PCDD/F AND PCB LEVELS IN BEEF FROM CATTLE RAISED ON FLOOD PLAINS

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Introduction

It has been demonstrated that levels of PCDD/Fs and PCBs are often higher in produce from farms close to urban areas or industrial facilities as opposed to those from farms in rural areas (e.g. milk)[1,2]. In addition to aerial deposition, transfer through river systems may also be important, as suspended particulate and bottom sediment in river systems can serve as a sink for PCDD/Fs and PCBs and then provide a long term source of release for these pollutants[3]. The mobilisation of contaminants from such sinks during episodes of river flooding provides another potential pathway for transfer to the human food chain and previous work has demonstrated that milk produced on flood-prone land on industrial river catchments has elevated levels of PCDD/Fs and PCBs[4]. However, milk production is only one form of farming on flood-prone land and this study represents the first controlled investigation into potential contaminant transfer to beef cattle grazing on flooded pastures. It was designed to explore the possibility that the overbank flooding of grazing land might influence the concentration of PCDD/Fs and PCBs in animals reared using conventional animal husbandry techniques. Beef products, specifically carcase meat, are important commodities because of their central place in the diet in many countries. The aims of the study were to:

1. Establish whether river flooding has an impact on PCDD/F and PCB levels in meat of beef cattle
2. Provide supporting evidence by analysing matched flood prone / control samples of soil, grass and commercial feed samples from each farm

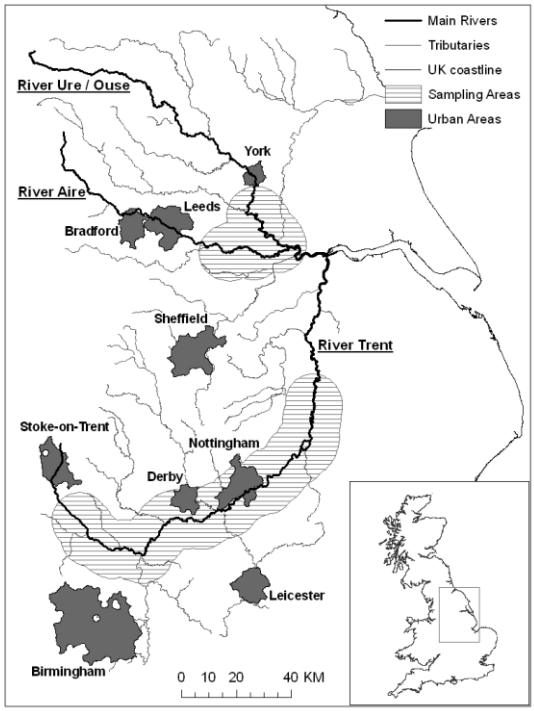
Materials and methods

The study focused on the Trent and the Aire/Ouse river systems in central England. The locations of these are presented in Figure 1 and both flow through substantial urban and industrial areas. The figure also indicates many rural areas within these catchments. Previous research has demonstrated elevated levels of industrial contamination (PCDD/Fs and PCBs) along the Trent river system[4] related to farms situated on flood-prone land. No comparable reports have been published on the Aire/Ouse river system. Maps of beef farm distributions and flood history along the length of the two river systems were obtained and used to identify beef farms where a significant proportion of the land was subject to regular flooding. For each flood-prone farm, a nearby farm whose land was not subject to flooding was selected as a control. Control farms were selected in areas where they would be expected to use similar farming practices and to be subject to similar levels of aerial deposition of PCDD/Fs and PCBs as the neighbouring flood-prone farms (e.g., similar proximity to industrial facilities and major roads). The application of sewage sludge to land can be a source of PCDD/Fs and PCBs, but none of these selected farms had received any sewage sludge over the past 2 decades.

Ten farms on the River Trent (5 flood-prone/control pairs) satisfied these criteria and consented to take part in the study, but one control farm was unable to provide any animals. A further 10 (5 flood-prone/control pairs) farms on the middle-lower reaches of the Aire/Ouse river system also agreed to take part, thus making a total of 19 farms in all. 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 second collection period) respectively when the beef herds would have been feeding outdoors for at least three months. Samples of meat (muscle tissue) were taken from each animal. The handling of the individual carcases at the abattoir was closely scrutinized to prevent cross contamination with other carcases. Some of the animals from which samples were

taken 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 eventual slaughter.

Figure 1: The sampling areas and catchments of the Trent and the Aire/Ouse



To provide supporting information for any trends emerging from the meat data, sources of dietary input to the beef cattle were also taken from all 19 farms during the same period that the animals themselves were collected. Grass is consumed by cattle while they are outdoors while soil is consumed inadvertently while foraging. Commercial feed is provided to the cattle during the period they are indoors and silage is often given to cattle as pasture starts to decline in the autumn. Soil and grass samples were collected from fields regularly grazed by the herd using previous published methods[4]. On flood-prone farms, samples were taken from places known to flood regularly.

