06
Pair 4	9.53, 9.41	9.47	6.55, 7.07	6.81
Pair 5	9.15, 7.71	8.43	6.55, 7.07&	6.81&
Aire/Ouse				
Pair 1	8.12, 8.79	8.46	+43.04, +52.62	47.83
Pair 2	+13.69, 9.27	11.48	7.34, 9.55	8.44
Pair 3	6.16, 7.74	6.95	10.36†, 7.68	9.02
Pair 4	+16.60, +14.73	15.66	6.80, 8.75	7.78
Pair 5	5.11, 6.37	5.74	2.86, 1.34	2.10

Notes
[1]These samples were not market ready as described in Ch 2
[&] Control farm same as used in pair 4 due to its close proximity to the flood-prone site in pair 5
[+] Samples exceeding Total TEQ maximum levels (12 ng TEQ/kg fat) in place at time of sampling
A Wilcoxon ranked signs test indicates no significant difference between type of site (p=0.386)

Although these samples were not market ready (See Chapter 2) and so not subject to regulation, the final thing to note on these tables is the numbers of samples that would have been above the regulation levels. Table 4-13 indicates that 7 from 38 liver samples would have been above the maximum permitted PCDD/F & PCB concentrations (12 $ngTEQ_{1998}$/kg fat) for liver under the prevailing EU regulations. This increases to 8 from 38 under the new maximum permitted concentrations (10.0 $ngTEQ_{2005}$/kg fat associated with the 2011 regulations). Table 4-15 indicates that 8 from 38 samples would have been above the dioxin-like PCB action levels prevailing at the time of sampling and analysis. There are no action levels for liver under the new recommendations (Commission Recommendation 2011/516/EU).

Figure 4.6: Mean and range of PCDD/F & PCB concentrations for matched pairs of farms

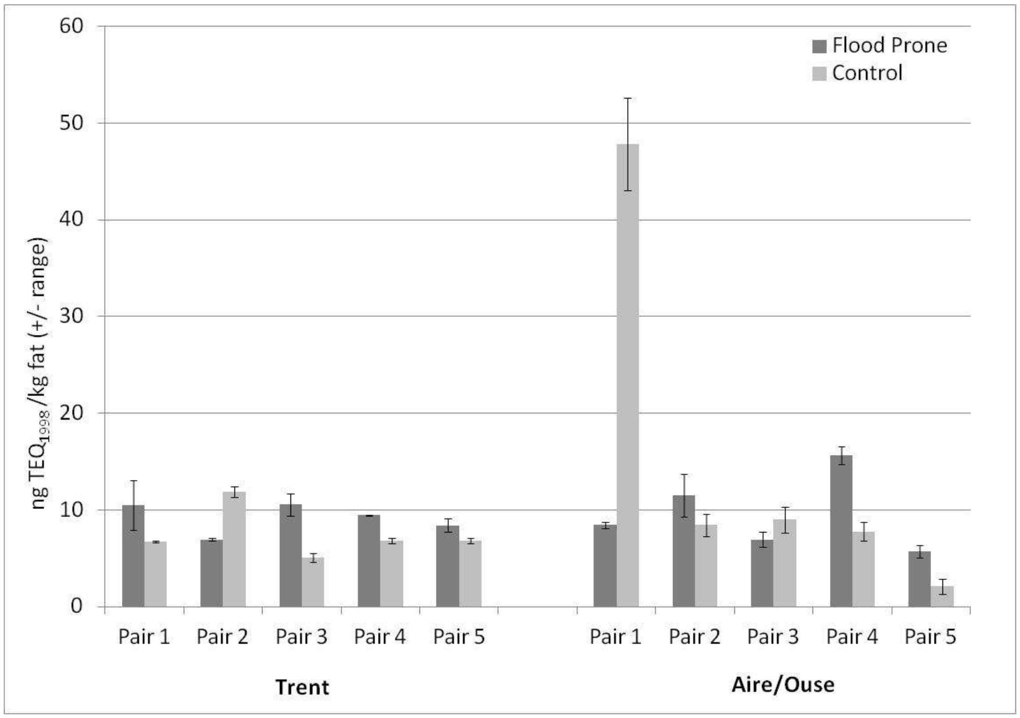


Table 4-14: Comparisons of ∑ICES6 PCB concentrations in liver by river system and type of site for matched pairs of farms

	µg/ kg fat			
	Flood-prone		Control	
Sample	Sample 1, Sample 2	Mean	Sample 1, Sample 2	Mean
Trent				
Pair 1	30.24, 40.69	35.47	15.16, 5.27	10.22
Pair 2	19.20, 16.12	17.66	12.08, 8.93	10.51
Pair 3	16.13, 16.33	16.23	10.53, 7.63	9.08
Pair 4	9.79, 5.75	7.77	8.21, 7.74	7.98
Pair 5	26.69, 11.81	19.25	8.21, 7.74[&]	7.98[&]
Aire/Ouse				
Pair 1	13.01, 11.95	12.48	24.66, 50.37	37.52
Pair 2	30.58, 16.81	23.70	6.15, 6.60	6.38
Pair 3	20.75, 26.23	23.49	18.34, 9.67	14.01
Pair 4	29.29, 20.85	25.07	3.78, 5.25	4.52
Pair 5	13.07, 21.28	17.18	11.52, 12.81	12.17

Notes
[&] Control farm same as used in pair 4 due to its close proximity to the flood-prone site in pair 5
A Wilcoxon ranked signs test indicates no significant difference between type of site (p=0.074)

Figure 4.7: Mean and range of ∑ICES6 PCB concentrations in liver by river system and type of site for matched pairs of farms

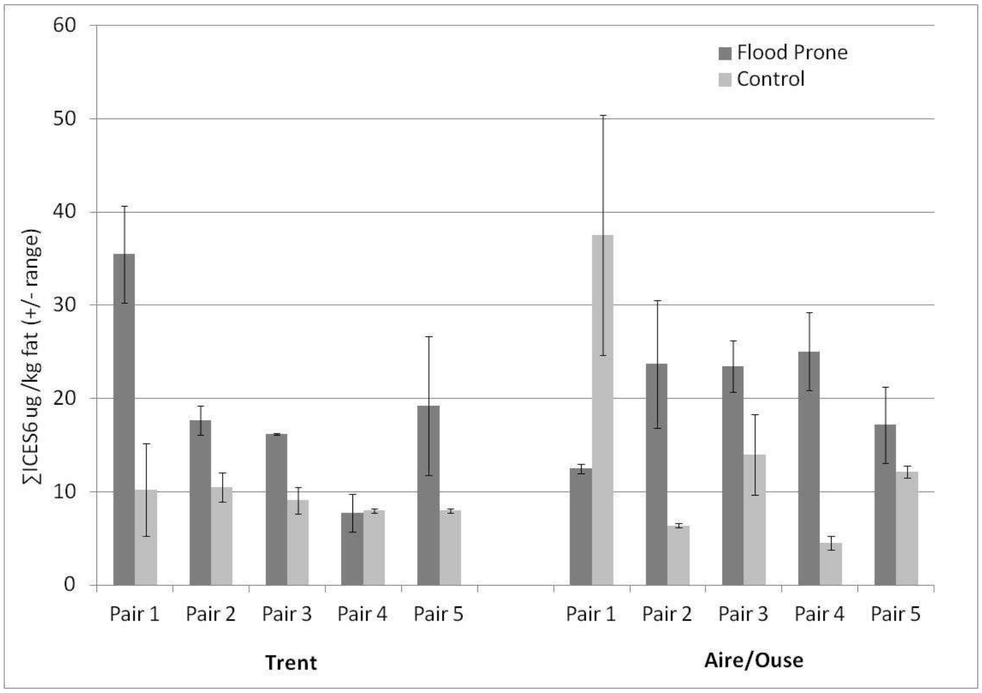
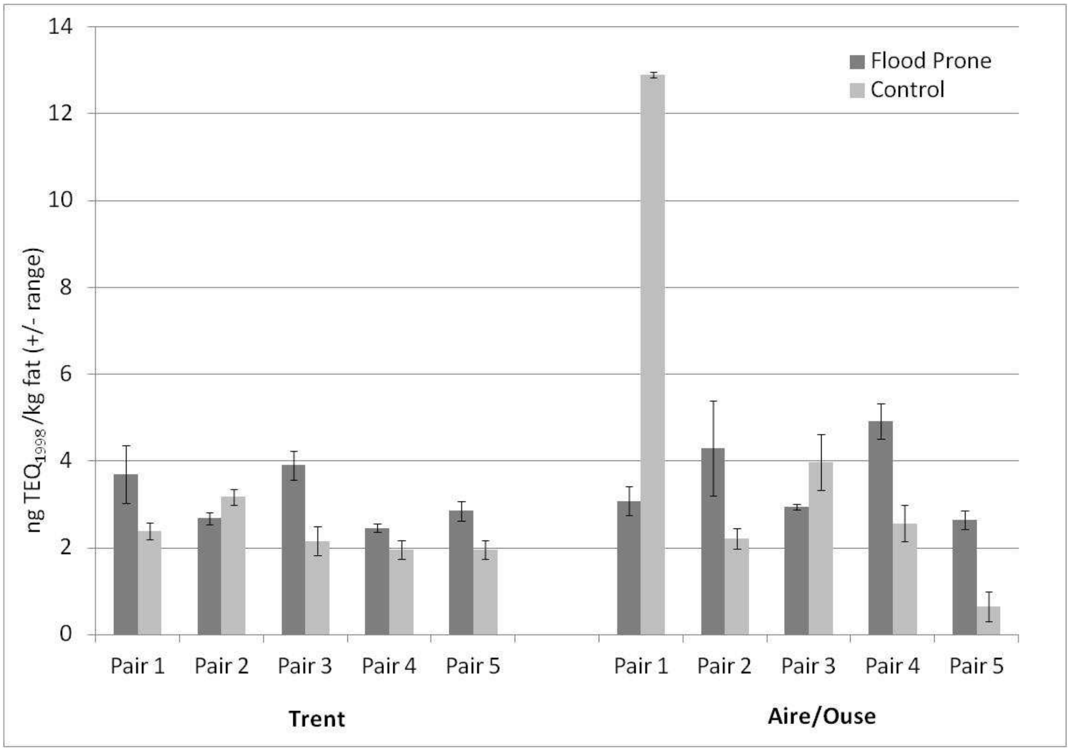


Table 4-15: Comparisons of dioxin-like PCB concentrations in liver[1] by river system and type of site for matched pairs of farms

	ng TEQ_{1998} /kg fat			
	Flood-prone		Control	
Sample	Sample 1 , Sample 2	Mean	Sample 1 , Sample 2	Mean
Trent				
Pair 1	†4.36, 3.03	3.70	2.59, 2.19	2.39
Pair 2	2.54, 2.82	2.68	2.98, 3.35	3.17
Pair 3	3.56, †4.23	3.90	2.49, 1.83	2.16
Pair 4	2.55, 2.37	2.46	1.74, 2.18	1.96
Pair 5	3.06, 2.63	2.85	1.74, 2.18[&]	1.96[&]
Aire/Ouse				
Pair 1	2.75, 3.41	3.08	†12.83, †12.96	12.90
Pair 2	†5.38, 3.20	4.29	1.94, 2.45	2.21
Pair 3	3.00, 2.89	2.95	†4.61, 3.33	3.97
Pair 4	†5.33, †4.51	4.92	2.14, 2.98	2.56
Pair 5	2.42, 2.85	2.64	0.99, 0.30	0.65

Notes
[1]These samples were not market ready as described in Ch 2
[&] Control farm same as used in pair 4 due to its close proximity to the flood-prone site in pair 5
†Samples exceeding dioxin-like PCB action levels (4 ngTEQ/kg fat) in place at time of sampling
A Wilcoxon ranked signs test indicates no significant difference between type of site (p=0.203)

Figure 4.8: Mean and range of dioxin like PCB concentrations for matched pairs of farms



Turning our attention to the PCDD/F data presented in Table 4-16 and Figure 4.9, PCDD/F concentrations were higher in 7/10 flood-prone farms in comparison to their control farm. This difference was not statistically significant. On six from 10 flood-prone farms levels were higher in both samples in comparison to the two samples from the control farm. Within the same proviso of the animals not being market-ready, the final thing to note on these tables is the numbers of samples that would have been above the maximum permitted levels and action levels. Table 4-16 indicates that 14 out of 38 (or 17 out of 38 using TEQ $_{2005}$ /2011regulations) liver samples would have been above the maximum permitted PCDD/F levels (6 ngTEQ$_{1998}$/kg fat or 4.5 ngTEQ $_{2005}$/kg fat under the new 2011regulations). In total 31 from 38 samples were above the prevailing dioxin action limits at the time. There are no action levels for liver under the new recommendations (Commission Recommendation 2011/516/EU).

The corresponding PBDE is presented in Table 4-17 and Figure 4.10. The results show very similar patterns to those evident in the PCDD/F and PCB data in that mean PBDE concentrations in liver from flood-prone farms were higher in 8/10 farm pairs. This difference is not statistically significant. In 3 from 10 pairs both liver samples from the flood-prone farms were higher than the 2 samples from the control farm.

Table 4-16: Comparisons of PCDD/F in liver[1] by river system and type of site for matched pairs of farms

	ng TEQ1998 /kg fat			
	Flood-prone		Control	
Sample	Sample 1 – Sample 2	Mean	Sample 1 - Sample 2	Mean
Trent				
Pair 1	*‡8.76, ‡4.89	6.82	‡4.21, ‡4.49	4.35
Pair 2	‡4.30, ‡4.24	4.27	*‡7.96, *‡9.47	8.72
Pair 3	‡5.82, *‡7.51	6.67	3.03, 2.76	2.90
Pair 4	*‡6.98, *‡7.04	7.01	‡4.81, ‡4.89	4.85
Pair 5	*‡6.09, ‡5.08	5.59	‡4.81, ‡4.89&	4.85&
Aire/Ouse				
Pair 1	‡5.37, ‡5.38	5.38	*‡30.21, *‡39.66	34.94
Pair 2	*‡8.31, *‡6.07	7.19	‡5.40, *‡7.10	6.25
Pair 3	3.16, ‡4.85	4.01	‡5.75, ‡4.35	5.05
Pair 4	*‡11.27, *‡10.22	10.75	‡4.66, ‡5.77	5.22
Pair 5	2.69, 3.52	3.11	1.87, 1.04	1.46

Notes
[1]These samples were not market ready as described in Ch 2
& Control farm same as used in pair 4 due to its close proximity to the flood-prone site in pair 5
* Samples exceeding dioxin maximum levels (6 ng TEQ/kg fat) in place at time of sampling
‡Samples exceeding dioxin action levels (4 ngTEQ/kg fat) in place at time of sampling
A Wilcoxon ranked signs test indicates no significant differences between type of site (p=0.514)

Figure 4.9: Mean and range of PCDD/F in liver for matched pairs of farms

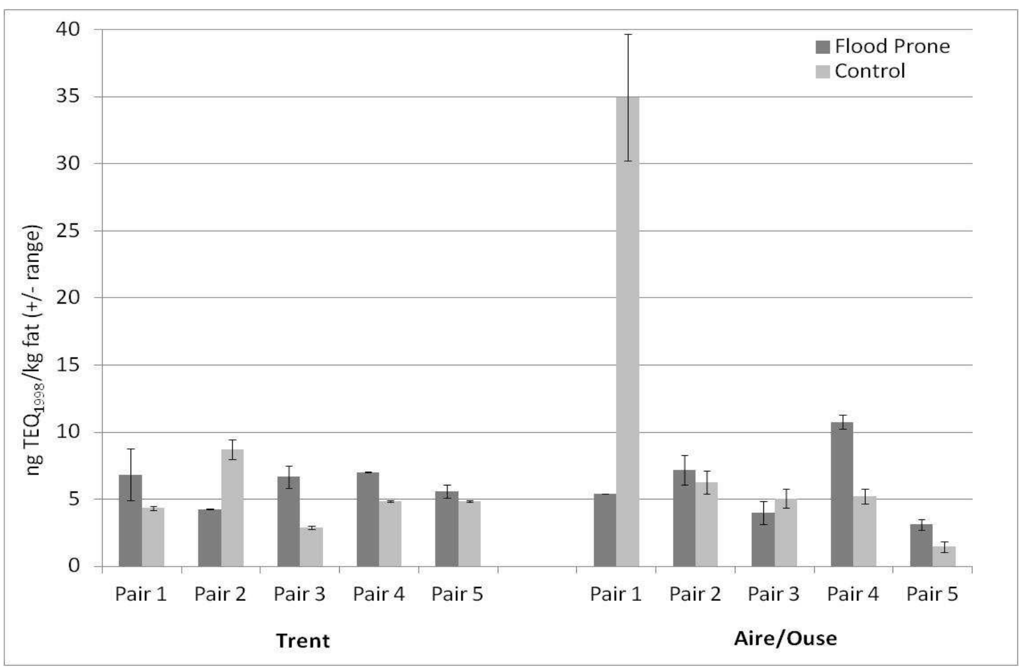


Table 4-17: Comparisons of PBDE concentrations in liver by river system and type of site for matched pairs of farms

	ng /kg fat			
	Flood-prone		Control	
Sample	Sample 1 , Sample 2	Mean	Sample 1 , Sample 2	Mean
Trent				
Pair 1	590, 370	480	360, 550	455
Pair 2	450, 450	450	660, 600	630
Pair 3	540, 580	560	590, 470	530
Pair 4	760,910	835	380,490	435
Pair 5	500, 490	495	380,490[&]	435[&]
Aire/Ouse				
Pair 1	510, 570	540	2050, 2080	2065
Pair 2	1240, 520	880	410, 450	430
Pair 3	810, 450	630	710, 540	625
Pair 4	710, 790	750	710, 350	530
Pair 5	360, 430	395	340, 280	310

Notes
[&] Control farm same as used in pair 4 due to its close proximity to the flood-prone site in pair 5
A Wilcoxon ranked signs test indicates no significant difference between type of site (p=0.241)

One notable feature of these data is the observation that liver samples with high PCDD/F & PCB concentrations tend to have high PBDE concentrations and vice versa. This was tested statistically using a spearman rank correlation which indicates a moderate correlation (Spearman's $\rho = 0.763$ $p < 0.001$) between PCDD/F & PCB and PBDE concentrations.

Comparison of the relative contributions of PCDD/Fs, non-ortho PCBs and ortho PCBs in liver

In order to examine trends in more detail the median percentage contribution of PCDD/Fs, non-ortho PCBs and ortho PCBs to total TEQ are presented in Table 4-18 subdivided by river system and type of site. The results indicate few differences between flood-prone and control farms or by river system.

Figure 4.10: Mean and range of PBDE concentrations in liver for matched pairs of farms

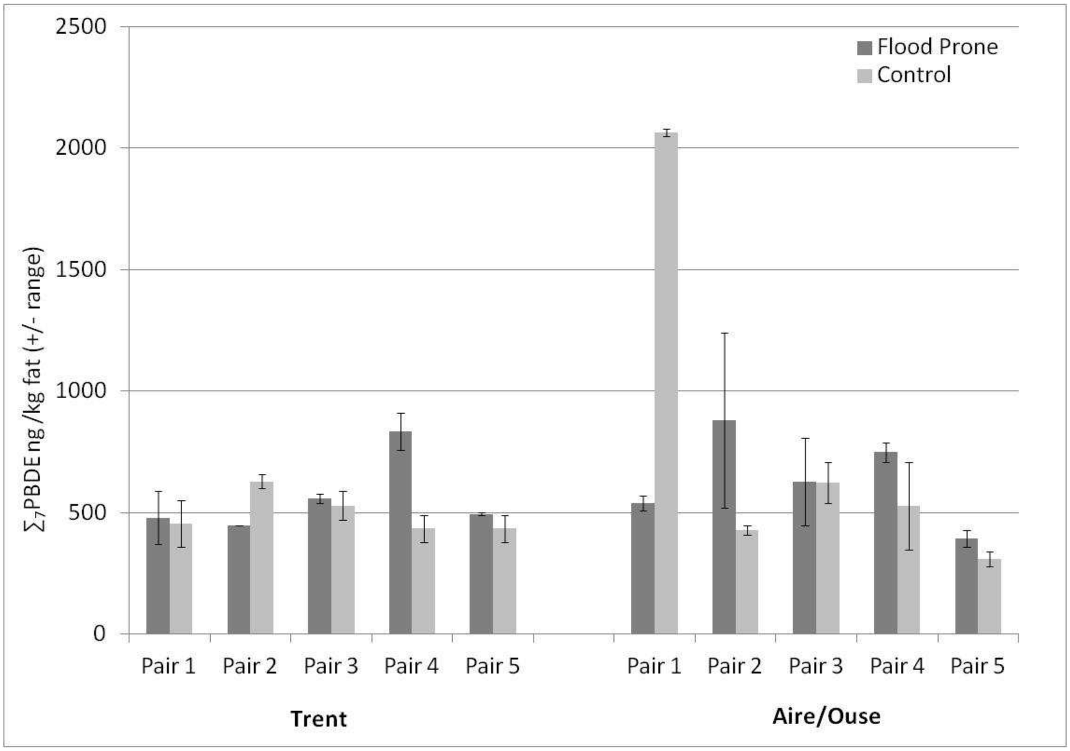


Table 4-18: Variations in the median percentage contribution of PCDD/Fs, Non-Ortho PCBs and Ortho PCBs to total TEQ in liver by river system and type of site

	% of Total WHO-TEQ$_{1998}$					
	PCDD/Fs		Non-Ortho PCBs		Ortho PCBs	
Sample Group	Control	Flood	Control	Flood	Control	Flood
Trent	68.19$_{(8)}$	64.93$_{(10)}$	29.77$_{(8)}$	32.02$_{(10)}$	2.05$_{(8)}$	3.20$_{(10)}$
Aire/Ouse	69.36$_{(10)}$	61.93$_{(10)}$	29.33$_{(10)}$	33.45$_{(10)}$	1.76$_{(10)}$	3.43$_{(10)}$

Notes
Numbers in **(subscript)** represent number of samples

Comparison with previous liver data

This section of the report compares the results from the present study to previous surveys. The results for PCDD/F & PCB concentrations are presented in Table 4-19. The corresponding PBDE data are given in Table 4-20.

Table 4-19: Comparison of mean PCDD/F and PCB concentrations (ng TEQ/kg fat) in liver from beef cattle with literature values.

PCDD/F TEQ	PCB TEQ non-ortho + ortho	Total TEQ[1]	%PCB TEQ contribution to total TEQ[1]	Sampling date	Reference
Ireland					
1.6	0.52	2.12	25	2004	FSAI 2005b[2]
UK					
2.29	1.62	3.91	41	2005	FSA 2006c[3]
1.95	1.30	3.25	40	2005	Fernandes et al 2010[4]
Present study - Trent					
5.69	2.81	8.49	34	2008	
Present study - Aire/Ouse					
8.33	4.01	12.35	35	2010	

Notes

1. Total concentrations of dioxins and PCBs may not equal the sum of individual dioxins and PCBs values due to rounding. % PCB TEQ contributions to total TEQ are calculated before rounding of PCB TEQ and total TEQ values.
2. Single retail sample.
3. Samples (n=3) from retail outlets. Range of total TEQ values 0.56-8.98.
4. Samples (n=13) of ox/calf liver from retail outlets.

Relatively little information on the levels of PCDD/Fs and PCBs in the livers of beef cattle is currently available and caution thus needs to be exercised when comparing the present data with previous literature values. An examination of the data in Table 4-19 does however suggest that the mean PCDD/F and PCB TEQ concentrations found in the present study are substantially higher than values published to date although the referred studies relate to retail foods. Again it is unknown how levels of PCDD/F and PCBs would alter during the period between when our samples were taken and when the animals were sent to market.

Table 4-20: Comparison of PBDE concentrations (ng/kg fat) in beef cattle liver samples with literature values

	BDE 47	BDE 99	BDE 100	BDE 153	BDE 154	$\sum_5$ BDE	Sampling date	Reference
Ireland	190	160	50	50	50	500	2004	FSAI 2005b[1]
USA	140	132	25	45	28	370	2003-4	Schechter et al 2006[2]
Ireland	140	120	40	60	20	380	2006-7	Fernandes et al 2009[3]
Present study - Trent	232	132	31	59	47	493	2008	
Present study - Aire/Ouse	217	219	37	97	61	630	2010	

Notes

1. Sample (n=1) collected from slaughterhouse (Congener values <LOD=LOD)
2. Concentrations calculated from fresh weight data using lipid content of 6.4% given by authors. Congener concentrations <LOD=LOD. Samples of calf liver collected from supermarkets.
3. Samples (n=2) collected at production/processing stage and destined for retail use.

The paucity of published data on the concentrations of PBDEs in the livers of beef cattle makes any comparisons somewhat tentative. However, a study of the data in Table 4-20 indicates that the individual and the $\sum_5$ congener levels found in the present study are consistent with the limited data reported thus far.

