DIOXIN AND PCBs IN FOOD PRODUCED ON INDUSTRIAL RIVER FLOODPLAINS

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Introduction

In river systems where contamination has occurred (typically those with an industrial history) suspended particulate and bottom sediment can act as a sink for dioxins and PCBs providing a long term source of release for these pollutants.[1,2] These contaminants can then be transferred to agricultural land during river flooding events. This may become an increasingly important pathway as climate change leads to increased flooding in some parts of the world, mobilising old sediments containing dioxins and PCBs. [3,4]

In 2005 we reported that soils on flood-prone land in industrial river catchments had higher levels of dioxins and PCBs and that milk produced on flood-prone land had higher levels of dioxins and PCBs than that produced on proximate, comparable use land.[5] (Lake et al. 2005). We have recently shown that such differences are also evident in beef produced on flood-prone land[6]. Here we describe data from two major exercises, the first conducted in 1998-1999 and the second in 2008-2010. This consists of over 200 samples including environmental samples (soil and grass), feed samples and food samples (milk, beef and lamb). The overall aims were:

- To assess the impact of overbank flooding on environmental contamination (soil and grass) in industrial river catchments.
- To establish the extent to which dioxins and PCBs transfer into the food chain and to examine any differences between food types (milk, beef and lamb).
- To establish whether the impact of flooding in industrial river catchments has changed over time with respect to dioxins and PCBs in food.
- To establish any implications for the risk management of producing food on the flood plains of industrial river catchments.

Materials and methods

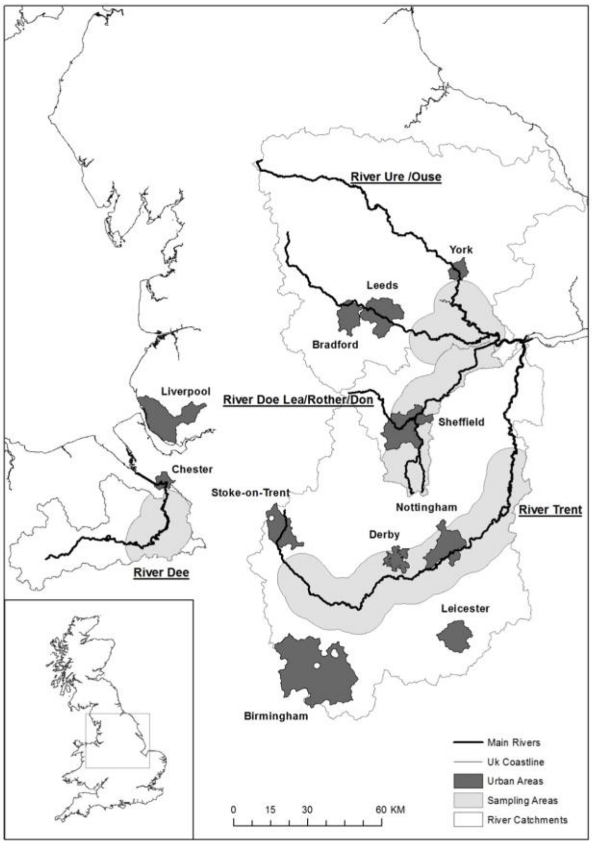
Four river systems in central UK were examined in this study. The first three were the Doe Lea / Rother / Don, the Trent and the Aire/Ouse (see Figure 1) which flow through substantial urban and industrial areas. Historically these catchments were home to a number of coking and chemical manufacturing plants and chlorinated chemical facilities. They also flow through several major cities. The River Dee was chosen as a comparator due to the lack of any significant industrial history associated with its catchment. Sampling was conducted on these river systems in 2 phases (phase 1: 1998-1999 & phase 2 2008-2010). Within each phase different livestock products (milk, beef and lamb) were collected from pairs of farms, one of which was prone to seasonal flooding and a nearby farm which was not. Livestock food products from each farm were collected from 2 animals to allow for within-herd variation; an overall breakdown of sampling by phase is presented in Table 1.

Maps of farm distribution and flood history were obtained along the length of the river systems. These were used to locate livestock farms (milk, beef and lamb) where a notable proportion of the land was subject to regular flooding. For each of these a nearby farm whose land was not subject to flooding was selected as a control. These were located in areas where they would be expected to use similar farming practices and to be subject to similar levels of aerial deposition of dioxins and PCBs (i.e. similar proximity to major transport routes and industrial facilities). None of these selected farms had received any sewage sludge, a potential source of dioxins and PCBs, over the past two decades. The comparison of dioxin and PCB levels between these farm pairs should provide strong evidence with which to examine the impact of flooding.

