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Environmental contaminants in fish from unmanaged inland UK waterways

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Environmental contaminants in fish from unmanaged inland UK waterways

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SUMMARY

1. There is growing evidence that more people are consuming freshwater fish. This change is resulting from increased numbers of migrants from Eastern Europe where this is part of traditional culture, and because of a desire to try new foods encouraged by celebrity chefs.

2. Fish can bio-accumulate environmental contaminants, and can contribute a signicant amount to dietary exposure to these chemicals. Rivers are the pathway that many of these chemicals enter the sea and due to the relatively limited volume of water within inland waters, can contain higher levels of pollution.

3. This study examines the changing habits of anglers and consumers and characterises a range of existing and emerging contaminants in freshwater fish species with a view to determine current levels of occurrence and to allow estimation of consumer exposure.

4. The project was conducted in two stages. The first stage was conducted by ADAS and consisted of (a) a study that identified freshwater systems that are contaminated either by anthropogenic activity or as a result of the geology of the area and (b) market research was conducted in order to assess the consumption habits of the public with respect of fish and shellfish from unmanaged freshwaters and the possible transfer of environmental contaminants to these consumers. Regional differences and population sub-groups were considered, and the habits of unlicensed anglers were included in the study where possible. This part of the study also identified those species most widely consumed by anglers and the public.

5. This first stage was followed by evaluation and selection of specific rivers and waterways that were chosen for investigation, along with the range of contaminants to be included in the analytical programme. The second stage of the project involved the collection of samples followed by analysis according to the protocol devised in the first stage.

6. A range of fish species from a variety of inland water habitats were obtained, comprising 46 freshwater fish samples. These were analysed for the following contaminants:

- Heavy Metals
- Polybrominated biphenyls (PBBs)
- Brominated dioxins (PBDD/Fs)
- Polybrominated diphenylethers (PBDEs)
- Organotin compounds
- Chlorinated Dioxins (PCDD/Fs)
- Polychlorinated biphenyls (PCBs)
- Polychlorinated naphthalenes (PCNs)
- OC Pesticides
- Organo-fluorine compounds

7. No samples were in breach of legal limits since these only apply to food on retail sale to the public. Some samples did exceed the existing regulated limits for dioxin and PCBs that apply to fish that is on retail sale to the public. The maximum detected dioxin and PCB WHO-TEQ was over 32 ng/kg for a sample of barbel from the River Don, and 6 samples in total exceeded the 8 ng/kg limit.

8. The results of this study confirm the occurrence of a wide range of environmental contaminants in freshwater fish species and underline the ubiquity and persistence of these compounds. This is evident from the occurrence of both, legacy contaminants (PBBs, PCNs and PCBs), as well as more recently introduced chemicals (deca-BDE and PFCs).

9. This report represents the first study of such a comprehensive set of contaminants in fish from unmagend inland waterways and as such is unique. The data will allow a preliminary estimation of dietary intake for consumers of these foods. However, considerable uncertainty would remain within these estimates, given the limited number of sites from where samples were taken and also the fact that these were identified as likely to be most contaminated. The data also provides information on the current background levels of these emerging and existing contaminants. A parallel study funded by the Food Standards Agency in Scotland, which investigates a similar range of contaminants in marine and freshwater fish and shellfish, has recently been completed. The combined information from these two sets of complementary data may allow more refined estimates of human exposure.

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Appendix 2: **Environmental Contaminants in Fish and Shellfish from Unmanaged Inland UK Waterways: Socio-economic Study. Report from ADAS**

GLOSSARY

Σ PBDD/F TEQ	Sum of WHO-TEQ for individual PBDD/F congeners
Σnon-*ortho* PBB TEQ	Sum of WHO-TEQ for individual non-*ortho* PBB congeners
∑PFC	Sum of perfluorinated compounds
BDE	Brominated Diphenylether
BCR	Community Bureau of Reference
BFR	Brominated Flame Retardant
CRM	Certified Reference Material
EFSA	European Food Safety Authority
GC-ECD	Gas chromatography with electron capture detection
GC-HRMS	Gas chromatography - high resolution mass spectrometry
HPGPC	High performance gel permeation chromatography
HPLC-MS/MS	LC-MS in multiple reaction monitoring mode
IUPAC	International Union of Pure and Applied Chemistry
LC-MS	High Pressure Liquid Chromatography - mass spectrometry
PAHs	Polycyclic aromatic hydrocarbons
PCB/PBB	Polychlorinated biphenyl/ Polybrominated biphenyl
PBDE	Polybrominated Diphenylether
PBDD/F	Polybrominated dibenzo-*p*-dioxin/ furan
PCDD/F	Polychlorinated dibenzo-*p*-dioxin/ furan
PFC	Perfluorinated compound
PTMI	Provisional tolerable monthly intake
PTV	Programmed temperature vaporisation
RM	Reference Material
SCF	EU Scientific Committee on Food
TDI	Tolerable Daily Intake
TDS	Total diet survey
TEF	Toxic Equivalence Factor
TEQ	Toxic equivalence
WHO	World Health Organisation
%U	Percentage Uncertainty

INTRODUCTION

Previous studies have shown that marine and farmed fish and shellfish are significant contributors to consumer intake of some contaminants due to their presence in the aquatic environment and their accumulation in the flesh of fish and shellfish (Clarke et al 2010; Fernandes et al, 2008; Fernandes et al, 2008B; Fernandes et al, 2009; Fernandes et al, 2009B). Some anglers are known to consume their catch, and other members of the population, such as migrant workers from Eastern Europe (where consumption of river fish is a cultural norm), some members of the population from deprived areas, and others who are keen to explore consumption of new or wild foods, are also known to consume freshwater fish.

The project was conducted in two stages. The first stage was conducted by ADAS and consisted of (a) a study that identified freshwater systems that are contaminated either by anthropogenic activity or as a result of the geology of the area and (b) a socio-economic study into the habits of anglers and others who may consume fish caught from unmanaged inland waters. Reports for this part of the project were submitted in (a) June 2007 and (b) December 2007 and are attached as Appendices 1 and 2 to this final report. This first stage was followed by evaluation and selection of specific rivers and waterways that were chosen for investigation, along with the range of contaminants (from e.g. chlorinated and brominated dioxins, PCBs, BFRs, trace elements, pesticides, PFOS, PCNs, etc.) to be included in the analytical programme. The second stage of the project involved the collection of samples followed by analysis according to the protocol devised in the first stage.

The project comprised:

- A UK wide survey of the levels of contamination of inland waterways including rivers, lakes, ponds and canals to give examples of industrial contamination resulting from anthropogenic activity and natural contamination resulting from regional geology.
- Market research to assess the consumption habits of the public with respect of fish and shellfish from unmanaged freshwaters and the possible transfer of environmental contaminants to these consumers. Regional differences and population sub-groups were considered, and the habits of unlicensed anglers were

included in the study where possible. This part of the study also identified those species most widely consumed by anglers and the public.

- Specific unmanaged freshwater sites were identified and species of fish were selected for further investigation, with the aim to provide the basis for advice to consumers of fish from these waters.

The first stage of the project identified particular groups, regional and seasonal differences in consumption of freshwater fish, and provided an estimate of the extent of these habits amongst the various sub-groups of the population and correlated this with data relating to contamination of inland waterways by various contaminants leading ultimately to an indication of exposure to environmental contaminants resulting from this practice. Because data already exists for many contaminants in salmon and trout which are widely consumed, this project focussed on other species.

The specific plan to emerge from the first stage of the project was that a range of fish species would be sampled at two sites (i.e. sites that were heavily fished and where high numbers of fish were consumed). The two sites selected for the first phase were the River Clyde (at Blantyre and/or Rosebank) and Sutton at Ashfield (the lake at Mansfield on the River Maun). The fish species to be sampled from The Clyde were to be perch, pike, brown trout and grayling, and roach. The species to be collected from the Sutton in Ashfield site were roach, bream, perch, roach, tench and rudd. In the second phase, one indicative species of fish - perch – was to be sampled at various waterways to understand the variation in pollutant levels in the fish across different sampling sites. Perch was to be sampled at the River Gryfe, River Don, River Trent, Mowden Hall, River Thames, Grantham Canal, Dog Kennel Pond and the River Derwent. The River Don was included given a known history of pollution (Lake et al, 2005).

Full details can be found in the reports attached at Appendices 1 and 2.

This report represents the second stage of the project and investigated the variation of heavy metals (arsenic, cadmium, lead and mercury in particular), dioxins, polychlorinated biphenyls (PCB) and brominated compounds levels in a range of species of fish from the samples collected from the sites identified in the first stage of the project.

Environmental contaminants in fish and shellfish

Aquatic environments are recognised sinks for a range of environmental contaminants, and uptake and bioaccumulation by various fish and shellfish species has been widely documented (eg in Fernandes et al, 2008; Fernandes et al, 2008B; Fernandes et al, 2009; Fernandes et al, 2009B). In particular, marine shellfish have a recognised potential for bio-accumulating contaminants and some species such as mussels, are commonly used as early indicators of local pollution. Consequently, marine fish and shellfish have been shown to make a significant contribution to human exposure of a range of environmental contaminants. Aquatic species also show a similar potential for contaminant bio-accumulation and there have been a number of reports of elevated contaminant levels in river and lake species such as trout, pike, carp, perch, etc. In many parts of the world, including the European Union, fish caught from rivers and other fresh waters are often included in the diet. Within the UK there is very little data on contaminants in river fish species and there is little information as to the extent to which these species are consumed. It is therefore unclear as to what degree these potential foods contribute to human exposure.

Trace elements

Some trace elements and in particular, heavy metals and arsenic are established toxic contaminants. Some elements, such as copper, chromium, selenium and zinc are essential to health but may be toxic at high levels of exposure. Other elements have no known beneficial biological function and long-term, high-level exposures may be harmful to health. Environmental sources are the main contributors to contamination of food which is the major source of the overall exposure of consumers to metals and other elements, although other routes may also be significant (for example, oral exposure via the drinking water, inhalation exposure via the occupational setting). The presence of metals and other elements in food and the environment can also be the result of contamination by certain agricultural practices (e.g. cadmium from phosphate fertilisers), manufacturing and packaging processes (e.g. aluminium and tin in canned foods) and endogenous sources (e.g. as in ground waters in certain parts of the world). Furthermore, certain food groups naturally accumulate some elements and consequently contain high concentrations of these elements compared to other foods. For example, fish and shellfish are known to accumulate arsenic and mercury and cereals can accumulate cadmium. Metals and other elements may enter marine and aquatic environments and bio-accumulate. Heavy metals may be present in waterways as a result of the geology of the region, for example naturally occurring lead or zinc are found in some areas. These and other potentially toxic elements may also be found in the location of certain industries, as a result of unauthorised discharge, or as a result of other anthropogenic activity.

There have been many surveys of sea-fish for trace elements, but fewer have been conducted on freshwater fish or on deep sea fish and very few that have been conducted with simultaneous analysis for organic contaminants. In the UK, the FSA recently conducted a study of metals and other elements as part of the Total diet study - TDS (FSA 2009). The results of the study indicated that current population dietary exposures to most of the metals and elements investigated did not raise specific concern for the health of consumers. However further investigation on some of the elements was recommended as well as continued efforts to reduce dietary exposure to inorganic arsenic and lead.

Dioxins and PCBs

Dioxins and PCBs are recognised environmental and food contaminants that are known to bio-accumulate in fish and shellfish. The extent of this accumulation is evident by the levels of these contaminants detected in various studies. In the UK TDS (FSA 2003) carried out over the last 2 decades, fish (including shellfish) has consistently been one of the highest dioxin and PCB containing food groups. Reports from other recent studies on the levels in fish and shellfish also support this observation (FSA 2006, Health Canada 2005, FSAI 2002, Fernandes et al 2004B). Specific surveys of marine and farmed fish and shellfish (FSA 2006a, FSAI 2002, Hites et al 2004, Hashimoto et al 1998, Jacobs et al 2002, Fernandes et al 2008, 2009A, 2009B) confirmed the relatively high concentrations of dioxins and PCBs in marine species, and also showed that fish with a high lipid content, or oily fish, and bottom feeding fish, such as plaice, contained a higher concentration of the contaminants as compared to white fish. Shellfish species, particularly oysters, crabs, mussels, whelks, etc. also showed relatively high concentrations of dioxins and PCBs. Human dietary exposure can therefore be significantly influenced by the fish and shellfish component of the diet, particularly in high level consumers and low body-weight individuals. Dioxin levels in fish and shellfish species used for food have been regulated by the EU following the introduction of maximum permitted levels (MPLs) in 2002 (Council Regulation 2375/2001) and amended in 2006 (Council Regulation 1881/2006). There is little data on dioxins and PCBs in coarse river fish, although an on-going survey of PCBs in French river fish has shown high levels of contamination (Verstraete, 2009).

Brominated Flame Retardants and Brominated dioxins

The term 'brominated contaminants' commonly refers to a range of additive and reactive brominated flame retardant chemicals (BFRs), brominated dioxins and furans (PBDD/Fs), and brominated biphenyls (PBBs). BFRs are used specifically to slow down or inhibit the initial phase of a developing fire. PBDEs (polybrominated diphenyl ethers) are BFRs that were mass produced and incorporated into a number of commonly used commercial materials such as plastics, rubbers, textiles and electronic components. PBBs were previously used for the same purpose, but their use has been banned since the 1970s. The use of BFRs has undoubtedly saved lives and reduced human injuries (Spiegelstein 2001, Emsley et al 2002), and figures of 20% reductions in fire deaths directly attributable to flame retardants have been quoted. PBDEs are mixed with other ingredients when flame retardant materials are produced and as this is an open-ended application, the chemical is available to diffuse from materials into the environment. This process can occur over the lifetime of the material - during manufacture, use, and disposal. The occurrence of BFRs in environmental compartments, such as water, sediments and biota (D'Silva et al 2004), accompanies an increasing amount of evidence suggesting that these chemicals may potentially have detrimental human health effects (Darnerud 2003, Hakk and Letcher 2003, D'Silva 2004). Emerging toxicological data shows that some PBDEs can cause liver and neurodevelopmental toxicity and affect thyroid hormone levels. In recent years the EU has carried out a comprehensive risk assessment under the Existing Substances Regulation (793/93/EEC) of commercial PBDE products. The outcome was a ban on the use of penta-and octa-BDE since 2004. The situation with regard to another mixture - deca-BDE remains fluid - in 2008 the European Court of Justice (ECJ) annulled the exemption to the EU Directive on the Restriction of the Use of Certain Hazardous Substances in Electrical and Electronic Equipment 2002/95/EC, commonly referred to as the Restriction of Hazardous Substances Directive or RoHS Directive as of 30 June 2008 that was granted in 2005 for deca-BDE.

There is very little information on the occurrence of other emerging brominated contaminants such as the polybrominated dibenzo-p-dioxins and polybrominated dibenzofurans (PBDD/Fs) in food. This is perhaps unsurprising given the relatively recent recognition of the global environmental distribution of these pollutants and the difficulties associated with making valid measurements. PBDD/Fs are inadvertent by-products of incineration processes and have physico-chemical properties that are similar to their chlorinated analogues. They originate from similar anthropogenic sources as chlorinated dioxins, such as incineration, or chemical manufacture e.g. PBDD/F are formed as by-products during the manufacture of PBDEs. Studies of incineration processes (Weber et al 2002, D'Silva et al 2004) show that the formation of these compounds are consistent with "*de novo*" hypothesis and are thus governed by the occurrence of bromine or chlorine sources in incinerator feed. There are studies (Barontini et al 2001, Weber and Kuch 2002) that show that the incineration of products containing BFRs as well as thermolysis of BFR material such as PBDEs is an important source of PBDD/F emissions. PBDD/Fs can also be formed from PBDEs, during thermal processing procedures such as extrusion, moulding and recycling, and degradation. It has also been demonstrated that PBDD/Fs can be formed during ultra-violet irradiation of decabromodiphenyl ether (Olsman et al 2002). Recently, there have been reports that some lower brominated PBDD congeners (tri- tetra-) may be produced through biogenic formation in the marine environment and bio-accumulate in some marine species (Malmvarn et al 2005, Haglund et al 2007). As the utilisation of BFRs continues to increase, a corresponding increase in PBDD/Fs levels can be expected. Studies on the toxicity of PBDD/Fs are limited but both, *in vivo* and *in vitro* studies demonstrate AhR agonist properties and dioxin-like effects (Birnbaum et al 2003, Environment Health Criteria 205). Although there are a number of methods reported for the analysis of dioxins, PCBs and PBDEs (Gilpin et al 2003, Krokos et al 1997, Fernandes et al 2004) very few methods exist for the determination of PBDD/Fs (Ashizuka et al 2004, Fernandes et al 2008). To date there is only a limited amount of available data on the occurrence of these compounds in foods (Fernandes et al 2009, Fernandes et al 2009c).

General observations from a recent study on fish and shellfish (FSA 2006b) showed the occurrence of both, BFRs and PBDD/Fs. PBDEs, particularly congeners 47, 49, 66, 99, 100, 153, 183 and 209 were detected in most of the samples apart from canned products. Lower brominated dioxins and furans were also detected in a number of samples, with tri-bromo analogues occurring at significant levels particularly in shellfish, as was observed in later studies on shellfish from Scotland (Fernandes et al 2008) and other parts of the UK (Fernandes et al 2009). This is an important observation as tri-brominated dioxins and furans have been reported to have a greater toxicological significance than their chlorinated counterparts (Behnisch et al 2003). The greater frequency of detection of PBDFs relative to PBDDs reflects the environmental occurrence and emission profiles for brominated dioxins and furans, which both show higher levels of the furans. Several other studies have been conducted that look at only PBDEs in freshwater fish and shellfish (Covaci et al 2005; Hale et al 2001; Webster et al 2008)

Chlorinated Naphthalenes

PCNs are industrial chemicals, produced over most of the last century, although manufacture is currently banned and use limited. They were sold as technical mixtures (e.g. Halowax in the US, Nibren in Germany, Seekay in the UK, etc) of the commercial PCN product in mineral oil. However, PCNs can also be formed through industrial thermodynamic processes such as incineration, and formation pathways resulting from *de novo* synthesis during combustion have been documented (Iino et al 1999, Takasuga et al 2004). The halogenated aromatic structure provides strong chemical stability and the molecule is resistant to attack by strong acids. PCNs are hydrophobic compounds that possess high thermal stability, good weather resistance, good electrical insulating properties and low flammability. They were therefore commonly used as dielectrics in electrical equipment. Unfortunately, the properties of physical and chemical stability are also responsible for the persistence of the compounds in environmental and biotic media.

All chloronaphthalene congeners are planar and lipophilic compounds, structurally similar to the highly toxic 2,3,7,8-tetrachlorodibenzo-p-dioxin molecule, and can contribute to an aryl hydrocarbon (Ah) receptor-mediated mechanism of toxicity, including a combination of toxic responses such as mortality, embryotoxicity, hepatotoxicity, immunotoxicity, dermal lesions, teratogenicity and carcinogenicity (Blankenship et al 1999, Blankenship et al 2000, Engwall et al 1994, Hanberg et al

1990, Villeneuve et al 2000). In humans, severe skin reactions (chloracne) and liver disease have both been reported after occupational exposure to PCNs. Other symptoms found in workers include cirrhosis of the liver, irritation of the eyes, fatigue, headache, anaemia, haematuria, anorexia, and nausea.

PCNs have been detected in several environmental compartments including biota. They have been measured in fish from the Great Lakes, in species such as trout, carp, bass, and pike, from low to sub-ppb levels of total PCN (Kannan et al 2000). Fish from the Detroit river showed concentrations of up to 31.4 ppb (Van de Plassche and Schwegler 2005) while harbour porpoises from the west coast of Sweden showed concentrations of up to 730 ng/kg wet weight in blubber, nuchal fat and liver (Ishaq et al 1999). A range of fish species from the Baltic Sea and three Finnish lakes were measured with levels ranging from 1 – 170 ng/kg whole weight for samples from the Baltic Sea and 2 – 66 ng/kg whole weight for samples from the lakes (Isosaari et al 2006). At present there is very little information on dietary exposure of humans to PCNs, but two surveys of foods have been carried out in Spain. These studies measured PCN homologue totals and showed that the highest concentrations were in fats and oils, cereals, fish, dairy products and meat. Within the UK, a study on food, targeting specific PCN congeners based on toxicity and occurrence, found that the highest levels of occurrence were in fish and shellfish (Fernandes et al 2009D).

Perfluorinated Compounds

PFOS and related perfluorinated compounds (PFCs) are industrial chemicals that are now understood to be Persistent Organic Pollutants (POPs). These compounds are widely used in the production of non-stick coatings, in water repellent and stain resistant coatings for fabrics and furnishings, in fire fighting foams and other applications. PFCs may bio-accumulate up the food chain through utilisation or disposal routes, or enter directly into food through primary contamination events. The assimilation pathway is different to other POPs since these compounds are not as lipophilic, and are in fact quite polar. Early information on occurrence in European environmental and food samples (mainly fish) confirms the presence of PFOS in fish particularly in the liver (EFSA 2008). Similarly investigations into Japanese foods (Guruge 2008) reported cattle, pig and chicken livers to contain mean PFOS concentrations of 34, 54 and 67 µg/kg, respectively, with the highest individual PFOS value at 92 µg/kg in a chicken liver.