Summary

The analysis presented in the above sections highlight a number of trends in the data from the liver samples. These are summarised below:

- For liver none of the differences between flood-prone and control farms for PCDD/F & PCBs, dioxin like PCBs, ∑ICES6, PCDD/Fs or PBDEs were statistically significant
- Although these samples were not market ready 7 out of 38 (or 8 out of 38 using TEQ $_{2005}$ /2011 regulations) liver samples would have been above the maximum level. Similarly 14 out of 38 (or 17 out of 38 using TEQ $_{2005}$ /2011regulations) liver samples would have been above the maximum level for PCDD/Fs.
- It is clear that if the revised 2011 regulations (Commission Regulation (EU) No 1259/2011 using WHO $_{2005}$- TEFs) were applied then the number of samples that would have exceeded the maximum levels remain broadly similar (with a few more samples exceeding the limits under the new regulations).
- Under the new 2011 regulation, one sample from a control farm on the Aire/Ouse would have exceeded the maximum level for non-dioxin-like PCBs (40 µg/kg fat)

- Mean PCDD/F and PCB concentrations appear to be higher than previously reported
- PBDE concentrations are consistent with the limited data reported to date

Kidney

Overall PCDD/F & PCB and PBDE concentrations in kidney and variations by river system and type of site

As indicated earlier in this report, 12 kidney samples were analysed. Table 4-21 presents a series of descriptive statistics for the PCDD/F & PCB concentrations in these samples subdivided by river system and type of site. Comparable data for the PBDE concentrations are presented in Table 4-22. Low sample numbers prevents the use of statistical tests in this section of the report.

Table 4-21: Variations in the concentrations of PCDD/Fs & PCBs in kidney by river system and type of site

Sample Group	Number of Samples	ng TEQ_{1998} /kg fat Minimum	Median	Mean	Maximum
Trent - Type of Site					
Control	2	2.40	2.52	2.52	2.64
Flood-prone	2	2.51	3.37	3.37	4.23
All Trent Samples	4	2.40	2.58	2.95	4.23
Aire/Ouse - Type of Site					
Control	4	1.52	2.50	2.51	3.52
Flood-prone	4	4.13	4.68	4.62	4.97
All Aire/Ouse Samples	8	1.52	3.83	3.56	4.97
All Samples – Type of Site					
Control	6	1.52	2.52	2.51	3.52
Flood-prone	6	2.51	4.32	4.20	4.97
All Samples	12	1.52	3.34	3.36	4.97

Table 4-22: Variations in the concentrations of PBDEs in kidney by river system and type of site

Sample Group	Number of Samples	$\sum_7$ ng/kg fat Minimum	Median	Mean	Maximum
Trent - Type of Site					
Control	2	310	390	390	470
Flood-prone	2	210	395	395	580
All Trent Samples	4	210	390	393	580
Aire/Ouse - Type of Site					
Control	4	250	290	305	390
Flood-prone	4	460	845	795	1030
All Aire/Ouse Samples	8	250	425	550	1030
All Samples – Type of Site					
Control	6	250	315	333	470
Flood-prone	6	210	680	662	1030
All Samples	12	210	425	498	1030

The data presented in Table 4-21 indicate that all the PCDD/F & PCB concentrations fell within a range of 1.52 – 4.97 (ngTEQ/kg fat). This table presents some evidence of elevated levels in kidney on flood-prone land. Table 4-22 presents comparable data for PBDE concentrations and the $\sum_7$ values range from 210 – 1030 (ng/kg fat). The data generally correlate well the PCDD/F and PCB data, presenting some evidence of elevated levels in kidney on flood-prone land.

For both these tables comparisons between flood-prone and control sites are complicated by the small sample numbers in each subgroup. A more sophisticated method of comparison is to examine the differences in the PCDD/F & PCB and PBDE concentrations between matched pairs of flood-prone and control farms. Three such pairs were identified as part of the experimental design. The mean PCDD/F & PCB concentrations for kidneys from these pairs of farms are presented in Table 4-23, the ∑ICES6 PCB levels in Table 4-24, the dioxin like PCB levels in Table 4-25, the PCDD/F data in Table 4-26 and the PBDE data are given in Table 4-27. For the comparison concentrations for the two animals in each pair have been averaged.

Table 4-23: Comparisons of PCDD/F & PCB concentrations in kidney by river system and type of site for matched pairs of farms

	ng TEQ_{1998} /kg fat			
	Flood-prone		Control	
Sample	Sample 1 – Sample 2	Mean	Sample 1 - Sample 2	Mean
Trent				
Pair 1	4.23, 2.51	3.37	2.64, 2.40	2.52
Pair 2				
Pair 3				
Pair 4				
Pair 5				
Aire/Ouse				
Pair 1				
Pair 2	4.96, 4.40	4.68	3.52, 3.15	3.34
Pair 3				
Pair 4	4.97, 4.13	4.55	1.52, 1.84	1.68
Pair 5				

Table 4-24: Comparisons of ∑ICES6 concentrations in kidney by river system and type of site for matched pairs of farms

	∑ICES6 PCBs, µg/ kg fat			
	Flood-prone		Control	
Sample	Sample 1, Sample 2	Mean	Sample 1, Sample 2	Mean
Trent				
Pair 1	12.55, 8.50	10.53	4.79, 3.03	3.91
Pair 2				
Pair 3				
Pair 4				
Pair 5				
Aire/Ouse				
Pair 1				
Pair 2	6.88, 5.74	6.31	3.03, 2.58	2.81
Pair 3				
Pair 4	6.31, 4.79	5.55	1.63, 2.74	2.19
Pair 5				

Table 4-25: Comparisons of dioxin-like PCB concentrations in kidney by river system and type of site for matched pairs of farms

	Dioxin-like PCBs ng TEQ_{1998} /kg fat			
	Flood-prone		Control	
Sample	Sample 1 – Sample 2	Mean	Sample 1 - Sample 2	Mean
Trent				
Pair 1	2.20, 1.49	1.85	1.52, 1.19	1.36
Pair 2				
Pair 3				
Pair 4				
Pair 5				
Aire/Ouse				
Pair 1				
Pair 2	2.76, 2.07	2.42	1.37, 1.25	1.31
Pair 3				
Pair 4	2.49, 1.86	2.18	0.78, 1.07	0.93
Pair 5				

Table 4-26: Comparisons of PCDD/F concentrations in kidney by river system and type of site for matched pairs of farms

	PCDD/F ng TEQ_{1998} /kg fat			
	Flood-prone		Control	
Sample	Sample 1 – Sample 2	Mean	Sample 1 - Sample 2	Mean
Trent				
Pair 1	4.23, 2.51	3.37	2.64, 2.40	2.52
Pair 2				
Pair 3				
Pair 4				
Pair 5				
Aire/Ouse				
Pair 1				
Pair 2	4.96 , 4.40	4.68	3.52, 3.15	3.34
Pair 3				
Pair 4	4.97, 4.13	4.55	1.52, 1.84	1.68
Pair 5				

Examination of the data in Table 4-23, Table 4-24, Table 4-25, Table 4-26 and Table 4-27 shows that the mean PCDD/F & PCB, ∑ICES6, dioxin like PCB, and PCDD/F concentrations for the samples from the 3 flood-prone farms are higher than those from the respective control farms. For ∑ICES6 on all 3 farm pairs, levels were higher in both flood-prone samples in comparison to the two control samples. For

PCDD/F & PCB, dioxin like PCB, PCDD/F and PBDE 2 from 3 farms had levels which were higher in both flood-prone samples in comparison to the two control samples.

Table 4-27: Comparisons of PBDE concentrations in kidney by river system and type of site for matched pairs of farms

	ng/kg fat			
	Flood-prone		Control	
Sample	Sample 1 – Sample 2	Mean	Sample 1 - Sample 2	Mean
Trent				
Pair 1	580, 210	395	310, 470	390
Pair 2				
Pair 3				
Pair 4				
Pair 5				
Aire/Ouse				
Pair 1				
Pair 2	910, 460	685	320, 390	355
Pair 3				
Pair 4	1030, 780	905	260, 250	255
Pair 5				

Comparison of the relative contributions of PCDD/Fs, Non-Ortho PCBs and Ortho PCBs in kidney

In order to examine trends in more detail the median percentage contribution of PCDD/Fs, Non-Ortho PCBs and Ortho PCBs to total TEQ are presented in Table 4-28 subdivided by river system and type of site . The results indicate few differences between flood-prone and control farms or by river system.

Table 4-28: Variations in the median percentage contribution of PCDD/Fs, Non-Ortho PCBs and Ortho PCBs to total TEQ in kidney by river system and type of site

	% of Total WHO-TEQ_{1998}					
	PCDD/Fs		Non-Ortho PCBs		Ortho PCBs	
Sample Group	Control	Flood	Control	Flood	Control	Flood
Trent	$46.42_{(2)}$	$44.31_{(2)}$	$43.77_{(2)}$	$46.01_{(2)}$	$9.81_{(2)}$	$9.67_{(2)}$
Aire/Ouse	$54.50_{(4)}$	$51.42_{(4)}$	$40.32_{(4)}$	$41.39_{(4)}$	$5.18_{(4)}$	$7.18_{(4)}$

Notes: Numbers in **(subscript)** represent number of samples

Comparison with previous kidney data

To our knowledge, no previous literature values exist for kidney from beef cattle.

Summary

The analysis presented in the above sections highlights a number of trends in the data from the kidney samples. These are summarised below:

- Differences in kidney between flood-prone and control sites could not be tested statistically due to low sample numbers
- Levels in kidney were very similar to those in meat

Soil

Overall PCDD/F & PCB and PBDE concentrations in soil and variations by river system and type of site

As indicated earlier in this report, 18 soil samples were analysed, 9 from flood-prone farms and 9 from control farms. Table 4-29 presents a series of descriptive statistics for the PCDD/F & PCB concentrations in these samples subdivided by river system and type of site. Comparable data for the PBDE concentrations are presented in Table 4-30.

Table 4-29: Variations in the concentrations of PCDD/Fs & PCBs in soil by river system and type of site

	Number	ng TEQ_{1998} /kg dry weight			
Sample Group	of Samples	Minimum	Median	Mean	Maximum
Trent - Type of Site					
Control	4	2.66	6.75	6.31	9.10
Flood-prone	4	5.71	19.23	17.68	26.55
All Trent Samples	8	2.66	8.23	12.00	26.55
Aire/Ouse - Type of Site					
Control	5	3.21	4.84	4.61	5.51
Flood-prone	5	6.22	7.96	10.04	19.27
All Aire/Ouse Samples	10	3.21	5.87	7.33	19.27
All Samples – Type of Site					
Control	9	2.66	5.41	5.37	9.10
Flood-prone	9	5.71	9.22	13.44	26.55
All Samples	18	2.66	6.79	9.40	26.55

Notes: A Mann-Whitney U test indicates a significant difference by type of site ($p=0.03$)

The data presented in Table 4-29 indicate that the PCDD/F & PCB concentrations in soil were variable ranging from 2.66 to 26.55 (ng TEQ /kg dry weight). A similar variability occurred with PBDE concentrations ranging from 180 to 16540 ($\sum_7$ ng/kg dry weight). This is a very wide range. The soil concentrations of PCDD/Fs & PCBs and PBDEs for the matched pairs of flood-prone and control farms are presented in Figure 4.11and Figure 4.12.

Table 4-30: Variations in the concentrations of PBDEs in soil by river system and type of site

Sample Group	Number of Samples	Minimum	∑₇ ng/kg dry weight Median	Mean	Maximum
Trent-Type of Site					
Control	4	180	355	335	450
Flood-prone	4	230	850	2623	8560
All Trent Samples	8	180	380	1479	8560
Aire/Ouse - Type of Site					
Control	5	480	720	862	1330
Flood-prone	5	1690	8260	8106	16540
All Aire/Ouse Samples	10	480	1510	4484	16540
All Samples – Type of Site					
Control	9	180	480	628	1330
Flood-prone	9	230	4940	5669	16540
All Samples	18	180	980	3148	16540

Notes: A Mann-Whitney U test indicates a significant difference by type of site (p=0.024)

Table 4-29 presents suggests that soil from flood-prone farms has higher PCDD/Fs & PCBs concentrations. The mean and median values are higher on all flood-prone farms in comparison to control sites. These contrasts are statistically significant ($p<0.05$). Turning our attention to PBDE concentrations, Table 4-30 indicates that the mean and median PBDE concentrations were also higher on flood-prone farms. These contrasts are also statistically significant ($p<0.05$). Stronger evidence emerges from Table 4-31 and Figure 4.11 which indicate that the concentrations of PCDD/Fs & PCBs in soil are higher on 8 from 9 flood-prone farms in comparison to their controls. Table 4-31 and Figure 4.12 also indicate a similar result with PBDE concentrations higher on 7 from 9 flood-prone versus control farms. Both these contrasts are statistically significant ($p<0.05$). On each river system there is a high level of farm to farm variation in PCDD/Fs & PCBs but especially PBDE levels.

Table 4-31: Comparisons of PCDD/F & PCB and PBDE concentrations in soil by river system and type of site for matched pairs of farms

	PCDD/F & PCB ng TEQ_{1998} /kg dry weight		PBDE $\sum_7$ ng/kg dry weight	
Sample	Flood-prone	Control	Flood-prone	Control
Trent				
Pair 1	26.55	2.66	1340	180
Pair 2	13.37	9.10	360	400
Pair 3	5.71	6.13	230	310
Pair 4	25.09	7.36	8560	450
Pair 5				
Aire/Ouse				
Pair 1	6.22	3.21	4940	720
Pair 2	9.22	4.84	1690	540
Pair 3	19.27	5.51	16540	1240
Pair 4	7.55	4.08	9100	480
Pair 5	7.96	5.41	8260	1330

Notes
In terms of PCDD/F and PCBs a Wilcoxon ranked signs test indicates a significant difference between type of site (p=0.011)
In terms of PBDEs a Wilcoxon ranked signs test indicates a significant difference between type of site (p=0.021)

Figure 4.11: Mean PCDD/F & PCB and concentrations in soil for matched pairs of farms

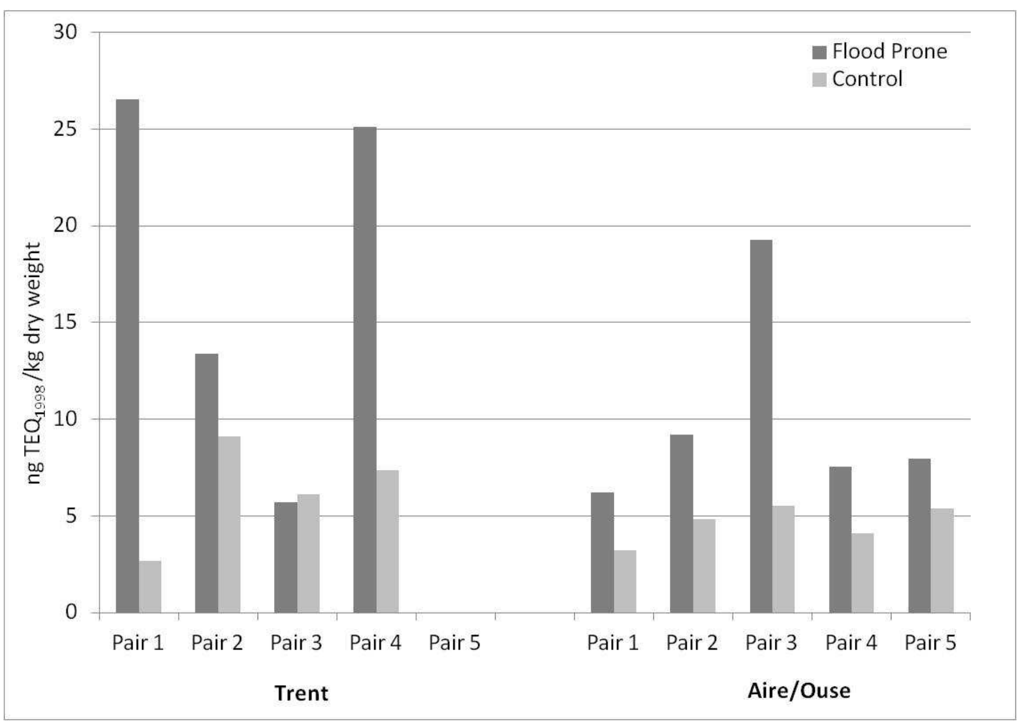
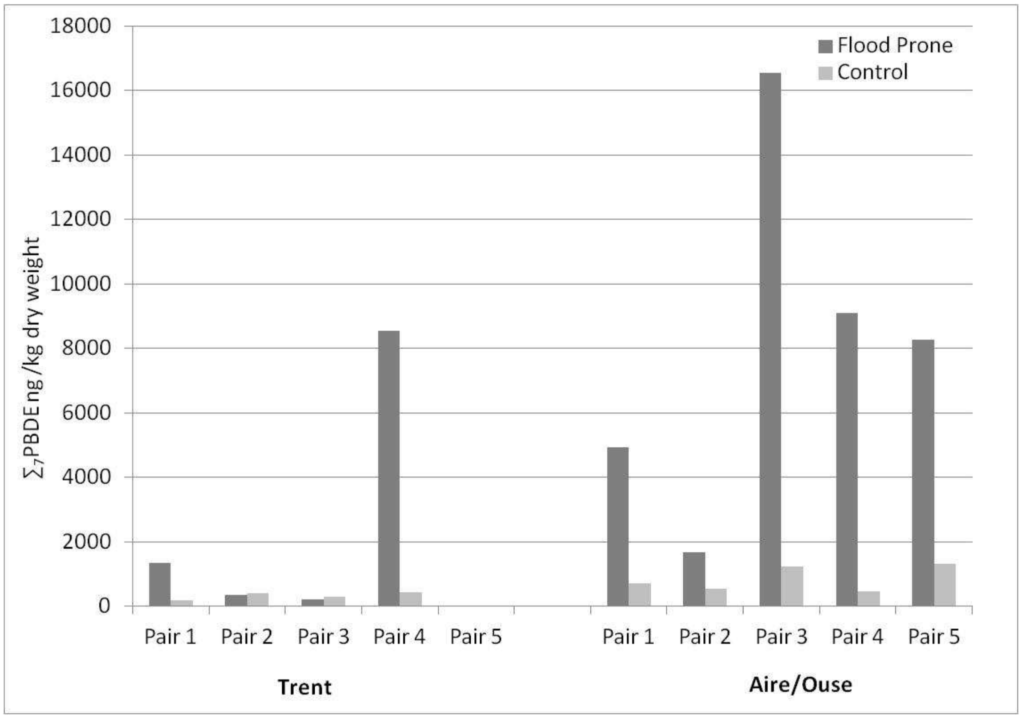


Figure 4.12: Mean PBDE concentrations in soil for matched pairs of farms



Again a correspondence between PCDD/F & PCB and PBDE concentrations emerges and a Spearman rank correlation test indicates a moderate correlation (Spearman's $\rho = 0.488$, $p < 0.05$) between PCDD/F & PCB and PBDE concentrations.

Comparison of TEQ and PBDE levels from adjacent sites on selected farms

The impact of flooding was examined further by comparing samples of soil simultaneously collected from pairs of flood-prone and control sites situated in the same field. Two such samples were collected from Farm pair 1 on the Aire/Ouse during the second sampling phase.

The TEQ and PBDE concentrations for the two samples are given in Table 4-32. The results clearly show that the TEQ and PBDE concentrations are higher on the flood-prone site in comparison to the control site. In view of the close proximity of each flood-prone site to the corresponding control, it would seem unlikely that differences in PCDD/F & PCB and PBDE aerial deposition rates would explain the differences observed. It would thus seem more likely that the elevated concentrations in soil from such flood-prone sites are associated with flooding events.

Table 4-32: TEQ concentrations in pairs of soil samples simultaneously collected from flood-prone and control locations in the same field

Comparison	PCDD/F & PCB ng TEQ_{1998} /kg dry weight		PBDE $\sum_7$ ng/kg dry weight	
	Flood-prone	Non-Flood-prone	Flood-prone	Non-Flood-prone
Aire/Ouse – Flood-prone farm Pair 1	6.22	1.41	4940	2020

Comparison with previous soil data

For previous soil data see similar section in Chapter 3.

Summary

The analysis presented in the above sections highlights a number of trends in the data from the soil samples. These are summarised below:

- PCDD/F & PCBs and PBDE levels in soil are significantly higher on flood-prone farms
- Considerable variations in PCDD/F & PCB and PBDE levels occur between flood-prone and control farms

Grass

Overall PCDD/F & PCB and PBDE concentrations in grass and variations by river system and type of site

As indicated earlier in this report, 18 grass samples were analysed. Table 4-33 presents a series of descriptive statistics for the PCDD/F & PCB concentrations in these samples subdivided by river system and type of site. Comparable data for the PBDE concentrations are presented in Table 4-34.

Table 4-33: Variations in the concentrations of PCDD/Fs & PCBs in grass by river system and type of site

Sample Group	Number of Samples	ng TEQ_{1998} /kg dry weight Minimum	Median	Mean	Maximum
Trent-Type of Site					
Control	4	0.26	0.30	0.29	0.32
Flood-prone	4	0.52	1.10	1.05	1.49
All Trent Samples	8	0.26	0.42	0.67	1.49
Aire/Ouse - Type of Site					
Control	5	0.96	1.20	1.20	1.37
Flood-prone	5	0.49	1.22	1.20	2.41
All Aire/Ouse Samples	10	0.49	1.21	1.20	2.41
All Samples – Type of Site					
Control	9	0.26	0.96	0.79	1.37
Flood-prone	9	0.49	1.22	1.13	2.41
All Samples	18	0.26	1.08	0.96	2.41

Notes: A Mann-Whitney U test indicates no significant difference by type of site (p=0.133)

Table 4-34: Variations in PBDEs concentrations in grass by river system and type of site

Sample Group	Number of Samples	Minimum	$\sum_7$ ng/kg dry weight Median	Mean	Maximum
Trent-Type of Site					
Control	4	130	175	183	250
Flood-prone	4	790	1170	1135	1410
All Trent Samples	8	130	520	659	1410
Aire/Ouse - Type of Site					
Control	5	310	320	378	490
Flood-prone	5	590	670	1092	2160
All Aire/Ouse Samples	10	310	540	735	2160
All Samples – Type of Site					
Control	9	130	310	290	490
Flood-prone	9	590	1070	1111	2160
All Samples	18	130	540	701	2160

Notes: A Mann-Whitney U test indicates a significant difference by type of site ($p<0.001$)

The data presented in Table 4-33 indicate that the PCDD/F & PCB concentrations in grass were variable ranging from 0.26 to 2.41 (ng TEQ /kg dry weight). A similar variability occurred with PBDE concentrations ranging from 130 to 2160 ($\sum_7$ ng/kg dry weight). The grass concentrations of PCDD/Fs & PCBs and PBDEs for the matched pairs of flood-prone and control farms are presented in Table 4-35.

Table 4-35: Comparisons of PCDD/F & PCB and PBDE concentrations in grass by river system and type of site for matched pairs of farms

Comparison	PCDD/F & PCB ng TEQ_{1998} /kg dry weight Flood-prone	Control	PBDE $\sum_7$ ng/kg dry weight Flood-prone	Control
Trent - Pair 1	1.29	0.32	1270	250
Trent - Pair 2	0.52	0.27	790	180
Trent - Pair 3	0.90	0.26	1070	170
Trent - Pair 4	1.49	0.32	1410	130
Trent - Pair 5				
Aire/Ouse - Pair 1	1.22	1.20	630	310
Aire/Ouse - Pair 2	0.51	1.37	670	320
Aire/Ouse - Pair 3	2.41	0.96	2160	490
Aire/Ouse - Pair 4	0.49	1.20	590	320
Aire/Ouse - Pair 5	1.37	1.25	1410	450

Notes
In terms of PCDD/F and PCBs a Wilcoxon ranked signs test indicates no significant difference between type of site ($p=0.173$)
In terms of PBDEs a Wilcoxon ranked signs test indicates a significant difference between type of site ($p=0.008$)

Table 4-33 indicates that grass from flood-prone farms has higher PCDD/F & PCB concentrations. The mean and median values are higher on flood-prone farms in comparison to control sites. These were not statistically significant. Turning our attention to PBDE concentrations, Table 4-34 indicates that the mean and median PBDE concentrations were higher on flood-prone farms. This was statistically significant. Stronger evidence emerges from Table 4-35 which indicates that the concentrations of PCDD/Fs & PCBs in grass are higher on 7 out of 9 flood-prone farms in comparison to their controls. All 9 pairs had higher PBDE concentrations on flood-prone sites. Again contrasts between flood-prone and control sites for PCDD/Fs & PCBs in grass were not significant. Contrasts were significant for PBDEs.

Again a correspondence between PCDD/F & PCB and PBDE concentrations emerges and a Spearman rank correlation test indicates a moderate correlation (Spearman's $\rho = 0.693$, $p < 0.01$) between PCDD/F & PCB and PBDE concentrations.

Comparison of TEQ levels from adjacent sites on selected farms

One way to examine further the impact of flooding would be to compare samples of grass simultaneously collected from pairs of flood-prone and control sites situated in the same field. Two such samples were collected from Farm pair 1 on the River Ouse during the second sampling phase.