Table 1: Study overview by livestock product and date

	Date				
	1998-1999 River System			2008-2010 River system	
	Dee	Doe Lea / Rother / Don	Trent	Trent	Aire/Ouse
Livestock product Number of flood-prone / control pairs	Milk 9	Milk 10	Milk 13	Milk 5	
Livestock product Number of flood-prone / control pairs				Beef 5	Beef 5
Livestock product Number of flood-prone / control pairs				Lamb 5	Lamb 1

Figure 1: The sampling areas and catchments of the Doe Lea/Rother/Don, Trent, the Aire/Ouse and the Dee



For the milk programme samples were taken from the bulk tank of each farm during the autumn when the animals would have been feeding outside for most of the summer. They therefore represent average dioxin and PCB levels in milk from the entire herd. For the lamb and beef programme two animals were selected from each flock/herd on each farm and immediately transported for slaughter. These animals were also collected during the autumn when the animals would have been outdoors for a long period. Samples of meat were taken from each animal and the handling of each animal at the abattoir was closely scrutinized to prevent cross contamination. Several of the beef cattle pairs were not market-ready, as they would normally be subject to an indoor finishing period during which they would be fed silage and commercial feed before slaughter. Levels of dioxins and PCBs in both animals from each farm were averaged to provide an overall value for the farm.

Results and discussion

Results for soil and grass are shown in Table 2 and results for food samples are shown in Table 3.

Using 41 pairs of soils samples from farms prone to flooding and control farms across 4 river systems (Doe Lea/Rother Don, River Trent, Aire/Ouse and Dee) and two time periods (1998-1999 and 2008-2010) in central England we were able to show that total TEQ, dioxin TEQ and ICES6 PCB levels were significantly higher on land prone to seasonal flooding, but only on river systems with a history of industrialisation. These results were corroborated by results from 22 pairs of grass samples collected from the same locations. The magnitude of the difference between flood-prone and control samples was larger for soil than for grass which is to be expected given the persistence of dioxins and PCBs in soil and also that levels of dioxins and PCBs on grass will be affected by short-term factors such as precipitation or air temperature and pasture management. Differences in concentrations of dioxins and PCBs in grass between flood-prone and control sites were still evident and statistically significant.

Table 2 Comparisons of median soil and grass total TEQ, dioxin TEQ and ICES6 across river systems and sampling phases

	1998-1999 Non-Industrial River			1998-1999 Industrial Rivers						2008-2010 Industrial Rivers					
	Dee			Doe Lea / Rother / Don			Trent			Trent			Aire/Ouse		
	Total TEQ^	Dioxin TEQ^	ICES6+	Total TEQ^	Dioxin TEQ^	ICES6+	Total TEQ^	Dioxin TEQ^	ICES6+	Total TEQ^	Dioxin TEQ^	ICES6+	Total TEQ^	Dioxin TEQ^	ICES6+
	Soil			Soil						Soil					
Flood Prone	4.03_{6}	3.55_{6}	1.84_{6}	12.81_{5}	12.04_{5}	1.48_{5}	21.62_{10}	19.17_{10}	3.19_{10}	22.34_{14}	17.36_{14}	32.47_{14}	8.59_{6}	8.07_{6}	3.95_{6}
Control	4.17_{6}	3.65_{6}	0.90_{6}	10.75_{5}	10.22_{5}	1.01_{5}	4.39_{10}	4.03_{10}	0.90_{10}	5.06_{14}	4.58_{14}	0.95_{14}	4.46_{6}	4.07_{6}	0.83_{6}
Overall	4.17_{12}	3.65_{12}	1.05_{12}	11.41_{10}	10.50_{10}	1.21_{10}	7.60_{20}	7.04_{20}	1.61_{20}	8.48_{28}	7.80_{28}	1.48_{28}	5.87_{12}	5.25_{12}	1.19_{12}
	Grass			Grass						Grass					
Flood Prone	0.12_{1}	0.08_{1}	0.23_{1}	1.31_{1}	0.99_{1}	0.90_{1}	0.25_{3}	0.17_{3}	0.27_{3}	0.52_{11}	0.38_{11}	1.65_{11}	0.87_{6}	0.70_{6}	0.43_{6}
Control	0.11_{1}	0.07_{1}	0.19_{1}	0.30_{1}	0.15_{1}	0.90_{1}	0.29_{3}	0.17_{3}	0.33_{3}	0.20_{11}	0.11_{11}	0.20_{11}	1.20_{6}	0.94_{6}	0.40_{6}
Overall	0.12_{2}	0.08_{2}	0.21_{2}	0.81_{2}	0.57_{2}	0.90_{2}	0.28_{6}	0.17_{6}	0.30_{6}	0.27_{22}	0.19_{22}	0.28_{22}	1.20_{12}	0.94_{12}	0.41_{12}