Studies on shellfish taken from South China and Japan showed PFOS levels in oysters from Tokyo bay at 3 μg/kg. PFOS has been shown to bio-accumulate in fish and a kinetic bio-concentration factor has been estimated to be in the range 1000 – 4000. The time to reach 50% clearance in fish has been estimated to be around 100 days.

Organochlorine Pesticides

Some organochlorine (OC) pesticides are included in the 'Stockholm 12' list of persistent organic pollutants (POPs) along with the dioxins, PCB etc. They may also be associated with specific on-farm or industrial more localised use. Other pesticides such as the organophosphurus (OP) class are used (or have been used in the past) for specific applications (such as sheep dipping), but these are not persistent in the environment and were not prioritised for measurement. Pesticides may arise from direct use in wetlands where they may be used to control vector insects, and they may also be used in fish farming eg some pesticides are used to control sea-lice infections of farmed salmon. Pesticides, especially herbicides, can also enter river systems as a result of rainwater and irrigation wash-off from agricultural land into rivers. There is then a strong potential for these compounds to bio-magnify and to accumulate in fish and other aquatic fauna. The residues will then re-enter the land-based food chain if fish are eaten by wildlife or are caught for human consumption. The organochlorine pesticides are highly lipophilic and can quickly accumulate in oily fish. There have been particular problems with eels caught in river estuaries, partly because of their oily nature and longevity, and also because of the environments they inhabit (Rose, 2004).

Organo-tin compounds

Antifouling paints contain toxic biocides to prevent marine life from colonising the bottoms of boats. These biocides are constantly released from the painted surface into the surrounding waters. Prior to a ban on vessels less than 25 m in length in 1989, tributyl tin (TBT) was widely used as a biocide on all vessels. Since this ban, organic booster biocides have been developed to improve the efficacy of both copper and TBT based formulations. Along with TBT, eight organic booster biocides are currently approved for use in the UK (CEFAS, 2001).

Study Objectives

The first stage of the project aimed to: (i) identify any particular socio-economic groups and regional or seasonal differences in habits of consumption of freshwater fish types, (ii) provide an estimate of the extent of consumption and establish what were habits amongst the anglers and other sub-groups of the population, and (iii) correlate the information with data relating to contamination of inland waterways with various contaminants. Details of the sites and fish species selected and the reasoning behind the choices are given in section 7.2 and Table 19 of the report at Appendix 2. All of the above will allow ultimately to estimate the exposure to environmental contaminants resulting from consumption of freshwater fish. A major obstacle to the risk assessment of human exposure to some of these contaminants is the acute shortage of reliable occurrence data. This is particularly true for contaminants such as PBDD/Fs, PCNs and PFOS where analytical accessibility is limited due to the difficulties encountered in making reliable measurements. This is mainly because food matrices are more analytically challenging than environmental matrices (for which relatively more data is available), and the requirement for measurements to be sufficiently sensitive to make the risk assessment meaningful. The second stage of the project addresses these issues. In addition to allowing the assessment of risk, the data it has generated will complement and extend the available knowledge on the occurrence of these contaminants in freshwater fish that may be consumed by anglers or other sub-groups of the population.

EXPERIMENTAL

First stage

Prioritisation of sites was undertaken using a GIS approach and drew upon various spatial and temporal datasets as part of the methodology. The methodology employed took advantage of the strengths of the readily available datasets while maintaining a level of consistency across the UK. A number of different options were considered at the outset ranging from a pure analysis of existing monitoring data to a pure modelling approach. Each of these has strengths and weaknesses and when considered along with data availability, quantity and quality, a spatial modelling approach that utilised no monitoring data was adopted. This approach draws on a range of spatial datasets coupled with simple Tier 1 models to assess metal, pesticide and organic pollutant pressures. It was felt that this approach was the most robust with respect to environmental contamination and was also consistent with the Water Framework Directive waterbody characterisation work that has already been undertaken in all of the UK nations (e.g. EA, 2007; Anthony *et al*., 2005; Hughes *et al*., 2006; SEPA, 2005; EHS, 2005). Experimental details relating to this part of the project are given in the report attached in Appendix 1

Market research was conducted via face to face interviews with anglers at selected fishing sites, by trained market research interviewers. Due to the scale of the survey and geographical distribution the interviewing was subcontracted to JK Research, specialists in conducting interviews within the rural environment. The face to face method was selected to ensure there was opportunity for those fishing without an Environment Agency rod licence in England and Wales to be included within the study. The Public Attitudes to Angling Study1 conducted by ADAS on behalf of the Environment Agency suggests that there are 3 million people in England and Wales who have fished in the last 2 years, however only in the region of 1 million licences are sold each year. Thus the number of people fishing without a licence is clearly significant. Also, as rod licences are not issued in Scotland it would not have been possible to access a database of anglers from which to conduct a telephone study. Full details of the questions used and analysis of the results is included in the report at Appendix 2.

Evaluation of the outcome of this work resulted in the plans for sampling and analysis that were carried out as outlined below.

Sampling

Phase 1A: Bream, perch and roach were obtained from a large pond in Sutton-in-Ashfield (Figure 1). This was done with cooperation from the angling club and with practical help from Environment Agency (EA) staff. The club was keen to cooperate because of on-going concerns about pollution in the pond. Fish were caught by electro-fishing, whereby the fish are stunned by an electric current and then removed from the pond with a net.

Phase 1B: Fish as available were obtained with assistance from the EA from a further 4 sites; Thornborough pond (Newton) – Perch; River Don (Doncaster) - chub, perch, flounder, bream, pike, carp, barbel; River Thames (London) - perch, bream, roach; Dog Kennel Pond (Rotherham) - perch, bream, roach.

Samples from Phase 1 were analysed for trace elements, PCDD/Fs, PCBs, PBDD/Fs, PBBs, PBDEs, deca-BDE and deca-BB, PCNs, organo-chlorine pesticides, organo-fluorine compounds (PFOS etc), and organo-tin compounds,

Phase 2: Fish were collected from a variety of sites, by EA staff, Food and Environment Research Agency (FERA) staff, or using sub-contractors employed specifically to undertake this work. Samples obtained were as follows: Greenfield Heritage Lake (Wales) – bronze bream; Dog Kennel Pond (Rotherham) – silver bream, perch; Chesterfield Canal – crucian carp, tench; Grantham Canal – perch, bream; River Mersey – bronze bream, perch, rudd, dace; Lough Neagh (Northern Ireland) – eels; River Trent (following cyanide poisoning incident) – perch, chub (4 samples), pike (4 samples), barbell (3 samples), eel (2 samples); River Gryfe – flounder, brown trout, rainbow trout.

Samples from phase 2 were analysed for a reduced set of compounds based on results from phase 1. These were trace elements, PCDD/Fs, PCBs, PBDEs, organo-fluorine compounds (PFOS etc) and PCNs.

From phases 1 and 2 combined, a total of 46 samples were obtained for this project, covering a variety of waterways and fish species. A list of samples and fat contents is provided in Table 1. It was necessary to deviate to some extent from the planned species from each phase and site due to teh availability of samples.

On receipt at the laboratory each sample was given a unique laboratory reference number and the sample details were logged into a database. The samples were stored frozen prior to analysis.

The samples were dissected to exclude non-edible parts and the tissue obtained from this process was homogenised by mincing and blending. Sub-samples were taken for the analysis of the various classes of contaminants monitored. For some samples there was insufficient material to perform all of the analysis planned and this was prioritised on a case by case basis. Where required, sub-samples were freeze-dried and the resulting powders were thoroughly mixed before taking aliquots for the analysis of dioxins, PCBs and other organic contaminants.

Fat Determinations

Fat determinations were performed by a UKAS (ISO 17025) accredited laboratory on sub-samples of the freeze-dried and homogenised samples using a standard method (British Standards Institute 1970).

Analytes

The majority of samples (except where limited by weight) were determined for the following analytes:

Trace elements – Al, Cr, Fe, Co, Ni, Cu, Zn, As, Se, Cd, Sn, Hg, Tl, Pb.

Dioxins - all 17, 2378-Cl substituted PCDDs and PCDFs,

PCBs - non-*ortho*-substituted PCBs - IUPAC numbers 77, 81, 126 and 169

ortho-substituted PCBs -IUPAC numbers 18, 28, 31, 47, 49, 51, 52, 99, 101, 105, 114, 118, 123, 128, 138, 153, 156, 157, 167, 180, 189.

Brominated dioxins - 2,3,7-T_3BDD, 2,3,8-T_3BDF, 2,3,7,8-Br substituted PBDD/Fs: and 10 tetra – hexa brominated congeners (note that this includes only 1 hexa-Br as no standards were available for the other 3 congeners)

PBDE congeners: IUPAC numbers 17, 28, 47, 49, 66, 71, 77, 85, 99, 100, 119, 126, 138, 153, 154 and 183.

PBB congeners: IUPAC numbers 15, 49, 52, 77, 101, 126, 169, and 153.

PBDE 209 and PBB 209 (deca bromo compounds).

PCNs - PCN-52/60, 53, 66/67, 68, 69, 71/72, 73, 74, & 75

Organo-fluorine compounds (PFOS and related congeners) – Perfluorooctanesulfonylamide (PFOSA); Perfluorobutane sulfonate (PFBSH); Perfluorohexane sulfonate (PFHxS); Perfluorooctane sulfonate (PFOS); Perfluorohexanoic acid (PFHxA); Perfluoroheptanoic acid (PFHpA); Perfluorooctanoic acid (PFOA); Perfluorononanoic acid (PFNA); Perfluorodecanoic acid (PFDeA); Perfluoroundecanoic acid (PFUnA); Perfluorododecanoic acid (PFDoA).

Organo-tin compounds – Dibutyltin (DBT) and Tributyltin (TBT)

OC pesticides - DDD – pp; DDE-pp; DDT-op; DDT-pp; HCH-alpha; HCH-beta; HCH-gamma; aldrin; chlordane (cis); chlordane (trans); dieldrin; endosulfan (I); endosulfan (II); endosulfan-sulphate; endrin; heptachlor; heptachlor epoxide (trans); hexachlorobenzene; oxychlordane.

Reference Standards

Reference standards for PCDD/Fs, PCBs, PBDD/Fs, PBBs, PBDEs, PCNs, organo-fluorine samples and $^{13}C_{12}$ materials for use as internal standards were sourced from either Cambridge Isotope Laboratories (Andover, MA, USA) or from Wellington Laboratories (Guelph, Ontario, Canada) as solutions in n-nonane, iso-octane, methanol or toluene with a specified 10% tolerance on concentration. Deca-BB was obtained as an iso-octane solution from Accustandard and deca-BDE was obtained as a toluene solution from Wellington. Standards for the other analytes measured, are detailed within the procedures.

PROCEDURES

Heavy Metals - Sample digestion and measurement

1 – 2 g (fresh weight) of each sample was weighed into alloted quartz digestion vessels and a mixture (4:1) of nitric acid and hydrochloric acid added (5.0 ml). The vessels were sealed and the contents digested using a high pressure microwave digestion system (Anton Paar 'Multiwave'). Reagent blanks, certified reference materials and a spiked blank were also taken through the procedure. The resulting solutions were transferred to

pre-marked acid-clean plastic test tubes and diluted to 10 ml with deionised water (18MΩ).

Seven calibration standards from certified stocks, in an acid matrix to match that of the samples, were prepared to cover the expected concentration range for each element. The digest solutions and standards were diluted further with internal standard (indium or rhodium) in dilute nitric acid (1 % v/v). Measurements were made using either a Perkin Elmer Elan 6000 ICP-MS instrument or an Agilent 7500ce ICP-MS instrument. The element concentrations in the diluted samples were calculated from the response curve of the standards at the beginning of each run. The concentrations of 14 elements were determined (Al, Cr, Fe, Co, Ni, Cu, Zn, As, Se, Cd, Sn, Hg, Tl and Pb).

Quality Control (Metals)

The analytical procedure is accredited to the ISO17025 standard. The criteria used to assess data included checks on instrument drift, spike recovery, replicate agreement, limits of detection and certified reference material values.

The limit of detection (LOD) was defined as three times the standard deviation of the signal from reagent blanks (which had been taken through the entire analytical procedure) when subsequently corrected for sample weight and dilution. The limit of quantification (LOQ) was defined as ten times the standard deviation of the signal from reagent blanks (which had been taken through the entire analytical procedure) when subsequently corrected for sample weight and dilution.

Analyses included re-measurement of a calibration standard at the end of each ICP-MS run. In order to pass this check, the re-measured standard had to be within ± 20 % of the initial value.

Data were accepted if the recovery of spike for each analyte was within the range 60 to 140 % with at least 75 % of these recoveries lying within the range 80-120 %. Replicate values for a given sample had to have a relative standard deviation of <20 % or a standard deviation of <LOQ, whichever was greater.

Results for reference materials (Table 13) had to be within the certified range, or 40% of the quoted value, whichever was greater. Where indicative values were shown on certificates, measured concentrations had to be within a factor of 2 of the quoted value. Data were accepted if results for at least two of the three reference materials passed the criteria above.

PCDD/Fs, PCBs, PBDD/Fs, PBDEs, PBBs and deca-BB/BDE

The PCDD/F internal standard solution contained nominal concentrations of 2 ng/ml of each of fifteen $^{13}C_{12}$ labelled 2,3,7,8-substituted internal standards. These compounds were labelled analogues of all the PCDDs and PCDFs of interest except for 1,2,3,7,8,9-HxCDD and OCDF. The PCB internal standard solution contained nominal concentrations of 200 ng/ml of eight $^{13}C_{12}$ labelled ortho-substituted PCBs (IUPAC numbers 28, 52, 101, 118, 138, 153, 180 and 194) and nominal concentrations of 2 ng/ml of four $^{13}C_{12}$ labelled non-ortho-PCBs (IUPAC numbers 77, 81, 126 and 169). The internal standard solution for the brominated dioxins contained nominal concentrations of 10 ng/ml each of five $^{13}C_{12}$ labelled 2,3,7,8-substituted internal standards (one each for tetra- and penta-Br substituted dioxin and furan, and one hexa-Br substituted dioxin). The internal standard solution for the PBBs and PBDEs contained nominal concentrations of 100 ng/ml of $^{13}C_{12}$ labelled PBBs (IUPAC numbers 52, 77 126 and 153), 100 ng/ml of $^{13}C_{12}$ labelled PBDEs (IUPAC numbers 28, 47, 99, 153, 154 and 183) and 300 ng/ml of $^{13}C_{12}$ labelled Deca-BDE.

The internal sensitivity standard solution used for ortho-PCB measurement contained $^{13}C_{12}$ -PCB 202 and $^{13}C_{12}$ -PCB 77 at a nominal concentration of 100 ng/ml. The internal sensitivity standard used for the PCDD/Fs and non-ortho PCBs contained $^{13}C_{12}$ -1,2,3,4-tetrachlorodibenzo-p-dioxin and $^{13}C_{12}$ - 1,2,3,7,8,9-hexachloro-dibenzo-p-dioxin, each at a nominal concentration of 4 ng/ml. The internal sensitivity standard solution used for PBDD/Fs PBBs and PBDEs contained $^{13}C_{12}$ -PCB 202 and $^{13}C_{12}$ -PBDE 139 at a nominal concentration of 100 ng/ml. All internal and sensitivity standard solutions were prepared in n-nonane.

Dichloromethane, methanol, toluene, hexane and n-nonane were purchased as doubly glass distilled (Rathburn, Scotland) and assessed for lack of contamination before use. Alumina (Sigma Chemical Company, USA) was activated by baking overnight in a muffle furnace at 450^{o} C. All other chemicals employed were Analytical Reagent grade materials.

Reagents, including base-modified and acid-modified silica gel, were prepared as previously reported (Fernandes et al 2004) and were assessed for contamination prior to use. All equipment was scrupulously cleaned and thoroughly rinsed with dichloromethane prior to use. Care was taken to avoid airborne contamination of containers by keeping vials capped even when empty and covering flasks and concentration tubes with cleaned aluminium foil.

The extraction, purification and analysis of samples for PCDD/Fs, PCBs, PBDEs was carried out as previously reported (Fernandes et al 2004). More details of the procedure used for the PBBs and PBDD/Fs have also been published elsewhere (Fernandes et al 2007). In brief, aliquots of the samples were fortified with the internal standard solutions described above and extracted by solvent action. The crude extract obtained was quantitatively transferred into an apparatus containing modified silicas followed by activated carbon on glass fibres where the analytes were fractionated on the basis of their planarity.

The two fractions containing i) ortho-PCBs ortho-PBBs and PBDEs, ii) non-ortho-PCBs, non-ortho-PBBs, PCDD/Fs and PBDD/Fs were purified using acid hydrolysis and activated alumina. Where required, fractions were further purified using acid hydrolysis and alumina. The extracts were concentrated and the appropriate sensitivity standard was added to each fraction prior to instrumental analysis.

GC-HRMS determination of PCDD/Fs, non-ortho PCBs, PBDD/Fs, PBDEs, PBBs and deca-BB/BDE

GC-high resolution mass spectrometry was performed on either one of two Micromass

Autospec Ultima instruments fitted with a Hewlett Packard 6890N gas chromatograph and a CTC Analytics PAL GC autosampler or a CTC A200SE autosampler. The gas chromatograph was fitted with a 60m J&W DB-5 MS fused silica capillary column. For PCDD/Fs and non-ortho-PCBs the oven temperature programme consisted of a 5 minute isothermal period at 60°C followed by heating at 120°C/min to 140°C and then at 15°C/min to 210°C followed by 3°C/min to 280°C with a final isothermal period of 10 min. The GC-MS interface was set to 220°C. Injections were made with a PTV injector using a temperature programme which consisted of a 3 minute isothermal period at 40°C followed by heating at 12°C/sec to 320°C, hold for 3 min and then at 12°C/sec to 350°C. For the PBDD/Fs and non-ortho PBBs, the oven temperature programme consisted of a 5 minute isothermal period at 80°C followed by heating at 14°C/min to 220°C for 1 min, then at 3°C/min to 280°C for 1 min, then 6°C/min to 310°C for 9 min, followed by 20°C/min to 330°C with a final isothermal period of 3 min. The GC-MS interface was set to 280°C. Injections were made with a PTV injector using a temperature programme which consisted of a 3 minute isothermal period at 60°C followed by heating at 12°C/sec to 320°C, hold for 3 min and then at 12°C/sec to 350°C. Electron ionisation was used and the mass spectrometer was operated at a resolution of at least 9000 (based on peak width at 10 % of peak height) with focussing optimised prior to each run. Selected ion monitoring was employed, using the two most intense ions in the molecular ion cluster for each homologue. These conditions were used to monitor PCDD/Fs and non-ortho-PCBs in one run, PBDD/Fs and non-ortho-PBBs in a second run, with the ortho substituted PBBs and PBDEs measured in a third run using the following oven temperature programme: 4 minute isothermal period at 60°C followed by heating at 11.3°C/min to 150°C for 1 min, then at 20°C/min to 230°C for 1 min, then 2°C/min to 270°C for 1 min, then 10°C/min to 310°C for 7 min followed by 20°C/min to 330°C with a final isothermal period of 4 min.

Decabromo analytes were measured in a separate run using a 15 m ZB5-MS column (Zebron, Phenomenex) operated using the following oven temperature programme: 3 min at 60°C, 20°C/min to 205°C for 21 min, then 66°C/min to 325°C for 10 min. The PTV injector in constant flow mode used the following transfer programme: 3 min at 60°C, 12°C/sec to 320°C for 3 min, then 12°C/sec to 350°C.

Ortho-PCBs

Ortho substituted PCBs were measured by GC-unit resolution mass spectrometry, performed on an Agilent GC-MS system, (6890N GC coupled to a 5973 MSInert, fitted with an Agilent 7683 autosampler). Chromatographic separation was effected, using a 60m J&W DB-5 capillary column. Sample introduction was carried out via a PTV injector typically programmed with a 1 minute isothermal period at 50°C followed by heating at 10°C/sec to 150°C then 10°C/sec to 260°C, hold for 1 min, then at 10°C/sec to 320°C for 40 min. The gas chromatograph temperature programme consisted of a 4 min isothermal period at 60°C followed by heating at 20°C/min to 180°C for 9 min, then at 0.5°C/min to 190°C and finally at 5.0°C/min to 280°C with an isothermal period of 5 min. The mass spectrometer was operated in electron ionisation mode. Selected ion monitoring was used, and the two most intense ions in the molecular ion cluster were measured for each ^{13}Carbon labelled PCB and native PCB homologue group.

Data handling

Data reduction for all GC-MS analyses, and processing to calculate the mass of each compound present was performed using Masslynx 3.5 software supplied by Micromass. These data were transcribed to Microsoft Excel for collation and quantitation of concentration data.