The TEQ and PBDE concentrations for the two samples are given in Table 4-36. The results show that the TEQ and PBDE levels were marginally higher on the flood-prone site in comparison to the control site.

Table 4-36: TEQ concentrations in pairs of grass samples simultaneously collected from flood-prone and control locations in the same field

Comparison	PCDD/F & PCB ng TEQ_{1998} /kg dry weight		PBDE $\sum_7$ ng/kg dry weight	
	Flood-prone	Non-Flood-prone	Flood-prone	Non-Flood-prone
Ouse – Flood-prone farm Pair 1	1.22	1.14	630	550

Comparison with previous grass data

For previous grass data refer to section in dairy chapter 3.

Summary

The analysis presented in the above sections highlights a number of trends in the data from the soil samples. These are summarised below:

- PCDD/F & PCBs were not significantly higher on flood-prone farms.
- PBDE concentrations were significantly higher on flood-prone farms.

Feed

Overall PCDD/F & PCB and PBDE concentrations in feed and variations by river system and type of site

As indicated earlier in this report, 10 feed samples were analysed. Table 4-37 presents a series of descriptive statistics for the PCDD/F & PCB concentrations in these samples subdivided by river system and type of site. Comparable data for the PBDE concentrations are presented in Table 4-38.

Table 4-37: Variations in the concentrations of PCDD/Fs & PCBs in feed by river system and type of site

Sample Group	Number of Samples	ng TEQ_{1998} /kg whole weight Minimum	Median	Mean	Maximum
Trent-Type of Site					
Control	2	0.06	0.06	0.06	0.06
Flood-prone	1	0.06	0.06	0.06	0.06
All Trent Samples	3	0.06	0.06	0.06	0.06
Aire/Ouse - Type of Site					
Control	3	0.06	0.06	0.06	0.07
Flood-prone	4	0.06	0.06	0.06	0.07
All Aire/Ouse Samples	7	0.06	0.06	0.06	0.07
All Samples – Type of Site					
Control	5	0.06	0.06	0.06	0.07
Flood-prone	5	0.06	0.06	0.06	0.07
All Samples	10	0.06	0.06	0.06	0.07

Notes
A Mann Whitney U test indicates no significant difference by type of site (p= 1.00)

Table 4-38: Variations in PBDE concentrations in feed by river system and type of site

Sample Group	Number of Samples	$\sum_7$ ng/kg whole weight Minimum	Median	Mean	Maximum
Trent-Type of Site					
Control	2	70	75	75	80
Flood-prone	1	70	70	70	70
All Trent Samples	3	70	70	73	80
Aire/Ouse - Type of Site					
Control	3	70	70	70	70
Flood-prone	4	70	70	88	140
All Aire/Ouse Samples	7	70	70	80	140
All Samples – Type of Site					
Control	5	70	70	72	80
Flood-prone	5	70	70	84	140
All Samples	10	70	78	70	140

Notes: A Mann Whitney U test indicates no significant difference by type of site (p= 0.881)

The data presented in Table 4-37 indicate that the PCDD/F & PCB concentrations in feed samples were similar ranging from 0.06-0.07 (ng TEQ /kg whole weight). Part of the reason for this narrow range was the relatively low occurrence of these contaminants in feed which resulted in many of the congeners being below the method limits of detection. The PBDE concentrations were slightly more variable at between 70 and 140 ($\sum_7$ ng/kg whole weight). Again many of the congeners were present at below the limits of detection. The feed concentrations of PCDD/Fs & PCBs and PBDEs for the matched pairs of flood-prone and control farms are presented in Table 4-39.

Table 4-37, Table 4-38 and Table 4-39 present no evidence that feed from flood-prone farms has higher PCDD/F & PCBs or PBDE concentrations than control farms.

Comparison with previous feed data

This section of the report compares the results from the present study to previous surveys of PCDD/F, PCB and PBDE concentrations in feed. The results for PCDD/F & PCB concentrations are presented in Table 4-40. No previous data on PBDE concentration in feed are available.

Table 4-39: Comparisons of PCDD/F & PCB and PBDE concentrations in feed by river system and type of site for matched pairs of farms

Comparison	PCDD/F & PCB ng TEQ_{1998} /kg whole weight Flood-prone	Control	PBDE $\sum_7$ ng/kg whole weight Flood-prone	Control
Trent - Pair 1		0.06		70
Trent - Pair 2				
Trent - Pair 3				
Trent - Pair 4		0.06		80
Trent - Pair 5	0.06		70	
Aire/Ouse - Pair 1	0.07		140	
Aire/Ouse - Pair 2				
Aire/Ouse - Pair 3	0.06	0.07	70	70
Aire/Ouse - Pair 4	0.06	0.06	70	70
Aire/Ouse - Pair 5	0.06[1]	0.06	70[1]	70

Notes: [1] Same feed used as on Aire/Ouse flood-prone pair 3

Table 4-40: Comparison of mean PCDD/F and PCB concentrations (ngTEQ/kg whole weight) in commercial beef cattle feed with UK literature values

PCDD/F TEQ	PCB TEQ non-ortho + ortho	Total TEQ[1]	%PCB TEQ contribution to total TEQ[1]	Sampling date	Reference
0.04	0.02	0.06	42	2003/4	Fernandes et al 2004[2]
0.04	0.03	0.07	46	2005/2006	Fernandes et al 2006[3]
0.03	0.03	0.06	48	2009/10	Present study[4]

Notes

1. Total concentrations of dioxins and PCBs may not equal the sum of individual dioxin and PCB values due to rounding.
2. Samples of commercial cattle feed (n=9) from farms/feed mills in England, Wales and Northern Ireland. In the absence of dairy designation, samples assumed to be destined for beef cattle.
3. Samples of commercial cattle feed (n=13) from UK farms/feed mills. Not clear from report whether samples destined for dairy or beef herds.
4. Samples of commercial beef cattle feed (n=10) from farms on Rivers Trent, Aire and Ouse.

Very few data on levels of PCDD/Fs and PCBs in commercial dairy commercial feed have been published. However, mean PCDD/F TEQ and total TEQ concentrations from our sample farms from the present study agree closely with the data arising from other studies.

Summary

The analysis presented in the above sections highlights trends in the data from the feed samples. These are summarised below:

- PCDD/F & PCBs and PBDEs concentrations in feed between flood-prone and control sites were not significantly different.
- PCDD/F & PCB concentrations in feed were similar to values reported in the literature.

Silage

Overall PCDD/F & PCB and PBDE concentrations in silage and variations by river system and type of site

As indicated earlier in this report, 14 silage samples were analysed. Table 4-41 presents a series of descriptive statistics for the PCDD/F & PCB concentrations in these samples subdivided by river system and type of site. Comparable data for the PBDE concentrations are presented in Table 4-42.

Table 4-41: Variations in the concentrations of PCDD/Fs & PCBs in silage by river system and type of site

	Number	ng TEQ_{1998} /kg dry weight			
Sample Group	of Samples	Minimum	Median	Mean	Maximum
Trent-Type of Site					
Control	2	0.15	0.22	0.22	0.29
Flood-prone	2	0.18	0.34	0.34	0.49
All Trent Samples	4	0.15	0.24	0.28	0.49
Aire/Ouse - Type of Site					
Control	5	0.08	0.14	0.17	0.35
Flood-prone	5	0.10	0.19	0.17	0.26
All Aire/Ouse Samples	10	0.08	0.16	0.17	0.35
All Samples – Type of Site					
Control	7	0.08	0.16	0.19	0.35
Flood-prone	7	0.10	0.19	0.22	0.49
All Samples	14	0.08	0.21	0.18	0.49

Notes: A Mann-Whitney U test indicates no significant difference by type of site (p=0.519)

Table 4-42: Variations in the PBDE concentrations of silage by river system and type of site

	Number	PBDEs $\sum_7$ ng/kg dry weight			
Sample Group	of Samples	Minimum	Median	Mean	Maximum
Trent-Type of Site					
Control	2	170	290	290	410
Flood-prone	2	130	130	130	130
All Trent Samples	4	130	150	210	410
Aire/Ouse - Type of Site					
Control	5	90	110	160	380
Flood-prone	5	90	160	144	180
All Aire/Ouse Samples	10	90	110	152	380
All Samples – Type of Site					
Control	7	90	140	212	410
Flood-prone	7	90	130	140	180
All Samples	14	90	130	173	410

Notes
A Mann-Whitney U test indicates no significant difference by type of site (p=0.829)

The data presented in Table 4-41 indicate that the PCDD/F & PCB concentrations in silage were variable ranging from 0.08 (ng TEQ /kg dry weight) to 0.49 (ng TEQ /kg dry weight). A similar variability occurred with PBDE concentrations ranging from 90 to 410 ($\sum_7$ ng/kg dry weight). The silage concentrations of PCDD/Fs & PCBs and PBDEs for the matched pairs of flood-prone and control farms are presented in Table 4-43.

Table 4-43: Comparisons of PCDD/F & PCB and PBDE concentrations in silage by river system and type of site for matched pairs of farms

	PCDD/F & PCB ng TEQ_{1998} /kg dry weight		PBDE $\sum_7$ ng/kg dry weight	
Comparison	Flood-prone	Control	Flood-prone	Control
Trent - Pair 1	0.49	0.29	130	410
Trent - Pair 2				
Trent - Pair 3				
Trent - Pair 4		0.15		170
Trent - Pair 5	0.18		130	
Aire/Ouse - Pair 1	0.26	0.35	160	380
Aire/Ouse - Pair 2	0.13	0.14, 0.18[2]	110	110, 110[2]
Aire/Ouse - Pair 3	0.19		180	
Aire/Ouse - Pair 4	0.10	0.08	90	90
Aire/Ouse - Pair 5	0.19[1]	0.10	180[1]	110

Notes
[1] Same feed used as on Aire/Ouse flood-prone pair 3
[2] As well as silage this sample also contained commercial feed, carrots and potatoes
In terms of PCDD/F and PCBs, a Wilcoxon ranked signs test indicates no significant difference between type of site (p=0.500)
In terms of PBDEs, a Wilcoxon ranked signs test indicates no significant difference between type of site (p=0.285)

Table 4-41 indicates higher mean and median concentrations on flood-prone farms. Turning our attention to PBDE concentrations, Table 4-42 presents no clear evidence of PBDE differences between flood-prone and control farms. Table 4-43 indicates that the concentrations of PCDD/Fs & PCBs in silage are higher on 3 out of 5 flood-prone farms in comparison to their controls. PBDE concentrations were higher on 1/5 flood-prone sites. None of these differences were statistically significant.

Comparison with previous silage data

This section of the report compares the results from the present study to previous surveys of PCDD/F, PCB and PBDE concentrations in silage. The results for PCDD/F & PCB concentrations are presented in Table 4-44. No previous data on PBDE concentration in silage are available.

Table 4-44: Comparison of mean PCDD/F and PCB concentrations (ngTEQ/kg dry weight) in grass silage with UK literature values.

PCDD/F TEQ	PCB TEQ non-ortho + ortho	Total TEQ[1]	%PCB TEQ contribution to total TEQ[1]	Sampling date	Reference
0.18	0.13	0.31	42	2005/06	Fernandes et al 2006[2]
0.19	0.06	0.25	24	2009/10	Present study[3]
0.14	0.07	0.20	33	2009/10	Present study[4]

Notes
1. Total concentrations of dioxins and PCBs may not equal the sum of individual dioxin and PCB values due to rounding.
2. Samples of silage (n=2) from farms in England. Reported results converted to dry weight basis using moisture contents given by authors. Report does not indicate whether feed destined for dairy or beef herds.
3. Samples of silage (n=8) from two dairy farms on the River Trent as part of a year- round project investigating seasonal variations of dioxins and PCBs in milk
4. Samples of silage (n=13) from beef farms on Rivers Trent, Aire and Ouse.

Very few data on levels of PCDD/Fs and PCBs in silage have been published. However, as indicated in the Table mean PCDD/F TEQ and total TEQ concentrations from our sample farms from the present study agree closely with the data arising from the previous flood project on the same river and with one other study in the literature.

Summary

The analysis presented in the above sections shows:

- PCDD/F & PCBs and PBDEs concentrations in silage were not significantly higher on flood-prone as opposed to control sites.
- PCDD/F & PCB concentrations in silage were similar to values reported in the literature.

Control farm pair 1

One notable feature of the results is the high PCB & PCDD/F levels in meat and liver from Aire/Ouse control farm 1. Levels in meat were nearly twice that observed on any other farm, which was particularly unusual as this was a control farm. PBDE levels in meat on this farm also appear somewhat elevated. Contrasts were even greater in liver. A detailed examination of the animal husbandry data for this farm led to two hypothesis for the elevated PCDD/F & PCB levels: (i) the two beef cattle were notably older than for other farms (26 and 31 months compared to an average age of 11 months on all other farms on the Aire/Ouse river system; there is evidence that the body burden of PCDD/F and PCB increases with age in some mammals) (Lorber et al., 1997) and (ii) that both animals were noted at slaughter as being somewhat emaciated. In this situation we suggest that mobilisation of fat within the animals may have contributed to elevated levels of PCDD/Fs and PCBs in the animals. Elevated levels of PCDD/Fs & PCBs have been observed in other animals during fasting (Bustnes et al., 2010; Debier et al., 2006).

Comparing PCDD/F & PCB and PBDE concentrations in milk and beef

The study farms were chosen on a programme by programme basis. Coincidentally, some farms were sampled in both the milk and beef programmes as they had beef as well as a dairy operation. This provides us with a limited opportunity to compare levels across programmes. A comparison of the results from these 3 farms is provided for PCB & PCDD/F in Table 4-45 and PCDD/Fs in Table 4-46. The farms are labelled A-C.

Table 4-45: Comparisons of PCB and PCDD/F concentrations between programmes on the River Trent

	ng TEQ_{1998} /kg fat	
Farm	Milk (2008)	Beef (2008) Animal1, animal2
A	0.94	2.89†, 2.62†
B	1.40	4.40†‡, 2.58†
C	0.92	2.21†, 1.91†

Notes
†Samples exceeding dioxin-like PCB action levels (1 ngTEQ/kg fat)
‡Samples exceeding dioxin action levels (4 ngTEQ/kg fat)

Table 4-45 indicates that on all 3 comparable farms PCB & PCDD/F concentrations in milk were consistently lower (32 to 54% of the corresponding beef levels) than the levels found in beef.

Table 4-46: Comparisons of PBDE concentrations between programmes on the River Trent

	ng /kg fat	
Farm	Milk (2008)	Beef (2008) Animal1, Animal2
A	200	330, 590
B	260	830, 370
C	300	300, 210

Table 4-46 presents the results for the PBDE levels on the 3 comparable farms. Although somewhat lower, levels appear more comparable between milk and beef.

Comparing PCDD/F & PCB concentrations between WHO-TEQ (1998 and 2005) in meat, liver and kidney

In January 2012, the WHO-2005 TEF values for PCDD/Fs and dioxin like PCBs were adopted within the EU and revised maximum permissible limits and action levels for a range of foodstuffs were simultaneously introduced. For purposes of comparison, the meat, liver and kidney data has been recalculated to reflect these changes and is presented in Table 4.47.

Table 4.47: Summarised WHO-TEQ (1998 and 2005) concentrations for meat liver and kidney samples.

TRENT				WHO TEQ (**1998**) ng/kg fat				WHO TEQ (**2005**) ng/kg fat			
Type	Sample#	Type	Pair	PCDD/F	non ortho-PCB	ortho -PCB	**Sum WHO-TEQ**	PCDD/F	non ortho-PCB	ortho -PCB	**Sum WHO-TEQ**
Meat	1	flooded	3	1.03	1.41	0.32	**2.76**	0.86	1.49	0.06	**2.42**
Meat	2	flooded	3	1.18	1.48	0.38	**3.04**	0.97	1.59	0.08	**2.63**
Meat	1	flooded	2	0.89	1.06	0.26	**2.21**	0.72	1.11	0.05	**1.89**
Meat	2	flooded	2	0.72	0.97	0.22	**1.91**	0.59	1.02	0.04	**1.66**
Meat	1	flooded	5	2.14	2.15	0.48	**4.77**	1.76	2.28	0.09	**4.13**
Meat	2	flooded	5	1.25	1.18	0.21	**2.64**	1.03	1.25	0.04	**2.33**
Meat	1	control	1	1.17	1.38	0.34	**2.89**	0.97	1.42	0.07	**2.47**
Meat	2	control	1	1.33	1.13	0.16	**2.62**	1.12	1.19	0.03	**2.34**
Meat	1	control	3	1.09	1.34	0.215	**2.65**	0.90	1.41	0.04	**2.35**
Meat	2	control	3	0.93	1.12	0.18	**2.23**	0.78	1.18	0.04	**2.00**
Meat	1	flooded	1	2.07	1.95	0.38	**4.4**	1.76	2.06	0.08	**3.89**
Meat	1	flooded	4	1.11	1.09	0.18	**2.38**	0.94	1.13	0.04	**2.12**
Meat	2	flooded	4	1.13	1.05	0.17	**2.35**	0.95	1.10	0.04	**2.09**
Meat	1	control	4	0.74	0.66	0.11	**1.51**	0.64	0.69	0.02	**1.35**
Meat	2	control	4	0.93	0.92	0.15	**2**	0.80	0.96	0.03	**1.79**
Meat	1	control	2	1.29	0.82	0.11	**2.22**	1.06	0.86	0.02	**1.94**
Meat	2	control	2	1.33	1.09	0.15	**2.57**	1.11	1.14	0.03	**2.28**
Meat	2	flooded	1	1.15	1.21	0.22	**2.58**	0.98	1.28	0.04	**2.30**
liver	1	flooded	2	4.3	2.26	0.28	**6.84**	3.53	2.31	0.06	**5.89**
liver	2	flooded	2	4.24	2.54	0.28	**7.06**	3.44	2.59	0.05	**6.09**
liver	1	flooded	5	6.09	2.76	0.3	**9.15**	4.99	2.83	0.06	**7.88**
liver	1	control	1	4.21	2.29	0.3	**6.8**	3.48	2.33	0.06	**5.87**
liver	2	control	1	4.49	2.04	0.15	**6.68**	3.69	2.08	0.03	**5.80**
liver	1	control	3	3.03	2.27	0.22	**5.52**	2.47	2.31	0.04	**4.83**
liver	2	control	3	2.76	1.66	0.17	**4.59**	2.26	1.70	0.03	**3.99**
liver	1	flooded	1	8.76	4	0.36	**13.12**	7.28	4.09	0.07	**11.44**
liver	1	control	2	9.47	2.75	0.23	**12.45**	7.92	2.80	0.04	**10.77**
liver	2	control	2	7.96	3.17	0.18	**11.31**	6.73	3.21	0.04	**9.98**
liver	2	flooded	1	4.89	2.66	0.37	**7.92**	4.15	2.72	0.07	**6.93**
liver	1	flooded	3	5.82	3.22	0.34	**9.38**	4.86	3.30	0.06	**8.22**
liver	2	flooded	3	7.51	3.88	0.35	**11.74**	6.18	3.99	0.06	**10.24**
liver	2	flooded	5	5.08	2.39	0.24	**7.71**	4.15	2.45	0.04	**6.64**
liver	1	flooded	4	6.98	2.37	0.18	**9.53**	5.79	2.41	0.04	**8.24**
liver	2	flooded	4	7.04	2.23	0.14	**9.41**	5.87	2.28	0.03	**8.18**
liver	1	control	4	4.81	1.63	0.11	**6.55**	4.08	1.65	0.03	**5.76**
liver	2	control	4	4.89	2.05	0.13	**7.07**	4.13	2.09	0.03	**6.24**
kidney	1	control	1	1.12	1.2	0.32	**2.64**	0.93	1.23	0.06	**2.22**
kidney	2	control	1	1.21	1.01	0.18	**2.4**	1.00	1.06	0.03	**2.09**
kidney	1	flooded	1	2.03	1.82	0.38	**4.23**	1.70	1.91	0.07	**3.69**
kidney	2	flooded	1	1.02	1.23	0.26	**2.51**	0.86	1.30	0.05	**2.20**

Table 4.47(cont'd): Summarised WHO-TEQ (1998 and 2005) concentrations for meat, liver and kidney.

AIRE/OUSE				WHO TEQ (**1998**) ng/kg fat				WHO TEQ (**2005**) ng/kg fat			
Type	Sample #	Type	Pair	PCDD/F	non ortho-PCB	ortho-PCB	**Sum WHO-TEQ**	PCDD/F	non ortho-PCB	ortho-PCB	**Sum WHO-TEQ**
Beef	1	flooded	2	1.96	2.4	0.4	**4.76**	1.62	2.50	0.08	**4.21**
Beef	1	control	2	2.39	1.44	0.17	**4**	1.98	1.52	0.03	**3.54**
Beef	2	flooded	2	1.94	2.19	0.37	**4.5**	1.60	2.29	0.08	**3.96**
Beef	2	control	2	2.08	1.14	0.14	**3.36**	1.70	1.21	0.03	**2.94**
Beef	1	control	4	0.82	0.81	0.1	**1.73**	0.69	0.85	0.02	**1.56**
Beef	1	flooded	3	1.11	1.43	0.44	**2.98**	0.95	1.53	0.08	**2.56**
Beef	2	control	4	0.8	1.06	0.14	**2**	0.66	1.10	0.03	**1.79**
Beef	2	flooded	3	1.86	1.56	0.47	**3.89**	1.64	1.66	0.09	**3.39**
Beef	1	flooded	5	2.4	2.03	0.72	**5.15**	2.13	2.18	0.14	**4.45**
Beef	1	control	5	0.41	0.43	0.06	**0.9**	0.35	0.44	0.01	**0.81**
Beef	2	flooded	5	1.19	1.49	0.31	**2.99**	0.97	1.57	0.06	**2.60**
Beef	1	flooded	4	2.69	2.43	0.36	**5.48**	2.22	2.55	0.08	**4.84**
Beef	2	flooded	4	2.08	1.59	0.25	**3.92**	1.74	1.66	0.05	**3.45**
Beef	1	control	3	1.43	1.88	0.29	**3.6**	1.17	1.97	0.06	**3.20**
Beef	2	control	3	1.69	2.01	0.23	**3.93**	1.40	2.12	0.05	**3.56**
Beef	2	control	5	0.17	0.11	0.03	**0.31**	0.15	0.12	0.00	**0.27**
Beef	1	flooded	1	1.49	1.7	0.24	**3.43**	1.22	1.80	0.05	**3.07**
Beef	2	flooded	1	1.69	1.71	0.61	**4.01**	1.40	1.82	0.12	**3.34**
Beef	1	control	1	4.64	3.78	0.43	**8.85**	3.82	4.01	0.08	**7.91**
Beef	2	control	1	3.92	3.22	0.47	**7.61**	3.25	3.45	0.09	**6.79**
kidney	1	flooded	2	2.2	2.37	0.39	**4.96**	1.84	2.49	0.08	**4.41**
kidney	1	control	2	2.15	1.22	0.15	**3.52**	1.77	1.30	0.03	**3.10**
kidney	2	flooded	2	2.33	1.73	0.34	**4.4**	1.89	1.84	0.07	**3.80**
kidney	2	control	2	1.9	1.11	0.14	**3.15**	1.53	1.19	0.03	**2.74**
kidney	1	control	4	0.74	0.69	0.09	**1.52**	0.62	0.72	0.02	**1.35**
kidney	2	control	4	0.77	0.94	0.13	**1.84**	0.64	0.97	0.03	**1.64**
kidney	1	flooded	4	2.48	2.16	0.33	**4.97**	2.07	2.26	0.07	**4.40**
kidney	2	flooded	4	2.27	1.62	0.24	**4.13**	1.92	1.70	0.05	**3.67**
liver	1	flooded	2	8.31	4.99	0.39	**13.69**	6.82	5.09	0.09	**12.00**
liver	1	control	2	5.4	1.8	0.14	**7.34**	4.43	1.85	0.03	**6.32**
liver	2	flooded	2	6.07	2.9	0.3	**9.27**	4.81	2.99	0.07	**7.87**
liver	2	control	2	7.1	2.28	0.17	**9.55**	5.80	2.35	0.04	**8.18**
liver	1	flooded	1	5.37	2.47	0.28	**8.12**	4.41	2.55	0.06	**7.01**
liver	2	flooded	1	5.38	3.11	0.3	**8.79**	4.41	3.19	0.06	**7.67**
liver	1	control	1	30.21	12.34	0.49	**43.04**	24.58	12.60	0.11	**37.28**
liver	2	control	1	39.66	12.33	0.63	**52.62**	32.75	12.72	0.13	**45.60**
liver	1	control	4	4.66	2.04	0.1	**6.8**	3.89	2.08	0.02	**5.99**
liver	1	flooded	3	3.16	2.5	0.5	**6.16**	2.62	2.59	0.09	**5.30**
liver	2	control	4	5.77	2.85	0.13	**8.75**	4.82	2.91	0.03	**7.76**
liver	2	flooded	3	4.85	2.44	0.45	**7.74**	4.07	2.51	0.10	**6.68**
liver	1	flooded	5	2.69	1.92	0.5	**5.11**	2.28	2.01	0.10	**4.40**
liver	1	control	5	1.87	0.94	0.05	**2.86**	1.63	0.96	0.01	**2.60**
liver	2	flooded	5	3.52	2.52	0.33	**6.37**	2.86	2.58	0.07	**5.51**
liver	2	control	5	1.04	0.27	0.03	**1.34**	0.96	0.27	0.01	**1.24**
liver	1	flooded	4	11.27	4.91	0.42	**16.6**	9.28	5.02	0.09	**14.39**
liver	2	flooded	4	10.22	4.12	0.39	**14.73**	8.39	4.21	0.09	**12.69**
liver	1	control	3	5.75	4.26	0.35	**10.36**	4.62	4.37	0.08	**9.06**
liver	2	control	3	4.35	3.11	0.22	**7.68**	3.55	3.18	0.05	**6.78**

PCDD/F & PCB Weight of Evidence Summary

In the statistical analysis of the PCDD/F and PCB data, the small numbers of samples meant that very pronounced differences were required between flood-prone and control sites to achieve statistically significant results. To overcome these limitations and to provide a more holistic overview of the data, they were also examined using a weights of evidence table in Table 4.48. The kidney data is not included in this table due to the limited number of samples analysed and its close correspondence with levels in meat.