PCDD/F and PCB concentrations were determined according to methods accredited to the ISO 17025 standard. All analyses were based on the seventeen 2,3,7,8-Cl substituted PCDD/F congeners, four non-ortho PCBs (77, 81, 126, and 129) 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). TEQ values were calculated using WHO-1998 TEFs[5] to facilitate comparison with previously published data. Concentrations are reported as upper-bound. In total, 133 samples (meat [muscle, liver, kidney], soil, grass and commercial feed) were analysed for PCDD/Fs and PCBs. As per the usual convention, and to allow easy comparison with other literature data, the meat (muscle tissue) data are presented throughout on a fat weight basis; grass and soil on a dry weight basis; feed on a whole weight basis.

Results and discussion

Total TEQ in soil was generally higher in samples from the Trent, than in those from the Aire/Ouse river system. In terms of flooding, on both river systems, median soil concentrations were higher on flood-prone farms. 8/9 flood-prone/control pairs had higher concentrations in flood-prone samples.

Meat, soil and grass samples from flood-prone farms generally have substantially higher levels of ortho-PCBs than samples from control farms. This difference was not apparent for non-ortho PCBs or PCDD/Fs. There was a similarity in ortho-PCB profiles between soil and grass, suggesting a common source of contamination. Low levels of lower chlorinated PCB congeners (18, 28 and 31) in meat samples, despite their prominence in soil and grass, suggests that such congeners are effectively metabolized, or have low uptake.

Figure 2: Distribution of total TEQ for meat (a), soil (b), grass (c) and commercial feed samples (d)

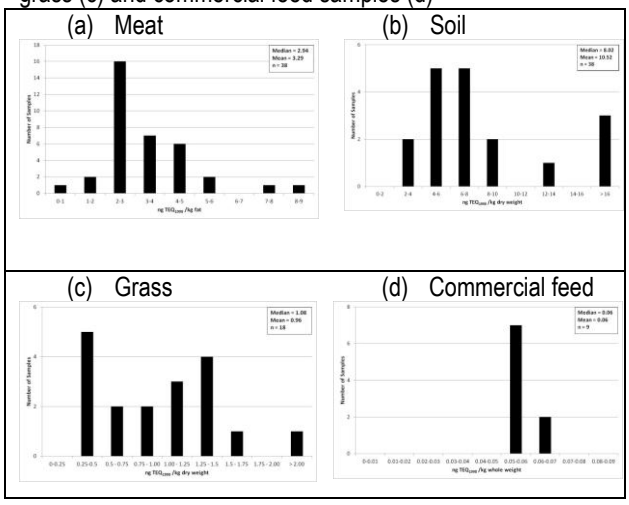
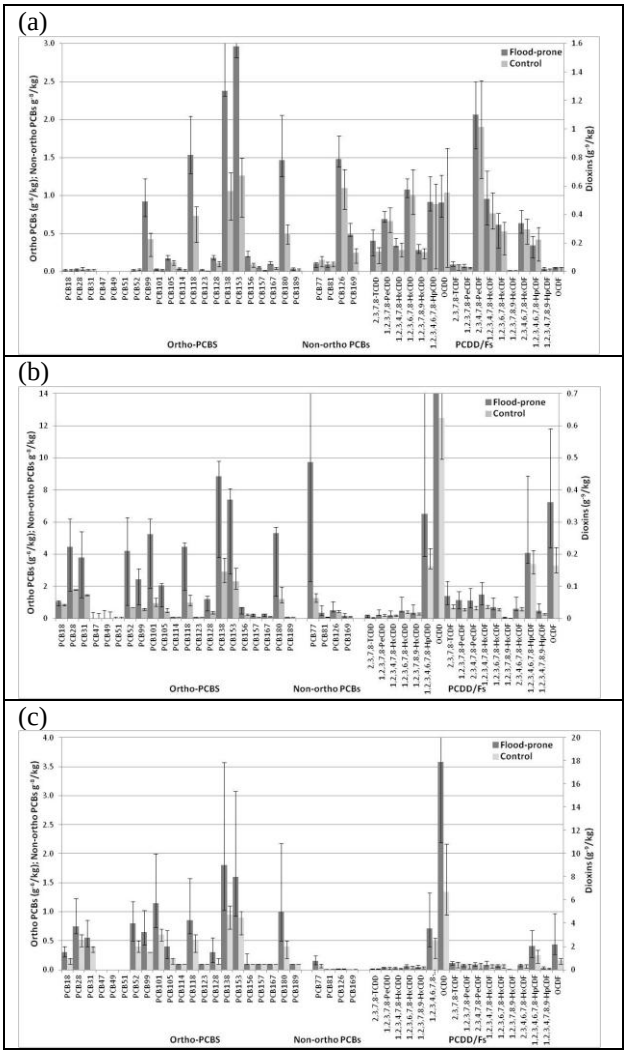


Figure 3: Median (+-inter-quartile range) congener profiles for meat (a), soil (b) and grass (c) subdivided by type of site.