Quality control

The methodology used for the determination of PCDD/F, PCBs, PBDD/Fs, PBDEs and PBBs has been accredited (UKAS) to the ISO17025 standard. The scope of the accreditation covers all congeners except deca-BDE/BB. Apart from PCDD/Fs and PCBs, there are no universal acceptance criteria for data quality, so quality control for the accompanying data has followed the criteria currently used for chlorinated dioxins and PCBs (Commission Directive 2002/69/EC). Further, the methodology used for brominated analytes is essentially the same as that used for chlorinated dioxins and PCBs – featuring the extensive use of ^{13}Carbon labelled analyte surrogates and measurement by high resolution mass spectrometry. Basic method quality data for PBDEs and PBDD/Fs using essentially the same method as that successfully used over several years for chlorinated dioxins and PCBs has been published before (Fernandes et al 2004).

The GC-MS analytical run of each batch of purified sample extracts was preceded by the analysis of a standard reference solution used to check system performance and calibration validity. The reference standard solution was also analysed during and at the end of the analytical run. All integrated chromatograms were scrutinised to assess chromatographic peak shape, resolution and signal-to-noise. Additionally, lock-mass traces were examined for evidence of ionisation suppression and isotope ratios were compared with theoretical abundances.

Sample extraction and purification was carried out in batches that included a full method blank. The blank was assessed for internal standard recoveries and for the presence of native analytes.

The quality control samples for PCDD/Fs and PCBs were reference materials prepared by the BCR (Maier et al 1995): - "RM 534, PCDDs and PCDFs in spiked milk powder-higher level" and "CRM 350, PCBs in mackerel oil" (Griepink et al 1988). Results obtained for certified congeners in these samples were in good agreement with the certified values. In the absence of reference materials for the brominated dioxins and PBBs, a number of different food matrices ranging from milk to fish were fortified with native analytes and analysed using the methodology described. Results obtained for these were in good agreement with fortification levels (Table 13). Additionally, the CRMs described above for chlorinated dioxins and PCBs analysis (Griepink et al 1988) was also investigated for brominated analytes. Where analytes were detectable (PBDEs and PBBs), data for the reference material analysed showed consistency during the course of the work.

FERA regularly participates in inter-comparison exercises, where these are available, for e.g. most recently, in 2003, 2005 and 2007 rounds of the inter-comparison exercise – "Dioxins in Food" (Norwegian Institute of Public Health 2003, 2005, 2007, 2009) and FAPAS (FAPAS 2003). In all cases results reported by the laboratory were in excellent agreement with consensus data. There are currently no exercises running for brominated dioxins or PBBs in food, but there are exercises for the determination of PBDEs in biota (Quasimeme 2004). For participation to date, results reported by the laboratory were in excellent agreement with consensus data. Additionally, the "Dioxins in Food" inter-comparison for 2005, 2007 and 2009 has also included measurements for PBDEs in fish matrices. Results reported for these fish based matrices were in agreement with consensus data.

PCNs

Extraction and Purification

An aliquot of the prepared, homogenized sample was fortified with a known amount (in typically 50 µL) of $^{13}C_{12}$ labeled PCN internal standard mix. The size of the aliquot was dependent on the proportion of lipid present and typically the equivalent of 2-5 g of lipid weight was taken for analysis. The fortified sample was left to equilibrate for an hour and then blended with 200 ml hexane and 75 g acid modified silica gel (prepared by roller mixing 1:1, H_2SO_4: Silica, for min. 6 hours). The mixture was quantitatively transferred to the top of a multi-layer column (70 x 600 mm) packed from top to bottom with; 30 g of anhydrous sodium sulphate, 50 g of acid modified silica gel, 10 g of sodium sulphate and silanised glass wool. The column was plugged with 2 glass fibre frits and connected in series to a carbon column (20 x 95 mm containing 0.1 g of activated carbon dispersed on 1 g of glass fibre) and an outflow reservoir. The columns were eluted with dichloromethane:hexane (40:60 v/v, 400 ml) and hexane (100 ml) to waste. The carbon column was disconnected and reverse eluted with 100 ml of toluene to yield a fraction containing the PCNs.

The toluene extract was concentrated using a TurboVap II™ (Zymark Corporation) apparatus at an evaporation temperature of < 30°C and solvent exchanged to ~0.5 ml of hexane. The concentrate was treated with 37N sulphuric acid (5 drops) and mixed by rotary shaking. The mixture was allowed to stand for 15 minutes to allow the aqueous acid and organic layers to separate. The bottom aqueous layer was discarded and the process was repeated. The organic layer was chromatographed on two micro-columns (6 mm x 100 mm) in series, the upper column packed with acid modified silica gel (~3.5 cm) and eluted directly on to the lower column containing activated (~7 cm) alumina. The columns were eluted with 15 ml of hexane to waste followed by disposal of the silica column and elution of the alumina column with 30 ml of dichloromethane:hexane (30:70). This eluate was concentrated with the addition of the $^{13}C_{12}$ labelled internal sensitivity standard contained in the keeper solvent to approximately 25 µl.

Measurement and Quantitation

Individual PCN congeners were analysed by high resolution gas chromatography – high resolution mass spectrometry (HRGC-HRMS). These measurements were performed on either one of two Micromass Autospec Ultima instruments fitted with a Hewlett Packard 6890N gas chromatograph and a CTC Analytics PAL GC autosampler or a CTC A200S autosampler. The gas chromatograph was fitted with a 60m x 0.25mm i.d. J&W DB-5 MS fused silica capillary column and operated in constant flow (~1ml/min helium) mode. The PCNs were monitored in a single run using a GC oven temperature programme consisting of a 5 minute isothermal period at 60°C followed by heating at 24°C/min to 180°C for 2 min, then at 5°C/min to 250°C for 2 min, followed by 10°C/min to 300°C with a final isothermal period of 8 min.

The GC-MS interface was set to 280°C. 10 µl injections were made with a PTV injector using a temperature programme which consisted of a 3 minute isothermal period at 60°C followed by heating at 12°C/sec to 320°C, for 3 min, then at 12°C/sec to 340°C to the end of the run.

The mass spectrometer was operated in electron ionisation (EI) mode at a mass resolution of ~10K (at 10% peak height). Selected ion monitoring (SIM) was used to record the two most intense ions in the molecular ion cluster for each homologue group. An acceleration voltage of 7kV was used with an electron energy of ~ 35-38 eV and a trap current of 400- 450 µA.

Quantification was carried out on the basis of stable isotope dilution of the ^{13}C labelled surrogates and internal standardisation. MassLynx™ software was used for targeting and quantitation of all the analytes.

Quality control (PCNs)

Measurement was carried out by HRGC-HRMS and limits of detection are typically of the order of ~0.1 ng/kg on a whole weight basis but can be lower for some individual congeners. Determination using this methodology is considerably aided by the use of ^{13}Carbon labelled PCN congeners and replicate measurements on the same matrix have shown an average precision of <10%, ranging from 1 to ~16%, as defined by the co-efficient of variation. The accuracy of the measurement has been confirmed by the successful analysis of fortified food matrices, returning concentrations that were in good agreement with the fortified values. There are no available reference materials (RMs) for PCNs, but the use of CRM 350 (Griepink et al 1988), a fish oil matrix that is used for other similar contaminants was investigated for use as an in-house RM during the course of this work. CRM 350 did contain appreciable amounts of PCNs the concentrations of which were established by the simultaneous analysis of PCN fortified samples.

Sample extractions (organo-fluorines; PFOS etc)

This procedure has been described elsewhere in more detail (Lloyd et al 2009). Briefly, quadruple 1-10 g portions of each homogenised sample were weighed out into Falcon tubes (50 ml). The appropriate volumes of internal standard (IS) and standard addition mixtures were added, to prepare two unspiked portions, one overspiked at the reporting level (1 µg/kg) and one portion at 10-times the reporting level (10 µg/kg. The fish portions were homogenised for 1-3 mins as required in 20 ml of methanol with an Ultra Turrax (T25 basic with S25N blade). When homogenised, more methanol was added (*ca.* 40 ml in total) and mixed, while withdrawing the Ultra Turrax blade. Samples were agitated overnight (16h), then centrifuged (15 min, 5000 rpm). The supernatant methanol extracts were evaporated under a nitrogen stream (80^{o}C, in silyanised glass vials) just to dryness, and the residues were re-dissolved in aqueous KOH (25 ml, 0.01 M, sonication 10 min). The aqueous extracts were then re-centrifuged (15 min, 5000 rpm). When required, the supernatants were poured in one continuous gentle movement, without breaking up the floating materials (fat), or disturbing the sediment, into a funnel connected onto the top of a preconditioned SPE cartridge (weak anion exchange). The cartridges were loaded at a constant drip rate, by increasing from gravity feed to full vacuum as required. After loading, the cartridges were washed with ammonium acetate (2 x 6 ml, 25 mM, pH 4.5) and eluted with basic methanol (4 ml, 0.1% ammonia). The eluates were reduced under a stream of nitrogen gas (60^{o}C), just to dryness and the residues taken up in methanol (400 µl, sonication 10 min). Extracts were transferred into silyanised glass microvials (300 µl) for LC-MS/MS determination.

LC-MS/MS measurement (organo-fluorines; PFOS etc)

Analysis was undertaken by LC-MS/MS. A CTC Pal autosampler (Presearch, UK) and an HP1100 HPLC system with column oven (Agilent, UK) were coupled to an API4000 triple quadrupole mass spectrometer (MDS Sciex Instruments, UK). The guard cartridge was C_8. The HPLC column (5 µm, 60A, 2.1 x 150 mm) was Fluorosep RP Octyl phase, thermostatically held at 30^{o}C in the column oven. The injection volume was generally 10 µl. The gradient programme (methanol: aqueous ammonium formate, 5 mM, pH 4) was: 10% methanol increasing to 30% at 0.1 min (linear gradient), to 75% at 7 min and 100% methanol at 10 min, this was held for 5 min (column washing), then decreased to 10% methanol at 15.1 min, this was held 4.9 min at 10% methanol (column re-conditioning). The eluate was diverted to the mass spectrometer between 7 and 19.5 min, and from 0-7 and 19.5-20 min it was discarded by valve switching to waste, in order to protect the ion source. Analyst 1.4.2 software was used for instrument control, file acquisition and peak integration. The MS detector in multiple MRM mode with a Turbo Ion Spray source was used for quantitative analysis. Data acquisition was conducted in one simultaneous acquisition schedule without separation into chromatographic acquisition windows. Instrumental parameters were optimised by infusion of standard solutions directly into the MS detector (1 µg/ml in 1:1 methanol: aqueous ammonium formate (5 mM, pH 4). The Turbo Ion Spray (TIS) conditions were; turbo-gas 50 psi, curtain-gas 12 psi, nebuliser-gas 50 psi, desolvation temperature 450^{o}C. An Excel spreadsheet was used to calculate PFC concentrations from the standard additions.

Quality control (organo-fluorines; PFOS etc.)

The use of LC-MS/MS in multiple MRM mode contributes much to the specificity of the measurement process for these compounds. Determination is aided by the use of ^{13}Carbon labelled and deuterated PFC compounds as internal standards. Each food sample was analysed in duplicate throughout the entire extraction method to ensure that advantageous point contamination was not mistaken for the presence of any native PFC. For a specific analyte to be considered present in a sample extract the following criteria must be met: i) the relative retention times of the analyte must be comparable to those of a retention time marker, an internal standard, and to authentic analytical standards of each analyte; ii) the peak must have the correct mass transition, maximising at the correct retention time; iii) the signal to noise ratio of any peak must be greater than 3:1. In order to prove the absence of a given PFC, the internal standard must be present in all extracts, the blank extract must show no signal at the retention time of the target PFC, whilst the overspiked extracts must show a peak for the target PFC at the required retention time.

OC pesticides

Samples were extracted with a mixture of hexane and acetone, prior to clean-up using high performance gel permeation chromatography (HPGPC) clean-up and subsequent determination using gas chromatography with electron capture detection (GC-ECD). Residues were not confirmed with mass spectrometric methods.

Organo-tin compounds

Samples were analysed under sub-contract by the Centre for Centre for Environment, Fisheries and Aquaculture Science. Sample extraction was carried out on a 1-2g sub-sample by alkaline saponification. The organotins compounds were then converted into their hydrides forms by the addition of sodium borohydride. The organotins hydrides were finally back extracted in hexane by liquid-liquid partition. Analysis was by Gas Chromatography fitted with a Flame Photometric Detector (GC-FPD) and quantification was done using external calibration. A certified reference material (CRM 477) and method blank were run within each sample batch for quality control.

RESULTS AND DISCUSSION

A list of samples including a description and FERA sample number is given in Table 1. More detail on the samples, including sampling locations and reasons for choice are given in the reports included at Appendix 1 and 2.

Results of analysis are presented in Tables 2–21. Methods of analysis for trace elements, PCDD/Fs, PCBs, PBDD/Fs, PBBs, (except deca-BDE and deca-BB) and OC pesticides were accredited by UKAS to the ISO 17025 standard; methods for organotin compounds (sub-contracted to CEFAS) and organo-fluorine compounds were not formally accredited to ISO 17025 but both methods were validated and were conducted with quality control to a similar rigour.

Data were rounded to two decimal places or fewer, as appropriate. For regulated contaminants, measurement uncertainty has been estimated in particular for PCDD/Fs, PCBs and also for PBDD/Fs, PBDEs and PBBs as per the Eurachem guide (Ellison et al 2000). The estimate takes into account contributory parameters such as the individual uncertainties associated with fat content, sample size, results of the analysis of fortified samples, and limits of detection. Typical uncertainties, for example, for dioxins are of the order of 20% at the 1 ng/kg fat level, but can rise to around 200% at the limit of detection (typically 0.01 ng/kg fat, but dependent on the fat content and sample size). In perspective, this is the same degree of uncertainty achieved by FERA in recent international inter-comparison exercises (Norwegian Institute of Public Health, FAPAS, Quasimeme) where measurements were made at similar concentrations and results reported by the laboratory were in excellent agreement with consensus data. The measurement uncertainty values and other quality indicators, such as the values of analysis of reference materials that was carried out alongside the samples, are not included in the report for reasons of simplification and brevity. All vaues for the analysis of reference materials and calculations of uncertainty were within the ranges normally expected and encountered when undertaking similar work.

The reporting limits (quoted as “<”) for all analytes are estimated as a dynamic parameter and are therefore the limits of determination that prevail during the course of the measurement. For PCDD/Fs, PCBs, and metals, the limits are consistent with the requirements of EU regulations. The limits for the PBDD/Fs and PCNs were typically as low as sub-ng/kg (parts per trillion) levels on a fat weight basis, and typically as low as 0.01 μg/kg for PBDE and PBB measurements. For PFCs the LOD was set at 1 μg/kg. In general, for all analytes, the limits are either better, or equivalent to those reported in the literature.

Concentrations of chlorinated dioxins and furans and dioxin-like PCBs are normally reported as a TEQ, which is calculated by multiplying the concentration of each congener of interest by its toxicity equivalency factor (TEF). The TEFs are based on the toxicity of each congener relative to 2,3,7,8-TCDD. The World Health Organisation

(WHO) defined a set of TEFs in 1998 (Van den berg et al 1998), but conducted a review and revised some of the values in 2005 (Van den berg et al 2006). Current EU regulations stipulate the use of the 1998 TEFs and these must therefore be used in assessing TEQ levels against regulatory limits. The data in the tables for PBDD/Fs and non-ortho PBBs is also supplemented by the addition of TEQs. The application of analogous chlorinated dioxin and PCB toxic equivalent factors (TEFs) to estimate toxicity (TEQs) arising from PBDD/Fs and non-ortho PBBs is limited because a full and specific set of TEFs for these brominated contaminants has not yet been established, and are unlikely to be identical to the chlorinated analogues. Using the TEFs for chlorinated analogues has been suggested as an interim measure (WHO 1998) since both chlorinated and brominated dioxins show similar biological effects, such as induction of aryl hydrocarbon hydroxylase (AHH)/EROD activity, and other toxic responses, such as wasting syndrome, thymic atrophy and liver toxicity in a range of test animals (Behnisch et al 2003). The estimation of TEQ for the brominated contaminants is thus an interim measure, until specific TEF values that cover all the brominated congeners that show dioxin-like toxicity become available in the literature. The toxicities for these compounds continue to be studied (Birnbaum et al 2005) and potencies of some congeners, relative to 2,3,7,8-TCDD have been reported (Behnisch et al 2003, Hornung et al 1997, Olsman et al 2007) in the literature.

This report represents the first study of such a comprehensive set of contaminants in freshwater fish, and as such is unique. The analysis of such a range of contaminants maximises the amount of information obtained from individual samples and may allow for a greater range of correlation analysis than would otherwise be possible. The occurrence of these contaminants is discussed below and makes reference to individual results tables (Tables 2-21) as well as to Table 22 which summarises the occurrence (whole weight) of the principal contaminants based on frequency and levels.

Legal limits apply only to fish that are available on retail sale for human consumption, and as such none of the samples breached legal limits. Some of the samples did however exceed the values of these limits and would not legally be allowed to be put on retail sale.

In combination with the work done on habits of consumption of freshwater fish, the report provides a basis for a preliminary assessment of risk to consumers.

Heavy Metals

The concentrations of heavy metals in mg/kg of whole weight tissue are given in Table 2 for phase 1 and Table 14 for phase 2, with a summary for the regulated elements (arsenic, cadmium, lead and mercury) given in Table 22. Some metals such as zinc, copper and mercury were detected in all or most of the samples. The concentrations of arsenic found in these freshwater fish ranged from 0.01 – 0.97 mg/kg which is lower than the range typically found in marine fish. The corresponding range of arsenic concentrations from an earlier study (FSA 2005) on a range of more commonly consumed fish was 0.12 mg/kg for surimi to 20.17 mg/kg for skate.

For mercury, the difference between the values found here and for marine species was less marked with a range of 0.03 mg/kg to 0.40 mg/kg. Mercury is regulated by the EC (Commission Regulation EC 1881/2006 as amended by 629/2008) with a general limit of 0.5 mg/kg for fish.

The levels of cadmium and lead were both low with ranges of 0.005-0.053 mg/kg and 0.005-0.063 mg/kg respectively, which can be compared against regulations set at 0.05 mg/kg for cadmium and 0.30 mg/kg for lead.

Dioxins and PCBs

Fish show a marked tendency to bio-accumulate persistent organic contaminants and the fish samples analysed for dioxins and PCBs showed near universal detection of all analysed congeners of these contaminants (Tables 3-6, 15-18 and summary Table 22). The few instances of no detection were usually caused by low available sample weight or were for congeners which do not normally tend to occur (1,2,3,7,8,9-HxCDF, 1,2,3,4,7,8,9,HpCDF and the higher chlorinated PCBs – 206, 208 and 209). This occurrence is not remarkable – in the TDS studies carried out by the FSA fish was one of the highest dioxin and PCB containing food groups and also the one with the slowest tendency to decline over time (Fernandes et al 2004B). In common with the other persistent organic pollutants measured in this work, the freshwater species consistently showed higher average concentrations than marine fish or shellfish from other studies.

Unlike most investigations into dioxins and PCBs in fish, these samples typically showed a larger contributuion to the toal TEQ from PCDD/Fs than from PCBs. Other studies on fish and shellfish in the UK (Fernandes et al 2008, 2009, 2009B), show a contribution to WHO-TEQ arising mainly from dioxin-like PCBs (~70–82 %), whereas in this study the mean and higher contaminated fish showed that most of the contribution to the TEQ was from PCDD/Fs.

The dioxin and PCB WHO-TEQ content of fish for retail sale has been regulated by the EC since 2002, with maximum permitted limits set at 4ng/kg WHO-TEQ on a whole weight basis for dioxins and 8 ng/kg WHO-TEQ for combined dioxin and PCB WHO-TEQ (Commision regulation 1881/2006). The maximum detected dioxin and PCB WHO-TEQ was over 32 ng/kg for a sample of barbel from the River Don, and 6 samples in total exceeded the 8 ng/kg value, although this does not apply as a legal limit since the fish were not available for sale toteh public.

Brominated contaminants

PBDEs were detected in all the samples investigated and confirm the findings of earlier studies on fish (Tables 7 and 19). The occurrence profiles for fish generally reflect the congeners present in the most commonly used commercial PBDE mixture –penta-BDE, with BDE-47 and BDE-99 generally dominating the profile with other prominent congeners - BDEs 49, 66 100, 153 and 154. Some of the concentrations of PBDEs were very high compared with fish from previous surveys, with a mean of 20.43 µg/kg and a maximum of almost 130 µg/kg. Some congeners exceeded the linear range of the detector.

Ortho- substituted PBBs were not found in any samples (Tables 7 and 19). The non-ortho substituted PBBs (congeners PBB77, PBB126 and PBB169) were measured in Phase 1 samples (Table 8), and of these, PBB 77 was the most frequently detected. The relative concentrations of the flame retardants – PBBs (low levels) and PBDEs (higher levels) is consistent with the greater and more recent usage of PBDEs in the UK. The low levels of PBBs observed are likely to arise from long range marine and aerial transport, as recently reported in tissue from Arctic polar bear (D’Silva et al 2006).