Table 4.48: Weight of evidence table examining the impact of river flooding upon PCDD/F and PCB concentrations in meat and liver

Strength of Association		
Hazard	Soil	• Higher total TEQ (median 9.2 vs. 5.4ng TEQ_{1998} /kg dry weight) on flood-prone farms • 8/9 flood-prone pairs have higher median total TEQ • One 1 field total TEQ was nearly 4 times higher on the flood-prone part compared to the non-flood-prone location
	Grass	• Similar median total TEQ (median 1.2 vs. 1.0 ng TEQ_{1998} /kg dry weight) on both farm types • 7/9 flood-prone pairs have higher median total TEQ • One 1 field total TEQ was slightly higher on the flood-prone part compared to the non-flood-prone location
Outcome	Meat	• Flood-prone farms have higher total TEQ (median 3.2 vs. 2.6 ng TEQ1998 /kg fat) • 7/10 flood-prone pairs have higher median total TEQ • In 6/10 flood-prone pairs total TEQ was higher in both animals • Association similar for dioxin-like PCBs, PCDD/Fs but appears stronger for ∑ICES6
	Liver	• Flood-prone farms have higher total TEQ (median 9.0 vs. 7.2 ng TEQ1998 /kg fat) • 7/10 flood-prone pairs have higher median total TEQ • In 6/10 flood-prone pairs total TEQ was higher in both animals • Association similar for dioxin-like PCBs, PCDD/Fs but appears stronger for ∑ICES6
Consistency of Association		
Hazard	Soil	• Contrasts observed on both river systems
	Grass	• Flood-prone differences on the Trent but not on the Aire/Ouse
Outcome	Meat	• Contrasts observed on both river systems
	Liver	• Contrasts appear stronger on the Trent than the Aire/Ouse
Alternative Explanations		• Commercial feed an unlikely confounder as similar total TEQ concentrations observed on both flood-prone and control farms • Unusually high concentrations on Aire/Ouse farm pair 1 are explained

Most of the evidence in the table implies that river flooding leads to elevated total TEQ in meat. There was a clear indication that PCDD/F and PCB levels were higher in soil from flood-prone farms and there was evidence of consistency in this result between river systems. In spite of the fact that PCDD/F and PCB concentrations in grass will be subject to short-term influences such as rainfall or air temperature, there was also some evidence of elevated PCDD/F and PCB concentrations in grass but this was not consistent between river systems. These factors indicate that a potential for elevated PCDD/F and PCB levels in beef exists and this concords with previous research (Lake et al., 2005; Lake et al., 2011). Cattle consume grass directly as forage, and in the UK summer this will be the major constituent of their diet. It is therefore possible to see why the elevated PCDD/F and PCB concentrations in grass present a clear pathway for these contaminants into beef. The situation with soil is different as cattle consume soil inadvertently while foraging. The few summer estimates of soil ingestion that exist suggest that soil constitutes a very small proportion (3.2 - 3.4% dry matter) of dietary intake (Healy, 1968; Thornton, 1983). However, given that in this study total, TEQ levels in soils were on average nearly 13 times higher than grass from the same location, even small amounts of soil ingestion have the potential to affect PCDD/F and PCB concentrations in beef.

The most direct evidence of the impact of flooding on PCDD/F and PCB concentrations emerges from the analysis of the meat and liver samples. These suggest that this potential for elevated PCDD/F and PCB concentrations was realised. Meat samples from flood-prone farms had total TEQ levels 20% higher (mean flood-prone value divided by the mean control value for both river system) than those from control farms. The corresponding percentage for liver was similar. The strongest evidence to examine the impact of flooding comes from the paired analysis, and a majority of flood-prone farm pairs had higher median levels than their control farm. Furthermore in most of these farms, both samples were higher than the corresponding pair from the control farm. This was observed in meat and liver. This result was consistent between the two river systems. In terms of alternative explanations, commercial feed samples were also analysed and found to have nearly identical PCDD/F and PCB concentrations between flood-prone and control farms. In any case most of the cattle were only fed, if at all, small amounts of commercial feed. Also, feed is supplied to farms on a regional basis so there is no reason why flood-prone farms would use a different source of feed in comparison to control farms. There was an anomaly in these data - control farm pair 1 on the Aire/Ouse, but it was possible to generate a number of hypotheses as to why levels appeared elevated on this farm. Based upon all the evidence presented above, in this case study we conclude that river flooding transfers PCDD/Fs and PCBs to meat and liver in beef cattle raised on the flood plains.

PBDE Weight of Evidence Summary

As the PBDE data would be subject to the same statistitical analysis limitations as the PCDD/F and PCB data, they were also examined using a weights of evidence table (Table 4.49). The kidney data is not included in this table due to the limited number of samples analysed and its close correspondence with levels in meat.

A majority of the evidence in Table 4.49 suggests that river flooding leads to elevated PBDE levels in meat. There was a clear indication that PBDE levels were higher in soil from flood-prone farms and there was evidence of consistency in this result between river systems. These indications were even stronger in grass in spite of the fact that grass will be more subject to short-term influences such as rainfall or air temperature. As previously argued, grass and soil are important constituents of cattle diet and so a potential for elevated PBDE levels in beef exists. The most direct evidence of the impact of flooding on PBDE concentrations emerges from the analysis of the meat and liver samples. The potential for elevated PBDE levels was only partially realised. Meat samples from flood-prone farms had PBDE levels that were around 25% higher than those from flood-prone farms. However, there was little contrast in the liver. The strongest evidence to examine the impact of flooding comes from the paired analysis and a majority of flood-prone farm pairs had higher median levels than their control farm. However, in only a few (3/10) of these farms were both samples higher than the corresponding pair from the control farm. This was observed in both beef and liver and indicates that the variation between the two animals on each farm is high in contrast to the differences between flood-prone and control farms. This is the main reason for caution in interpretation of flood-prone vs. control contrasts. These results were consistent between the two river systems. In terms of alternative explanations commercial feed samples were also analysed and found to have nearly identical PBDE concentrations between flood-prone and control farms. In any case most of the cattle were only fed, if any, small amounts of commercial feed. Additionally, feed is supplied to farms on a regional basis so there is no reason why flood-prone farms would use a different source of feed in comparison to control farms. There was an anomaly in these data, control farm pair 1 on the Aire/Ouse, but it was possible to generate a number of hypotheses as to why levels appeared elevated on this farm. Based upon all the evidence presented above, we conclude that river flooding may transfer PBDEs to meat and liver of beef cattle raised on flood plains.

Table 4.49: Weight of evidence table examining the impact of river flooding upon PBDE concentrations in meat and liver

Strength of Association		
Hazard	Soil	• Higher PBDE (median 4940 vs. 480 ng /kg dry weight) on flood-prone farms • 7/9 flood-prone pairs have higher median PBDE • One 1 field PBDE was over twice as high on the flood-prone part compared to the non-flood-prone location
	Grass	• Higher median PBDE (median 1070 vs. 310 ng /kg dry weight) on both farm types • All flood-prone pairs have higher PBDE levels • One 1 field PBDE was slightly higher (630 vs. 550 ng /kg dry weight) on the flood-prone part compared to the non-flood-prone location
Outcome	Meat	• Flood-prone farms have higher PBDE (median 560 vs. 445 ng /kg fat) • 7/10 flood-prone pairs have higher median PBDE • In 3/10 flood-prone pairs PBDE levels were higher in both animals
	Liver	• Flood-prone farms have higher PBDE (median 530 vs. 515 ng /kg fat) • 8/10 flood-prone pairs have higher median PBDE • In 3/10 flood-prone pairs PBDE levels were higher in both animals
Consistency of Association		
Hazard	Soil	• Contrasts observed on the Aire/Ouse but not on the river Trent
	Grass	• Flood-prone differences on both river systems
Outcome	Meat	• Contrasts observed on both river systems
	Liver	• Contrasts on both river systems
Alternative Explanations		• Commercial feed an unlikely confounder as similar PBDE concentrations observed on both flood-prone and control farms • Unusually high concentrations on Aire/Ouse farm pair 1 are explained

5. Lamb programme

This chapter focuses upon the results from the lamb sampling and consists of five sections. These focus upon the meat, liver, kidney, soil and grass. The final 2 sections conduct a weight of evidence analysis for the impact of flooding on PCDD/F and PCB levels in lamb followed by a similar analysis for PBDE levels in lamb.

Meat

Overall PCDD/F & PCB and PBDE concentrations in meat and variations by river system and type of site

As indicated earlier, 22 lamb (leg) samples were analysed. On the River Trent, 10 samples were from flood-prone farms and 8 from control farms. On the River Ouse 2 samples were from flood-prone farms and two from control farms. Four lamb shoulder samples were also analysed but as these are from animals for which lamb leg samples were also available, these data are only presented in the section comparing concentrations in leg versus shoulder samples. Table 5-1 presents a series of descriptive statistics for the PCDD/F & PCB concentrations in these samples subdivided by river system and type of site. Comparable data for the PBDE concentrations are presented in Table 5-2.

Table 5-1: Variations in the concentrations of PCDD/Fs & PCBs in lamb leg by river system and type of site

Sample Group	Number of Samples	ng TEQ_{1998} /kg fat Minimum	Median	Mean	Maximum
Trent - Type of Site					
Control	8	0.53	1.07	1.13	1.91
Flood-prone	10	0.72	1.26	1.26	1.93
All Trent Samples	18	0.53	1.16	1.20	1.93
Aire/Ouse - Type of Site					
Control	2	0.62	0.69	0.69	0.76
Flood-prone	2	0.37	0.48	0.48	0.58
All Aire/Ouse Samples	4	0.37	0.60	0.58	0.76
All Samples – Type of Site					
Control	10	0.53	0.95	1.04	1.91
Flood-prone	12	0.37	1.00	1.13	1.93
All Samples	22	0.37	0.95	1.09	1.93

Notes
A Mann-Whitney test indicates no significant difference between types of site (p=0.715)

Table 5-2: Variations in the concentrations of PBDEs in lamb leg by river system and type of site

Sample Group	Number of Samples	$\sum_7$ ng/kg fat Minimum	Median	Mean	Maximum
Trent - Type of Site					
Control	8	360	1000	884	1370
Flood-prone	10	260	650	706	1320
All Trent Samples	18	260	730	785	1370
Aire/Ouse - Type of Site					
Control	2	220	265	265	310
Flood-prone	2	250	285	285	320
All Aire/Ouse Samples	4	220	280	275	320
All Samples – Type of Site					
Control	10	220	750	760	1370
Flood-prone	12	250	590	639	1320
All Samples	22	220	590	692	1370

Notes
A Mann-Whitney test indicates no significant difference between types of site ($p=0.584$)

The data presented in Table 5-1 indicate that all the PCDD/F & PCB concentrations fell within a range of between 0.37 (ngTEQ/kg fat) and 1.93 (ng TEQ/kg fat). These concentrations are low in comparison to the EU maximum levels (Council Regulation 199/2006) that were prevalent during the period of sampling. They are also below the corresponding recommended action level (Commission Recommendation (2006/88/EC). As mentioned in earlier chapters, it is noted that from 2012, maximum and action levels have been revised to take into account the re-evaluation of TEFs (WHO-TEF_{2005}), which resulted in a reduction in maximum/action levels that is also generally reflected in calculated WHO-TEQ_{2005} values. Thus if applied here, the relative values of the sample TEQs (if revised using WHO-TEF_{2005}) will be similarly low in relation to the revised EU maximum levels or action levels. This has been demonstrated in Chapter 4 where calculated TEQ values were much closer to the prevalent EU levels, and were therefore re-examined using the revised WHO-$TEFs_{2005}$ relative to the revised maximum or action levels, and confirmed similar overall conclusions whichever system was used.

Table 5-1 indicates that on the River Trent, flood-prone farms have higher mean and median concentrations than control farms but the differences observed are relatively small. On the River Ouse, the small number of samples precludes any firm assessment of differences between flood-prone vs. control farms. These differences were not statistically significant.

Examination of the PBDE data presented in Table 5-2 indicates that the values range from 220-1370 ng/kg fat. There is no evidence of elevated PBDE concentrations on flood-prone farms on the River Trent. The small sample numbers on the River Ouse preclude any firm assessment of flood-prone vs. control differences. These differences were not statistically significant.

Comparisons between flood-prone and control sites are complicated by the relatively small sample numbers in each subgroup. A more sophisticated method of comparison is to examine the differences in PCDD/F & PCB and PBDE concentrations between matched pairs of flood-prone and control farms. Six such pairs were identified as part of the experimental design and the meat concentrations for these farms are presented in Table 5-3 and illustrated in Figure 5.1. For the comparison the PCDD/F & PCB concentrations between the two animals in each pair have been averaged.

Table 5-3: Comparisons of PCDD/F & PCB concentrations in lamb leg by river system and type of site for matched pairs of farms

Comparison	ng TEQ_{1998}/kg fat			
	Flood-prone		Control	
	Sample 1 – Sample 2	Mean	Sample 1 - Sample 2	Mean
Trent				
Pair 1	0.72, 0.83	0.78	1.91, 1.63	1.77
Pair 2	1.93, 1.37	1.65	0.53, 0.62	0.58
Pair 3	1.90, 1.65	1.78	0.94, 1.18	1.06
Pair 4	0.82, 0.86	0.84	0.94, 1.18[&]	1.06[&]
Pair 5	1.14, 1.37	1.26	0.95, 1.25	1.10
Aire/Ouse				
Pair 1	0.37, 0.58	0.48	0.62, 0.76	0.69

Notes
[&]This control farm is the same as that used in pair 3 due to its close proximity to the flood-prone site in pair 4.
For PCDD/F & PCB a Wilcoxon ranked signs test indicates no significant differences between the mean farm values by types of site (p = 0.917)

The data in Table 5-3 and Figure 5.1 does not indicate that flooding affects contaminant levels in lamb. A comparison of the mean total PCDD/F and PCB levels for the six pairs of farms reveals that three out of six flood-prone farms had higher concentrations than their comparator control farm. This was statistically insignificant. On 2 from 6 farms both flood-prone samples were higher than the 2 samples from control farms.

Figure 5.1: Mean and range of PCDD/F & PCB levels in lamb leg in matched pairs of farms

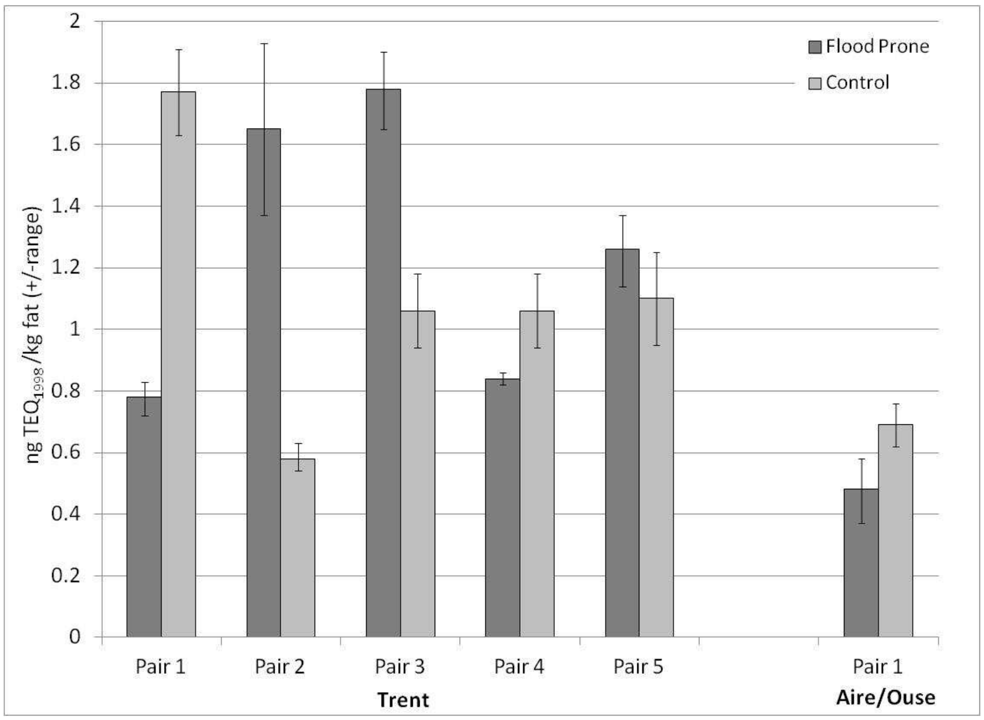
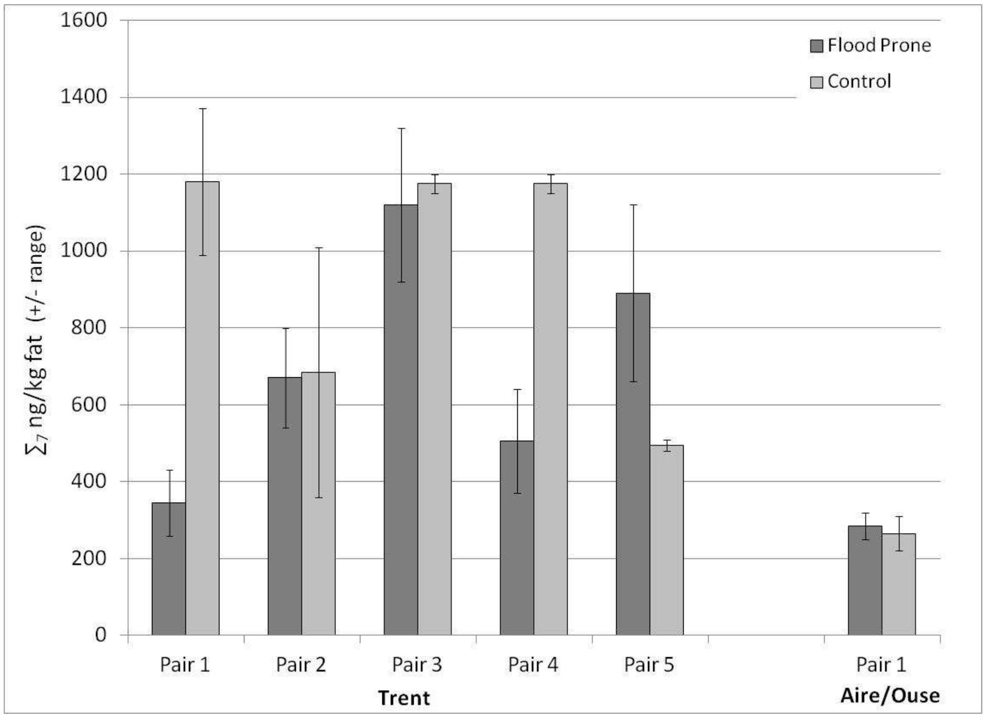


Figure 5.2: Mean and range of PBDE levels in lamb leg in matched pairs of farms



The corresponding PBDE data is presented in Table 5-4 and illustrated in Figure 5.2. Mean PBDE concentrations in meat are higher on only two of 6 flood-prone farm pairs. These differences were statistically insignificant. On 1 from 6 farm pairs both flood-prone samples were higher than the 2 samples from control farms.

Table 5-4: Comparisons of PBDE concentrations in lamb leg by river system and type of site for matched pairs of farms

	ng/kg fat			
	Flood-prone		Control	
Sample	Sample 1 – Sample 2	Mean	Sample 1- Sample 2	Mean
Trent				
Pair 1	260, 430	345	1370, 990	1180
Pair 2	800, 540	670	1010, 360	685
Pair 3	1320, 920	1120	1150, 1200	1175
Pair 4	640, 370	505	1150, 1200[&]	1175[&]
Pair 5	660, 1120	890	510, 480	495
Aire/Ouse				
Pair 1	250, 320	285	220, 310	265

Notes
[&]This control farm is the same as that used in pair 3 due to its close proximity to the flood-prone site in pair 4.
A Wilcoxon ranked signs test indicates no significant difference between the mean farm values by types of site (p= 0.345)

One notable feature of these data is the observation that meat samples with high PCDD/F & PCB concentrations tend to have high PBDE concentrations and vice versa. This was tested statistically using a spearman rank correlation which indicates a moderate correlation (Spearman's $\rho = 0.69$ $p < 0.01$) between PCDD/F & PCB and PBDE concentrations.

To examine whether the PCDD/F & PCB and PBDE concentrations in lamb varied according to the cut of meat, samples of lamb leg and shoulder were taken from identical animals from pair 1 on the River Ouse. The results are presented in Table 5-5 for PCDD/Fs & PCBs and PBDEs and indicate close agreement between the PCDD/F & PCB and PBDE concentrations in the different cuts. For PCDD/F & PCBs concentrations the mean difference is 0.03 ng TEQ/kg fat, representing an average percentage difference of 5.2%. For PBDE concentrations the mean difference is 5 ng TEQ/kg fat, representing an average percentage difference of 2.1%.

Table 5-5: Comparisons of PCDD/F & PCB and PBDE concentrations in lamb leg versus lamb shoulder from the same animal

	PCDD/F & PCB ng TEQ_{1998} /kg fat		$\sum_7$ PBDE ng/kg fat	
	Lamb leg	Lamb shoulder	Lamb leg	Lamb shoulder
Comparison				
Ouse – animal 1 Flood-prone	0.37	0.40	250	240
Ouse – animal 2 Flood-prone	0.58	0.53	320	320
Ouse – animal 1 Control	0.62	0.63	220	230
Ouse – animal 2 Control	0.76	0.78	310	310

Comparison of the relative contributions of PCDD/Fs, Non-Ortho PCBs and Ortho PCBs in meat

The median percentage contribution of PCDD/Fs, Non-Ortho PCBs and Ortho PCBs and to total TEQ are presented in Table 5-6 subdivided by river system and type of site. The results indicate few differences between flood-prone and control farms.

Table 5-6: Variations in the median percentage contribution of PCDD/Fs, Non-Ortho PCBs and Ortho PCBs to total TEQ in lamb leg by river system and type of site

	% of Total WHO-TEQ_{1998}					
	PCDD/Fs		Non-Ortho PCBs		Ortho PCBs	
Sample Group	Control	Flood	Control	Flood	Control	Flood
Trent	$55.15_{(8)}$	$53.04_{(10)}$	$27.86_{(8)}$	$32.01_{(10)}$	$15.84_{(8)}$	$12.42_{(10)}$
Aire/Ouse	$50.66_{(2)}$	$51.05_{(2)}$	$42.02_{(2)}$	$40.10_{(2)}$	$7.32_{(2)}$	$8.85_{(2)}$

Notes
Numbers in **(subscript)** represent number of samples

Comparison with previous meat data

This section of the report compares the results from the present study to previous surveys of (i) PCDD/F and PCB and (ii) PBDE concentrations in meat. The results for PCDD/F & PCB concentrations are presented in Table 5-7 and those for PBDEs in Table 5-8.