There was a clear indication that PCDD/F and PCB levels were higher in soil from flood prone farms. PCDD/F and PCB concentrations in grass will be more subject than soil to short-term influences such as rainfall or air temperature. Despite this, there was evidence of elevated PCDD/F and PCB concentrations in grass but this was not consistent between river systems. This indicated a potential for elevated PCDD/F and PCB levels in meat, in agreement with previous research[4,6].

Meat samples from flood-prone farms had total TEQ levels that were around 20% higher than those from control farms. The congener profiles of beef produced on flood-prone vs. control sites was similar to the congener profiles of soil and grass from flood-prone vs. control sites i.e. elevated ortho-PCB concentrations, suggesting soil and grass as the source of the elevated PCBs in beef. However, for some of the farm pairs, elevated PCDD/F and PCB concentrations in soil or grass did not translate to higher concentrations in beef. Commercial feed samples were also analysed and found to have nearly identical PCDD/F and PCB concentrations for both types of farms.

Cattle on flood-prone farms have access to large amounts of land that does not flood. In our sample of farms the percentage of land on each flood-prone farm that was subject to seasonal flooding varied from 9% to 93% with a median percentage of 50%. Farms will also flood for different durations and floods will have different depositional characteristics in different locations. In spite of these variations, the fact that differences between flood-prone farms and control farms emerge suggests that the amount of PCDD/Fs and PCBs received on flood-prone land is not entirely masked by the time spent on non-flood prone sites. While the cattle are outdoors they are not usually provided with commercial feed and they forage almost exclusively on pasture. Therefore, commercial feed does not provide the masking effect suggested on studies of other foodstuffs[6].

The aim of this study was to examine the impact of river flooding upon PCDD/F and PCB in beef. However, it was also observed that PCDD/F and PCB concentrations in beef were above those reported by the latest UK Total Diet Study (mean 3.3 vs. 0.9 ng TEQ /kg fat) [7]. This was anticipated because both river systems were selected on the basis that their catchments contained substantial urban and industrial areas. The elevated levels were such that several samples of meat were above maximum permitted total TEQ and PCDD/F TEQ permitted in meat under regulations present at the time of sampling. A larger number of samples exceeded action levels. It is important to recognise that these samples would not have entered the food chain at this stage, because under current husbandry practice, after being taken indoors the cattle would typically have undertaken a finishing-off period. This usually consists of around 6 months indoors before being sent to market. During this period they would have been fed a larger proportion of commercial feed as well as silage (usually from the farm). However, the feed analysis indicated relatively low levels of total TEQ in comparison to the environmental (soil and grass) samples. There is limited data on the half lives of PCDD/Fs and PCBs in beef although one study has suggested

3-5 months for PCDD/Fs in 10 month old beef cattle[8] dosed over a 28 day period. Another study indicated 13 months for PCBs in beef[9]. We also note that, especially on the Aire/Ouse, several of the beef samples were taken up to half way through this indoor period. Taken together, it is not appropriate to speculate what effect the period of finishing-off cattle to market readiness would have on the levels of PCDD/Fs and PCBs in meat observed in this study if it were to go to market. This could only be verified by actual measurement. Feed is an unlikely source of these elevated levels as the concentrations of total TEQ in feed was consistent with levels found in a wider, nationwide study of commercial feed samples[10]. This suggests that the source of the elevated levels in some animals reared in these river systems results from a historical legacy of contamination due to previous industrialisation, as well as more recent combustion activity or pollution events.

This study is the first controlled investigation into the effects of flooded river pastures on beef production. It presents evidence that, in catchments with a history of urbanisation and industrialisation, flooding is a mechanism for transferring PCDD/Fs and PCBs into meat and thereby into the human food chain. There are a number of other river systems worldwide where contamination of river sediments with PCDD/Fs or PCBs has been reported[11-13]. Our study indicates that, within such areas, farming on flood-prone land may present an additional source of elevated PCDD/F and PCB levels in beef. In many parts of the world PCDD/F and PCB levels in soils similar to those observed in this study have been found. These occur in both more and less developed) countries[14,15]. Our results indicate that, depending upon the specifics of animal husbandry[6], in such areas there is the potential to find elevated levels of PCDD/F and PCBs in beef.

Acknowledgements
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