PBDD/Fs were measured in samples from Phase 1. As with most foods investigated to date, the fish species studied here show a higher frequency of occurrence of brominated furans compared to the brominated dioxins. Some congeners were not detected in any of the samples, which is consistent with the environmental occurrence of these compounds. However the tri-bromo- and tetra-bromo- furans were detected, confirming earlier incidences (Malmvern et al 2005, Fernandes et al 2009). A biogenically mediated formation mechanism has been proposed for the tri- and tetra-brominated dioxins (Haglund et al 2007). In order to allow comparison with other studies, a TEQ has been calculated for the PBDD/Fs (Table 9), using analogous chlorinated dioxin TEFs. The mean TEQ value was 0.034 ng/kg with a range from 0.030 – 0.051 ng WHO-TEQ/kg.

Polychlorinated Naphthalenes

PCNs were detected in all samples (Tables 10 and 20). Fish are known to bio-accumulate PCNs and the most abundant congeners were PCNs 52/60, 53 and the toxicologically significant PCNs 66/67, 68 and 69. PCN 71/72 also occurred to a significant extent in line with the freshwater fish from the survey of Scottish fish and shellfish. The more highly chlorinated congeners, particularly 74 and 75 were less frequently detected.

In common with the other lipophilic and persistent contaminants, PCNs were found at high levels in the freshwater fish occurring at approximately an order of magnitude higher level than for shellfish and ~3 fold higher average concentrations than marine fish from the survey of Scottish samples.

The levels of PCNs observed in this study are broadly similar to the few, recently reported levels (Domingo et al 2003, Isosaari et al 2006, Fernandes et al 2009). In a recent study on PCNs in food in the UK, the highest levels were observed in retail fish and shellfish samples and the reported mean of 19.9 ng/kg whole weight compares with the average value of 22 ng/kg for freshwater fish in this study and 7.64 ng/kg for marine fish. However, 10% of the samples in this study showed levels (37-103 ng/kg) that were at or above the maximum value reported for the food study (37 ng/kg). In another recent study in Spain, the reported sum of PCNs in fish was 39 ng/kg. However it should be noted that this literature value quoted refers to homologue totals as opposed to the sum of 11 congeners reported in this work. The choice of congeners selected in this study was based principally on the toxicological characteristics of individual PCN congeners and the levels of patterns of occurrence.

Perfluorinated compounds (PFCs)

PFOS was the most prevalent compound detected of those measured. It was found in every sample tested with concentrations ranging from 2 to 153 mg/kg. PFDoA was the next most prevalent and was found in 12 out of the 33 samples tested, at concentrations ranging from <1 to 16 mg/kg (Tables 13 (b) and 21). In a recent study of perfluorinated compounds in food (Clarke et al, 2010), the highest individual concentrations were 59 mg/kg perfluorooctanesulphonic acid (PFOS) and 63 mg/kg total PFCs (∑PFCs) in an eel sample, and 40 mg/kg PFOS (62 ∑PFCs) in a whitebait sample. There were six samples with ∑ FCs415 mg/kg (fish and crustaceans), a further seven samples with ∑PFCs in the range 11–15 mg/kg (including a liver), nine with ∑PFCs in the range 6–10 mg/kg (fish and livers), 31 with ∑PFCs in the range 2–5 mg/kg (including kidneys, popcorn and processed peas) and 22 with ∑PFCs at the reporting level of 1 mg/kg (including eggs and potatoes).

The tolerable daily intakes for these chemicals are 0.15 and 1.5 mg/kg bodyweight/day for PFOS and PFOA respectively as set by the European Food Safety Authority (EFSA, 2008).

Contaminants by river system

Preliminary inspection of the data shows that the river system or sampling site that the fish came from had a larger bearing on contaminant load than either the species or size of the fish that made up the sample. Contamination loads of fish from the River Don and River Mersey were generally high compared with fish from other sites. There are insufficient sample numbers and too many variables, when species, age of fish and details of sampling location are taken into account, to enable detailed statistical analysis of the data

Contaminants by fish species

Variations in contamination levels for different species were not as evident as variations seen for the location from where the samples came, but as expected, eels showed a high content of lipophilic contaminants due to their fatty composition (eg Tables 15-20). The data when corrected on a fat weight basis showed relatively lower levels of contamination. The general observation for specific fish species was that organic contaminants appeared to be of greater concern than the trace elements.

Concluding Remarks

The results of this study confirm the occurrence of a wide range of environmental contaminants in fish, and underline the ubiquity and persistence of these compounds. This is evident from the occurrence of both, legacy contaminants such as the PBBs, PCNs, PCBs and metals, as well as more recently introduced chemicals such as deca-BDE and the PFCs. All of these contaminants elicit toxic responses in both, animals and humans, and the mechanisms and magnitude of these responses has led to some of these contaminants being regulated or near-regulated (ie possible subject to future regulation such as the non-dioxin-like PCBs, or where there is general guidance to minimise exposure etc), whereas (the absence of regulation for the others may simply result from a lack of toxicological information or data. Some samples greatly exceeded limits that apply to fish on retail sale for dioxins and PCBs, and may pose a threat to human health if consumed in large quantities.

It is also clear that for the major contaminants, freshwater fish show higher levels of contamination (apart from heavy metals, especially arsenic and mercury which occur at relatively higher levels in marine fish) than the marine species. This is remarkable given that unlike most of the marine fish samples, many of the freshwater samples received were made up of a number of small sized fish (average 15-20 cm in length). The size of fish within a species taken from different locations did not show a clear correlation with the levels of contamination. It is likely that occurrence of contaminants in fish is influenced primarily by location. It is also likely, given the bio-accumulative nature of these contaminants, that larger and older fish, within the same location would be expected to show higher levels of contamination, but the limited number of samples did not allow this to be confirmed.

This data may be used to estimate levels of dietary intake for those members of the population who consume these fish, but considerable uncertainty would remain within these estimates, given the observations made above, particularly for the freshwater fish. The data also provide an essential measure of the background levels of contamination for a wide range of emerging and existing contaminants. A parallel study funded by the Food Standards Agency in Scotland, which investigates a similar range of contaminants in marine and freshwater fish and shellfish, has recently been completed. This will provide another set of data on fish within the UK. The two sets of complementary data will provide a better picture of contemporary contamination levels and may allow more refined estimates of human exposure.

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Figure 1. Sampling at Sutton in Ashfield.

Table 1: Description of Samples

CSL Sample No.	Description	% Fat (Whole weight)
2008 Samples – Phase 1		
16211	Bream - Millpond, Fished 21/02/08	3.93
16212	Perch - Millpond, Fished 21/02/08	3.38
16213	Roach - Millpond, Fished 21/02/08	4.38
16356	Perch, Thornborough pond, nr Corbridge Northumberland, NGR N2 009 642, Collected 25th July 2008, 4.42kg	1.87
16594	Chub - River Don, 1.14kg	4.12
16595	Perch - River Don, 0.32kg (5 fishes)	0.75
16596	Flounder - River Don, 2.67kg, (9 fishes)	1.22
16597	Common Bream - River Don, 2.56kg, (2 fishes)	4.05
16598	Pike - River Don, 1.65kg	0.44
16599	Carp - River Don, 3.60kg	9.11
16600	Barbel - River Don, 3.69kg	2.98
16612	Bream - Dog Kennel Pond, 1.37kg	0.89
16613	Perch - Dog Kennel Pond, 1.36kg	0.57
16614	Roach - Dog Kennel Pond, 1.20kg	1.31
16631	Perch, 23rd & 24th Sept 2008 , River Thames, Penton Hook to Chertsey, (TQ04468 69425 - TQ05416 66953), Ref: 563 - 346, 4.11kg	0.84
16678	Bream x 2, ~ 856.81g (removed from above sample 16631)	0.68
16679	Roach, ~240.05g (removed from above sample 16631)	2.66
2009 Samples – Phase 2		
17380	Bronze bream Greengield Heritage Site Holywell	9.01
17381	Silver Bream Dog Kennel Pond Rotherham, 10/08/09	1.65
17391	Perch, Dog Kennel Pond, Rotherham, 10/08/09	0.54
17392	Tench, Chesterfield Canal, 17/08/09	1.30
17393	Crucian Carp x 4, Chesterfield Canal, 17/08/09	0.80
17404	Perch x 3 Grantham Canal, 28/08/09, ~912g incl bag	1.08
17405	Silver Bream x 7 Grantham Canal, 28/08/09, ~1124g incl bag	1.84
17487	Bronze Bream, R.Mersey (Warrington).Sampled-20/9/09	5.68
17488	Perch x 7, R.Mersey (Warrington).Sampled-20/9/09	1.24
17489	Rudd x 11, R.Mersey (Warrington).Sampled-20/9/09	3.20
17490	Dace, R.Mersey (Warrington).Sampled-20/9/09	1.80
17500	Eels x 4, (Deheaded & Gutted), Lough Neagh Fishermans Cooperative, Sent: 21.09.09	27.42
17627	Perch, River Trent Staffordshire	2.21
17628	Chub - 1, River Trent Staffordshire	2.35
17629	Chub - 2 River Trent Staffordshire	1.75

17630	Chub – 3 River Trent Staffordshire	2.61
17631	Chub – 4 River Trent Staffordshire	0.34
17632	Pike – 1 River Trent Staffordshire	1.18
17633	Pike – 2 River Trent Staffordshire	1.70
17634	Pike – 3 River Trent Staffordshire	0.43
17635	Pike – 4 River Trent Staffordshire	1.43
17636	Barbel – 1 River Trent Staffordshire	4.80
17637	Barbel – 2 River Trent Staffordshire	4.59
17638	Barbel – 3 River Trent Staffordshire	3.54
17639	Eel – 1 River Trent Staffordshire	29.91
17640	Eel – 2 River Trent Staffordshire	24.02
17930	Flounder - 1 Fish, River Gryff	0.80
17931	Brown Trout - 17 Fish, River Gryff	1.76
17932	Rainbow Trout - 13 Fish, River Gryff	2.20

Phase 1
results tables

Table 2: Trace elements in river fish (Phase 1)

[Bracketed values are between the LoD and LoQ]

Fera LIMS code	S08-010747	S08-010748	S08-010749	S08-019661	S08-027479	S08-027480	S08-027481	S08-027482
OPHA sample code	16211	16212	16213	16356	16594	16595	16596	16597
Sample description	Bream	Perch	Roach	Perch	Chub	Perch	Flounder	Common Bream
	Millpond	Millpond	Millpond	Thornborough pond	River Don	River Don	River Don	River Don
Element concentration (fresh weight) mg/kg								
Al	<1	<1	5	<1	<1	<1	5	<1
Cr	(0.03)	<0.03	(0.04)	<0.03	<0.03	(0.08)	<0.03	1.37
Fe	14.9	8.2	17.5	2.9	5.2	2.1	9.0	22.8
Co	(0.009)	(0.006)	0.014	<0.003	(0.004)	(0.007)	0.014	0.015
Ni	(0.04)	<0.03	(0.04)	<0.03	<0.03	<0.03	(0.04)	(0.07)
Cu	0.66	0.35	0.76	0.18	0.38	0.17	0.37	0.42
Zn	20.56	12.20	40.16	5.89	4.55	5.03	9.17	4.68
As	0.07	(0.03)	0.09	(0.03)	0.25	0.44	0.97	0.12
Se	1.25	1.12	0.74	0.64	(0.17)	0.63	0.54	0.51
Cd	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005
Sn	0.04	0.05	0.05	<0.01	<0.01	<0.01	<0.01	<0.01
Hg	0.028	0.071	0.043	0.091	0.163	0.162	0.185	0.269
Tl	<0.005	<0.005	<0.005	<0.005	<0.005	(0.005)	<0.005	<0.005
Pb	0.040	(0.016)	0.065	<0.005	<0.005	(0.006)	0.046	(0.016)

Table 2: Trace elements in river fish (Phase 1) contd.

[Bracketed values are between the LoD and LoQ]

Fera LIMS code	S08-027483	S08-027484	S08-027485	S08-027836	S08-027837	S08-027838	S08-028919
OPHA sample code	16598	16599	16600	16612	16613	16614	16631
Sample description	Pike	Carp	Barbel	Bream	Perch	Roach	Perch
	River Don	River Don	River Don	Dog Kennel Pond	Dog Kennel Pond	Dog Kennel Pond	River Thames
Element concentration (fresh weight) mg/kg							
Al	<1	<1	<1	(2)	(1)	(2)	<1
Cr	0.44	0.11	0.51	(0.05)	<0.03	<0.03	0.25
Fe	5.3	17.2	9.6	7.2	4.1	6.2	5.0
Co	(0.004)	(0.004)	(0.005)	(0.010)	(0.005)	(0.006)	(0.007)
Ni	(0.03)	<0.03	(0.03)	<0.03	<0.03	<0.03	<0.03
Cu	0.25	0.65	0.35	0.38	0.22	0.28	0.22
Zn	6.80	19.13	3.58	6.78	5.31	16.10	6.15
As	0.55	0.10	0.06	0.06	0.07	0.08	0.06
Se	0.31	0.44	0.41	0.23	0.23	0.22	0.51
Cd	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005
Sn	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Hg	0.282	0.110	0.402	0.029	0.061	0.043	0.117
Tl	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005
Pb	<0.005	(0.008)	<0.005	(0.010)	(0.007)	(0.005)	(0.006)

Table 3: PCDD/Fs in river fish (Phase 1)

CSL Sample No.	16211	16212	16213	16356
LIMS No.	S08-010747	S08-010748	S08-010749	S08-019661
Sample Details:	Bream - Millpond, Fished 21/02/08	Perch - Millpond, Fished 21/02/08	Roach - Millpond, Fished 21/02/08	Perch, Thornborough pond, NGR N2 009 642, 25/7/08
ng/kg whole weight				
2,3,7,8-TCDD	0.21	0.26	0.12	<0.01
1,2,3,7,8-PeCDD	0.29	0.25	0.17	0.01
1,2,3,4,7,8-HxCDD	0.10	0.04	0.04	<0.01
1,2,3,6,7,8-HxCDD	0.24	0.12	0.11	<0.01
1,2,3,7,8,9-HxCDD	0.05	0.02	0.03	<0.01
1,2,3,4,6,7,8-HpCDD	0.54	0.17	0.25	0.03
OCDD	0.59	0.30	0.95	0.09
2,3,7,8-TCDF	2.19	1.24	1.32	0.07
1,2,3,7,8-PeCDF	0.14	0.08	0.09	0.01
2,3,4,7,8-PeCDF	0.71	0.64	0.42	0.03
1,2,3,4,7,8-HxCDF	0.11	0.07	0.05	<0.01
1,2,3,6,7,8-HxCDF	0.07	0.03	0.03	<0.01
1,2,3,7,8,9-HxCDF	<0.01	<0.01	<0.01	<0.01
2,3,4,6,7,8-HxCDF	0.06	0.03	0.03	<0.01
1,2,3,4,6,7,8-HpCDF	0.06	0.02	0.04	<0.01
1,2,3,4,7,8,9-HpCDF	<0.01	<0.01	<0.01	<0.01
OCDF	0.01	<0.01	0.03	<0.01
WHO TEQ (ng/kg whole) lower	1.150	0.991	0.668	0.033
WHO TEQ (ng/kg whole) upper	1.151	0.992	0.670	0.050

Table 3: PCDD/Fs in river fish (Phase 1) contd.

CSL Sample No.	16594	16595	16596	16597
LIMS No.	S08-027479	S08-027480	S08-027481	S08-027482
Sample Details:	Chub - River Don	Perch - River Don	Flounder - River Don	Common Bream - River Don
ng/kg whole weight				
2,3,7,8-TCDD	8.65	2.83	5.01	22.42
1,2,3,7,8-PeCDD	0.39	0.11	0.26	1.30
1,2,3,4,7,8-HxCDD	0.02	<0.01	<0.01	0.06
1,2,3,6,7,8-HxCDD	0.26	0.06	0.18	0.85
1,2,3,7,8,9-HxCDD	0.08	0.01	0.04	0.17
1,2,3,4,6,7,8-HpCDD	0.07	<0.02	0.03	0.09
OCDD	0.13	0.08	0.06	0.05
2,3,7,8-TCDF	1.97	0.46	1.30	6.32
1,2,3,7,8-PeCDF	0.38	0.16	0.44i	0.72
2,3,4,7,8-PeCDF	0.54	0.15	0.39	1.65
1,2,3,4,7,8-HxCDF	0.06	0.02	0.05	0.13
1,2,3,6,7,8-HxCDF	0.05	0.01	0.03	0.12
1,2,3,7,8,9-HxCDF	<0.01	<0.01	<0.01	0.02
2,3,4,6,7,8-HxCDF	0.05	<0.01	0.03	0.11
1,2,3,4,6,7,8-HpCDF	0.03	<0.01	0.02	0.03
1,2,3,4,7,8,9-HpCDF	<0.01	<0.01	<0.01	<0.01
OCDF	0.01	<0.01	0.01	<0.01
WHO TEQ (ng/kg whole) lower	9.579	3.079	5.651	25.360
WHO TEQ (ng/kg whole) upper	9.580	3.082	5.653	25.360

Table 3: PCDD/Fs in river fish (Phase 1) contd.

CSL Sample No.	16598	16599	16600	16612
LIMS No.	S08-027483	S08-027484	S08-027485	S08-027836
Sample Details:	Pike - River Don	Carp - River Don	Barbel - River Don	Bream - Dog Kennel Pond
ng/kg whole weight				
2,3,7,8-TCDD	11.34	12.83	23.98	0.03
1,2,3,7,8-PeCDD	0.58	0.89	1.28	0.04
1,2,3,4,7,8-HxCDD	0.01	0.15	0.04	0.01
1,2,3,6,7,8-HxCDD	0.23	1.32	0.59	0.02
1,2,3,7,8,9-HxCDD	0.05	0.26	0.13	<0.01
1,2,3,4,6,7,8-HpCDD	0.02	0.61	0.05	0.01
OCDD	0.02	0.59	0.05	0.01
2,3,7,8-TCDF	2.93	1.55	2.56	0.46
1,2,3,7,8-PeCDF	0.51	0.95	1.19	0.04
2,3,4,7,8-PeCDF	0.64	1.42	1.27	0.12
1,2,3,4,7,8-HxCDF	0.05	0.32	0.14	0.02
1,2,3,6,7,8-HxCDF	0.03	0.24	0.09	0.01
1,2,3,7,8,9-HxCDF	<0.01	0.02	0.02	<0.01
2,3,4,6,7,8-HxCDF	0.03	0.16	0.07	0.01
1,2,3,4,6,7,8-HpCDF	<0.01	0.18	0.02	0.01
1,2,3,4,7,8,9-HpCDF	<0.01	0.01	<0.01	<0.01
OCDF	<0.01	0.01	<0.01	<0.01
WHO TEQ (ng/kg whole) lower	12.599	14.888	26.319	0.185
WHO TEQ (ng/kg whole) upper	12.600	14.888	26.319	0.187

Table 3: PCDD/Fs in river fish (Phase 1) contd.