Table 5-7: Comparison of mean PCDD/F and PCB concentrations (ng TEQ/kg fat) in lamb meat with literature values

PCDD/F TEQ	PCB TEQ non-ortho + ortho	Total TEQ[1]	% PCB TEQ contribution to total TEQ	Origin of samples	Number of samples	Sampling date	Reference
1.8	2.0	3.8	53	Netherlands	2	1990	Liem and Theelen (1997)[2]
1.5	1.6	3.1	50	Belgium	2	2000-2001	Focant et al (2002)[3]
3.2	1.8	5.0	37	UK	4	2001	FSA (2002)[4]
1.1	0.94	2.0	46	UK	2	2002	Foxall et al (2004a)[5]
0.41	0.44	0.85	52	UK	2	2002	Foxall et al (2004a)[6]
0.35	0.29	0.64	45	Ireland	8	2004	FSAI (2005b)[7]
1.4	0.63	2.0	32	Belgium	1	2008	Windal et al (2010)[8]
Present study							
0.58	0.50	1.1	47	UK	22	2009-10	

Notes
[1]Total concentrations of dioxins and PCBs may not equal the sum of the individual dioxins and PCBs due to rounding.
[2]Nationally representative composite samples of mutton fat from animals collected from slaughterhouses across the country. Values <LOD=LOD.
[3]Samples collected from slaughterhouses or purchased in local supermarkets in 2000-2001. Values <LOD=0.
[4]Control samples collected from farms in Gwynedd and Carmarthenshire during study of foot and mouth disease pyres. All samples from 1 month old lambs. Values <LOD=LOD.
[5] Lowland lambs from Norfolk farm. Market ready animals aged 127 days. Values <LOD=LOD.
[6] Highland lambs from Northumberland hill farm. Market ready animals aged 153 days. Values <LOD=LOD.
[7] Samples collected from slaughterhouses. Values <LOD = LOD.
[8] Composite of ten retail samples from supermarkets and butchers shops. Values <LOD=0.5 LOD

An examination of the data in Table 5-7 indicates that the PCDD/F TEQ and total TEQ concentrations in lamb meat from the present study are generally consistent with those previously reported. The % contribution of PCBs to the total TEQ also falls within the range expected.

Table 5-8: Comparison of PBDE concentrations (ng/kg fat) in lamb meat with literature values

BDE 47	BDE 99	BDE 100	BDE 153	BDE 154	$\sum_5$ BDE	Origin of samples	Number of samples	Sampling date	Reference
58	288	85	49	32	512	USA	1	2003-4	Schecter et al (2006)[1]
70	130	50	110	50	410	Ireland	8	2004	FSAI (2005b) [2]
110	120	50	180	40	500	Ireland	10	2006-7	Fernandes et al (2009) [3]
Present study									
95	209	132	179	49	654	UK	22	2009-10	

Notes
[1] Sample of ground lamb purchased from supermarket. Figures calculated from wet weight data using lipid concentration (19.7%) given by authors. Values< LOD=0.5 LOD
[2] Samples collected from slaughterhouses. Values <LOD = LOD.
[3] Composite samples each made up of 10-40 individual subsamples collected at production or processing stage and destined for retail use. Values <LOD=LOD.

Relatively few data on PBDEs in lamb have so far been published. An examination of the data presented in Table 5-8 indicates that the mean $\sum_5$ PBDE concentrations from the present study are similar to those previously reported.

Summary

The analysis presented in the above sections highlights a number of trends in the data from the meat samples. These are summarised below:

- There were no significant differences between PCDD/F & PCB and PBDE concentrations in meat from flood-prone farms as opposed to control farms
- All the samples were within maximum levels and action levels for PCDD/Fs & PCBs, including ∑ICES-6 PCBs
- PCDD/F & PCB and PBDE levels in meat were significantly correlated
- There was very close agreement between PCDD/Fs & PCBs and PBDE levels between lamb leg and lamb shoulder samples taken from the same animals
- PCDD/F & PCB levels in lamb meat were consistent with those reported in other studies
- PBDE concentrations in lamb meat from the present study are similar to those previously reported

Liver

Overall PCDD/F & PCB & PBDE concentrations in liver and variations by river system and type of site

As indicated earlier in this report, 20 liver samples were analysed. Table 5-9 presents a series of descriptive statistics for the PCDD/F & PCB concentrations subdivided by river system and type of site. Comparable data for PBDE are presented in Table 5-10.

Table 5-9: Variations in the concentrations of PCDD/Fs & PCBs in lamb's liver by river system and type of site

	Number	ng TEQ_{1998}/kg fat			
Sample Group	of Samples	Minimum	Median	Mean	Maximum
Trent - Type of Site					
Control	8	10	14.43	14.30	20.35
Flood-prone	8	6.32	18.03	16.65	28.39
All Trent Samples	16	6.32	14.53	15.47	28.39
Aire/Ouse - Type of Site					
Control	2	6.64	9.04	9.04	11.43
Flood-prone	2	7.92	8.05	8.05	8.17
All Aire/Ouse Samples	4	6.64	8.05	8.54	11.43
All Samples – Type of Site					
Control	10	6.64	13.95	13.25	20.35
Flood-prone	10	6.32	15.16	14.93	28.39
All Samples	20	6.32	13.95	14.09	28.39

Notes
A Mann-Whitney test indicates no significant difference between types of site (0.917)

Table 5-10: Variations in the concentrations of PBDEs in lamb's liver by river system and type of site

Sample Group	Number of Samples	$\sum_7$ ng/kg fat Minimum	Median	Mean	Maximum
Trent - Type of Site					
Control	8	390	815	791	1100
Flood-prone	8	220	640	608	980
All Trent Samples	16	220	745	699	1100
Aire/Ouse - Type of Site					
Control	2	280	315	315	350
Flood-prone	2	390	435	435	480
All Aire/Ouse Samples	4	280	370	375	480
All Samples – Type of Site					
Control	10	280	785	696	1100
Flood-prone	10	220	530	573	980
All Samples	20	220	660	635	1100

Notes
A Mann-Whitney test indicates no significant difference between types of site (0.602)

The data presented in Table 5-9 indicate that all the PCDD/F & PCB concentrations fell within a range of between 6.32 ($ngTEQ_{1998}$/kg fat) and 28.39 ($ngTEQ_{1998}$/kg fat). Table 5-9 presents some evidence that on the River Trent, flood-prone farms have higher mean and median concentrations than control farms. On the River Aire/Ouse, the small number of samples precluded any firm assessment of flood-prone vs. control differences. TEQ concentrations appear higher on the River Trent but this evidence is very weak due to the small number of samples on the River Ouse. Overall these differences were statistically insignificant. From the 20 samples analysed, 12 from 20 were above the prevalent maximum level for dioxins plus dioxin-like PCBs (12 $ngTEQ_{1998}$/kg fat) and 15 from 20 were above the prevalent maximum level for dioxins (6 $ngTEQ_{1998}$/kg fat). All liver samples were above the prevailing action level for dioxins (4 $ngTEQ_{1998}$/kg fat). Five from 20 liver samples were above the prevailing dioxin-like PCB action level (4 $ngTEQ_{1998}$/kg fat).

Examination of the PBDE data presented in Table 5-10 indicates that the values range from 220-1100 ng/kg fat. There is no evidence of elevated PBDE concentrations on flood-prone farms on the River Trent. Again the small sample numbers on the River Ouse preclude any firm assessment of flood-prone vs. control differences.

Comparisons between flood-prone and control sites are complicated by the relatively small sample number in each subgroup. A more sophisticated method of comparison is to examine the differences in PCDD/F & PCB and PBDE concentrations between matched pairs of flood-prone and control farms. Six such pairs were identified and the liver concentrations for samples from those farms are presented in Table 5-11 and Figure 5.3. The corresponding PBDE data are given in Table 5-12 and Figure 5.4. For the comparisons, the concentrations for the two animals in each pair have been averaged.

Table 5-11: Comparisons of PCDD/F & PCB concentrations in liver by river system and type of site for matched pairs of farms

	ng TEQ_{1998} /kg fat			
	Flood-prone		Control	
Sample	Sample 1 – Sample 2	Mean	Sample 1 - Sample 2	Mean
Trent				
Pair 1	9.18, 18.14	13.66	16.63, 20.35	18.49
Pair 2	6.32, 12.40	9.36	10.50, 10.00	10.25
Pair 3	20.43, 28.39	24.41	13.55, 14.34	13.95
Pair 4				
Pair 5	17.92, 20.39	19.16	14.52, 14.53	14.53
Aire/Ouse				
Pair 1	7.92, 8.17	8.05	6.64, 11.43	9.04

Notes: A Wilcoxon ranked signs test indicates no significant difference between the mean farm values by types of site (p= 0.893)

An examination of the data in Table 5-11 and Figure 5.3 reveals that the mean total PCDD/F and PCB concentrations were only higher in 2 from 5 flood-prone farms in comparison to the corresponding control farms. In 2 from 5 pairs, both samples from the flood-prone farm had higher levels than both samples from the control farm. Table 5-12 and Figure 5.4 reveal that PBDEs levels were also higher in 2 from 5 flood-prone farms. All these differences were insignificant. In 2 from 5 pairs, both samples from the flood-prone farm had higher levels than both samples from the control farm.

As observed for the meat, liver samples with high PCDD/F & PCB concentrations tend to have high PBDE concentrations and vice versa. This was tested statistically using a spearman rank correlation which indicates a moderate correlation (Spearman's $\rho = 0.65$ $p = 0.002$) between PCDD/F & PCB and PBDE concentrations.

Table 5-12: Comparisons of PBDE concentrations in liver by river system and type of site for matched pairs of farms

	ng/kg fat			
	Flood-prone		Control	
Sample	Sample 1 – Sample 2	Mean	Sample 1 - Sample 2	Mean
Trent				
Pair 1	250, 580	415	810, 760	785
Pair 2	220, 440	330	820, 390	605
Pair 3	730, 700	715	840, 950	895
Pair 4				
Pair 5	960, 890	925	620, 1100	860
Aire/Ouse				
Pair 1	480, 390	435	280, 350	315

NotesA Wilcoxon ranked signs test indicates no significant difference between the mean farm values by types of site (p= 0.225)

Comparison of the relative contributions of PCDD/Fs, Non-Ortho PCBs and Ortho PCBs in liver

To examine trends in more detail the median percentage contribution of PCDD/Fs, Non-Ortho PCBs and Ortho PCBs to total TEQ are presented in Table 5-13 subdivided by river system and type of site .

Table 5-13: Variations in the median percentage contribution of PCDD/Fs, Non-Ortho PCBs and Ortho PCBs to total TEQ in liver by river system and type of site

	% of Total WHO-TEQ$_{1998}$					
	PCDD/Fs		Non-Ortho PCBs		Ortho PCBs	
Sample Group	Control	Flood	Control	Flood	Control	Flood
Trent	$77.40_{(8)}$	$75.99_{(8)}$	$21.43_{(8)}$	$23.00_{(8)}$	$1.21_{(8)}$	$1.12_{(8)}$
Aire/Ouse	$69.60_{(2)}$	$69.63_{(2)}$	$29.80_{(2)}$	$29.69_{(2)}$	$0.60_{(2)}$	$0.68_{(2)}$

Notes: Numbers in **(subscript)** represent number of samples

The table indicates few differences between control and flood-prone farms. It also indicates that in comparison to lamb carcase meat (Table 5-5) liver has a higher percentage contribution from PCDD/Fs and a lower contribution from Ortho PCBs. This is consistent with previously reported data (Fernandes et al 2010).

Comparison with previous liver data

This section of the report compares the results from the present study to previous surveys of PCDD/Fs and PCBs concentrations in liver. The results for PCDD/F & PCB concentrations are presented in Table 5-14. The corresponding PBDE data are given in Table 5-15.

Figure 5.3: Mean and range of PCDD/F and PCB concentrations in liver for matched pairs of farms

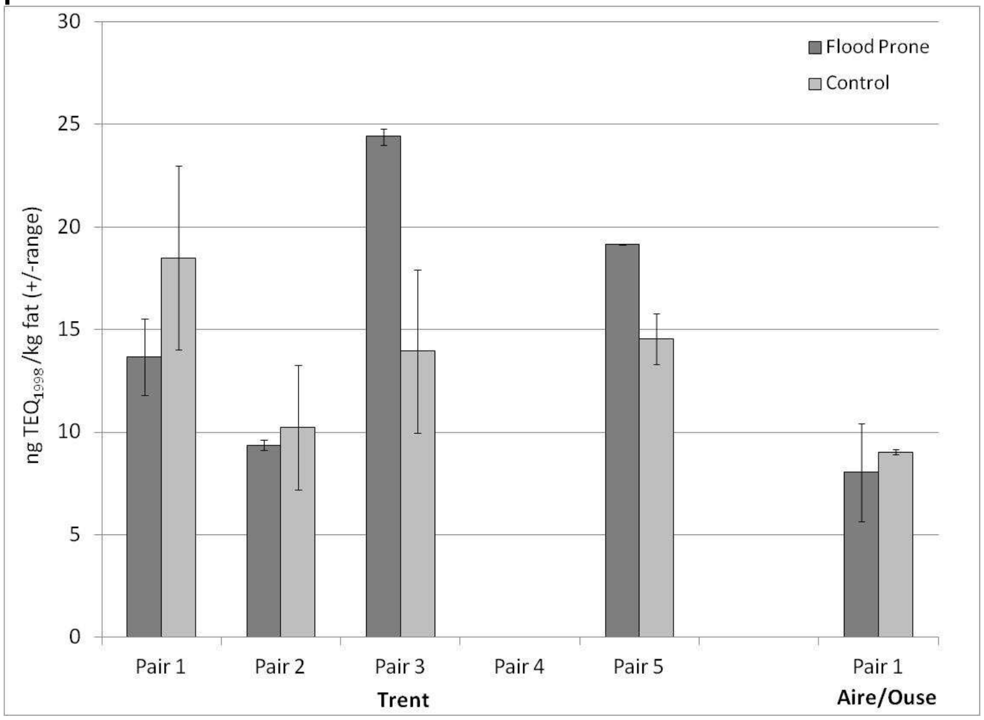


Figure 5.4: Mean and range of PBDE concentrations in liver for matched pairs of farms

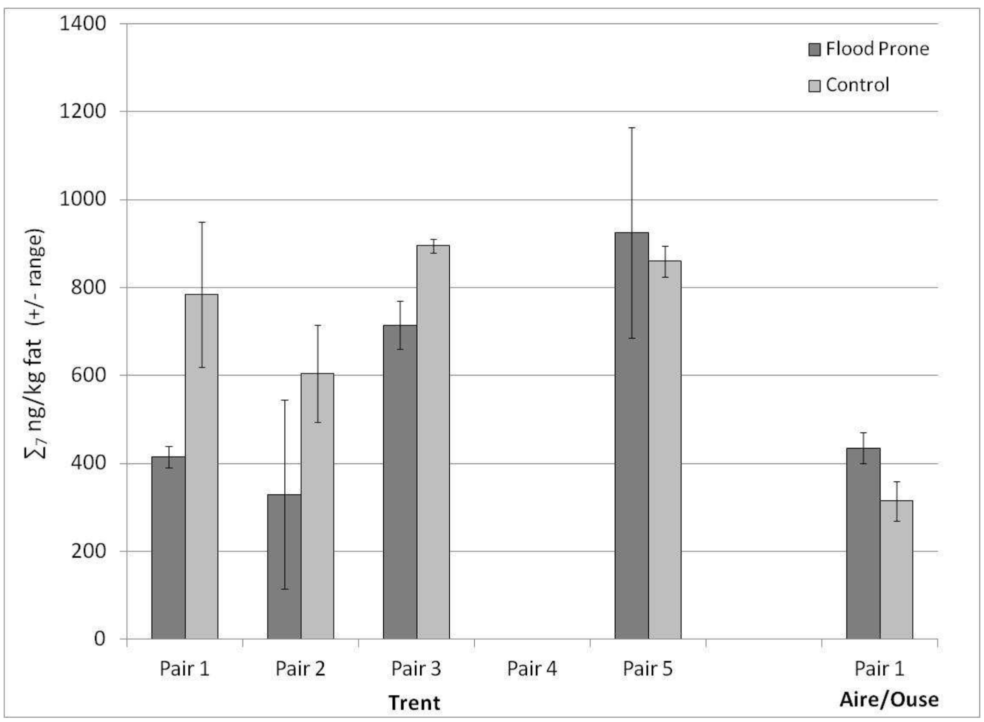


Table 5-14: Comparison of mean PCDD/F and PCB concentrations (ng TEQ/kg fat) in lambs liver with literature values

PCDD/F TEQ	PCB TEQ non-ortho + ortho	Total TEQ[1]	% PCB TEQ contribution to total TEQ	Origin of samples	Number of samples	Sampling date	Reference
30.0	15.0	45.0	33	Netherlands	2	1990	Liem and Theelen (1997)[2]
10.3	2.9	13.2	22	UK	1	1992	MAFF (1997)[3]
6.3	2.5	8.8	28	UK	1	1997	FSA (2000)[4]
13.5	3.0	16.5	18	UK	1	2001	FSA (2002)[5]
14.0	5.5	19.6	28	UK	1	2002	Foxall et al (2004a)[6]
6.4	1.8	8.2	22	UK	1	2002	Foxall et al (2004a)[7]
3.4	0.80	4.2	19	Eire	11	2005	FSAI (2005a)[8]
4.0	1.4	5.5	25	Eire	1	2004	FSAI (2005b)[9]
7.0	1.4	8.4	17	UK	19	2005	Fernandes et al (2010)[10]
23.9	19.0	42.9	44	Germany	77	2008	Bruns-Weller (2010)[11]
Present study							
10.6	3.5	14.1	26	UK	20	2009-10	

Notes
[1]Total concentrations of dioxins and PCBs may not equal the sum of individual dioxins and PCBs due to rounding.
[2]National representative samples of liver from animals collected from slaughterhouses across the country. Values <LOD=LOD.
[3]Material analysed was composite of retail offal samples from 24 locations across the UK collected as part of the 1992 Total Diet Study. Figure quoted are: TEQ values from FSIS No. 105, re-expressed as WHO-TEQs. Values <LOD=LOD.
[4]Material analysed was composite of retail offal samples from 24 locations across the UK collected as part of the 1997 Total Diet Study. Values <LOD=LOD.
[5]Control sample collected from farm in Gwynedd during study of foot and mouth disease pyres. Sample from 1 month old lamb. Values <LOD=LOD.
[6] Lowland lambs from Norfolk farm. Market ready animals aged 127 days. Values <LOD=LOD.
[7] Highland lambs from Northumberland hill farm. Market ready animals aged 153 days. Values <LOD=LOD
[8] Samples from retail outlets. Values <LOD=LOD.
[9] Retail sample. Values <LOD=LOD.
[10]Samples collected from a range of retail outlets including supermarkets and smaller shops. Values <LOD=LOD.
[11]Samples collected from slaughterhouses. Animals from farms across the federal state of Lower Saxony.

An examination of the data in Table 5-14 indicate that PCDD/F and total TEQ concentrations from the present study on the River Trent are somewhat higher than the levels reported from the more recent studies in the UK and the Republic of Ireland. The % contribution of PCBs to the total TEQ is however in good agreement with UK literature values.

Table 5-15: Comparison of PBDE Concentrations (ng/kg fat) in lambs liver with literature values

BDE 47	BDE 99	BDE 100	BDE 153	BDE 154	$\sum_5$ BDE	Origin of samples	Number of samples	Sampling date	Reference
130	140	50	50	50	420	Eire	1	2004	FSAI (2005b)[1]
223	577	380	287	47	1514	Eire	3	2006-7	Fernandes et al (2009)[2]
Present study									
119	189	72	133	40	552	UK	20	2009-10	

Notes
[1] Samples collected from slaughterhouses. Values <LOD = LOD
[2] Composite samples each made up of 10-40 individual subsamples collected at production or processing stage and destined for retail use. Values <LOD=LOD

As was the case with the meat data, the scarcity of published data on the levels of PBDEs in lambs liver makes any comparisons somewhat tentative. However, an examination of the data in Table 5-15 indicates that the individual and $\sum_5$ congener levels found in the present study fall well within the range of the limited data reported to date.

Summary

The analysis presented in the above sections highlights a number of trends in the data from the liver samples. These are summarised below:

- PCDD/F & PCB levels were not statistically higher in liver from flood-prone farms
- 12/20 liver samples were above the 12ng PCDD/F & PCB WHO-TEQ$_{1998}$/kg fat maximum level
- 15/20 liver samples were above 6ng PCDD/F WHO-TEQ$_{1998}$/kg fat maximum level
- 6/20 samples were above the action level of 4 ng WHO-TEQ$_{1998}$/kg fat for dioxin-like PCBs that was in force at the time that the samples were collected
- There was no evidence of significantly higher PBDEs levels in liver from flood-prone farms
- PCDD/F & PCB levels and PBDE concentrations in liver were significantly correlated
- PCDD/F & PCB levels in liver were slightly higher than those reported in recent UK studies
- Few previous studies have looked at PBDE concentrations in lamb liver.

Kidney

Overall PCDD/F & PCB and PBDE concentrations in kidney and variations by river system and type of site

As indicated earlier in this report, 10 kidney samples were analysed. Table 5-16 presents a series of descriptive statistics for the PCDD/F & PCB concentrations in these samples subdivided by river system and type of site. Comparable data for the PBDE concentrations are presented in Table 5-17. In these data the kidneys from both animals on the River Trent pair 3 were combined prior to analysis. This was due to small kidney size from the two animals on this farm which if analysed separately would lead to relatively high limits of detection.

Table 5-16: Variations in the concentrations of PCDD/Fs & PCBs in kidney by river system and type of site

Sample Group	Number of Samples	ng TEQ_{1998}/kg fat Minimum	Median	Mean	Maximum
Trent - Type of Site					
Control	3	0.98	1.14	1.13	1.27
Flood-prone	3	1.47	1.10	1.71	2.06
All Trent Samples	6	0.98	1.37	1.42	2.06
Aire/Ouse - Type of Site					
Control	2	0.67	0.68	0.68	0.69
Flood-prone	2	0.51	0.55	0.55	0.59
All Aire/Ouse Samples	4	0.51	0.63	0.62	0.69
All Samples – Type of Site					
Control	5	0.67	0.98	0.95	1.27
Flood-prone	5	0.51	1.47	1.25	2.06
All Samples	10	0.51	1.06	1.10	2.06

Notes

A Mann Whitney U test indicates no significant difference by type of site (p=0.602)

The data presented in Table 5-16 indicate that all the PCDD/F & PCB concentrations fell within a range of 0.51 – 2.06 (ngTEQ/kg fat). Table 5-16 presents little evidence from either river system that flood-prone farms have higher concentrations of PCDD/Fs & PCBs than control farms. Differences between flood-prone and control farms were not statistically significant.

Examination of the PBDE data presented in Table 5-17 indicates that the levels range from 290-3160 ng/kg fat. There is no evidence of elevated PBDE concentrations on flood-prone farms on either river system. Differences between flood-prone and control farms were not statistically significant.

Comparisons between flood-prone and control sites are complicated by the relatively small sample numbers in each subgroup. A more sophisticated method of comparison is to examine the differences in PCDD/F & PCB and PBDE concentrations between matched pairs of flood-prone and control farms on each river system. Three such pairs were identified as part of the experimental design and the kidney concentrations for these farms are presented in Table 5-18. For the comparison the PCDD/F & PCB concentrations between the two animals in each pair have been averaged. Examination of the data in Table 5-18 shows that the mean PCDD/F and PCB concentrations are higher on 2 of the 3 flood-prone farms. On only 1 of these pairs were both samples higher on the flood-prone farm in comparison to the control farm.

Table 5-17: Variations in the concentrations of PBDEs in kidney by river system and type of site

Sample Group	Number of Samples	$\sum_7$ ng/kg fat Minimum	Median	Mean	Maximum
Trent - Type of Site					
Control	3	640	1720	1840	3160
Flood-prone	3	580	1310	1290	1980
All Trent Samples	6	580	1515	1565	3160
Aire/Ouse - Type of Site					
Control	2	290	360	360	430
Flood-prone	2	350	610	610	870
All Aire/Ouse Samples	4	290	390	485	870
All Samples – Type of Site					
Control	5	290	640	1248	3160
Flood-prone	5	350	870	1018	1980
All Samples	10	290	755	1133	3160

Notes
A Mann Whitney U test indicates no significant difference by type of site (p=0.917)

Table 5-18: Comparisons of PCDD/F & PCB concentrations in kidney by river system and type of site for matched pairs of farms

	ng TEQ_{1998} /kg fat			
	Flood-prone		Control	
Sample	Sample 1 – Sample 2	Mean	Sample 1 - Sample 2	Mean
Trent				
Pair 1				
Pair 2				
Pair 3		1.47[1]		0.98[1]
Pair 4				
Pair 5	1.60, 2.06	1.83	1.14, 1.27	1.21
Aire/Ouse				
Pair 1	0.51, 0.59	0.55	0.69, 0.67	0.68

Notes
[1] The samples from both animals were combined to produce a composite sample

The corresponding PBDE data is presented in Table 5-19. Mean PBDE concentrations in kidney are higher on 1 from 3 flood-prone farms. A test of the correspondence between PCDD/F & PCB and PBDE levels (Spearman rank correlation) indicates little correlation (Spearman's ρ = 0.37 p = 0.29). This is unsurprising given the small number of sample pairs (n= 10).

Table 5-19: Comparisons of PBDE concentrations in kidney by river system and type of site for matched pairs of farms

	ng/kg fat			
	Flood-prone		Control	
Sample	Sample 1 – Sample 2	Mean	Sample 1 - Sample 2	Mean
Trent				
Pair 1				
Pair 2				
Pair 3		580[1]		640[1]
Pair 4				
Pair 5	1980, 1310	1645	1720, 3160	2440
Aire/Ouse				
Pair 1	870, 350	610	290, 430	360

Notes
[1] The samples from both animals were combined to produce a composite sample

Comparison of the relative contributions of PCDD/Fs, Non-Ortho PCBs and Ortho PCBs in kidney

In order to examine trends in more detail the median percentage contribution of PCDD/Fs, Non-Ortho PCBs and Ortho PCBs and to total TEQ are presented in Table 5-20 subdivided by river system and type of site .