Figures in subscript are sample sizes
^ng TEQ/kg dry
+ug/kg dry wt

Table 3: Comparisons of median total TEQ, dioxin TEQ and ICES6 concentrations between food types and across river systems and sampling phases

	1998-1999 Non-Industrial Rivers			1998-1999 Industrial Rivers						2008-2010 Industrial Rivers					
	Dee			Doe Lea / Rother / Don			Trent			Trent			Aire/Ouse		
	TEQ^	Dioxin TEQ^	ICES 6+	TEQ^	Dioxin TEQ^	ICES6+	TEQ^	Dioxin TEQ^	ICES6+	TEQ^	Dioxin TEQ^	ICES6+	TEQ^	Dioxin TEQ^	ICES6+
	Milk			Milk						Milk					
Flood Prone	1.73_{4}	0.93_{4}	2.18_{4}	4.29_{10}	2.14_{10}	3.99_{10}	3.09_{13}	2.60_{13}	3.25_{13}	1.36_{5}	0.72_{5}	1.59_{5}			
Control	1.92_{4}	1.04_{4}	1.83_{4}	2.49_{10}	1.45_{10}	4.23_{10}	2.17_{13}	1.51_{13}	2.81_{13}	0.94_{5}	0.45_{5}	1.17_{5}			
Overall	1.77_{8}	0.95_{8}	2.09_{8}	2.69_{20}	1.12_{20}	3.52_{20}	2.51_{26}	1.34_{26}	2.78_{26}	0.97_{10}	0.54_{10}	1.28_{10}			
										Beef					
Flood Prone										2.90_{5}	1.12_{5}	7.55_{5}	4.07_{5}	1.80_{5}	7.06_{5}
Control										2.42_{4}	1.13_{4}	3.19_{4}	3.68_{5}	1.56_{5}	2.70_{5}
Overall										2.44_{9}	1.12_{9}	4.16_{9}	3.75_{10}	1.70_{10}	6.18_{10}
										Lamb					
Flood Prone										1.26_{5}	0.65_{5}	6.01_{5}	0.48_{1}	0.25_{1}	0.69_{1}
Control										1.06_{4}	0.60_{4}	3.99_{4}	0.69_{1}	0.35_{1}	1.07_{1}
Overall										1.10_{9}	0.63_{9}	4.88_{9}	0.59_{2}	0.30_{2}	0.88_{2}

Notes
Figures in subscript are sample sizes
^ng TEQ/kg fat wt
+ug/kg fat wt

Dioxins and PCBs in milk were shown to decrease by about a half between 1998-1999 and 2008-2010, and this mirrors national trends seen in retail milk over the same decade. Levels in soil and grass levels were stable on the same river systems over the same time period. Therefore, these reductions are unlikely to be due to reduced environmental contamination, but more likely due to lower dioxin and PCB concentrations in commercial feed. Increasing use of commercial feed, which is relatively low in dioxins and PCBs, and an increase in dairy cow productivity, may also contribute to reductions in dioxins and PCBs in milk.

When differences between food produced on flood-prone farms and control farms were examined, higher dioxin and PCB levels were found in milk produced in 1998-1999 on flood-prone farms and in beef produced in 2008-2010 on flood-prone farms. Such differences were not seen in milk or lamb produced in 2008-2010. The common feature of these latter two food types was the relatively low overall dioxin and PCB concentrations meaning that if a small difference between flood-prone and control farms existed, the sample size may not have been large enough to detect it.

Conclusions

Dioxins and PCBs can be transferred from contaminated rivers to the soil and grass of floodplains. The amount of dioxins and PCBs in soil and grass on such floodplains was shown to be relatively consistent between 1998-1999 and 2008-2010, in spite of pollution control measures and a general downward trend of these pollutants in the environment over the same time period. Such flood-prone land therefore has implications for food production, and the impact can be seen in milk produced on flood-prone farms from 1998-1999 and in beef from 2008-2010. However, such an impact was not observed on all food produced on flood-prone land in all time periods and this provides important insight as to how flood-prone land on industrial river systems may be managed to minimise dioxin and PCB levels in food produced in such areas. This may also be applicable to other types of land with elevated dioxin and PCB levels. Supplementing commercial feed given to dairy cattle to increase milk yield together with regulations to control concentrations of dioxins and PCBs in animal feeds, have resulted in lower amounts of dioxins and PCBs in milk at a time when environmental levels (soil and grass) have remained relatively constant.

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