CSL Sample No.	16613	16614	16631	16678	16679
LIMS No.	S08-027837	S08-027838	S08-028919	S08-029884	S08-029885
Sample Details:	Perch - Dog Kennel Pond	Roach - Dog Kennel Pond	Perch, 23/24-9-08, River Thames, Penton Hook to Chertsey, (TQ04468 69425 - TQ05416 66953), Ref: 563 - 346	Bream x 2 (removed from above sample 16631- River Thames, Penton Hook to Chertsey)	Roach, (removed from above sample 16631- River Thames, Penton Hook to Chertsey)
ng/kg whole weight					
2,3,7,8-TCDD	0.02	0.04	0.02	0.01	0.05
1,2,3,7,8-PeCDD	0.02	0.04	0.02	0.02	0.09
1,2,3,4,7,8-HxCDD	<0.01	<0.01	<0.01	<0.01	0.02
1,2,3,6,7,8-HxCDD	0.02	0.02	0.02	0.02	0.04
1,2,3,7,8,9-HxCDD	<0.01	<0.01	<0.01	<0.01	0.01
1,2,3,4,6,7,8-HpCDD	0.03	0.04	0.02	0.02	0.03
OCDD	0.15	0.08	0.07	0.02	0.05
2,3,7,8-TCDF	0.10	0.46	0.25	0.35	1.33
1,2,3,7,8-PeCDF	0.10	0.2	0.09	0.07	0.13
2,3,4,7,8-PeCDF	0.08	0.12	0.09	0.07	0.25
1,2,3,4,7,8-HxCDF	0.01	0.02	0.01	0.01	0.02
1,2,3,6,7,8-HxCDF	<0.01	0.01	<0.01	<0.01	0.01
1,2,3,7,8,9-HxCDF	<0.01	<0.01	<0.01	<0.01	<0.01
2,3,4,6,7,8-HxCDF	<0.01	0.01	<0.01	<0.01	0.02
1,2,3,4,6,7,8-HpCDF	<0.01	<0.01	<0.01	<0.01	0.01
1,2,3,4,7,8,9-HpCDF	<0.01	<0.01	<0.01	<0.01	<0.01
OCDF	<0.01	<0.01	<0.01	<0.01	<0.01
WHO TEQ (ng/kg whole) lower	0.098	0.202	0.118	0.107	0.417
WHO TEQ (ng/kg whole) upper	0.104	0.206	0.123	0.112	0.418

Table 4: ortho-PCBs in river fish (Phase 1)

CSL Sample No.	16211	16212	16213	16356
LIMS No.	S08-010747	S08-010748	S08-010749	S08-019661
Sample Details:	Bream - Millpond, Fished 21/02/08	Perch - Millpond, Fished 21/02/08	Roach - Millpond, Fished 21/02/08	Perch, Thornborough pond, NGR N2 009 642, 25/7/08
ug/kg whole weight				
PCB18	0.21	0.13	0.47	<0.01
PCB28	3.84	4.62	2.53	0.03
PCB31	0.58	1.18	0.28	0.02
PCB47	ND	ND	ND	ND
PCB49	ND	ND	ND	ND
PCB51	ND	ND	ND	ND
PCB52	3.96	5.64	3.16	0.04
PCB99	2.73	4.59	2.05	0.05
PCB101	5.83	10.62	5.16	0.08
PCB105	1.29	2.19	1.02	0.02
PCB114	0.10	0.18	0.08	<0.01
PCB118	4.44	7.79	3.61	0.07
PCB123	0.17	0.29	0.15	<0.01
PCB128	0.91	1.66	0.70	0.01
PCB138	7.96	14.39	6.86	0.17
PCB153	7.48	14.31	6.87	0.21
PCB156	0.52	0.81	0.39	0.01
PCB157	0.10	0.22	0.09	<0.01
PCB167	0.23	0.40	0.19	<0.01
PCB180	3.52	6.20	3.37	0.10
PCB189	0.05	0.04	0.02	<0.01
WHO TEQ (ng/kg Whole) lower	0.957	1.640	0.762	0.014
WHO TEQ (ng/kg Whole) upper	0.957	1.640	0.762	0.026

Table 4: ortho-PCBs in river fish (Phase 1) contd.

CSL Sample No.	16594	16595	16596	16597
LIMS No.	S08-027479	S08-027480	S08-027481	S08-027482
Sample Details:	Chub - River Don	Perch - River Don	Flounder - River Don	Common Bream - River Don
ug/kg whole weight				
PCB18	1.02	0.07	0.36	0.17
PCB28	4.31i[R]	0.68	1.00	8.54
PCB31	0.74	0.27	0.35	1.05
PCB47	ND	ND	ND	ND
PCB49	ND	ND	ND	ND
PCB51	ND	ND	ND	ND
PCB52	4.79	1.09	1.76	12.29
PCB99	1.75	0.50	1.00	5.99
PCB101	5.13	1.20	2.20	14.10
PCB105	1.16	0.24	0.42	3.60
PCB114	0.09	0.02	0.03	0.29
PCB118	3.78	0.81	1.56	11.44
PCB123	0.06	0.02	0.03	0.12
PCB128	0.71	0.15	0.27	1.88
PCB138	7.53	1.87	3.24	20.00
PCB153	5.40	1.37	2.83	16.83
PCB156	0.38	0.10	0.18	1.16
PCB157	0.11	0.03	0.04	0.28
PCB167	0.19	0.05	0.09	0.52
PCB180	2.43	0.72	1.41	9.45
PCB189	0.03	<0.01	<0.01	0.03
WHO TEQ (ng/kg Whole) lower	0.795	0.183	0.327	2.389
WHO TEQ (ng/kg Whole) upper	0.795	0.184	0.328	2.389

Table 4: ortho-PCBs in river fish (Phase 1) contd.

CSL Sample No.	16598	16599	16600	16612
LIMS No.	S08-027483	S08-027484	S08-027485	S08-027836
Sample Details:	Pike - River Don	Carp - River Don	Barbel - River Don	Bream - Dog Kennel Pond
ug/kg whole weight				
PCB18	0.65	1.61	0.65	<0.01
PCB28	2.36	6.23	6.30	0.07i[R]
PCB31	0.78	3.15	1.60	0.03
PCB47	ND	ND	ND	ND
PCB49	ND	ND	ND	ND
PCB51	ND	ND	ND	ND
PCB52	4.05	12.89	9.74	0.14
PCB99	2.27	8.16	4.75	0.19
PCB101	5.29	18.72	14.53	0.32
PCB105	1.14	3.80	3.58	0.08
PCB114	0.09	0.31	0.31	<0.01
PCB118	4.07	13.30	12.68	0.28
PCB123	0.06	0.13	0.10	<0.01
PCB128	0.62	2.41	1.89	0.07
PCB138	7.38	23.81	22.44	0.64
PCB153	6.18	24.37	20.04	0.64
PCB156	0.46	1.31	1.50	0.03
PCB157	0.11	<0.59	0.43	<0.01
PCB167	0.21	0.74	0.63	0.02
PCB180	3.11	17.90	8.49	0.23
PCB189	0.02	0.09	0.04	<0.01
WHO TEQ (ng/kg Whole) lower	0.861	2.549	2.766	0.051
WHO TEQ (ng/kg Whole) upper	0.861	2.844	2.766	0.063

Table 4: ortho-PCBs in river fish (Phase 1) contd.

CSL Sample No.	16613	16614	16631	16678	16679
LIMS No.	S08-027837	S08-027838	S08-028919	S08-029884	S08-029885
Sample Details:	Perch - Dog Kennel Pond	Roach - Dog Kennel Pond	Perch, 23/24-9-08 , River Thames, Penton Hook to Chertsey, (TQ04468 69425 - TQ05416 66953), Ref: 563 - 346	Bream x 2 (removed from above sample 16631- River Thames, Penton Hook to Chertsey)	Roach, (removed from above sample 16631- River Thames, Penton Hook to Chertsey)
ug/kg whole weight					
PCB18	<0.01	0.03	0.02	<0.01	0.12
PCB28	0.05	0.13	0.53	0.10	0.65
PCB31	0.02	0.04	0.20	0.03	0.18
PCB47	ND	ND	ND	ND	ND
PCB49	ND	ND	ND	ND	ND
PCB51	ND	ND	ND	ND	ND
PCB52	0.10	0.24	0.80	0.17	1.00
PCB99	0.16	0.29	0.71	0.29	0.86
PCB101	0.28	0.51	1.11	0.46	1.86
PCB105	0.07	0.13	0.39	0.08	0.39
PCB114	<0.01	0.01	0.03	0.01	0.03
PCB118	0.27	0.45	1.35	0.52	1.50
PCB123	<0.01	<0.01	0.01	0.01	0.02
PCB128	0.07	0.10	0.30	0.10	0.25
PCB138	0.64	0.97	2.30	1.08	2.86
PCB153	0.63	1.02	2.07	1.18	3.02
PCB156	0.03	0.05	0.17	0.07	0.17
PCB157	<0.01	0.01	0.04	<0.01	0.05
PCB167	0.02	0.03	0.06	0.04	0.09
PCB180	0.22	0.35	0.68	0.58	1.11
PCB189	<0.01	<0.01	0.01	<0.01	0.02
WHO TEQ (ng/kg Whole) lower	0.049	0.093	0.297	0.101	0.319
WHO TEQ (ng/kg Whole) upper	0.061	0.095	0.297	0.107	0.319

Table 5: non-ortho-PCBs in river fish (Phase 1)

CSL Sample No.	16211	16212	16213	16356	16594	16595	16596	16597
LIMS No.	S08-010747	S08-010748	S08-010749	S08-019661	S08-027479	S08-027480	S08-027481	S08-027482
Sample Details:	Bream - Millpond, Fished 21/02/08	Perch - Millpond, Fished 21/02/08	Roach - Millpond, Fished 21/02/08	Perch, Thornborough pond, NGR N2 009 642, 25/7/08	Chub - River Don	Perch - River Don	Flounder - River Don	Common Bream - River Don
ng/kg whole weight								
PCB77	164	188.	120.	2.37	143	43.2	70.9	408
PCB81	13.1	20.7	10.2	0.27	12.1	2.88	4.60	42.6
PCB126	14.7	23.5	13.7	0.50	12.4	3.19	6.70	40.8
PCB169	1.46	1.36	0.95	0.07	0.97	0.16	0.50	2.96
WHO TEQ (ng/kg whole) lower	1.503	2.380	1.395	0.051	1.261	0.325	0.683	4.154
WHO TEQ (ng/kg whole) upper	1.503	2.380	1.395	0.051	1.261	0.325	0.683	4.154

Table 5: non-ortho-PCBs in river fish (Phase 1) contd.

CSL Sample No.	16598	16599	16600	16612	16613	16614	16631	16678	16679
LIMS No.	S08-027483	S08-027484	S08-027485	S08-027836	S08-027837	S08-027838	S08-028919	S08-029884	S08-029885
Sample Details:	Pike - River Don	Carp - River Don	Barbel - River Don	Bream - Dog Kennel Pond	Perch - Dog Kennel Pond	Roach - Dog Kennel Pond	Perch, 23/24-9-08 , River Thames, Penton Hook to Chertsey, (TQ04468 69425 - TQ05416 66953), Ref: 563 - 346	Bream x 2 (removed from above sample 16631- River Thames, Penton Hook to Chertsey)	Roach, (removed from above sample 16631- River Thames, Penton Hook to Chertsey)
ng/kg whole weight									
PCB77	95.6	162.	218	8.26	4.31	11.6	43.4	7.31	51.6
PCB81	11.6	10.4	23.4	0.74	0.56	1.11	2.02	0.67	3.22
PCB126	14.9	21.4	31.7	1.63	1.44	2.32	3.80	1.26	8.00
PCB169	0.94	3.02	2.42	0.27	0.18	0.32	0.21	0.30	0.69
WHO TEQ (ng/kg whole) lower	1.505	2.187	3.219	0.167	0.146	0.236	0.387	0.130	0.812
WHO TEQ (ng/kg whole) upper	1.505	2.187	3.219	0.167	0.146	0.236	0.387	0.130	0.812

Table 6: Total TEQ (PCDD/Fs and PCBs) in river fish (Phase 1); whole and fat weight basis.

CSL Sample No.	16211	16212	16213	16356	16594	16595	16596	16597
LIMS No.	S08-010747	S08-010748	S08-010749	S08-019661	S08-027479	S08-027480	S08-027481	S08-027482
Sample Details:	Bream - Millpond, Fished 21/02/08	Perch - Millpond, Fished 21/02/08	Roach - Millpond, Fished 21/02/08	Perch, Thornborough pond, NGR N2 009 642, 25/7/08	Chub - River Don	Perch - River Don	Flounder - River Don	Common Bream - River Don
% Fat Whole	3.93	3.38	4.38	1.87	4.12	0.75	1.22	4.05
WHO TEQ ng/kg whole								
Dioxin	1.151	0.992	0.670	0.050	9.580	3.082	5.653	25.360
non ortho-PCB	1.503	2.380	1.395	0.051	1.261	0.325	0.683	4.154
ortho-PCB	0.957	1.640	0.762	0.026	0.795	0.184	0.328	2.389
Sum of WHO TEQs (upper)	**3.611**	**5.012**	**2.827**	**0.127**	**11.64**	**3.591**	**6.664**	**31.90**
WHO TEQ ng/kg Fat								
Dioxin	29.136	29.542	15.287	2.438	232.525	410.727	462.887	626.484
non ortho-PCB	38.284	70.439	31.865	2.701	30.624	43.377	55.959	102.611
ortho-PCB	24.420	48.490	17.377	1.056	19.266	24.012	27.295	59.066
Sum of WHO TEQs (upper)	**91.84**	**148.5**	**64.53**	**6.195**	**282.4**	**478.1**	**546.1**	**788.2**

Table 6: Total TEQ (PCDD/Fs and PCBs) in river fish (Phase 1); whole and fat weight basis (contd.)

CSL Sample No.	16598	16599	16600	16612	16613	16614	16631	16678	16679
LIMS No.	S08-027483	S08-027484	S08-027485	S08-027836	S08-027837	S08-027838	S08-028919	S08-029884	S08-029885
Sample Details:	Pike - River Don	Carp - River Don	Barbel - River Don	Bream - Dog Kennel Pond	Perch - Dog Kennel Pond	Roach - Dog Kennel Pond	Perch, 23/24-9-08 , River Thames, Penton Hook to Chertsey, (TQ04468 69425 - TQ05416 66953), Ref: 563 - 346	Bream x 2 (removed from above sample 16631- River Thames, Penton Hook to Chertsey)	Roach, (removed from above sample 16631- River Thames, Penton Hook to Chertsey)
% Fat Whole	0.44	9.11	2.98	0.89	0.57	1.31	0.84	0.68	2.66
WHO TEQ ng/kg whole									
Dioxin	12.600	14.888	26.319	0.187	0.104	0.206	0.123	0.112	0.418
non ortho-PCB	1.505	2.187	3.219	0.167	0.146	0.236	0.387	0.130	0.812
ortho-PCB	0.861	2.844	2.766	0.063	0.061	0.095	0.297	0.107	0.319
Sum of WHO TEQs (upper)	**14.97**	**19.92**	**32.30**	**0.417**	**0.311**	**0.537**	**0.807**	**0.349**	**1.549**
WHO TEQ ng/kg Fat									
Dioxin	2874.541	163.352	884.467	19.791	18.273	15.523	14.149	16.873	15.797
non ortho-PCB	343.377	24.007	108.211	18.650	25.699	18.076	45.921	19.009	30.574
ortho-PCB	196.380	31.214	93.016	6.944	10.569	7.511	35.659	15.667	11.981
Sum of WHO TEQs (upper)	**3414.**	**218.6**	**1086**	**45.39**	**54.54**	**41.11**	**95.73**	**51.55**	**58.35**

Table 7: PBDEs and ortho-PBBs in river fish, including Deca BDE and deca BB (Phase 1).
i* - beyond linear measurement range, indicative data

OPHA Sample Number	16211	16212	16213	16356	16594	16595	16596	16597	16598
FERA LIMS No.	S08-010747	S08-010748	S08-010749	S08-019661	S08-027479	S08-027480	S08-027481	S08-027482	S08-027483
Sample Details:	Bream - Millpond, Fished 21/02/08	Perch - Millpond, Fished 21/02/08	Roach - Millpond, Fished 21/02/08	Perch, Thornborough pond, NGR N2 009 642, 25/7/08	Chub - River Don	Perch - River Don	Flounder - River Don	Common Bream - River Don	Pike - River Don
ug/kg whole weight									
BDE-17	0.02	0.05	0.08	<0.01	0.05	0.02	0.03	0.09	0.08
BDE-28	0.58	0.78	0.90	<0.01	1.98	0.06	0.19	0.86i*	1.01i*
BDE-47	23.72i*	23.03i*	16.74i*	0.07	27.35i*	4.79i*	15.29i*	103.71i*	41.35i*
BDE-49	0.28	0.97	0.21	0.02	0.26	0.3	0.6	0.78	0.6
BDE-66	0.03	0.41	0.02	<0.01	0.04	0.17	0.25	0.02	0.18
BDE-71	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
BDE-77	<0.01	0.02	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
BDE-85	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	0.01	0.01
BDE-99	0.13	6.13i*	0.07	0.03	0.12	3.80i*	1.51i*	0.05	1.72i*
BDE-100	3.15	3.88i*	2.07	0.02	4.17i*	1.24	2.71i*	15.49i*	6.04i*
BDE-119	0.05	0.07	0.04	<0.01	0.06	0.01	0.03	0.2	0.07
BDE-126	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
BDE153	0.95	0.96	0.27	0.01	1.47	0.35	0.3	2.96i*	0.89i*
BDE138	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
BDE 154	1.56	1.32	1.03	0.02	1.29	0.31	0.54	5.33i*	1.54i*
BDE-183	0.03	0.03	<0.01	<0.01	0.02	<0.01	<0.01	0.01	0.01
BB-15	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
BB-49	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
BB-52	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
BB-80	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
BB-101	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	0.01	<0.01
BB-153	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	0.02	<0.01
Deca BDE and decaBB									
BDE-209	0.05	0.03	0.15	0.03	0.01	0.04	0.07	0.04	0.02
BB-209	<0.01	<0.01	<0.01	<0.01	0.09	0.03	<0.01	<0.01	<0.01

Table 7: PBDEs and ortho-PBBs in river fish, including Deca BDE and deca BB (Phase 1) contd.

OPHA Sample Number	16599	16600	16612	16613	16614	16631	16678	16679
FERA LIMS No.	S08-027484	S08-027485	S08-027836	S08-027837	S08-027838	S08-028919	S08-029884	S08-029885
Sample Details:	Carp - River Don	Barbel - River Don	Bream - Dog Kennel Pond	Perch - Dog Kennel Pond	Roach - Dog Kennel Pond	Perch, 23/24-9-08 , River Thames, Penton Hook to Chertsey	Bream x 2 (removed from above sample 16631-River Thames, Penton Hook to Chertsey)	Roach, (removed from above sample 16631- River Thames, Penton Hook to Chertsey)
ug/kg whole weight								
BDE-17	0.21	0.08	<0.01	<0.01	0.01	<0.01	<0.01	0.02i
BDE-28	1.7	1.16i*	<0.01	<0.01	0.04	0.07	<0.01	0.07
BDE-47	23.05i*	85.39i*	0.25	0.17	0.46	3.56	0.12	0.86
BDE-49	1.69	1.38i*	0.04	0.04	0.05	0.21	0.01	0.08
BDE-66	0.02	0.06	<0.01	0.01	<0.01	0.08	<0.01	<0.01
BDE-71	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
BDE-77	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
BDE-85	<0.01	0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
BDE-99	<0.01	0.1	<0.01	0.10	<0.01	1.45	<0.01	<0.01
BDE-100	3.16i*	9.38i*	0.03	0.05	0.06	0.64	0.03	0.13
BDE-119	0.02	0.11	<0.01	<0.01	<0.01	0.01i	<0.01	<0.01
BDE-126	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
BDE153	0.17	3.16i*	0.01	0.02	0.02	0.23	0.02	0.03
BDE138	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
BDE 154	1.03	4.84i*	0.03	0.03	0.06	0.27	0.09	0.14
BDE-183	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
BB-15	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
BB-49	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
BB-52	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
BB-80	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
BB-101	<0.01	0.02	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
BB-153	<0.01	0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Deca BDE and decaBB								
BDE-209	0.02	0.01	0.02	0.02	0.01	0.02	0.01	<0.02
BB-209	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01

Table 8: Non-ortho-PBBs in river fish (Phase 1).

OPHA Sample Number	16211	16212	16213	16356	16594	16595	16596	16597	16598
FERA LIMS No.	S08-010747	S08-010748	S08-010749	S08-019661	S08-027479	S08-027480	S08-027481	S08-027482	S08-027483
Sample Details:	Bream - Millpond, Fished 21/02/08	Perch - Millpond, Fished 21/02/08	Roach - Millpond, Fished 21/02/08	Perch, Thornborough pond, NGR N2 009 642, 25/7/08	Chub - River Don	Perch - River Don	Flounder - River Don	Common Bream - River Don	Pike - River Don
ng/kg Whole weight									
PBB-77	0.04	0.09	0.05	<0.01	0.08	0.04	<0.01	0.06	0.06
PBB-126	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
PBB-169	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
TEQ lower, ng/kg whole	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
TEQ upper, ng/kg whole	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01

Table 8: Non-ortho-PBBs in river fish (Phase 1) contd.

OPHA Sample Number	16599	16600	16612	16613	16614	16631	16678	16679
FERA LIMS No.	S08-027484	S08-027485	S08-027836	S08-027837	S08-027838	S08-028919	S08-029884	S08-029885
Sample Details:	Carp - River Don	Barbel - River Don	Bream - Dog Kennel Pond	Perch - Dog Kennel Pond	Roach - Dog Kennel Pond	Perch, 23/24-9-08 , River Thames, Penton Hook to Chertsey	Bream x 2 (removed from above sample 16631-River Thames, Penton Hook to Chertsey)	Roach, (removed from above sample 16631-River Thames, Penton Hook to Chertsey)
ng/kg Whole weight								
PBB-77	0.03	0.03	0.01	0.01	0.01	0.03	<0.01	0.04
PBB-126	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.02
PBB-169	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.02
TEQ lower, ng/kg whole	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
TEQ upper, ng/kg whole	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01

Table 9: Brominated 'dioxins' PBDD/Fs in river fish (Phase 1).