Table 5-20: Variations in the median percentage contribution of PCDD/Fs, Non-Ortho PCBs and Ortho PCBs to total TEQ in kidney by river system and type of site

	% of Total WHO-TEQ$_{1998}$					
	PCDD/Fs		Non-Ortho PCBs		Ortho PCBs	
Sample Group	Control	Flood	Control	Flood	Control	Flood
Trent	$72.45_{(3)}$	$69.42_{(3)}$	$17.54_{(3)}$	$17.48_{(3)}$	$10.20_{(3)}$	$13.11_{(3)}$
Aire/Ouse	$64.08_{(2)}$	$64.96_{(2)}$	$29.31_{(2)}$	$27.73_{(2)}$	$6.61_{(2)}$	$7.31_{(2)}$

Notes
Numbers in **(subscript)** represent number of samples
There are few differences between control and flood-prone farms

Comparison with previous kidney data

Table 5-21: Comparison of mean PCDD/F and PCB concentrations (ng TEQ/kg fat) in lamb kidney with literature values

PCDD/F TEQ	PCB TEQ non-ortho + ortho	Total TEQ[1]	% PCB TEQ contribution to total TEQ	Origin of samples	Number of samples	Sampling date	Reference
0.7	0.6	1.3	46	UK	1	2001	FSA (2002)[2]
1.2	0.78	2.0	40	UK	1	2002	Foxall et al (2004a)[3]
0.67	0.48	1.2	42	UK	1	2002	Foxall et al (2004a)[4]
0.73	0.38	1.1	34	UK	8	2005	Fernandes et al (2010.)[5]
Present study							
0.76	0.34	1.10	32	UK	10	2009-10	

Notes
[1]Total concentrations of dioxins and PCBs may not equal the sum of individual dioxins and PCBs due to rounding.
[2]Control sample collected from farm in Gwynedd during study of foot and mouth disease pyres. Sample from 1 month old lamb. Values <LOD=LOD
[3] Lowland lamb from Norfolk farm. Market ready animal aged 127 days. Values <LOD=LOD
[4] Highland lamb from Northumberland hill farm. Market ready animal aged 153 days. Values <LOD=LOD
[5]Samples collected from a range of retail outlets including supermarkets and smaller shops. Values <LOD=LOD

Relatively little information on the levels of PCDD/Fs and PCBs in lamb kidneys is currently available and some caution needs to be exercised when comparing the present data with literature values. An examination of the data in Table 5-21 does however indicate the mean PCDD/F and PCB TEQ concentrations found in the present study are entirely consistent with the levels previously reported for the UK. The % contribution of PCBs to the total TEQ is also in general agreement with UK literature values. To our knowledge, no previous literature values exist for PBDE levels in lamb kidney.

Summary

The analyses presented in the above sections highlight a number of trends in the data from the liver samples. These are summarised below:

- PCDD/F & PCB and PBDE levels were not significantly higher in kidney from flood-prone farms
- There was little correspondence between PCDD/F & PCB levels and PBDE concentrations but this is likely to be affected by small sample sizes
- PCDD/F & PCB levels in lamb kidney were similar to those reported in other studies

Soil

Overall PCDD/F & PCB and PBDE concentrations in soil and variations by river system and type of site

As indicated earlier in this report, 11 soil samples were analysed. Table 5-22 presents a series of descriptive statistics for the PCDD/F & PCB concentrations in these samples subdivided by river system and type of site. Comparable data for PBDE are presented in Table 5-23.

Table 5-22: Variations in the concentrations of PCDD/Fs & PCBs in soil by river system and type of site

	Number	ng TEQ_{1998} /kg dry weight			
Sample Group	of Samples	Minimum	Median	Mean	Maximum
Trent - Type of Site					
Control	4	3.33	5.12	14.96	46.27
Flood-prone	5	17.84	30.08	33.35	56.43
All Trent Samples	9	3.33	26.04	25.17	56.43
Aire/Ouse - Type of Site					
Control	1	3.25	3.25	3.25	3.25
Flood-prone	1	12.85	12.85	12.85	12.85
All Aire/Ouse Samples	2	3.25	8.05	8.05	12.85
All Samples – Type of Site					
Control	5	3.25	5.06	12.62	46.27
Flood-prone	6	12.85	28.06	29.93	56.43
All Samples	11	3.25	17.84	22.06	56.43

Notes
A Mann-Whitney test indicates no significant difference between types of site (p=0.068)

The data presented in Table 5-22 indicate that the PCDD/F & PCB concentrations in soil were variable ranging from 3.25 to 56.43 (ng TEQ /kg dry weight). A similar variability occurred with PBDE concentrations ranging from 260 to 33700 (ng/kg dry weight). The soil concentrations of PCDD/Fs & PCBs and PBDEs for the matched pairs of flood-prone and control farms are presented in Table 5-24. The first thing of note in this table is the unusually high PCDD/F & PCB concentration on control farm pair 1. This value is nearly 9 times higher than any other control farm soil sample. The PBDE concentration on flood-prone farm pair 3 is also over 4 times higher than any other flood-prone farm.

Table 5-23: Variations in the concentrations of PBDEs in soil by river system and type of site

	Number	$\sum_7$PBDEs ng/kg dry weight			
Sample Group	of Samples	Minimum	Median	Mean	Maximum
Trent - Type of Site					
Control	4	260	320	350	500
Flood-prone	5	2920	7880	12010	33700
All Trent Samples	9	260	2920	6828	33700
Aire/Ouse - Type of Site					
Control	1	320	320	320	320
Flood-prone	1	2800	2800	2800	2800
All Aire/Ouse Samples	2	320	1560	1560	2800
All Samples – Type of Site					
Control	5	260	320	344	500
Flood-prone	6	2800	7580	10475	33700
All Samples	11	260	33700	5870	33700

Notes
A Mann-Whitney test indicates a significant difference between types of site (p=0.006)

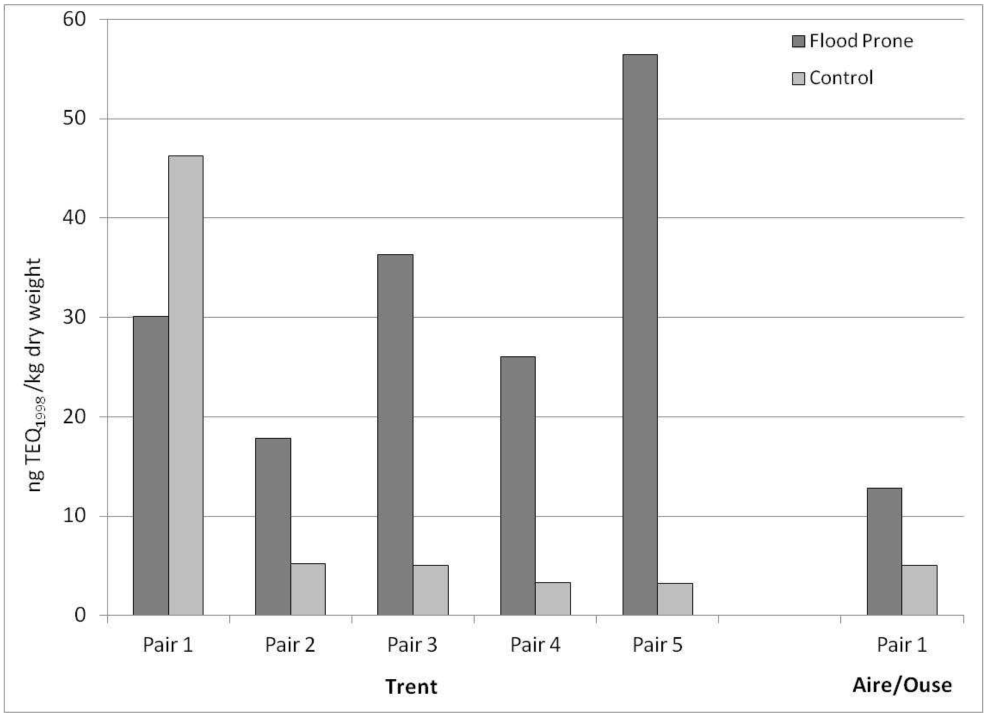
Table 5-24: Comparisons of PCDD/F & PCB and PBDE concentrations in soil by river system and type of site for matched pairs of farms

	PCDD/F & PCB ng TEQ_{1998} /kg dry weight		PBDE $\sum_7$ ng/kg dry weight	
Sample	Flood-prone	Control	Flood-prone	Control
Trent				
Pair 1	30.08	46.27	7880	260
Pair 2	17.84	5.18	2920	290
Pair 3	36.34	5.06	33700	350
Pair 4	26.04	5.06[&]	8270	350&
Pair 5	56.43	3.33	7280	500
Aire/Ouse				
Pair 1	12.85	3.25	2800	320

Notes
[&]This control farm is the same as pair 3 due to its close proximity to the flood-prone farm pair 4
For PCDD/F & PCB a Wilcoxon ranked signs test indicates no significant differences between type of site (p = 0.116)
For PBDE a Wilcoxon ranked signs test indicates a significant difference between type of site (p= 0.028)

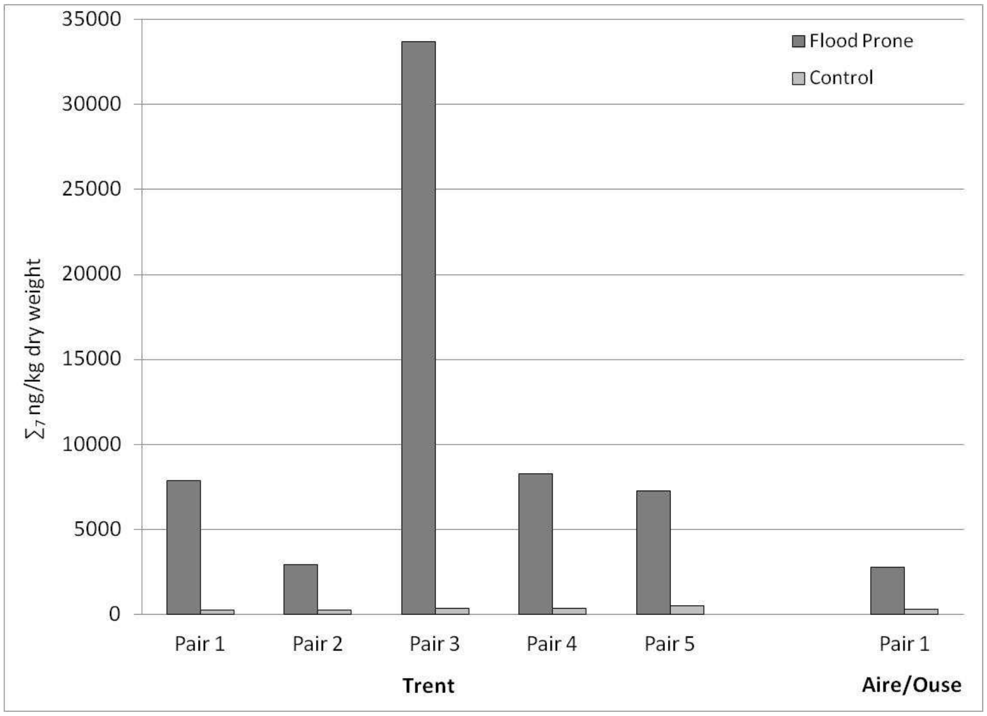
Table 5-22 indicates that soil from flood-prone farms has higher PCDD/Fs & PCBs concentrations. The mean and median values are twice as high on all flood-prone farms in comparison to control sites. This is statistically significant. Turning our attention to PBDE concentrations, Table 5-23 indicates that the mean and median PBDE concentrations were markedly higher on flood-prone farms. Again this is statistically significant. More robust evidence emerges from the paired analysis in Table 5-24 and Figure 5.5 which indicates that the concentrations of PCDD/Fs & PCBs in soil are higher on 5 from 6 flood-prone farms in comparison to their controls. However, this is not statistically significant. On these farms levels are 10-20 times higher than on their comparator control farms. Table 5-24 and Figure 5.6 also indicates that all 6 pairs had higher PBDE concentrations on flood-prone sites and this is statistically significant.

Figure 5.5: Mean PCDD/F and PCB concentrations in soil for matched pairs of farms.



A test of the correspondence between PCDD/F & PCB and PBDE soil concentrations suggested little correlation between the two (Spearman's $\rho = 0.44$ $p = 0.18$). This is unsurprising given the small number of sample pairs.

Figure 5.6: Mean PBDE concentrations in soil for matched pairs of farms



Comparison of TEQ levels from adjacent sites on selected farms

One way to further examine the impact of flooding would be to compare samples of soil simultaneously collected from pairs of flood-prone and control sites situated in the same field. Two such samples were collected from Farm pair 1 on the Aire/Ouse during the second sampling phase. Total TEQ and PBDE concentrations for the two samples are given in Table 5-25. They clearly show that the TEQ and PBDE concentrations are higher on the flood-prone site than in the corresponding control site.

Table 5-25: TEQ concentrations in pairs of soil samples simultaneously collected from flood-prone and control locations in the same field

	PCDD/F & PCB ng TEQ_{1998} /kg dry weight		PBDE $\sum_7$ ng/kg dry weight	
Comparison	Flood-prone	Non-Flood-prone	Flood-prone	Non-Flood-prone
Aire/Ouse – Flood-prone farm Pair 1	12.85	2.82	2800	290

Comparison with previous soil data

This section of the report compares the results from the present study to previous surveys of PCDD/Fs & PCBs and PBDE concentrations in soil.

Table 5-26: Comparison of mean PCDD/F & PCB concentrations in rural and flood plain soils with UK literature values

PCDD/F (ng TEQ /kg dry weight)	PCB non-ortho + ortho (ng TEQ /kg dry weight)	Total[1] (ng TEQ /kg dry weight)	%PCB TEQ contribution to total TEQ[1]	Sampling Date	Reference
Rural background					
5.2					Defra 2002[2]
2.8	0.15	3.0	5.1		FSA 2002[3]
2.5	0.25	2.7	9.2	2002	Foxall et al 2004a[4]
5.7	0.40	6.1	6.4	1998-9	Foxall et al 2004b[5]
5.3	0.62	5.9	10.4	2001-2	EA 2007[6]
3.8	0.39	4.2	9.3	2009-10	Present study[7]
Flood plains					
24.8	2.5	27.2	9.1	1998-9	Foxall et al 2004b[8]
24.5	5.4	29.9	15.7	2009-10	Present study[9]

Notes

1. Total concentrations of dioxins and PCBs may not equal the sum of individual dioxin and PCB values due to rounding.
2. Values quoted based on I-TEF system
3. Samples (n=2) collected from farms in Gwynedd and Cornwall during study of foot and mouth pyres.
4. Samples (n=5) collected from rural locations in Norfolk and Northumbria.
5. Samples (n=11) collected from control farms on River Trent
6. Samples (n=183) collected from rural areas in England as part of UK soil and herbage survey.
7. Samples (n=5) collected from control farms on Rivers Trent and Ouse
8. Samples (n=11) collected from flood-prone farms on River Trent
9. Samples (n=4) collected from flood-prone farms on Rivers Trent and Ouse excluding Trent control farm pair 1

Table 5-27: Comparison of mean PBDE concentrations in soil samples with literature values

	ng/kg dry weight							
	BDE 47	BDE 99	BDE 100	BDE 153	BDE 154	$\sum_5$ BDE	Sampling date	Reference
Rural background								
UK	66	113	21	24	17	242	2003-4	Harrad et al 2006[1]
UK	61	280	36	72	22	440	1998	Hassanin et al 2004[2]
Sweden	35	50	12	1.0	2.8	101	2002	Sellstrom et al 2005[3]
UK	128	118	24	22.5	15	300	2009-10	Present study[4]
Flood plains								
Sweden	1400	2300	560	290	270	4820	2002	Sellstrom et al 2005[5]
China	629	137	28	45	29	868	2002	Zou et al 2007[6]
USA	1490	1380	290	120	130	3410	2004	Yun et al 2008[7]
UK	1758	2638	534	308	258	5434	2009-10	Present study[8]

Notes

1. Rural soils-sites 1,3,9,11. Mean of monthly samples taken over period of one year
2. Remote rural grassland soils (n=21). Median concentrations for individual congeners-mean not given
3. Agricultural soils (n=5). Samples from agricultural research stations (3) and private farms
4. Samples (n=5) from control farms on Rivers Trent and Ouse
5. Sample from flood-prone farm adjacent to river known to be polluted with PBDEs. River floods annually including summer immediately prior to sampling
6. Samples from vegetable growing regions of Pearl river delta
7. Floodplain soils (n=10) from Shiawassee River, Michigan
8. Samples (n=5) from flood-prone farms on Rivers Trent and Ouse excluding sample from Trent flood-prone pair 3

The PCDD/F & PCB data for the UK studies listed in Table 5-26 have been divided into two categories, rural background and those from flood plain locations. Examination of the data presented in Table 5-26 shows that the mean PCDD/F TEQ and total TEQ values from control farms are similar to the values previously reported for rural background soils in the UK. The mean total TEQ concentration (29.9 ngTEQ/kg dry weight) in soils from flood-prone sites is similar to that found in the previous flood project.

For PBDEs in soils the data in Table 5-27 have been divided into two categories-rural background and those from flood plain sites. As is apparent from the Table, the ∑5 PBDE data from control farms agree well with rural background values reported previously. The corresponding data from flood-prone farms are marginally higher to the concentrations reported for flood plains in other countries.

Summary

The analysis presented in the above sections highlight a number of trends in the data from the soil samples. These are summarised below:

- Using the most robust paired analysis, PCDD/F & PCB concentrations were not significantly higher in soils from flood-prone farms
- PBDE concentrations were significantly higher in soils from flood-prone farms
- Within the same field, PCDD/F & PCB and PBDE concentrations were higher on the flood-prone sections
- There was little correspondence between PCDD/F & PCB levels and PBDE concentrations
- PCDD/F & PCB concentrations on control farm soils were similar to rural background levels reported in other studies. Flood-prone soil concentrations were consistent with previous research
- PBDE concentrations on control farm soils were similar to levels reported in other studies. Flood-prone soil PBDE concentrations were slightly higher than those reported by previous studies.

Grass

Overall PCDD/F & PCB and PBDE concentrations in grass and variations by river system and type of site

As indicated earlier in this report, 8 grass samples were analysed. Table 5-28 presents a series of descriptive statistics for the PCDD/F & PCB concentrations in these samples subdivided by river system and type of site. Comparable data for the PBDE concentrations are presented in Table 5-29. Small sample sizes preclude the use of statistical tests in this section.

Table 5-28: Variations in the concentrations of PCDD/Fs & PCBs in grass by river system and type of site

Sample Group	Number of Samples	ng TEQ_{1998} /kg dry weight Minimum	Median	Mean	Maximum
Trent - Type of Site					
Control	3	0.12	0.20	0.20	0.27
Flood-prone	3	0.14	0.23	0.42	0.90
All Trent Samples	6	0.12	0.22	0.31	0.90
Aire/Ouse - Type of Site					
Control	1	0.15	0.15	0.15	0.15
Flood-prone	1	0.40	0.40	0.40	0.40
All Aire/Ouse Samples	2	0.15	0.28	0.28	0.40
All Samples – Type of Site					
Control	4	0.12	0.18	0.19	0.27
Flood-prone	4	0.14	0.32	0.42	0.90
All Samples	8	0.12	0.22	0.30	0.90

The data presented in Table 5-28 indicate that the PCDD/F & PCB concentrations in grass were variable ranging from 0.12 to 0.90 (ng TEQ /kg dry weight). A similar variability occurred with PBDE concentrations ranging from 110 to 550 (ng/kg dry weight). The grass concentrations of PCDD/Fs & PCBs and PBDEs for the matched pairs of flood-prone and control farms are presented in Table 5-30.

Table 5-29: Variations in the concentrations of PBDEs in grass by river system and type of site

Sample Group	Number of Samples	Minimum	$\sum_7$ ng/kg dry weight Median	Mean	Maximum
Trent - Type of Site					
Control	3	130	140	273	550
Flood-prone	3	110	110	180	320
All Trent Samples	6	110	135	227	550
Aire/Ouse - Type of Site					
Control	1	110	110	110	110
Flood-prone	1	320	320	320	320
All Aire/Ouse Samples	2	110	210	210	310
All Samples – Type of site					
Control	4	110	135	233	550
Flood-prone	4	110	213	213	320
All Samples	8	110	135	223	550

Table 5-30: Comparisons of PCDD/F & PCB and PBDE concentrations in grass by river system and type of site for matched pairs of farms

	PCDD/F & PCB ng TEQ_{1998} /kg dry weight		PBDE $\sum_7$ ng/kg dry weight	
Comparison	Flood-prone	Control	Flood-prone	Control
Trent				
Pair 1	0.14	0.27	320	140
Pair 2				
Pair 3	0.23	0.20	110	130
Pair 4				
Pair 5	0.90	0.12	110	550
Aire/Ouse				
Pair 1	0.40	0.15	310	110

Table 5-28 presents little evidence that grass from flood-prone farms has higher PCDD/Fs & PCBs concentrations. On the River Trent the mean values were higher on flood-prone farms but the median values were marginally lower on flood-prone farms in comparison to control sites. Both mean and median values were higher on the flood-prone farm on the Aire/Ouse. Table 5-29 indicates that the mean and median PBDE concentrations were higher on control farms on the River Trent. The one flood-prone farm on the River Ouse had higher PBDE levels that its control farm. Stronger evidence emerges from Table 5-30 which indicates that the concentrations of PCDD/Fs & PCBs in grass are higher on 3 from 4 flood-prone farms in comparison to their controls. The table also indicates that 2 of the 4 farms had higher PBDE concentrations on flood-prone sites.

A Spearman rank correlation test indicates no correlation (Spearman's $\rho = -0.49$, $p = 0.22$) between PCDD/F & PCB and PBDE concentrations. Given the low number of pairs (n=8) this is unsurprising.

Comparison of TEQ levels from adjacent sites on selected farms

One way to examine further the impact of flooding would be to compare samples of grass simultaneously collected from pairs of flood-prone and control sites situated in the same field. Two such samples were collected from Farm pair 1 on the Aire/Ouse. The TEQ and PBDE concentrations for the two samples are given in Table 5-31. The results show that the TEQ was lower on the flood-prone site in comparison to the control site. PBDE concentrations showed little difference between the flood-prone and non-flood-prone location.

Table 5-31: TEQ concentrations in pairs of grass samples simultaneously collected from flood-prone and control locations in the same field

	PCDD/F & PCB ng TEQ_{1998} /kg dry weight		PBDE $\sum_7$ ng/kg dry weight	
Comparison	Flood-prone	Non-Flood-prone	Flood-prone	Non-Flood-prone
Aire/Ouse – Flood-prone farm Pair 1	0.40	1.15	310	320

Comparison with previous grass data

This section compares the results from the present study to previous surveys of PCDD/Fs & PCBs and PBDE concentrations in grass.

Table 5-32: Comparison of mean PCDD/F and PCB concentrations in grass with UK literature values

PCDD/F (ng TEQ /kg dry weight)	PCB TEQ non-ortho + ortho (ng TEQ /kg dry weight)	Total TEQ[1] (ng TEQ /kg dry weight)	%PCB TEQ contribution to total TEQ[1]	Sampling date	Reference
Rural background					
0.45	0.10	0.55	18	2001	FSA 2002[2]
0.04	0.04	0.08	53	2002	Foxall et al 2004a[3]
0.19	0.10	0.29	34	1998-9	Foxall et al 2004b[4]
2.0	0.36	2.4	15	2001-2	EA 2007[5]
0.13	0.06	0.19	33.5	2009-10	Present study[6]
Flood plains					
0.19	0.11	0.30	36	1998-9	Foxall et al 2004b[7]
0.29	0.13	0.42	32.7	2009-10	Present study[8]

Notes
1. Total concentrations of dioxins and PCBs may not equal the sum of individual dioxin and PCB values due to rounding.
2. Samples (n=2) collected from farms in Gwynedd and Cornwall during study of foot and mouth pyres.
3. Samples (n=5) collected from rural locations in Norfolk and Northumbria.
4. Samples (n=3) collected from control farms on River Trent
5. Samples (n= 42) collected from rural areas as part of UK soil and herbage pollutant survey.
6. Sample (n=5) collected from control farms on the Rivers Trent and Ouse
7. Samples (n=3) collected from flood-prone farms on River Trent
8. Samples (n=6) collected from flood-prone farms on the Rivers Trent and Ouse

Table 5-33: Comparison of Mean PBDE concentrations in grass samples with literature

	ng /kg dry weight							
	BDE 47	BDE 99	BDE 100	BDE 153	BDE 154	$\sum_5$ BDE	Sampling date	Reference
UK	74	78	14	25	<44	191	2004	Hassanin et al 2005[1]
Present study[2]	76	78	16	14	14	198	2009-10	

Notes
Samples from agricultural research station in semi-rural location. BDE-154 concentration taken as zero in calculation of $\sum_5$ BDEs.

