Investigation into the long-term effects of river flooding on levels of organic environmental contaminants in food from livestock reared on flood-prone pastures

Area of research interest: Chemical hazards in food and feed
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Background

Previous research (FSA project C01037: Study of the effects of flooding on concentrations of PCDD/Fs and PCBs in milk from cattle grazing on affected pastureland) showed that milk from flood-prone farms along the River Trent and the Doe Lea/Rother/Don river system generally contained higher levels of dioxins and polychlrorinated biphenyls (PCBs) than milk from matched control farms. This was attributable to elevated levels of these contaminants in soil and herbage on flood-prone pastureland caused by sediment deposited during repeated flooding events. However, the effects of flooding on dioxin and PCB levels in meat or offal from grazing livestock were not investigated.

The European Union recognised that levels of dioxins and PCBs in food products originating from flood-prone regions could be affected as a consequence of flooding, and recommended monitoring the levels of these contaminants in foodstuffs from flood-prone regions. Increased river-flooding associated with climate change could result in contaminated sediment deposition onto pasture becoming a more significant source of contamination of the terrestrial food chain.

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Research Approach

Three interlinked strands of work have been conducted to provide further knowledge about the long-term effects of river flooding on the levels of persistent organic environmental contaminants in milk, or in meat and offal. The experimental approach used for the two main strands of work was the same as that used in the previous research. The impact of flooding on contaminant levels in milk or in meat and offal was assessed by comparing contaminant levels in these food products (and in soil and grass samples) from matched pairs of flood-prone and non-flooding control dairy or beef farms.

The previous research demonstrated increased levels of dioxins and PCBs in milk from flood-prone farms near rivers containing contaminated sediment. The current study assessed the impact of flooding on dioxin, PCB and Polybrominated diphenyl ethers (PBDE) levels in meat and offal from beef cattle and sheep along the River Trent and the Aire/Ouse river system. These rivers have urban and industrial catchments.

In 2008, further monitoring was carried out for dioxins and PCBs in milk and environmental samples from selected flood-prone farms along the River Trent, where milk was shown, in 1998/99, to contain elevated levels of dioxins and PCBs compared with their matched controls. Since the previous study, trends in dioxin and PCB levels in milk, soil and grass have been examined. PBDE levels in the milk and environmental samples were also monitored for the current study.

Seasonal variation in levels of dioxins, PCBs and PBDEs were investigated. This was done by periodically monitoring levels of these contaminants in milk, soil, grass, silage, feed and bedding at one selected flood-prone farm and one non-flooding farm along the River Trent.

Results were interpreted using conventional statistical analysis. However, due to the relatively small number of farms investigated, a ‘weights of evidence approach’, based on Bradford Hill’s causation criteria methodology (i.e. establishing minimal conditions necessary to provide adequate evidence of a causal relationship between an incidence and a consequence), was also used to provide a more holistic interpretation.

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Results

The differences between contaminant concentrations in cows’ milk from flood-prone and control farms on the River Trent in 2008 were not statistically significant for dioxins, PCBs or PBDEs. The levels of dioxin and PCB in milk had declined significantly between August 1999 and August 2008 and contaminant levels in milk were in the range of previous UK studies. PBDE levels closely correlated with concentrations of dioxins and PCBs in milk. Levels of dioxins, PCBs and PBDEs in grass samples collected in August 2008 were not significantly higher on flood-prone dairy farms and the concentrations of these contaminants were within the normal background range for rural grass samples. In contrast to milk and grass, dioxin, PCB and PBDE levels were all statistically significantly higher in soils from the flood-prone dairy farms and there had been no decrease in dioxin and PCB levels in soil since 1999. However, concentrations of dioxins, PCBs and PBDEs on control dairy farms were similar to normal rural background values.

The investigation of seasonal variation in contaminant levels in milk over a 12 month period, at a flood-prone and a control farm, showed that dioxin, PCB and PBDE levels fluctuated by a factor of 2 during the 6 week intervals between monitoring. These fluctuations are partly attributable to changes in contaminant concentrations in grass, silage and other feed inputs. Consequently, data for contaminants in milk from individual farms could vary considerably depending what time of year samples are taken.

Overall, the beef samples from flood-prone farms contained approximately 20% higher levels of dioxins + dioxin-like PCBs than beef from control farms but the results were variable. The ?ICES6 PCB levels (namely the sum of the 6 PCB congeners, - 28, 52, 101, 138, 153 & 180, identified by the International Council for the Exploration of the Sea (ICES), and used as an indicator of PCB levels), were statistically significantly higher in meat from flood-prone farms than from control farms, but for levels of dioxins & dioxin-like PCB, and for PBDEs in beef, there was no significant difference between flood-prone and control farms. The dioxins and PCB levels were higher than expected in some of the meat samples. For liver, there were no statistically significant differences between flood-prone and control farms for dioxins, dioxin-like PCBs, ?ICES6 PCBs or PBDEs. For grass, PBDE concentrations were significantly higher on flood-prone farms than control farms but there were no statistically significant differences for dioxin and PCB levels. For soil, dioxin, PCB and PBDE levels were all significantly higher on flood-prone farms. Therefore this study provides evidence that flooding of rivers with urban industrial catchments can result in increased contamination of pasture with dioxins, PCBs and PBDEs and that this can cause additional transfer of these contaminants to beef or liver from cattle reared on affected flood-prone land.

For meat and liver from sheep, no statistically significant difference between contaminant levels was observed for flood-prone and control samples although only six pairs of farms were available for this investigation and the results were quite variable.

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Published Papers

1. Lake, I R, Foxall, C D, Fernandes, A, Lewis, M, Rose, M, White, O, and Dowding, A. (2011) Effects of River Flooding on Polybrominated Diphenly Ether (PBDE) Levels in Cows' Milk, Soil, and Grass. Environmental Science and Technology 45: (11), pp 5017–5024 DOI: 10.1021/es2007098
2. Lake, I R, Foxall, C D, Fernandes, A, Lewis, M, Rose, M, White, O, and Dowding, A. (2013) Seasonal variations in the levels of PCDD/Fs, PCBs and PBDEs in cows' milk. Chemosphere 90: 72-79 DOI: 10.1016/j.chemosphere.2012.07.038
3. Lake, I R, Foxall, C D, Fernandes, A, Lewis, M, White, O, Mortimer, D, Dowding, A, & Rose, M. (2014) The effects of river flooding on dioxin and PCBs in beef. Science of the Total Environment xxx (2014) xxx–xxx (Article in Press) DOI: 10.1016/j.scitotenv.2014.01.080

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