OPHA Sample Number	16211	16212	16213	16356	16594	16595	16596	16597	16598
FERA LIMS No.	S08-010747	S08-010748	S08-010749	S08-019661	S08-027479	S08-027480	S08-027481	S08-027482	S08-027483
Sample Details:	Bream - Millpond, Fished 21/02/08	Perch - Millpond, Fished 21/02/08	Roach - Millpond, Fished 21/02/08	Perch, Thornborough pond, NGR N2 009 642, 25/7/08	Chub - River Don	Perch - River Don	Flounder - River Don	Common Bream - River Don	Pike - River Don
ng/kg Whole weight									
237-TriBDD	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
2378-TetraBDD	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
12378-PentaBDD	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
123478/123678-HexaBDD	<0.01	<0.01	<0.01	<0.02	<0.02	<0.02	<0.01	<0.01	<0.01
123789-HexaBDD	<0.01	<0.01	<0.01	<0.02	<0.01	<0.02	<0.01	<0.01	<0.01
238-TriBDF	<0.01	0.07	0.02	<0.01	0.01	0.01	0.03	0.01	<0.01
2378-TetraBDF	0.05	0.12	0.03	<0.01	0.03	0.07	<0.01	0.01	0.07
12378-PentaBDF	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
23478-PentaBDF	<0.01	<0.01	<0.01	<0.01	<0.01	0.01	<0.01	<0.01	<0.01
123478-HexaBDF	<0.01	<0.01	<0.01	<0.02	<0.02	<0.03	<0.01	<0.01	<0.01
1234678-HeptabromoBDF	0.08	0.07	0.28	<0.06	<0.07	<0.11	0.04	<0.02	<0.02
TEQ lower, ng/kg whole	0.006	0.013	0.006	<0.001	0.003	0.012	<0.001	0.001	0.007
TEQ upper, ng/kg whole	0.034	0.041	0.034	0.033	0.034	0.041	0.030	0.030	0.036

Table 9: Brominated ‘dioxins’ PBDD/Fs in river fish (Phase 1) contd.

Sample Number	16599	16600	16612	16613	16614	16631	16678	16679
FERA LIMS No.	S08-027484	S08-027485	S08-027836	S08-027837	S08-027838	S08-028919	S08-029884	S08-029885
Sample Details:	Carp - River Don	Barbel - River Don	Bream - Dog Kennel Pond	Perch - Dog Kennel Pond	Roach - Dog Kennel Pond	Perch, 23/24-9-08 , River Thames, Penton Hook to Chertsey,	Bream x 2 (removed from above sample 16631- River Thames, Penton Hook to Chertsey)	Roach, (removed from above sample 16631- River Thames, Penton Hook to Chertsey)
ng/kg Whole weight								
237-TriBDD	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
2378-TetraBDD	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
12378-PentaBDD	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.02
123478/123678-HexaBDD	<0.01	<0.01	<0.02	<0.02	<0.02	<0.02	<0.01	<0.04
123789-HexaBDD	<0.01	<0.01	<0.02	<0.01	<0.01	<0.01	<0.01	<0.02
238-TriBDF	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
2378-TetraBDF	<0.01	0.01	<0.01	0.01	<0.01	0.03	<0.01	<0.01
12378-PentaBDF	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
23478-PentaBDF	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.02
123478-HexaBDF	<0.01	<0.01	<0.02	<0.01	<0.01	<0.02	<0.01	<0.02
1234678-HeptabromoBDF	<0.06	<0.02	<0.05	<0.04	<0.05	<0.04	<0.03	<0.1
TEQ lower, ng/kg whole	<0.001	0.001	<0.001	0.001	<0.001	0.003	<0.001	<0.001
TEQ upper, ng/kg whole	0.030	0.030	0.033	0.031	0.031	0.034	0.030	0.051

Table 10: Polychlorinated naphthalenes (PCNs) in river fish (Phase 1).

Sample No.	16211	16212	16213	16356	16594	16595	16596	16597	16598
Sample Details	Bream - Millpond, Fished 21/02/08	Perch - Millpond, Fished 21/02/08	Roach - Millpond, Fished 21/02/08	Perch, Thornborough pond, NGR N2 009 642, 25/7/08	Chub - River Don	Perch - River Don	Flounder - River Don	Common Bream - River Don	Pike - River Don
Fat %	3.93	3.38	4.38	1.87	4.12	0.75	1.22	4.05	0.44
ng/kg whole weight									
PCN 52/60	167.74	163.3	90.81	2.21	51.68	20.94i	38.82	164.16	70.29
PCN 53	20.33	32.49	9.57	0.52	3.86	11.58i	6.88	10.21	16.74
PCN 66/67	8.58	7.9	4.37	0.25	5.34	2.05	5.04	16.2	10.93
PCN 68	16.52	11.78	7.47	0.12	4.34	2.79	4.74	11.13	9.93
PCN 69	22.82	13.67	11.3	0.15	7.53	3.79	8.43	12.16	14.0
PCN 71/72	52.78	29.42	25.88	0.22	17.06	7.37	11.71	36.98	26.41
PCN 73	1.61	0.62	1.25	<0.02	0.7	0.2	0.59	0.35	1.04
PCN 74	1.63	0.55	1.04	0.01	0.32	0.16	0.3	0.43	0.63
PCN 75	0.04	0.06	0.13	<0.04	<0.04	<0.04	0.04	<0.04	<0.03
Sum PCNs (upper bnd)	292.05	259.8	151.83	3.53	90.87	48.9	76.56	251.65	150.01

Table 10: Polychlorinated naphthalenes (PCNs) in river fish (Phase 1) contd.

Sample No.	16599	16600	16612	16613	16614	16631	16678	16679
Sample Details	Carp - River Don	Barbel - River Don	Bream - Dog Kennel Pond	Perch - Dog Kennel Pond	Roach - Dog Kennel Pond	Perch, , River Thames, Penton Hook to Chertsey,	Bream River Thames, Penton Hook to Chertsey	Roach, River Thames, Penton Hook to Chertsey
Fat %	9.11	2.98	0.89	0.57	1.31	0.84	0.68	2.66
ng/kg whole weight								
PCN 52/60	84.07i	99.81i	7.11	3.56	7.98i	12.79	7.16i	23.98
PCN 53	9.61i	8.11i	2.25	1.2	1.85i	4.57	1.62i	5.95
PCN 66/67	21.26	11.52	1.05	0.47	0.9	0.81	0.62	1.53
PCN 68	7.95	10.63	0.71	0.3	0.6	1.1	0.85	1.9
PCN 69	25.28	23.61	0.76	0.28	0.68	1.96	1.36	3.25
PCN 71/72	53.48	48.48	1.39	0.58	1.16	3.79	2.77	5.72
PCN 73	1.25	0.80	0.06	0.02	0.09	0.03	0.05	0.21
PCN 74	1.49	0.59	0.03	0.01	0.03	0.03	0.03	0.13
PCN 75	0.03	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.05
Sum PCNs (upper bnd)	204.41	203.57	13.37	6.43	13.31	25.1	14.49	42.72

Table 11: Organochlorine pesticides in river fish (Phase 1).

OPHA Sample Number **FERA LIMS No.** **Sample Details:** **(mg/kg)**	16211 S08-010747 Bream - Millpond, Fished 21/02/08	16212 S08-010748 Perch - Millpond, Fished 21/02/08	16213 S08-010749 Roach - Millpond, Fished 21/02/08	16356 S08-019661 Perch, Thornborough pond, NGR N2 009 642, 25/7/08	16594 S08-027479 Chub - River Don	16595 S08-027480 Perch - River Don	16596 S08-027481 Flounder - River Don	16597 S08-027482 Common Bream - River Don	16598 S08-027483 Pike - River Don
DDD - pp	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005
DDE-pp	<0.005	<0.005	<0.005	<0.005	**0.004**	<0.005	<0.005	**0.01**	**0.006**
DDT-op	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005
DDT-pp	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005
HCH-alpha	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005
HCH-beta	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005
HCH-gamma	**0.001**	**0.003**	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005
aldrin	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005
chlordane (cis)	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005
chlordane (trans)	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005
dieldrin	<0.005	<0.005	<0.005	<0.005	**0.003**	**0.002**	<0.005	**0.01**	**0.003**
endosulfan (I)	<0.005	**0.002**	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005
endosulfan (II)	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005
endosulfan-sulphate	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005
endrin	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005
heptachlor	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005
heptachlor epoxide (trans)	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005
hexachlorobenzene	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005
oxychlordane	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005

Table 11: Organochlorine pesticides in river fish (Phase 1) contd.

OPHA Sample Number	16599	16600	16612	16613	16614	16631
FERA LIMS No.	S08-027484	S08-027485	S08-027836	S08-027837	S08-027838	S08-028919
Sample Details: (mg/kg)	Carp - River Don	Barbel - River Don	Bream - Dog Kennel Pond	Perch - Dog Kennel Pond	Roach - Dog Kennel Pond	Perch, 23/24-9-08 , River Thames, Penton Hook to Chertsey,
DDD - pp	**0.04**	<0.005	<0.005	<0.005	<0.005	<0.005
DDE-pp	**0.04**	**0.01**	<0.005	<0.005	**0.002**	**0.001**
DDT-op	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005
DDT-pp	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005
HCH-alpha	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005
HCH-beta	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005
HCH-gamma	**0.002**	<0.005	<0.005	<0.005	<0.005	<0.005
aldrin	<0.005	**0.003**	<0.005	<0.005	<0.005	<0.005
chlordane (cis)	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005
chlordane (trans)	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005
dieldrin	**0.02**	**0.009**	<0.005	<0.005	**0.001**	**0.002**
endosulfan (I)	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005
endosulfan (II)	**0.01**	<0.005	<0.005	<0.005	<0.005	<0.005
endosulfan-sulphate	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005
endrin	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005
heptachlor	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005
heptachlor epoxide (trans)	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005
hexachlorobenzene	**0.006**	**0.002**	<0.005	<0.005	<0.005	<0.005
oxychlordane	<0.005	**0.002**	<0.005	<0.005	<0.005	<0.005

Table 12: Organotin compounds in river fish (Phase 1).

OPHA Sample Number	16211	16356	16594	16596	16597	16598
FERA LIMS No.	S08-010747	S08-019661	S08-027479	S08-027481	S08-027482	S08-027483
Sample Details: (mg/kg)	Bream - Millpond, Fished 21/02/08	Perch, Thornborough pond, NGR N2 009 642, 25/7/08	Chub - River Don	Flounder - River Don	Common Bream - River Don	Pike - River Don
DBT	0.057	<0.004	<0.008	<0.004	<0.005	<0.004
TBT	0.346	<0.006	<0.012	<0.006	<0.007	<0.006

Table 12: Organotin compounds in river fish (Phase 1) contd.

OPHA Sample Number	16599	16600	16612	16613	16614	16631
FERA LIMS No.	S08-027484	S08-027485	S08-027836	S08-027837	S08-027838	S08-028919
Sample Details: (mg/kg)	Carp - River Don	Barbel - River Don	Bream - Dog Kennel Pond	Perch - Dog Kennel Pond	Roach - Dog Kennel Pond	Perch, 23/24-9-08 , River Thames, Penton Hook to Chertsey,
DBT	<0.005	<0.005	<0.010	<0.010	<0.012	<0.007
TBT	<0.008	<0.007	<0.016	<0.016	<0.021	<0.012

Table 13 (a): Organofluorine compounds in river fish – list of analytes and abreviations.

No	Class	Abbrev.	Code	Name
1	Amide	C8 Amide	PFOSA	Perfluorooctanesulfonylamide
2	Sulfonates	C4 Sulfonate	PFBSH	Perfluorobutane sulfonate
3		C6 Sulfonate	PFHxS	Perfluorohexane sulfonate
4		C8 Sulfonate	PFOS	Perfluorooctane sulfonate
5	Acids	C6 Acid	PFHxA	Perfluorohexanoic acid
5		C7 Acid	PFHpA	Perfluoroheptanoic acid
6		C8 Acid	PFOA	Perfluorooctanoic acid
7		C9 Acid	PFNA	Perfluorononanoic acid
8		C10 Acid	PFDeA	Perfluorodecanoic acid
9		C11 Acid	PFUnA	Perfluoroundecanoic acid
10		C12 Acid	PFDoA	Perfluorododecanoic acid

Table 13 (b): Organofluorine compounds in river fish (Phase 1).

OPHA Sample Number **FERA LIMS No.** **Sample Details:** **(mg/kg)**	16211 S08-010747 Bream - Millpond, Fished 21/02/08	16356 S08-019661 Perch, Thornborough pond, NGR N2 009 642, 25/7/08	16594 S08-027479 Chub - River Don	16596 S08-027481 Flounder - River Don	16597 S08-027482 Common Bream - River Don	16598 S08-027483 Pike - River Don
PFHxA	<5	<1	<1	<1	<5	<1
PFHpA	<5	<1	<1	<1	<1	<1
PFOA	<1	<1	<1	<1	<1	<1
PFNA	<1	<1	<1	<1	<1	<1
PFDeA	**3**	<1	<1	**2**	**1**	**1**
PFUnA	<1	<1	<1	**2**	**1**	<1
PFDoA	<1	<1	<1	**5**	**2**	<1
PFBSH	<1	<1	<1	<1	<1	<1
PFHxSH	<1	<1	<1	<1	<1	<1
PFOS	**64**	**2**	**33**	**107**	**53**	**56**
PFOSA	**2**	<1	<1	2	<1	<5

Table 13 (b): Organofluorine compounds in river fish (Phase 1) contd.

OPHA Sample Number **FERA LIMS No.** **Sample Details:** **(mg/kg)**	16599 S08-027484 Carp - River Don	16600 S08-027485 Barbel - River Don	16612 S08-027836 Bream - Dog Kennel Pond	16613 S08-027837 Perch - Dog Kennel Pond	16614 S08-027838 Roach - Dog Kennel Pond	16631 S08-028919 Perch, 23/24-9-08 , River Thames, Penton Hook to Chertsey,
PFHxA	<1	<1	<1	<1	<1	<5
PFHpA	<1	<1	<1	<1	<1	<1
PFOA	<1	<1	<1	<1	<1	<1
PFNA	<1	<1	<1	<1	<1	<1
PFDeA	**1**	**3**	**1**	**1**	**1**	**2**
PFUnA	<1	**2**	<1	<1	<1	<1
PFDoA	<5	**5**	<1	<1	<1	**1**
PFBSH	<1	<1	<1	<1	<1	<1
PFHxSH	<1	<1	<1	<1	<1	<1
PFOS	**50**	**76**	**34**	**49**	**51**	**111**
PFOSA	<5	**1**	<1	<1	<1	<1

Phase 2 results tables

Table 14: Trace elements in river fish (Phase 2)

[Bracketed values are between the LoD and LoQ]

Fera LIMS code	S09-013107	S09-013108	S09-017169	S09-017170	S09-020924	S09-020925	S09-020926	S09-020927	S09-020929	S09-020930
OPHA sample code	17392	17393	17487	17488	17627	17628	17629	17630	17632	17633
Sample description	Tench	Carp	Bronze Bream	Perch	Perch	Chub - 1	Chub - 2	Chub - 3	Pike - 1	Pike - 2
	Chesterfield Canal, 17/08/09 ref 17392		R.Mersey (Warrington). Sampled- 20/9/09 ref 17487	x 7, R.Mersey (Warrington). Sampled- 20/9/09 ref 17488	ref 17627					
Element concentration (fresh weight) mg/kg										
Al	<1	<1	<1	<1	(2)	<1	<1	4	<1	<1
Cr	<0.03	3.33	<0.03	<0.03	<0.03	<0.03	<0.03	<0.03	<0.03	<0.03
Fe	4.2	26.4	5.906	2.577	3.243	4.9	5.9	6.6	3.6	2.7
Co	(0.005)	(0.007)	(0.009)	(0.005)	(0.006)	(0.005)	(0.008)	(0.006)	(0.005)	(0.005)
Ni	<0.03	0.11	(0.04)	<0.03	<0.03	<0.03	<0.03	<0.03	<0.03	<0.03
Cu	0.3	0.3	0.285	0.203	0.239	0.5	0.4	0.4	0.3	0.2
Zn	4.24	9.77	3.42	5.14	4.72	16.35	6.75	3.82	13.81	9.21
As	0.07	0.04	0.106	0.276	(0.03)	0.08	0.12	(0.02)	0.55	0.09
Se	0.32	0.23	0.49	0.55	0.76	0.64	0.66	0.82	0.53	0.42
Cd	<0.005	<0.005	<0.005	<0.005	<0.005	(0.014)	0.019	(0.005)	<0.005	<0.005
Sn	<0.01	<0.01	<0.01	(0.01)	<0.01	(0.01)	<0.01	(0.03)	(0.02)	<0.01
Hg	0.109	0.080	0.056	0.114	0.069	0.163	0.228	0.226	0.240	0.146
Tl	<0.005	<0.005	<0.005	<0.005	<0.005	(0.007)	<0.005	<0.005	<0.005	<0.005
Pb	(0.007)	(0.011)	(0.007)	(0.012)	(0.010)	(0.013)	<0.005	0.020	(0.007)	<0.005

Table 14: Trace elements in river fish (Phase 2) contd.

[Bracketed values are between the LoD and LoQ]

Fera LIMS code	S09-020931	S09-020932	S09-020933	S09-020934	S09-020935	S09-020936	S09-020937	S09-022054	S09-022055	S09-022056
OPHA sample code	17634	17635	17636	17637	17638	17639	17640	17930	17931	17932
Sample description	Pike - 3	Pike - 4	Barbel - 1	Barbel - 2	Barbel - 3	Eel - 1	Eel - 2	Flounder	Brown Trout	Rainbow Trout
							ref 17640	1 Fish, River Gryff		
Element concentration (fresh weight) mg/kg										
Al	<1	<1	(1)	(2)	<1	<1	<1	<1	(2)	<1
Cr	<0.03	<0.03	<0.03	<0.03	<0.03	<0.03	<0.03	<0.03	(0.06)	(0.07)
Fe	2.0	3.0	7.2	9.1	4.9	4.6	6.135	3.3	6.1	4.4
Co	<0.003	(0.008)	(0.008)	(0.007)	(0.003)	0.012	0.013	(0.008)	0.016	0.012
Ni	<0.03	<0.03	<0.03	<0.03	<0.03	<0.03	(0.06)	<0.03	<0.03	<0.03
Cu	0.2	0.3	0.5	0.4	0.4	0.6	0.330	0.4	0.5	0.4
Zn	4.09	7.09	3.88	3.78	3.67	20.14	18.69	7.73	12.20	8.45
As	0.17	0.19	(0.02)	(0.03)	(0.03)	(0.01)	<0.01	0.07	0.33	0.17
Se	0.51	0.55	0.77	0.91	0.89	0.94	1.18	0.32	0.52	0.33
Cd	<0.005	<0.005	(0.007)	(0.006)	<0.005	0.053	0.020	<0.005	<0.005	<0.005
Sn	(0.03)	<0.01	(0.03)	(0.01)	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Hg	0.171	0.257	0.194	0.155	0.122	0.155	0.186	0.043	0.068	0.060
Tl	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005
Pb	<0.005	<0.005	0.063	0.023	(0.015)	0.021	(0.008)	<0.005	(0.005)	(0.005)

Table 15: PCDD/Fs in river fish (Phase 2)

OPHA Sample No.	17380	17381	17391	17392	17393
FERA LIMS No.	S09-012713	S09-012714	S09-013102	S09-013107	S09-013108
Sample Details:	Bronze Bream Greengield Heritage Site Holywell	Silver Bream Dog Kennel Pond Rotherham, 10/08/09	Perch, Dog Kennel Pond, Rotherham, 10/08/09	Tench, Chesterfield Canal, 17/08/09	Crucian Carp, Chesterfield Canal, 17/08/09
ng/kg whole weight					
2,3,7,8-TCDD	0.12	0.03	<0.01	0.04	0.02
1,2,3,7,8-PeCDD	0.18	0.05	<0.01	0.05	0.02
1,2,3,4,7,8-HxCDD	0.06	0.02	<0.01	0.01i	<0.01
1,2,3,6,7,8-HxCDD	0.12	0.03	<0.01	0.02i	0.01
1,2,3,7,8,9-HxCDD	0.02	<0.01	<0.01	0.02	<0.01
1,2,3,4,6,7,8-HpCDD	0.14	0.02	<0.01	0.11	0.06
OCDD	0.06	<0.04	0.05	0.19	0.20
2,3,7,8-TCDF	3.46	0.49	0.04	0.08	0.17
1,2,3,7,8-PeCDF	0.30	0.06	<0.01	0.02	0.02
2,3,4,7,8-PeCDF	0.67	0.13	0.01	0.10	0.07
1,2,3,4,7,8-HxCDF	0.09	0.02	<0.01	<0.01	0.01
1,2,3,6,7,8-HxCDF	0.07	0.02	<0.01	0.01	<0.01
1,2,3,7,8,9-HxCDF	<0.01	<0.01	<0.01	<0.01	<0.01
2,3,4,6,7,8-HxCDF	0.05	0.01	<0.01	0.02	<0.01
1,2,3,4,6,7,8-HpCDF	0.06	0.02i	<0.01	0.02i	0.01
1,2,3,4,7,8,9-HpCDF	<0.01	<0.01	<0.01	<0.01	<0.01
OCDF	<0.01	<0.01	<0.01	<0.02	0.01
WHO TEQ (ng/kg whole) lower	1.039	0.207	0.009	0.158	0.096
WHO TEQ (ng/kg whole) upper	1.040	0.210	0.037	0.160	0.101

Table 15: PCDD/Fs in river fish (Phase 2) contd.