Samples (n=11; 6 flood-prone and 5 control farms) on the Rivers Trent and Ouse

From an examination of the data in Table 5-32, it is apparent that the PCDD/F TEQ and the total TEQ values for the control farms from the present study fall within the range for rural background sites previously reported. The corresponding concentrations in samples from flood-prone sites agree well with the results from the previous flood project.

Few data are available for the levels of PBDEs in grass. The mean PBDE concentration in grass from the present study (Table 5-33) agrees with the values reported by a recent UK study.

Summary

The analysis presented in the above sections highlight a number of trends in the data from the grass samples. These are summarised below:

- Due to small sample sizes it was not possible to test statistically whether PCDD/F & PCB concentrations and PBDE concentrations were higher in grass from flood-prone farms
- Within the same field no indication that PCDD/F & PCB concentrations and PBDE concentrations are higher on the sections that are flood-prone
- Little correspondence between PCDD/F & PCB levels and PBDE concentrations but this is likely to be affected by small sample sizes
- Levels of PCDD/Fs & PCBs and PBDEs on grass are consistent with previous studies

PCDD/F & PCB Weight of Evidence Summary

In the statistical analysis of the PCDD/F and PCB data, the small numbers of samples meant that very pronounced differences were required between flood-prone and control sites to achieve statistically significant results. To overcome these limitations and to provide a more holistic overview of the data (i.e. look at the meat, liver, soil, grass and feed data together), they were also examined using a weights of evidence table as described in Chapter 2. The results are presented in Table 5.34. The kidney data is not included in this table due to the limited number of samples analysed and its close correspondence with levels in meat.

There is very little evidence in the table 5.34 that river flooding leads to elevated total TEQ in meat. There was a clear indication that PCDD/F and PCB levels were higher in soil from flood-prone farms. These contrasts also appeared on the grass samples. Although it was not possible to assess consistency of association due to the lack of samples on the Aire/Ouse, we conclude that a potential for elevated PCDD/F and PCB levels in sheep exists due to the results presented, as well as the soil and grass results from Chapter 4. The most direct evidence of the impact of flooding on PCDD/F and PCB concentrations emerges from the analysis of the meat and liver samples. These suggest that this potential for elevated PCDD/F and PCB concentrations was not realised. Meat samples from flood-prone farms had similar total TEQ levels to those from control farms and there was only a small percentage difference (7%) in liver. The strongest evidence to examine the impact of flooding comes from the paired analysis, but there was no clear contrasts between flood-prone and control farms in the paired analysis. Based upon all evidence presented above, we conclude that river flooding does not transfer PCDD/Fs and PCBs to meat and liver in sheep raised on the flood plains.

Table 5.34: Weight of evidence table examining the impact of river flooding upon PCDD/F and PCB concentrations in meat

Strength of Association		
Hazard	Soil	• Higher total TEQ (median 28.1 vs. 5.1ng TEQ_{1998} /kg dry weight) on flood-prone farms • 5/6 flood-prone pairs have higher median total TEQ • One 1 field total TEQ was over 4 times higher on the flood-prone part compared to the non-flood-prone location (12.85 vs. 2.82 ng TEQ_{1998} /kg dry weight)
	Grass	• Similar median total TEQ (median 0.32 vs. 0.18 ng TEQ_{1998} /kg dry weight) on both farm types • 3/4 flood-prone pairs have higher median total TEQ • One 1 field total TEQ was lower on the flood-prone part compared to the non-flood-prone location (0.40 vs. 1.15 ng TEQ_{1998} /kg dry weight)
Outcome	Meat	• Flood-prone farms have similar total TEQ (median 1.0 vs. 1.0 ng TEQ1998 /kg fat) • 3/6 flood-prone pairs have higher median total TEQ • In 3/6 flood-prone pairs total TEQ was higher in both animals
	Liver	• Flood-prone farms have higher total TEQ (median 15.2 vs. 14.0 ng TEQ1998 /kg fat) • 2/5 flood-prone pairs have higher median total TEQ • In 2/5 flood-prone pairs total TEQ was higher in both animals
Consistency of Association		
Hazard	Soil	• Consistency difficult to assess as only one farm pair on the Aire/Ouse
	Grass	• Consistency difficult to assess as only one farm pair on the Aire/Ouse
Outcome	Meat	• Consistency difficult to assess as only one farm pair on the Aire/Ouse
	Liver	• Consistency difficult to assess as only one farm pair on the Aire/Ouse
Alternative Explanations		• No reason to believe that commercial feed concentrations vary between flood-prone and control farms

PBDE Weight of Evidence Summary

In the statistical analysis of the PBDE data, the small numbers of samples meant that very pronounced differences were required between flood-prone and control sites to achieve statistically significant results. To overcome these limitations and to provide a more holistic overview of the data, they were also examined using a weights of evidence table in Table 5.35. The kidney data is not included in this table due to the limited number of samples analysed and its close correspondence with levels in meat.

Table 5.35: Weight of evidence table examining the impact of river flooding upon PBDE concentrations in meat

Strength of Association		
Hazard	Soil	• Higher PBDE (median 7580 vs. 320 ng /kg dry weight) on flood-prone farms • 6/6 flood-prone pairs have higher median PBDE • One field had PBDE concentrations over nine times higher on the flood-prone part compared to the non-flood-prone location
	Grass	• Higher median PBDE (median 213 vs.135 ng /kg dry weight) on both farm types • 2/4 flood-prone pairs have higher PBDE levels • One field had PBDE concentrations nearly identical on the flood-prone part compared to the non-flood-prone location
Outcome	Meat	• Flood-prone farms have lower PBDE (median 590 vs. 750 ng /kg fat) • 2/6 flood-prone pairs have higher median PBDE • In 1/6 flood-prone pairs PBDE levels were higher in both animals
	Liver	• Flood-prone farms have lower PBDE (median 530 vs. 785 ng /kg fat) • 2/5 flood-prone pairs have higher median PBDE • In 2/5 flood-prone pairs PBDE levels were higher in both animals
Consistency of Association		
Hazard	Soil	• Consistency difficult to assess as only one farm pair on the Aire/Ouse
	Grass	• Consistency difficult to assess as only one farm pair on the Aire/Ouse
Outcome	Meat	• Consistency difficult to assess as only one farm pair on the Aire/Ouse
	Liver	• Consistency difficult to assess as only one farm pair on the Aire/Ouse
Alternative Explanations		• No reason to believe that commercial feed concentrations vary between flood-prone and control farms

There is very little evidence in this table that river flooding leads to elevated PBDE levels in meat. There was a clear indication that PBDE levels were higher in soil from flood-prone farms. These contrasts also appeared on the grass samples. Although it was not possible to assess consistency of association due to the lack of samples on the Aire/Ouse, we conclude that a potential for elevated PBDE levels in sheep exists due to the results presented as well as the soil and grass results from Chapter 4. The most direct evidence of the impact of flooding on PBDE concentrations emerges from the analysis of the meat and liver samples. These suggest that this potential for elevated PBDE concentrations was not realised. Meat samples from flood-prone farms had lower PBDE levels to those from control farms and liver samples showed similar trends. The strongest evidence to examine the impact of flooding comes from the paired analysis, but there was no clear contrasts between flood-prone and control farms in the paired analysis. Based upon all evidence presented above, we conclude that river flooding does not transferring PBDEs to meat and liver in sheep raised on the flood plains.

6. Seasonal monitoring programme

This chapter focuses upon the results from the seasonal monitoring of milk samples from the two dairy farms. The chapter is written in the form of an academic publication.

Introduction

Polychlorinated dibenzo-p-dioxins, polychlorinated dibenzofurans (PCDD/Fs, collectively referred to as "dioxins") and polychlorinated biphenyls (PCBs) are well known environmental and food contaminants which mainly arise from industrial sources and motorized transport activity. Their presence in the environment has been and still remains a matter of considerable concern due to their widespread distribution, persistence, ability to bioaccumulate and their toxic properties (Schecter and Gasiewicz, 2003). The brominated flame retardants, PBDEs, are structurally similar to PCBs and as such are also chemically stable, strongly lipophilic and are increasingly being recognized as persistent environmental and food contaminants (D'Silva et al., 2004; Schecter et al., 2008).

Cow's milk and dairy products are a major source of human exposure to PCDD/Fs (Furst et al., 1990; Theelen et al., 1993), PCBs (Duarte-Davidson and Jones, 1994) and PBDEs (Domingo, 2004). The majority of diet related studies involve either the collection of 'spot' samples taken at a single point in the year (e.g. Fernandes et al., 2009; Lake et al., 2011) or, as is the case with the UK Total Diet Studies, are designed to average geographical or seasonal variations in consumed food over a calendar year (Peattie et al., 1983; MAFF, 1994; FSA, 2003).

It is quite conceivable, however, that PCDD/F, PCB and PBDE concentrations in milk and dairy products may fluctuate quite substantially during the year as a result of changes in animal feeding regimes, periods spent indoors etc. Seasonal changes in atmospheric deposition fluxes and any corresponding variations in soil and grass concentrations may also contribute to such temporal fluctuations (Harrad and Mao, 2004; Motelay-Massei et al., 2005; Hovmand et al., 2007). Should substantial seasonal variations in concentrations in milk, dairy products and indeed other foodstuffs, occur, this would have profound implications not just for the general design of monitoring studies but also for the accurate assessment of the dietary intake of such contaminants.

Although a few studies have focused on temporal (year on year) trends in PCDD/F and PCB concentrations in cow's milk sourced directly from farms (Schmid et al., 2003; Durand et al., 2008), much less attention has been paid to possible seasonal fluctuations and their potential sources. One such study (Sweetman et al., 1999) carried out over the summer months at a small UK farm suggested that PCB concentrations in milk taken from the bulk tank may decline slightly over the period. It is worth noting however that the investigation was somewhat restricted in scope as it only covered the outdoor grazing period and was confined to the measurement of PCBs. In a later study (Mamontova et al., 2007), PCB concentrations in milk collected directly from farms in Siberia were found to vary little on average between summer feeding (herbage with small quantities of supplementary feed) and winter feeding (mainly hay, corn silage, sunflower and lucerne) regimes. The study was also somewhat limited in that it was confined to PCBs and did not include the analysis of any feed or environmental samples. To our knowledge no data on the seasonal variation of PBDE concentrations in cow's milk has yet been reported.

This study represents the first detailed investigation into the seasonal variation of PCDD/F, PCB and PBDE concentrations in cow's milk from individual farms over the period of a year. To provide supporting evidence for any trends emerging from the milk data, soil, grass, silage, commercial feed, and bedding samples were simultaneously collected along with the milk.

The aims of the study were to:

- Establish the extent to which PCDD/Fs, PCBs and PBDE concentrations in milk vary over the period of a year.
- Understand the sources of this variation through an analysis of soil, grass, silage, commercial feed and bedding samples.

Materials and Methods

The study was focused on the River Trent which, at 274km long, is one of the longest rivers in England. The river flows through substantial urban and industrial areas and along the river system, previous research has demonstrated elevated levels of industrial contamination, specifically PCDD/Fs and PCBs (Lake et al., 2005) and PBDEs (Lake et al., 2011).

Along the length of this river, five dairy farms whose pastures were regularly flooded, were selected alongside a corresponding set of individually matched nearby control farms whose pastures were not subject to flooding. Further details on the selection of these five pairs of flood-prone/control farms are provided elsewhere (Lake et al., 2011). Milk from these five pairs of flood-prone/control farms have been previously investigated (Lake et al., 2011) as part of a wider study examining the long-term effects of river flooding on levels of organic environmental contaminants from livestock reared on flood-prone pastures. From these five pairs one pair was chosen to take part in this study. In this report the flood-prone farm is referred to as Farm F and the control farm as Farm C. This pair was chosen because the farms were adjoining and would thus be expected to be subject to very similar levels of atmospheric deposition of contaminants. On both farms the breed of dairy cattle (Holstein-Friesian) was identical; herd sizes and annual milk yields were similar (Farm F 7000l/cow p/a; Farm C 7500 l/cow p/a) and both farms operated a year- round calving pattern. The main difference between the two farms was on Farm F, around 28% of its pastureland was subject to regular flooding. No pasture was subject to flooding on Farm C. It is important to recognize that these two farms are not part of a controlled experiment, but are two working farms with similar characteristics.

The sampling design was based around the animal husbandry of both farms and the need to identify the levels of PCDD/Fs & PCBs and PBDEs in all major dietary inputs to the cattle. In these two farms and across the UK, dairy cattle normally graze on pasture grass from April to October and on silage (often produced on the same farm) during the winter months when they are kept indoors. The exact dates when cattle are moved indoors and outdoors will vary from year to year depending upon the amount of pasture herbage which itself depends upon the weather conditions. It is also important to recognize that as grass levels begin to decrease in the autumn, cattle will be provided with increasing amounts of silage in the 3-4 weeks before being brought indoors. In contrast, when the cows return to pasture in the spring, the provision of supplementary silage is less common. In addition to grass and silage around 50% of the cow's intake is commercial feed, fed to the cattle at milking time throughout the year.

Beginning in August 2009 and at approximately six weekly intervals thereafter, a series of nine milk samples were collected from the bulk tank of each farm representing the average of all productive cows on the farm. Samples were stored frozen (-20^{o}C) until analysed. Soil and grass (when the cattle were outdoors) samples were also collected along with the milk samples using standard techniques detailed previously (Lake et al., 2011). The soil and grass samples were collected from locations regularly grazed by the herd. In the case of Farm F, samples were taken from a location with a known history of flooding. Samples of commercial feed that were fed to the cows were also simultaneously collected. A series of silage and bedding samples were also collected during the period when the cattle were housed indoors. Overall, a total of 58 samples (milk 18, soil 6, grass 10, silage 8, commercial feed 12, bedding 4) were collected and analysed for PCDD/Fs & PCBs and PBDEs.

PCDD/F and PCB concentrations were analyzed according to methods fully UKAS accredited to the ISO 17025 standard (Fernandes et al., 2004). For PCDD/Fs and PCBs all analyses were based on the seventeen 2,3,7,8-Cl substituted PCDD/F congeners, four non-ortho PCBs (77, 81, 126, and 169) and twenty-one ortho congeners (18, 28, 31, 47, 49, 51, 52, 99, 101, 105, 114, 118, 123, 128, 138, 153, 156, 157, 167, 180, and 189). WHO-TEQ$_{1998}$ values were calculated using WHO-TEFs (Van Den Berg et al., 1998) and all values are reported in this report as upper-bound total TEQs incorporating PCDD/F, mono-ortho and non-ortho substituted PCB concentrations. The WHO-TEQ$_{1998}$ values were used rather than the more recent 2005 (Van Den Berg et al., 2006) values to allow easy comparison with previous results and with literature values. The methodology (UKAS accredited to the ISO17025 standard) used for the determination of PBDEs (BDEs 17, 28, 47, 49, 66, 71, 77, 85, 99, 100, 119, 126, 138, 153, 154, and 183) is essentially the same as that used for chlorinated dioxins and PCBs (Fernandes et al., 2004)—featuring the extensive use of $^{13}C_{12}$ labelled analyte surrogates and measurement by high-resolution mass spectrometry. There are no universal acceptance criteria for data quality for PBDEs, so quality control followed the criteria currently used for PCDD/Fs and PCBs (Ambidge et al., 1990; EC, 2002). The basic method performance data for PBDEs has been published before (Fernandes et al., 2009). Due to the fact that congeners 28, 47, 99, 100, 153, 154, and 183 were detected in most samples, and are commonly reported by other workers, data are reported as the sum of these seven congeners (Σ7). Unless stated otherwise all concentrations are reported as upper-bound. In order to minimise analytical variability, all milk samples were analysed at the same time.

Quality control and assurance measures for all analytes were similar. Sample extraction and purification was carried out in batches that included a full method blank and a reference material. The blank was used to compute LODs, and was assessed for the presence of native analytes and data rejected if any levels detected were unacceptable. Data were similarly rejected if reference material results were not in good agreement with published or established values (e.g. Griepink et al., 1988) The analytical recovery rate (measured using $^{13}C_{12}$ surrogates) in samples was typically of the order of 60-90%. The gas chromatography-mass spectrometry analysis of sample extracts was preceded by the analysis of a standard reference solution used to check system performance and calibration validity. This solution was also analyzed during and at the end of the analytical run. All integrated chromatograms were scrutinized to assess chromatographic peak shape, resolution, and signal-to-noise. Additionally, lock-mass traces were examined for evidence of ionization suppression and isotope ratios were compared with theoretical abundances. The laboratory participates regularly in intercomparison exercises such as the 2009 rounds of the intercomparison exercise "Dioxins in Food" which included PBDEs (Norwegian Institute of Public Health, 2009).

Results

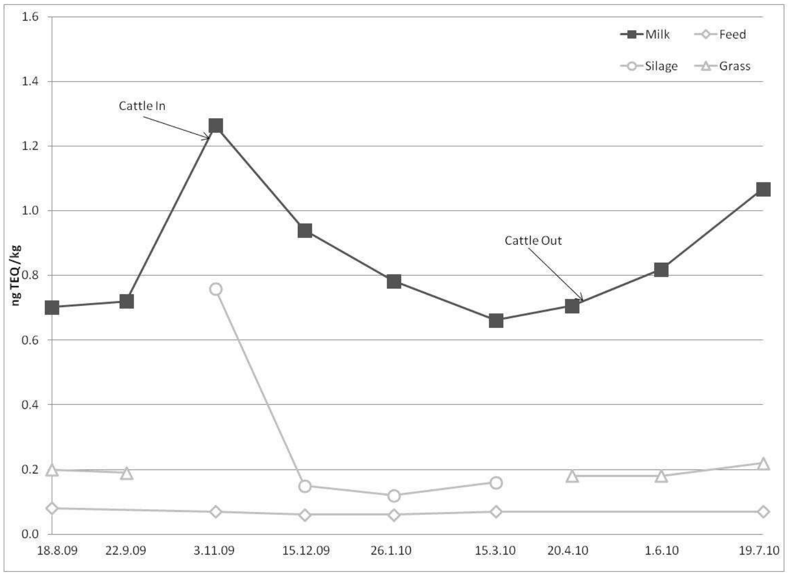
The overall time trends for the levels of PCDD/Fs & PCB WHO-TEQ in milk on Farms F and C are presented in Figure 6.1a and Figure 6.1b respectively. For comparison the ∑ICES6 PCB time trends are presented for Farms F and C in Figure 6.1c and Figure 6.1d respectively. In Figure 6.2a-Figure 6.2d time trends of levels of dioxins and dioxin-like PCBs in each sample are additionally presented. On these graphs the dates when the cattle were moved indoors/outdoors are indicated. On Farm F total TEQ in milk varied from 0.70-1.27 (ng TEQ/kg fat weight) over a 12 month period. In terms of time trends, levels were fairly similar in the first 2 samples before rising rapidly to 1.27 (ng TEQ/kg fat weight) at the point around when the animals were moved indoors. Levels then drop before recovering later in the year. The rise between Sep 22 and Nov 3 reflects a change of 0.55 (ng TEQ/kg fat weight) or a near doubling of milk levels over a 6 week period. Figure 6.1c indicates that the ∑ICES6 levels in milk of Farm F broadly follow the total TEQ levels although the Nov 3 peak is less pronounced in the ∑ICES6 data. Additionally the ∑ICES6 levels in milk nearly double between June 1 and July 19 an increase which is not as marked as for total TEQ. On Farm C over a 12 month period total TEQ in milk varied from 0.72-1.55 (ng TEQ/kg fat weight). In terms of time trends (Figure 6.1), TEQ levels demonstrate an increasing trend from the start of sampling and reach a peak on Apr 20 when the animals have just moved outdoors. The total TEQ levels in June and July 2010, by which time the cattle would have fully adjusted to outdoor grazing, are substantially lower than those characteristic of the indoor period (November - March) and interestingly very similar to the concentrations recorded for the outdoor grazing period (August and September) for the previous year. The reduction in levels after the animals have moved outdoors represents a drop in total TEQ of 0.82 (ng TEQ/kg fat weight) or an approximate halving of levels. Figure 6.1d indicates that the ∑ICES6 levels in the milk from Farm C shares some similarities with the total TEQ levels but overall it appears more stable over time.

The samples of diet from Farm F (silage, grass and animal feed) provide some explanation for the changing total TEQ levels especially the peak in milk observed on Nov 3. This coincides with a high level in the silage fed to the cattle. Although this milk sample was taken just before the cattle moved indoors, the cattle had been fed increasing quantities of silage for 3-4 weeks before the indoor move to compensate for declining grass levels on pasture. Silage would thus appear to be a possible source of these contaminants. The high total TEQ levels in silage fed to cattle is not entirely unexpected as a grass sample from the same farm a year earlier in August 2008 had similar TEQ levels (0.70 ng TEQ/kg dry weight; FSA, 2010). Part of Farm F is prone to seasonal flooding which may be the source of these elevated levels (Lake et al., 2011). After Nov 3 the total TEQ levels in milk decline probably as the cattle are fed silage with lower total TEQ levels. Levels rise again around Mar 15 until the end of sampling, although there is no clear explanation for this trend. On Farm C there is some relationship between total TEQ in milk and those of the inputs. The peak on April 20 corresponds to higher levels in silage and grass around the period. Comparing the 2 farms, apart from the November 3 sample, Farm F demonstrates lower total TEQ during the indoor period than Farm C. During the indoor period the total TEQ in silage fed to cattle is lower on Farm F which may explain this contrast.

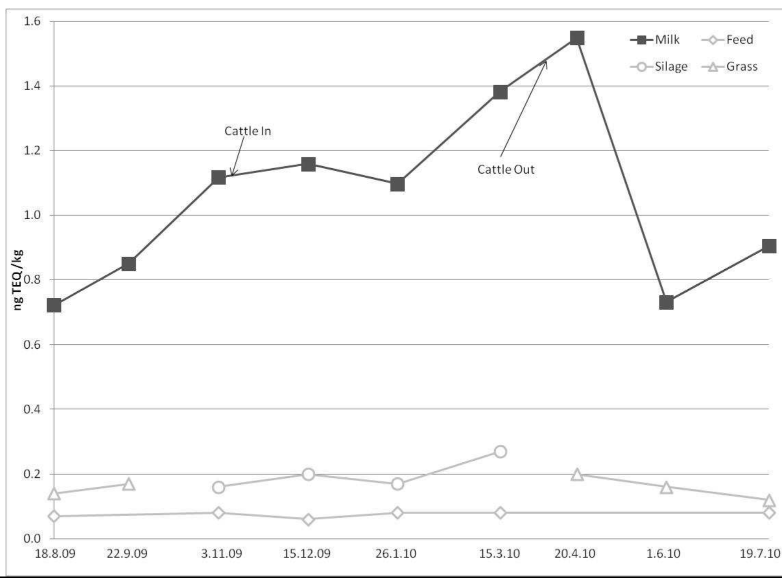
The time trends for the levels of PBDEs in milk on Farm F and Farm C are presented in Figure 6.3a Figure 6.3b respectively. The graphs present the upper bound PBDE concentrations in milk. Towards the end of the data collection (from January onwards) the fat content in milk from both farms was low (Table 6-1), which elevates the analytical limits of detection, increasing our uncertainty as to the true PBDE concentration. On Farm F over a 12 month period PBDE levels in milk varied from 150 to 280 (∑7 PBDE ng/kg fat weight) and some of these variations occurred over short time periods such as the 100 (∑7 PBDE ng/kg fat weight) increase which occurred between November 11 and December 15. Over the same time period levels on Farm C were slightly more variable at between 140 and 320 (∑7 PBDE ng/kg fat weight). Again there was much variability over short time periods such as the 130 (∑7 PBDE ng/kg fat weight) increase which occurred between Jan 26 and Mar 5. To understand these time trends in PBDE concentrations in milk, samples of diet (i.e. silage, grass and animal feed) on both farms were taken as part of the sampling design. However, the generally low levels of PBDEs (in comparison to other studies e.g. Hassanin et al., 2005; Lake et al., 2011), most of which were close to the analytical detection limits preclude a detailed analysis of how these may affect PBDE levels in milk.