OPHA Sample No. **FERA LIMS No.** **Sample Details:**	17404 S09-015105 Perch, Grantham Canal, 28/08/09	17405 S09-015106 Silver Bream, Grantham Canal, 28/08/09	17487 S09-017169 Bronze Bream, R.Mersey (Warrington). Sampled-20/9/09	17488 S09-017170 Perch, R.Mersey (Warrington). Sampled-20/9/09	17489 S09-017171 Rudd, R.Mersey (Warrington). Sampled-20/9/09
ng/kg whole weight					
2,3,7,8-TCDD	<0.01	0.01	0.47	0.11	0.16
1,2,3,7,8-PeCDD	<0.01	0.01	0.57	0.10	0.17
1,2,3,4,7,8-HxCDD	<0.01	<0.01	0.26i	0.02	0.06
1,2,3,6,7,8-HxCDD	<0.01	0.02	0.56	0.06	0.12
1,2,3,7,8,9-HxCDD	<0.01	<0.01	0.12	0.02	0.03
1,2,3,4,6,7,8-HpCDD	0.02	0.02	0.84	0.10	0.17
OCDD	<0.07	<0.06	0.55	0.27	0.20
2,3,7,8-TCDF	0.02	0.12	14.95	1.88	4.11
1,2,3,7,8-PeCDF	0.01	0.04	3.17	0.47	0.75
2,3,4,7,8-PeCDF	0.02	0.04	5.61	1.05	1.58
1,2,3,4,7,8-HxCDF	<0.01	0.01	4.81	0.51	0.74
1,2,3,6,7,8-HxCDF	<0.01	<0.01	0.76	0.10	0.14
1,2,3,7,8,9-HxCDF	<0.01	<0.01	0.08	<0.01	<0.01
2,3,4,6,7,8-HxCDF	<0.01	<0.01	0.33	0.05	0.09
1,2,3,4,6,7,8-HpCDF	<0.01	<0.01	0.47	0.05	0.09
1,2,3,4,7,8,9-HpCDF	<0.01	<0.01	0.13	0.01	0.02i
OCDF	<0.01	<0.01	0.05	0.02	0.03
WHO TEQ (ng/kg whole) lower	0.013	0.057	6.205	1.024	1.689
WHO TEQ (ng/kg whole) upper	0.040	0.062	6.205	1.025	1.690

Table 15: PCDD/Fs in river fish (Phase 2) contd.

OPHA Sample No.	17490	17500	17627	17628	17629
FERA LIMS No.	S09-017172	S09-017192	S09-020924	S09-020925	S09-020926
Sample Details:	Dace, R.Mersey (Warrington). Sampled- 20/9/09	Eels, Lough Neagh Fishermans Cooperative, Sent: 21.09.09	Perch, River Trent Staffordshire, 7/10/09	Chub - 1, River Trent Staffordshire, 7/10/09	Chub - 2, River Trent Staffordshire, 7/10/09
ng/kg whole weight					
2,3,7,8-TCDD	0.02	0.09	0.05	0.09	0.02
1,2,3,7,8-PeCDD	0.02	0.31	0.07	0.07	0.03
1,2,3,4,7,8-HxCDD	<0.01	0.21	<0.01	<0.01	<0.01
1,2,3,6,7,8-HxCDD	0.01	0.87	0.03	0.01	<0.01
1,2,3,7,8,9-HxCDD	<0.01	0.07	<0.01	<0.01	<0.01
1,2,3,4,6,7,8-HpCDD	0.02	0.77	0.02	0.01	<0.01
OCDD	0.13	0.83	0.07	0.03	0.02
2,3,7,8-TCDF	0.47	0.05	0.37	0.63	0.14
1,2,3,7,8-PeCDF	0.11	0.06	0.12	0.07i	0.05i
2,3,4,7,8-PeCDF	0.19	0.35	0.17	0.14	0.04
1,2,3,4,7,8-HxCDF	0.10	0.12	0.02	0.03	0.05
1,2,3,6,7,8-HxCDF	0.02	0.09	0.01	<0.01	<0.01
1,2,3,7,8,9-HxCDF	<0.01	<0.01	<0.01	<0.01	<0.01
2,3,4,6,7,8-HxCDF	0.01	0.07	0.02	<0.01	<0.01
1,2,3,4,6,7,8-HpCDF	0.01	0.07	<0.01	<0.01	<0.01
1,2,3,4,7,8,9-HpCDF	<0.01	<0.01	<0.01	<0.01	<0.01
OCDF	0.01	0.05	<0.01	<0.01	<0.01
WHO TEQ (ng/kg whole) lower	0.202	0.734	0.256	0.301	0.092
WHO TEQ (ng/kg whole) upper	0.205	0.736	0.259	0.306	0.098

Table 15: PCDD/Fs in river fish (Phase 2) contd.

OPHA Sample No.	17630	17631	17632	17633	17634
FERA LIMS No.	S09-020927	S09-020928	S09-020929	S09-020930	S09-020931
Sample Details:	Chub - 3, River Trent Staffordshire, 7/10/09	Chub - 4, River Trent Staffordshire, 7/10/09	Pike - 1, River Trent Staffordshire, 7/10/09	Pike - 2, River Trent Staffordshire, 7/10/09	Pike - 3, River Trent Staffordshire, 7/10/09
ng/kg whole weight					
2,3,7,8-TCDD	0.11	0.01	0.07	0.11	0.02
1,2,3,7,8-PeCDD	0.11	0.03i	0.08	0.13i	0.03
1,2,3,4,7,8-HxCDD	0.01	<0.01	<0.01	0.01	<0.01
1,2,3,6,7,8-HxCDD	0.03	<0.01	0.03	0.06	0.01
1,2,3,7,8,9-HxCDD	<0.01	<0.01	<0.01	0.01i	<0.01
1,2,3,4,6,7,8-HpCDD	0.02	0.03	0.02	0.03	<0.01
OCDD	0.03	0.17	0.07	0.13	<0.06
2,3,7,8-TCDF	0.28	0.10	0.48	1.11	0.12
1,2,3,7,8-PeCDF	0.11i	0.02i	0.25	0.39	0.12
2,3,4,7,8-PeCDF	0.17	0.02i	0.12	0.28	0.05
1,2,3,4,7,8-HxCDF	0.04i	0.01	0.03	0.05	0.01
1,2,3,6,7,8-HxCDF	0.01	<0.01	0.02	0.02	<0.01
1,2,3,7,8,9-HxCDF	<0.01	<0.01	<0.01	<0.01	<0.01
2,3,4,6,7,8-HxCDF	<0.01	0.01	0.01	0.02	<0.01
1,2,3,4,6,7,8-HpCDF	<0.01	0.02	<0.01	0.02	<0.01
1,2,3,4,7,8,9-HpCDF	<0.01	<0.01	<0.01	<0.01	<0.01
OCDF	<0.01	0.02	<0.01	<0.01	<0.01
WHO TEQ (ng/kg whole) lower	0.348	0.064	0.280	0.528	0.095
WHO TEQ (ng/kg whole) upper	0.351	0.069	0.283	0.529	0.100

Table 15: PCDD/Fs in river fish (Phase 2) contd.

OPHA Sample No.	17635	17636	17637	17638	17639
FERA LIMS No.	S09-020932	S09-020933	S09-020934	S09-020935	S09-020936
Sample Details:	Pike - 4, River Trent Staffordshire, 7/10/09	Barbel - 1, River Trent Staffordshire, 7/10/09	Barbel - 2, River Trent Staffordshire, 7/10/09	Barbel - 3, River Trent Staffordshire, 7/10/09	Eel - 1, River Trent Staffordshire, 7/10/09
ng/kg whole weight					
2,3,7,8-TCDD	0.02	0.24	0.17	0.15	0.13
1,2,3,7,8-PeCDD	0.03	0.34	0.22	0.24	0.56
1,2,3,4,7,8-HxCDD	<0.01	0.04	0.03	0.03	0.13
1,2,3,6,7,8-HxCDD	0.01	0.09	0.07	0.07	0.49
1,2,3,7,8,9-HxCDD	<0.01	0.03	0.02	0.03	0.10
1,2,3,4,6,7,8-HpCDD	<0.01	0.06	0.06	0.05	0.28
OCDD	<0.07	0.08	0.08	<0.08	0.45
2,3,7,8-TCDF	0.16	0.36	0.34	0.39	0.03
1,2,3,7,8-PeCDF	0.05	0.55i	0.34	0.24	0.23i
2,3,4,7,8-PeCDF	0.05	0.43	0.31	0.29	0.19
1,2,3,4,7,8-HxCDF	<0.01	0.06	0.04	0.03	0.12
1,2,3,6,7,8-HxCDF	<0.01	0.03	0.02	0.02	0.05
1,2,3,7,8,9-HxCDF	<0.01	<0.01	<0.01	<0.01	<0.01
2,3,4,6,7,8-HxCDF	<0.01	0.03	0.02	0.02	0.09
1,2,3,4,6,7,8-HpCDF	<0.01	0.02	0.01	0.01	0.12
1,2,3,4,7,8,9-HpCDF	<0.01	<0.01	<0.01	<0.01	<0.01
OCDF	<0.01	<0.01	<0.01	<0.01	<0.03
WHO TEQ (ng/kg whole) lower	0.095	0.887	0.617	0.607	0.902
WHO TEQ (ng/kg whole) upper	0.101	0.888	0.618	0.608	0.903

Table 15: PCDD/Fs in river fish (Phase 2) contd.

OPHA Sample No.	17640	17930	17931	17932
FERA LIMS No.	S09-020937	S09-022054	S09-022055	S09-022056
Sample Details:	Eel - 2, River Trent Staffordshire, 7/10/09	Flounder - 1 Fish, River Gryff, 21/10/09	Brown Trout - 17 Fish, River Gryff, 21/10/09	Rainbow Trout - 13 Fish, River Gryff, 21/10/09
ng/kg whole weight				
2,3,7,8-TCDD	0.11	0.02	0.04	0.04
1,2,3,7,8-PeCDD	0.54	<0.01	0.03	0.04
1,2,3,4,7,8-HxCDD	0.15	<0.01	<0.01	<0.01
1,2,3,6,7,8-HxCDD	0.49	<0.01	0.03	0.03
1,2,3,7,8,9-HxCDD	0.08	<0.01	<0.01	<0.01
1,2,3,4,6,7,8-HpCDD	0.26	0.02	0.05	0.04
OCDD	0.38	0.06	0.13	0.13
2,3,7,8-TCDF	0.02	0.10	0.18	0.18
1,2,3,7,8-PeCDF	0.03i	0.04	0.36	0.05
2,3,4,7,8-PeCDF	0.19	0.03	0.10	0.11
1,2,3,4,7,8-HxCDF	0.10	0.02i	0.01i	0.02
1,2,3,6,7,8-HxCDF	0.05	<0.01	0.02	0.01
1,2,3,7,8,9-HxCDF	<0.01	<0.01	<0.01	<0.01
2,3,4,6,7,8-HxCDF	0.09	<0.01	0.01	0.01
1,2,3,4,6,7,8-HpCDF	0.11	<0.01	0.01	<0.01
1,2,3,4,7,8,9-HpCDF	<0.01	<0.01	<0.01	<0.01
OCDF	0.02	<0.01	0.01	0.01
WHO TEQ (ng/kg whole) lower	0.848	0.049	0.164	0.163
WHO TEQ (ng/kg whole) upper	0.849	0.065	0.167	0.166

Table 16: ortho-PCBs in river fish (Phase 2)

i – indicative due to interference
iR – indicative due to reference material data out of range

OPHA Sample No.	17380	17381	17391	17392	17393
FERA LIMS No.	S09-012713	S09-012714	S09-013102	S09-013107	S09-013108
Sample Details:	Bronze Bream Greengield Heritage Site Holywell	Silver Bream Dog Kennel Pond Rotherham, 10/08/09	Perch, Dog Kennel Pond, Rotherham, 10/08/09	Tench, Chesterfield Canal, 17/08/09	Crucian Carp, Chesterfield Canal, 17/08/09
ug/kg whole weight					
PCB18	0.02	<0.01	<0.01	0.15	0.03
PCB28	0.30	0.06	0.01	0.38	0.24
PCB31	0.09	0.03	<0.01	0.17	0.14
PCB47	ND	ND	ND	0.19	0.07
PCB49	ND	ND	ND	0.37	0.26
PCB51	ND	ND	ND	<0.01	<0.01
PCB52	1.65	0.13	0.02	0.88	0.57
PCB99	2.73	0.20	0.04	0.54	0.32
PCB101	5.34	0.34	0.07	1.01	0.77
PCB105	1.31	0.08	0.02	0.32	0.16
PCB114	0.09	<0.01	<0.01	0.02	0.01
PCB118	5.14	0.30	0.06	0.93	0.62
PCB123	0.18	0.02	<0.01	0.03	0.03
PCB128	0.74	0.05	0.01	0.10	0.07
PCB138	7.68	0.67	0.13	0.95	0.80
PCB153	7.55	0.74	0.15	0.74	0.68
PCB156	0.63	0.04	<0.01	0.08	0.05
PCB157	0.14	<0.01	<0.01	0.02	0.01
PCB167	0.50	0.02	<0.01	0.04	0.02
PCB180	2.07	0.28	0.06	0.18	0.16
PCB189	0.04	<0.01	<0.01	<0.01	<0.01
WHO TEQ (ng/kg Whole) lower	**1.100**	**0.060**	**0.010**	**0.190**	**0.120**
WHO TEQ (ng/kg Whole) upper	**1.100**	**0.070**	**0.030**	**0.190**	**0.120**

Table 16: ortho-PCBs in river fish (Phase 2) contd.

OPHA Sample No.	17404	17405	17487	17488	17489
FERA LIMS No.	S09-015105	S09-015106	S09-017169	S09-017170	S09-017171
Sample Details:	Perch, Grantham Canal, 28/08/09	Silver Bream, Grantham Canal, 28/08/09	Bronze Bream, R.Mersey (Warrington). Sampled-20/9/09	Perch, R.Mersey (Warrington). Sampled-20/9/09	Rudd, R.Mersey (Warrington). Sampled-20/9/09
ug/kg whole weight					
PCB18	<0.05	<0.05	1.85	0.29	2.87
PCB28	<0.02	<0.02	12.31	3.34	5.90
PCB31	<0.03	<0.02	8.25	3.36	3.99
PCB47	ND	ND	ND	ND	ND
PCB49	ND	ND	ND	ND	ND
PCB51	ND	ND	ND	ND	ND
PCB52	<0.02	0.03	10.79	3.47	5.40
PCB99	0.02	0.05	4.46	1.62	1.98
PCB101	0.03	0.08	8.64	2.64	4.30
PCB105	0.01	0.02	1.73	0.53	0.94
PCB114	<0.01	<0.01	0.10	0.03	0.06
PCB118	0.04	0.09	6.64	1.81	3.18
PCB123	<0.01	<0.01	0.27	0.07i	0.13i
PCB128	<0.01	0.03	1.01	0.31	0.48
PCB138	0.08	0.20	9.25	2.43	4.23
PCB153	0.13	0.26	8.28	2.27	3.95
PCB156	<0.01	0.01	0.61	0.14	0.29
PCB157	<0.01	<0.01	0.18	0.03	0.09
PCB167	<0.01	<0.01	0.28	0.10	0.13
PCB180	0.06	0.12	3.86	0.85	1.74
PCB189	<0.01	<0.01	0.04	0.02i	0.02
WHO TEQ (ng/kg Whole) lower	**0.005**	**0.016**	**1.320**	**0.340**	**0.650**
WHO TEQ (ng/kg Whole) upper	**0.022**	**0.028**	**1.320**	**0.340**	**0.650**

Table 16: ortho-PCBs in river fish (Phase 2) contd.

OPHA Sample No.	17490	17500	17627	17628	17629
FERA LIMS No.	S09-017172	S09-017192	S09-020924	S09-020925	S09-020926
Sample Details:	Dace, R.Mersey (Warrington). Sampled-20/9/09	Eels, Lough Neagh Fishermans Cooperative, Sent: 21.09.09	Perch, River Trent Staffordshire, 7/10/09	Chub - 1, River Trent Staffordshire, 7/10/09	Chub - 2, River Trent Staffordshire, 7/10/09
ug/kg whole weight					
PCB18	0.20	0.06	0.03	0.04	0.02
PCB28	1.13	0.27	0.48	0.73	0.19
PCB31	0.79	0.16	0.24	0.17	0.08
PCB47	ND	ND	ND	ND	ND
PCB49	ND	ND	ND	ND	ND
PCB51	ND	ND	ND	ND	ND
PCB52	0.96	0.49	1.21	1.86	0.37
PCB99	0.27	1.30	1.07	1.79	0.40
PCB101	0.67	0.90	1.99	5.36	1.12
PCB105	0.21	0.59	0.43	1.18	0.28
PCB114	0.01	0.03	0.02	0.07	0.02
PCB118	0.64	1.97	1.34	3.43	0.81
PCB123	0.01	0.07	0.12	0.48	0.06
PCB128	0.13	0.52	0.49	1.24	0.31
PCB138	0.87	4.16	4.51	17.49	3.86
PCB153	0.92	4.17	4.58iR	17.45iR	3.64iR
PCB156	0.07	0.21	0.17	0.61	0.14
PCB157	0.02	0.06	0.05	0.23	0.05
PCB167	0.04	0.20	0.09	0.42	0.08
PCB180	0.45	1.38	3.10	15.67	3.05
PCB189	<0.01	0.03i	0.03	0.15	0.04
WHO TEQ (ng/kg Whole) lower	**0.136**	**0.420**	**0.313**	**0.983**	**0.225**
WHO TEQ (ng/kg Whole) upper	**0.137**	**0.420**	**0.313**	**0.983**	**0.225**

Table 16: ortho-PCBs in river fish (Phase 2) contd.

OPHA Sample No.	17630	17631	17632	17633	17634
FERA LIMS No.	S09-020927	S09-020928	S09-020929	S09-020930	S09-020931
Sample Details:	Chub - 3, River Trent Staffordshire, 7/10/09	Chub - 4, River Trent Staffordshire, 7/10/09	Pike - 1, River Trent Staffordshire, 7/10/09	Pike - 2, River Trent Staffordshire, 7/10/09	Pike - 3, River Trent Staffordshire, 7/10/09
ug/kg whole weight					
PCB18	0.07	<0.05	0.11	0.07	<0.05
PCB28	0.87	0.16	0.58	0.64	0.15
PCB31	0.25	0.09	0.42	0.32	0.07
PCB47	ND	ND	ND	ND	ND
PCB49	ND	ND	ND	ND	ND
PCB51	ND	ND	ND	ND	ND
PCB52	4.21	0.41	1.16	2.17	0.24
PCB99	2.51	0.24	0.61	2.28	0.20
PCB101	16.22	0.74	1.33	5.67	0.50
PCB105	3.84	0.16	0.33	1.10	0.09
PCB114	0.27	<0.01	0.02	0.07	<0.01
PCB118	11.92	0.54	0.76	4.11	0.30
PCB123	0.89	0.01	0.08	0.20	0.03
PCB128	3.91	0.14	0.27	0.88	0.09
PCB138	50.28	1.26	2.64	7.79	0.97
PCB153	50.71iR	1.47iR	2.44iR	8.34	1.06
PCB156	1.53	0.08	0.10	0.56	0.05
PCB157	0.47	0.02	0.04	0.13	0.01
PCB167	0.98	0.05	0.05	0.29	0.03
PCB180	37.62	0.87	1.69	4.47	0.81
PCB189	0.22	<0.01	0.01	0.05	<0.01
WHO TEQ (ng/kg Whole) lower	**2.832**	**0.122**	**0.199**	**0.929**	**0.072**
WHO TEQ (ng/kg Whole) upper	**2.832**	**0.128**	**0.199**	**0.929**	**0.078**

Table 16: ortho-PCBs in river fish (Phase 2) contd.

OPHA Sample No.	17635	17636	17637	17638	17639
FERA LIMS No.	S09-020932	S09-020933	S09-020934	S09-020935	S09-020936
Sample Details:	Pike - 4, River Trent Staffordshire, 7/10/09	Barbel - 1, River Trent Staffordshire, 7/10/09	Barbel - 2, River Trent Staffordshire, 7/10/09	Barbel - 3, River Trent Staffordshire, 7/10/09	Eel - 1, River Trent Staffordshire, 7/10/09
ug/kg whole weight					
PCB18	<0.05	0.35	0.34	0.12	<0.23
PCB28	0.10	2.20	2.42	1.55	1.51
PCB31	0.05	1.04	1.33	0.92	0.69
PCB47	ND	ND	ND	ND	ND
PCB49	ND	ND	ND	ND	ND
PCB51	ND	ND	ND	ND	ND
PCB52	0.25	4.54	7.78	2.08	16.97
PCB99	0.21	4.53	2.08	2.30	11.55
PCB101	0.49	15.60	11.03	5.34	15.73
PCB105	0.11	4.29	2.47	1.71	7.64
PCB114	<0.01	0.30	0.17	0.10	0.40
PCB118	0.32	12.37	6.94	4.22	18.00
PCB123	0.03	0.99	0.58	0.36	1.86
PCB128	0.11	3.24	2.15	1.47	6.63
PCB138	1.06	39.19	22.22	14.72	70.79
PCB153	1.06	36.67	20.19	12.39	57.89
PCB156	0.05	1.71	0.94	0.57	2.46
PCB157	0.01	0.53	0.31	0.15	0.77
PCB167	0.03	0.99	0.46	0.33	1.24
PCB180	0.73	27.80	15.82	9.57	41.13
PCB189	<0.01	0.21	0.15	0.08	0.41
WHO TEQ (ng/kg Whole) lower	**0.076**	**3.066**	**1.729**	**1.050**	**4.618**
WHO TEQ (ng/kg Whole) upper	**0.082**	**3.066**	**1.729**	**1.050**	**4.618**

Table 16: ortho-PCBs in river fish (Phase 2) contd.