Figure 6.1: Temporal trends in PCDD/Fs & PCB concentrations in milk, Silage, Grass and Feed[1]

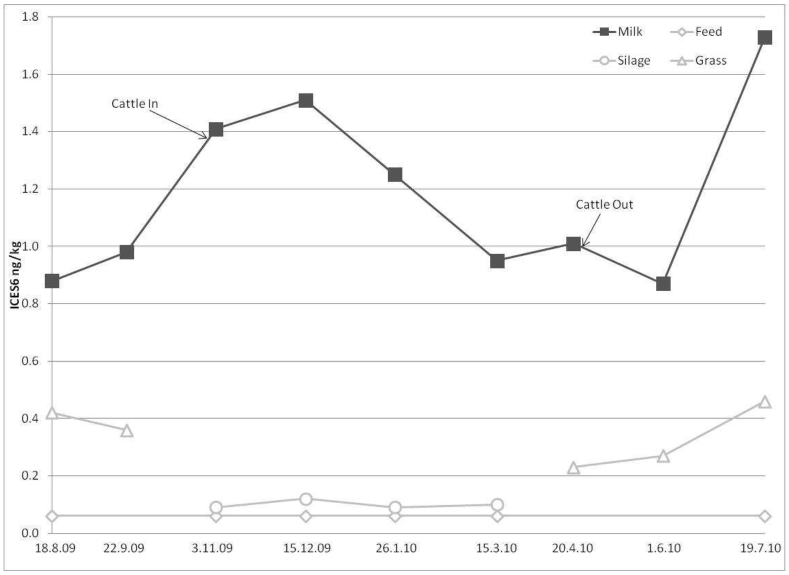
(a) Farm F Total TEQ



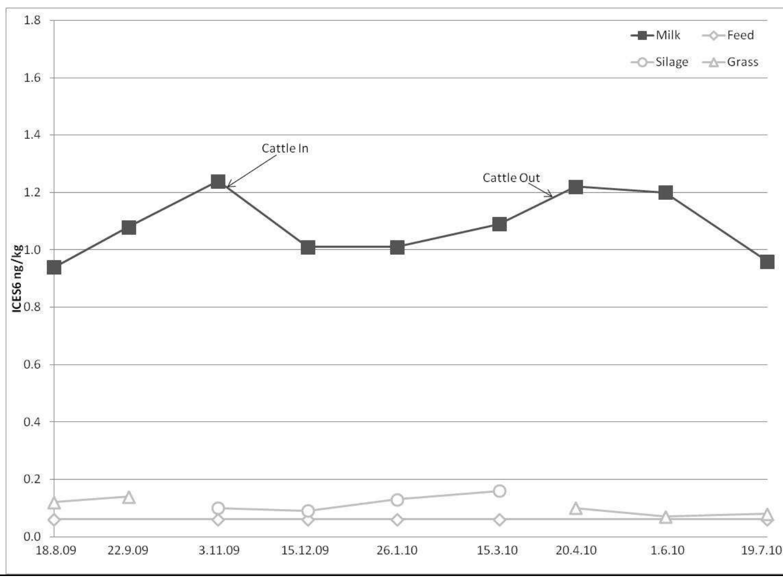
(b) Farm C Total TEQ



(c) Farm F ∑ICES6



(d) Farm C ∑ICES6

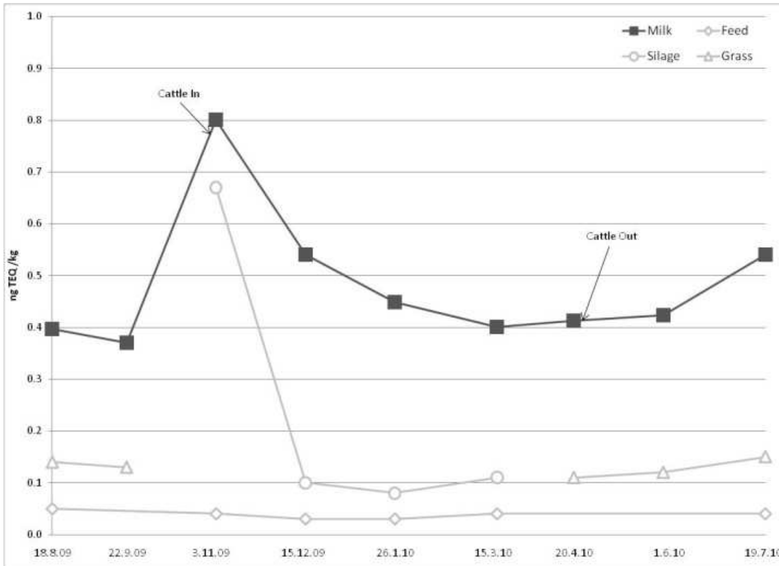


Notes

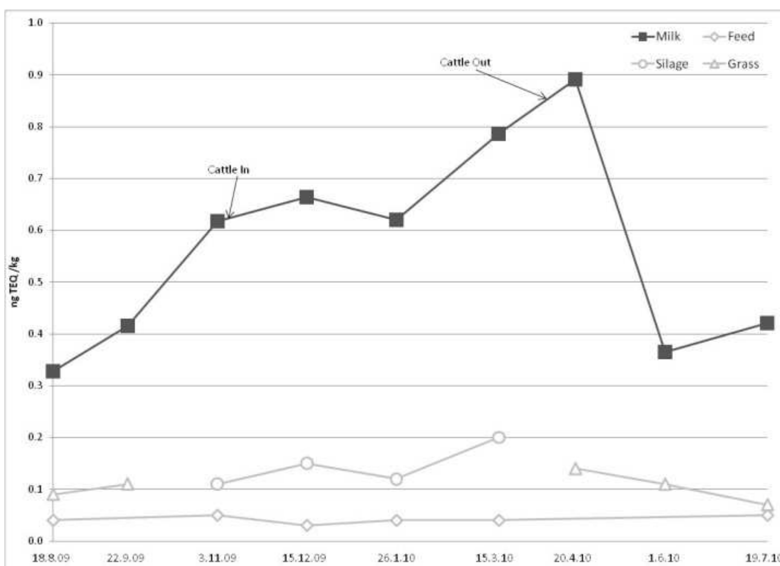
[1] Milk data are calculated on a fat weight basis; silage and grass are calculated on a dry weight basis; feed is calculated on a whole weight basis

Figure 6.2: Temporal trends in Dioxins and Dioxin like PCBs[1]

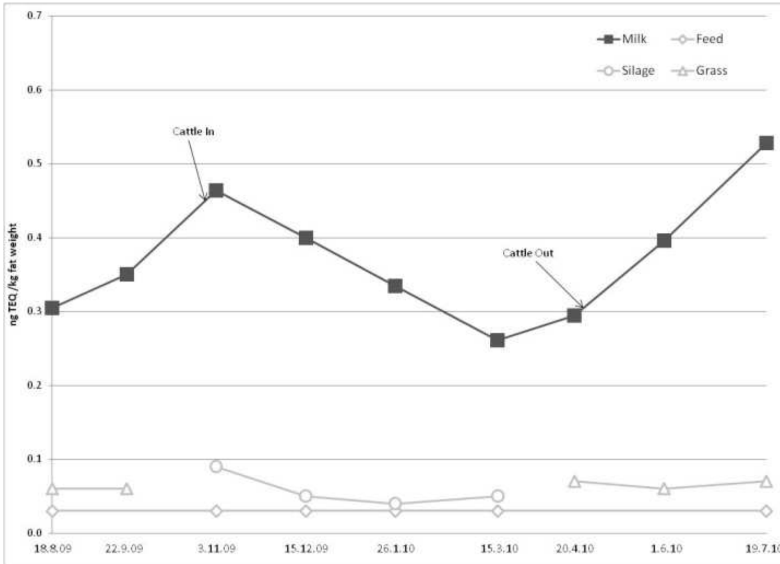
(a) Farm F Dioxin TEQ



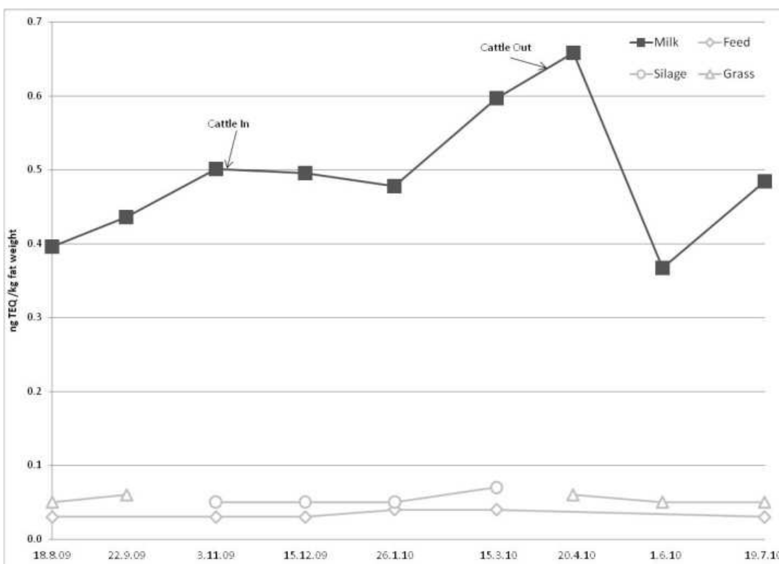
(b) Farm C Dioxin TEQ



(c) Farm F Dioxin-like PCBs



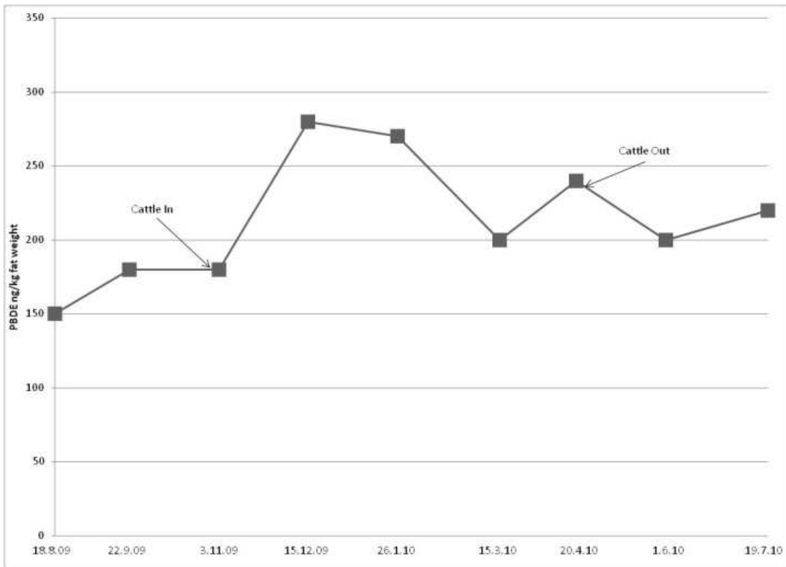
(d) Farm C Dioxin-like PCBs



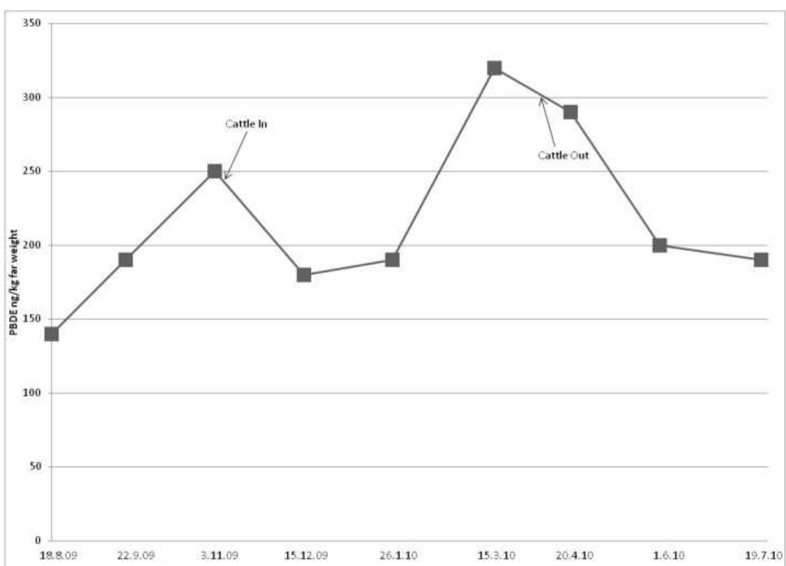
Notes
[1] Milk data are calculated on a fat weight basis; silage and grass are calculated on a dry weight basis; feed is calculated on a whole weight basis

Figure 6.3: Temporal trends in PBDEs concentrations in milk

(a) Farm F



(b) Farm C



Notes

The raw PBDE data is presented in Table 6-3

Table 6-1: Milk fat contents

	Milk fat content %	
Sampling Date	Farm F	Farm C
18.8.09	4.99	4.12
22.9.09	4.40	4.16
3.11.09	4.63	4.22
15.12.09	4.26	4.58
26.1.10	4.13	4.34
15.3.10	3.97	3.78
20.4.10	3.30	3.30
1.6.10	3.99	3.81
19.7.10	7.13	4.17

As well as helping us to understand variations in PCDD/F & PCB and PBDE levels in milk, the dietary intake data also provide important information about the temporal variability in PCDD/F & PCB dietary inputs to dairy farming. Commercial feed given to cattle over the 12 month period of this project exhibits little variability in total TEQ. Higher variability was observed in the grass samples. As the location from which the grass samples were taken constitutes a minor part of the total grazing area used by the cattle, this variability is likely to be due to short-term fluctuations in atmospheric deposition, rainfall and air temperature. Levels in silage show even greater variability, and this could arise from geographical differences in total TEQ levels in the grass from which the silage was sourced. This is exemplified by the total TEQ levels in silage collected from Farm F on Nov 3. This farm was prone to seasonal flooding and given that previous research has indicated that floodplains can be a source of both PCDD/Fs & PCBs (Lake et al., 2005) it is unsurprising that one silage sample from this farm, possibly from a flood-prone location, had total TEQ levels nearly 5 times higher than any other sample from this farm.

Samples of animal bedding were taken from both farms during the period the cattle were housed indoors. The results from these analyses (Table 6-2) indicated that the TEQ levels in bedding were low. Soil samples were also taken from each farm and the total TEQ and ∑7 PBDEs concentrations (Table 6-2) indicate that levels in soil were higher than levels in grass, silage, or commercial feed. Additionally levels were much higher on the flood-prone Farm F than Farm C. In silage and grass, total TEQ and ∑7 PBDEs concentrations varied little over time.

Table 6-2: Temporal trends in PCDD/Fs & PCBs and PBDEs in bedding and soil

Comparison	PCDD/F & PCB ng TEQ /kg dry weight		PBDE $\sum_7$ ng/kg dry weight	
	Farm F	Farm C	Farm F	Farm C
Bedding				
15-12-09	0.13	0.13	-[1]	-[1]
26-1-10	0.15	0.15	-[1]	-[1]
Soil				
18-8-09	17.26	3.86	960	310
01-6-10	19.20	4.39	770	350
19-7-10	19.01	4.27	710	330

Notes
[1] The levels of PDBEs were close to the analytical detection limits

Both PCDD/Fs & PCBs and PBDEs have similar chemical and physical properties; they are chemically stable, strongly lipophilic, and widespread in the environment, although PBDEs do not show dioxin-like toxicity (EFSA, 2011). A relationship between PBDE levels and those of PCDD/Fs & PCBs might therefore be expected. To test this, Figure 6.4 plots the PBDE levels against the PCDD/F & PCBs level in each milk sample. It indicates that the two samples with the highest levels of PCDD/Fs & PCBs also had the highest levels of PBDEs. However, apart from these 2 samples the graph indicates very little co-relation between the concentrations of these congener groups.

Figure 6.4: Relationship between PCDD/F & PCB and PBDE concentrations in milk

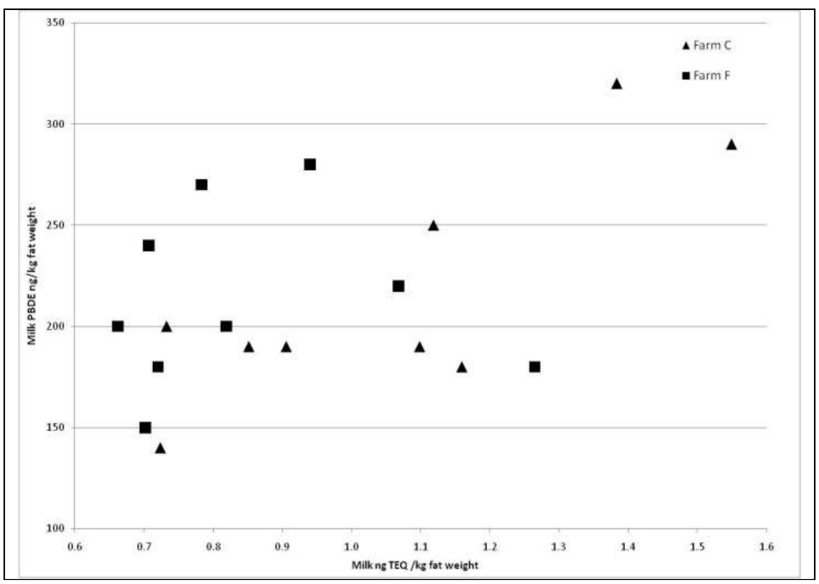


Table 6-34: PCDD/F & PCB and PBDE concentrations in milk, silage, grass and feed

Sampling Date	PCDD/Fs & PCB concentration ng TEQ /kg[1] Farm F Milk	Farm F Silage	Farm F Grass	Farm F Feed	Farm C Milk	Farm C Silage	Farm C Grass	Farm C Feed	PBDE concentration $\sum_7$ ng/kg fat Farm F Milk	Farm C Milk
18.8.09	0.70		0.20	0.08	0.72		0.14	0.07	150	140
22.9.09	0.72		0.19		0.85		0.17		180	190
3.11.09	1.27	0.76		0.07	1.12	0.16		0.08	180	250
15.12.09	0.94	0.15		0.06	1.16	0.20		0.06	280	180
26.1.10	0.78	0.12		0.06	1.10	0.17		0.08	270	190
15.3.10	0.66	0.16		0.07	1.38	0.27		0.08	200	320
20.4.10	0.71		0.18		1.55		0.20		240	290
1.6.10	0.82		0.18		0.73		0.16		200	200
19.7.10	1.07		0.22	0.07	0.91		0.12	0.08	220	190

Notes

[1] Milk data are calculated on a fat weight basis; silage and grass are calculated on a dry weight basis; feed is calculated on a whole weight basis

Discussion

In one of the first investigations into the seasonality of organic contaminant occurrence in milk from dairy farms, levels of PCDD/Fs & PCBs and PBDEs in milk over a 12 month period were seen to exhibit marked variability. It is important to emphasise that because the milk samples were taken from the bulk tank of each farm, they average out variations between different animals over the year. Analytical variations were also minimised by analysing all the milk samples at the same time. Furthermore, because both farms have similar all year calving patterns and are subject to similar environmental conditions, the variations seen should predominantly be due to changes in dietary inputs. In terms of the level of variability over the year for both PCDD/Fs & PCBs and PBDEs, the highest observed levels were nearly double the lowest levels. Furthermore, much of this variability occurred over relatively short 6 week periods. This short term variability in total TEQ and ∑7 PBDE levels in milk is feasible at least for dioxins as the elimination time in milk for these compounds is around 40 - 80 days (Tuinstra et al., 1992; Huwe and Smith, 2005). Given that milk represents a relatively rapid excretion mechanism for such compounds it is likely that less short term variability would be found in other food samples such as meat (Thorpe et al., 2001).

The implications of these results are that dietary monitoring studies of PCDD/Fs & PCBs and PBDE levels in milk from individual farms, which rely upon samples taken at a single point in time may not reflect this variability. The same is likely to be true of other food products arising from animal sources. These results suggest that such monitoring studies should take samples from multiple sites and/or multiple time periods. They also imply that careful thought needs to be given to the timing of sample collection because diet composition in the weeks preceding the collection of a sample can have a substantial influence upon the result. This was highlighted by the near doubling of PCDD/F & PCB levels in milk from Farm F, attributed to silage fed to the animals in the previous 3-4 weeks.

The levels of PCDD/Fs & PCBs and PBDEs in milk were shown to vary over time with contrasting trends between both farms. It was also demonstrated for PCDD/Fs & PCBs that some of this variability could be explained through an examination of the dietary inputs to cattle. The two major dietary inputs to cattle, which are consumed in roughly equal quantities throughout the year, are commercial feed and grass (consumed as silage when the cattle are indoors). Within these the levels of PCDD/Fs & PCBs is relatively constant over time in commercial feed. Most of the variability in milk levels seems to be related to concentrations in grass/silage. In this study we demonstrate the variability in these to be considerable over the year and imply that some of these variations may be the cause of changes in PCDD/F & PCB levels in milk.

In the study other potential sources of dietary input such as bedding were considered. Under normal animal husbandry conditions, dairy cattle consume very little bedding material and it was also found that levels of PCDD/Fs & PCBs in bedding were low and similar to that of silage. These lead us to conclude that bedding is unlikely to be an important source of variability. Conversely levels in soil were found to be higher than those in any other dietary input. Cattle only consume soil inadvertently with forage, and under normal conditions it is estimated that soil constitutes a minor proportion (3.2-3.4% dry matter) of cattle dietary intake (Healey, 1968; Thornton and Abrahams, 1983). However, there is little information on how soil input varies over the year and it is possible that later in the year, when grass levels are low, intake of soil is elevated (Fries, 1996). Under such conditions, given the higher contaminant levels in soil, It is possible that soil may be a more important source of PCDD/F & PCB and PBDE variability in milk especially in flood-prone locations.

In the results, the lack of correspondence between levels of PCDD/Fs & PCBs and PBDEs in milk was demonstrated. To some extent this is a reflection of the very low concentrations of PBDEs in milk. It also suggests that although both these sets of compounds have similar physical and chemical properties, the differences in their environmental sources have the greatest influence upon their distribution. PCDD/Fs & PCBs are generally produced by point sources such as incinerators and industrial facilities (Schecter and Gasiewicz, 2003). PBDEs on the other hand have a broader distribution and are extensively used in commercial and household products such as furniture upholstery, textiles, cars, plastics, polyurethane foam, and electrical equipment (D'Silva et al., 2004).

Conclusion

This is the first controlled investigation to monitor how, at the farm level, PCDD/Fs & PCBs and PBDE levels in milk fluctuate over time. It concludes that the levels of these sets of compounds fluctuate notably over short time periods. This is despite the samples being sourced from the bulk milk tanks of the farms and therefore representing the pooled milk of around 80 cows. This variability was such that the highest observed levels were nearly double the lowest levels detected for both PCDD/Fs & PCBs and PBDEs. To a certain degree these fluctuations may be explained by changes in the contaminant levels of dietary inputs, most notably grass and silage, inputs to the cattle. Given this variability the results from PCDD/Fs & PCBs and PBDEs monitoring studies on individual farms may be highly dependent upon when the samples were taken and we highlight the importance of samples taken from multiple locations and times, to overcome these issues.

7. Overall study conclusion

This study has successfully concluded a series of individual investigations on the effects of river flooding on the concentrations of PCDD/Fs, PCBs and PBDEs in affected pastures used by cows and sheep, and some of the food (milk, meat, liver and kidneys) raised on them. This was achieved through investigations on the River Trent and the Rivers Aire/Ouse by comparing farms with flood-prone pastures against proximate, comparable and matched control farms. The study has also investigated the variability of the concentrations of these contaminants in milk sampled at regular intervals over a year-long period.

Although data were analysed statistically, the small data sets that were obtained require very pronounced differences between flood-prone and control sites to achieve statistical significance. To overcome these limitations and to provide a more holistic overview of the data, the data from the milk, beef and sheep programmes were also examined using weights of evidence tables where appropriate.

Both, the statistical tests and weights of evidence table, analyses for the dairy and the sheep programmes fail to support the earlier study (C01037) which shows that contaminant concentrations in milk produced on flood-prone pastures are significantly higher than matched controls. This may in part be influenced by the lower numbers of samples analysed in this study (e.g. 10 milk samples were analysed in this study, compared to the larger number analysed earlier – a total of 111 when control river samples are included). The lower concentrations across control and flood-prone farms recorded in this study may also influence this outcome as the magnitude of the differences would also be smaller. Although the statistical analysis of the beef programme data generally did not show significant impact of flooding, the weights of evidence analysis did provide support for the conclusion on the effects of flooding seen in the earlier study on milk. This effect was seen for PCDD/Fs and PCBs but not for PBDEs. Relatively higher analyte concentrations were observed in the meat and liver tissues from the animals studied (n=38) in this programme.

The investigation on the variability of the contaminant concentrations in milk over a year, showed that the levels of dioxins, PCBs and PBDEs can vary markedly (almost by a factor of two) over short time periods. The fluctuations can partly be attributed to changes in the contaminant concentrations of dietary inputs to the cattle, most notably grass and silage. Thus contaminant concentrations observed in monitoring studies on individual farms are likely to vary considerably depending on the period of sampling.

The study has also provided current data on contaminant concentrations in the food matrices mentioned above, as well as in environmental matrices such as soil and grass, and feedstuff such as silage and commercially produced feed. In general, contaminant concentrations for lamb (meat, kidney, liver) and milk observed in this study were consistent with literature data (where available), but PCDD/F and PCB WHO-TEQ_{1998} concentrations for beef (meat, kidney, liver) were higher than reported literature values from the UK and other EU countries over the last decade. PBDE concentrations were comparable with other studies in the literature. Contaminant concentrations in commercial animal feed were relatively low across all the programmes in this study.

8. Acknowledgements

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