OPHA Sample No.	17640	17930	17931	17932
FERA LIMS No.	S09-020937	S09-022054	S09-022055	S09-022056
Sample Details:	Eel - 2, River Trent Staffordshire, 7/10/09	Flounder - 1 Fish, River Gryff, 21/10/09	Brown Trout - 17 Fish, River Gryff, 21/10/09	Rainbow Trout - 13 Fish, River Gryff, 21/10/09
ug/kg whole weight				
PCB18	<0.19	0.01	0.26	0.14
PCB28	1.35	0.07	1.37	0.52
PCB31	0.60	0.03	0.90	0.30
PCB47	ND	0.05	ND	ND
PCB49	ND	0.15	ND	ND
PCB51	ND	<0.01	ND	ND
PCB52	14.78	0.52	1.95	1.05
PCB99	9.45	0.67	1.48	1.37
PCB101	13.50	1.51	2.67	2.72
PCB105	5.87	0.54	0.94	0.98
PCB114	0.34	0.03	0.06	0.06
PCB118	14.97	1.44	2.74	2.99
PCB123	1.10	0.04	0.09i	0.09i
PCB128	5.29	0.23	0.42	0.54
PCB138	47.86	1.67	3.50	3.81
PCB153	44.52	1.25	3.10	3.30
PCB156	2.15	0.17	0.30	0.35
PCB157	0.64	0.04	0.06	0.07
PCB167	1.01	0.08	0.13	0.14
PCB180	32.45	0.27	0.97	0.78
PCB189	0.34	<0.01	0.01	0.01
WHO TEQ (ng/kg Whole) lower	**3.803**	**0.323**	**0.589**	**0.648**
WHO TEQ (ng/kg Whole) upper	**3.803**	**0.324**	**0.589**	**0.648**

Table 17: non-ortho-PCBs in river fish (Phase 2)

OPHA Sample No.	17380	17381	17391	17392	17393	17404	17405	17487	17488	17489
FERA LIMS No.	S09-012713	S09-012714	S09-013102	S09-013107	S09-013108	S09-015105	S09-015106	S09-017169	S09-017170	S09-017171
Sample Details:	Bronze Bream Greengield Heritage Site Holywell	Silver Bream Dog Kennel Pond Rotherham, 10/08/09	Perch, Dog Kennel Pond, Rotherham, 10/08/09	Tench, Chesterfield Canal, 17/08/09	Crucian Carp, Chesterfield Canal, 17/08/09	Perch, Grantham Canal, 28/08/09	Silver Bream, Grantham Canal, 28/08/09	Bronze Bream, R.Mersey (Warrington) .Sampled-20/9/09	Perch, R.Mersey (Warrington) .Sampled-20/9/09	Rudd, R.Mersey (Warrington) .Sampled-20/9/09
ng/kg whole weight										
PCB77	76.79	8.28	1.46	6.40	11.72	0.97	2.06	709.7i	174.52i	283.58i
PCB81	3.90	0.74	0.16	1.59	0.88	0.12	0.21	27.81	7.35	12.77
PCB126	16.47	1.66	0.35	3.57	1.40	0.40	0.54	23.70	5.85	10.43
PCB169	1.82	0.33	<0.04	0.19	0.10	0.07	0.15	3.64	0.59	1.15
WHO TEQ (ng/kg whole) lower	1.673	0.170	0.035	0.360	0.142	0.041	0.056	2.480	0.609	1.084
WHO TEQ (ng/kg whole) upper	1.673	0.170	0.036	0.360	0.142	0.041	0.056	2.480	0.609	1.084

Table 17: non-ortho-PCBs in river fish (Phase 2) contd.

OPHA Sample No.	17490	17500	17627	17628	17629	17630	17631	17632	17633	17634
FERA LIMS No.	S09-017172	S09-017192	S09-020924	S09-020925	S09-020926	S09-020927	S09-020928	S09-020929	S09-020930	S09-020931
Sample Details:	Dace, R.Mersey (Warrington). Sampled-20/9/09	Eels, Lough Neagh Fishermans Cooperative, Sent: 21.09.09	Perch, River Trent Staffordshire, 7/10/09	Chub - 1, River Trent Staffordshire, 7/10/09	Chub - 2, River Trent Staffordshire, 7/10/09	Chub - 3, River Trent Staffordshire, 7/10/09	Chub - 4, River Trent Staffordshire, 7/10/09	Pike - 1, River Trent Staffordshire, 7/10/09	Pike - 2, River Trent Staffordshire, 7/10/09	Pike - 3, River Trent Staffordshire, 7/10/09
ng/kg whole weight										
PCB77	48.85	2.82	39.88	103.99	21.17	36.61	12.85	44.62	66.21	5.42
PCB81	2.29	0.26	2.45	9.82	2.12	5.91	0.91	5.29	8.55	0.7
PCB126	1.68	9.55	4.67	10.46	2.64	14.34	1.57	3.59	15.38	1.37
PCB169	0.19	3.23	0.35	0.69	0.20	1.04	0.12	0.22	1.03	0.13
WHO TEQ (ng/kg whole) lower	0.175	0.988	0.475	1.064	0.268	1.449	0.160	0.366	1.556	0.139
WHO TEQ (ng/kg whole) upper	0.175	0.988	0.475	1.064	0.268	1.449	0.160	0.366	1.556	0.139

Table 17: non-ortho-PCBs in river fish (Phase 2) contd.

OPHA Sample No.	17635	17636	17637	17638	17639	17640	17930	17931	17932
FERA LIMS No.	S09-020932	S09-020933	S09-020934	S09-020935	S09-020936	S09-020937	S09-022054	S09-022055	S09-022056
Sample Details:	Pike - 4, River Trent Staffordshire, 7/10/09	Barbel - 1, River Trent Staffordshire, 7/10/09	Barbel - 2, River Trent Staffordshire, 7/10/09	Barbel - 3, River Trent Staffordshire, 7/10/09	Eel - 1, River Trent Staffordshire, 7/10/09	Eel - 2, River Trent Staffordshire, 7/10/09	Flounder - 1 Fish, River Gryff, 21/10/09	Brown Trout - 17 Fish, River Gryff, 21/10/09	Rainbow Trout - 13 Fish, River Gryff, 21/10/09
ng/kg whole weight									
PCB77	8.89	115.27	98.42	92.11	4.91	3.13	9.48	104.33	38.75
PCB81	0.89	26.45	16.63	12.28	0.82	0.61	0.72	8.31	2.15
PCB126	1.43	25.84	14.87	11.81	16.63	15.48	1.21	3.8	2.49
PCB169	0.12	2.08	1.15	0.8	3.91	3.65	0.08	0.23	0.24
WHO TEQ (ng/kg whole) lower	0.145	2.619	1.510	1.199	1.703	1.585	0.123	0.394	0.255
WHO TEQ (ng/kg whole) upper	0.145	2.619	1.510	1.199	1.703	1.585	0.123	0.394	0.255

Table 18: Total TEQ (PCDD/Fs and PCBs) in river fish (Phase 2); whole and fat weight basis.

OPHA Sample No.	17380	17381	17391	17392	17393	17404	17405	17487	17488	17489
FERA LIMS No.	S09-012713	S09-012714	S09-013102	S09-013107	S09-013108	S09-015105	S09-015106	S09-017169	S09-017170	S09-017171
Sample Details:	Bronze Bream Greengield Heritage Site Holywell	Silver Bream Dog Kennel Pond Rotherham, 10/08/09	Perch, Dog Kennel Pond, Rotherham, 10/08/09	Tench, Chesterfield Canal, 17/08/09	Crucian Carp, Chesterfield Canal, 17/08/09	Perch, Grantham Canal, 28/08/09	Silver Bream, Grantham Canal, 28/08/09	Bronze Bream, R.Mersey (Warrington).Sampled-20/9/09	Perch, R.Mersey (Warrington).Sampled-20/9/09	Rudd, R.Mersey (Warrington).Sampled-20/9/09
% Fat Whole	9.01	1.65	0.54	1.30	0.80	1.08	1.84	5.68	1.24	3.20
WHO TEQ ng/kg whole										
Dioxin	1.040	0.210	0.037	0.160	0.101	0.040	0.062	6.205	1.025	1.690
non ortho-PCB	1.673	0.170	0.036	0.360	0.142	0.041	0.056	2.480	0.609	1.084
ortho-PCB	1.100	0.070	0.030	0.190	0.120	0.022	0.028	1.320	0.340	0.650
Sum of WHO TEQs (upper)	**3.813**	**0.450**	**0.103**	**0.710**	**0.363**	**0.103**	**0.146**	**10.005**	**1.974**	**3.424**
WHO TEQ ng/kg Fat										
Dioxin	11.572	12.362	5.479	12.053	12.268	2.835	3.494	109.235	82.673	52.566
non ortho-PCB	18.569	10.324	6.604	27.657	17.839	3.776	3.030	43.674	48.998	33.828
ortho-PCB	12.190	4.050	2.440	14.890	14.970	1.026	1.155	23.170	28.040	20.160
Sum of WHO TEQs (upper)	**42.331**	**26.736**	**14.523**	**54.600**	**45.077**	**7.637**	**7.679**	**176.079**	**159.711**	**106.554**

Table 18: Total TEQ (PCDD/Fs and PCBs) in river fish (Phase 2); whole and fat weight basis - contd.

OPHA Sample No.	17490	17500	17627	17628	17629	17630	17631	17632	17633	17634
FERA LIMS No.	S09-017172	S09-017192	S09-020924	S09-020925	S09-020926	S09-020927	S09-020928	S09-020929	S09-020930	S09-020931
Sample Details:	Dace, R.Mersey (Warrington).Sampled-20/9/09	Eels, Lough Neagh Fishermans Cooperative, Sent: 21.09.09	Perch, River Trent Staffordshire, 7/10/09	Chub - 1, River Trent Staffordshire, 7/10/09	Chub - 2, River Trent Staffordshire, 7/10/09	Chub - 3, River Trent Staffordshire, 7/10/09	Chub - 4, River Trent Staffordshire, 7/10/09	Pike - 1, River Trent Staffordshire, 7/10/09	Pike - 2, River Trent Staffordshire, 7/10/09	Pike - 3, River Trent Staffordshire, 7/10/09
% Fat Whole	1.80	27.42	2.21	2.35	1.75	2.61	0.34	1.18	1.70	0.43
WHO TEQ ng/kg whole										
Dioxin	0.205	0.736	0.259	0.306	0.098	0.351	0.069	0.28	0.53	0.10
non ortho-PCB	0.175	0.988	0.475	1.064	0.268	1.449	0.160	0.37	1.56	0.14
ortho-PCB	0.137	0.420	0.313	0.983	0.225	2.832	0.128	0.20	0.93	0.08
Sum of WHO TEQs (upper)	**0.517**	**2.144**	**1.047**	**2.353**	**0.591**	**4.632**	**0.357**	**0.85**	**3.01**	**0.32**
WHO TEQ ng/kg Fat										
Dioxin	11.286	2.678	11.731	12.913	5.298	13.481	22.692	23.90	31.24	21.61
non ortho-PCB	9.753	3.601	21.519	45.287	15.336	55.584	46.431	31.01	91.70	32.05
ortho-PCB	7.837	1.520	14.417	41.867	12.627	108.632	37.047	16.71	54.74	17.82
Sum of WHO TEQs (upper)	**28.876**	**7.799**	**47.667**	**100.067**	**33.261**	**177.697**	**106.170**	**71.62**	**177.68**	**71.49**

Table 18: Total TEQ (PCDD/Fs and PCBs) in river fish (Phase 2); whole and fat weight basis - contd.

OPHA Sample No.	17635	17636	17637	17638	17639	17640	17930	17931	17932
FERA LIMS No.	S09-020932	S09-020933	S09-020934	S09-020935	S09-020936	S09-020937	S09-022054	S09-022055	S09-022056
Sample Details:	Pike - 4, River Trent Staffordshire, 7/10/09	Barbel - 1, River Trent Staffordshire, 7/10/09	Barbel - 2, River Trent Staffordshire, 7/10/09	Barbel - 3, River Trent Staffordshire, 7/10/09	Eel - 1, River Trent Staffordshire, 7/10/09	Eel - 2, River Trent Staffordshire, 7/10/09	Flounder - 1 Fish, River Gryff, 21/10/09	Brown Trout - 17 Fish, River Gryff, 21/10/09	Rainbow Trout - 13 Fish, River Gryff, 21/10/09
% Fat Whole	1.43	4.80	4.59	3.54	29.91	24.02	0.80	1.76	2.20
WHO TEQ ng/kg whole									
Dioxin	0.10	0.89	0.62	0.61	0.90	0.85	0.07	0.17	0.17
non ortho-PCB	0.15	2.62	1.51	1.20	1.70	1.59	0.12	0.39	0.26
ortho-PCB	0.08	3.07	1.73	1.05	4.62	3.80	0.32	0.59	0.65
Sum of WHO TEQs (upper)	**0.33**	**6.57**	**3.86**	**2.86**	**7.22**	**6.24**	**0.51**	**1.15**	**1.07**
WHO TEQ ng/kg Fat									
Dioxin	6.67	18.54	13.38	17.10	2.99	3.50	8.07	9.52	7.18
non ortho-PCB	10.20	54.56	32.87	33.92	5.69	6.60	15.42	22.42	11.63
ortho-PCB	5.73	63.76	37.63	29.75	15.46	15.85	40.16	33.80	29.61
Sum of WHO TEQs (upper)	**22.60**	**136.85**	**83.88**	**80.77**	**24.14**	**25.94**	**63.64**	**65.75**	**48.42**

Table 19: PBDEs and ortho-PBBs in river fish, including Deca BDE and deca BB (Phase 2).

OPHA Sample Number	17380	17381	17391	17392	17393	17404	17405	2.2	17488	17489
FERA LIMS No.	S09-012713	S09-012714	S09-013102	S09-013107	S09-013108	S09-015105	S09-015106	S09-017169	S09-017170	S09-017171
Sample Details:	Bronze Bream Greengield Heritage Site Holywell	Silver Bream Dog Kennel Pond Rotherham, 10/08/09	Perch, Dog Kennel Pond, Rotherham, 10/08/09	Tench, Chesterfield Canal, 17/08/09	Crucian Carp, Chesterfield Canal, 17/08/09	Perch, Grantham Canal, 28/08/09	Silver Bream, Grantham Canal, 28/08/09	Bronze Bream, R.Mersey (Warrington). Sampled-20/9/09	Perch, R.Mersey (Warrington). Sampled-20/9/09	Rudd, R.Mersey (Warrington). Sampled-20/9/09
ug/kg whole weight										
BDE-17	<0.01	<0.01	<0.01	0.01	<0.01	<0.01	<0.01	0.02	0.03	0.08
BDE-28	0.27	0.01	<0.01	0.07	0.03	<0.01	<0.01	0.60	0.14	0.44
BDE-47	5.54	0.25	0.04	0.97	0.45	0.07	0.12	17.95	5.17	12.38
BDE-49	0.24	0.03	<0.01	0.06	0.04	<0.01	<0.01	0.87	0.36	0.32
BDE-66	0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	0.07	0.15	0.03
BDE-71	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
BDE-77	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
BDE-85	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
BDE-99	0.04	<0.01	0.02	<0.01	<0.01	0.01	<0.01	0.19	2.97	0.11
BDE-100	1.17	0.04	<0.01	0.12	0.06	0.02	0.03	2.48	1.01	1.61
BDE-119	0.03	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	0.07	0.02	0.04
BDE-126	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
BDE153	0.39	0.02	<0.01	<0.01	<0.01	<0.01	0.01	1.35	0.40	0.73
BDE138	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
BDE 154	0.62	0.04	<0.01	0.04	0.02	0.02	0.04	1.60	0.36	1.22
BDE-183	0.02	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	0.09	0.03	0.04
BB-15	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
BB-49	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
BB-52	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
BB-80	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
BB-101	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
BB-153	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Deca BDE and decaBB										
BDE-209	<0.06	<0.05	<0.04	<0.14	<0.09	0.04	0.02	0.08	0.02	0.14
BB-209	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01

Table 19: PBDEs and ortho-PBBs in river fish, including Deca BDE and deca BB (Phase 2) contd.

OPHA Sample Number	17490	17500	17627	17628	17629	17630	17631	17632	17633	17634
FERA LIMS No.	S09-017172	S09-017192	S09-020924	S09-020925	S09-020926	S09-020927	S09-020928	S09-020929	S09-020930	S09-020931
Sample Details:	Dace, R.Mersey (Warrington). Sampled-20/9/09	Eels, Lough Neagh Fishermans Cooperative, Sent: 21.09.09	Perch, River Trent Staffordshire, 7/10/09	Chub - 1, River Trent Staffordshire, 7/10/09	Chub - 2, River Trent Staffordshire, 7/10/09	Chub - 3, River Trent Staffordshire, 7/10/09	Chub - 4, River Trent Staffordshire, 7/10/09	Pike - 1, River Trent Staffordshire, 7/10/09	Pike - 2, River Trent Staffordshire, 7/10/09	Pike - 3, River Trent Staffordshire, 7/10/09
ug/kg whole weight										
BDE-17	<0.01	<0.01	0.03	<0.01	<0.01	0.01	<0.01	0.02	0.07	<0.01
BDE-28	0.11	0.09	0.19	1.34	0.28	0.25	0.15	0.10	1.50	0.06
BDE-47	1.75	6.95	13.80i	11.32i	3.52i	27.32i	2.19	9.32i	<13.99	3.98
BDE-49	0.04	1.15	0.66	0.30	0.07	0.45	0.03	0.67	1.13	0.07
BDE-66	<0.01	0.15	0.23	<0.01	<0.01	<0.01	<0.01	0.07	0.19	0.02
BDE-71	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
BDE-77	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
BDE-85	0.09	<0.01	<0.01	0.03i	<0.01	0.04	<0.01	<0.01	<0.01	<0.01
BDE-99	0.02	0.23	3.30i	0.02	0.02	0.03	0.02	0.95	1.81	0.49
BDE-100	0.41	2.67	1.90	4.38i	0.99	1.78	0.61	1.29	8.74	0.80
BDE-119	0.02	0.09	0.03	0.06	0.02	0.05	<0.01	0.01	0.13	<0.01
BDE-126	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
BDE153	0.52	0.37	0.49	1.15	0.31	0.85	0.30	0.23	1.59	0.14
BDE138	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
BDE 154	0.87	0.84	0.48	1.41	0.31	2.46i	0.24	0.33	3.66	0.24
BDE-183	0.04	0.04	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	0.03	<0.01
BB-15	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
BB-49	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
BB-52	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
BB-80	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
BB-101	<0.01	<0.01	<0.01	<0.01	<0.01	0.01	<0.01	<0.01	<0.01	<0.01
BB-153	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Deca BDE and decaBB										
BDE-209	0.22	0.05	0.02	0.11	0.02	0.03	0.13	<0.01	0.02	0.03
BB-209	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01

Table 19: PBDEs and ortho-PBBs in river fish, including Deca BDE and deca BB (Phase 2) contd.

OPHA Sample Number	17635	17636	17637	17638	17639	17640	17930	17931	17932
FERA LIMS No.	S09-020932	S09-020933	S09-020934	S09-020935	S09-020936	S09-020937	S09-022054	S09-022055	S09-022056
Sample Details:	Pike - 4, River Trent Staffordshire, 7/10/09	Barbel - 1, River Trent Staffordshire, 7/10/09	Barbel - 2, River Trent Staffordshire, 7/10/09	Barbel - 3, River Trent Staffordshire, 7/10/09	Eel - 1, River Trent Staffordshire, 7/10/09	Eel - 2, River Trent Staffordshire, 7/10/09	Flounder - 1 Fish, River Gryff, 21/10/09	Brown Trout - 17 Fish, River Gryff, 21/10/09	Rainbow Trout - 13 Fish, River Gryff, 21/10/09
ug/kg whole weight									
BDE-17	<0.01	0.05	0.02	0.02	0.04	0.03	<0.01	<0.01	<0.01
BDE-28	0.03	0.49	0.28	0.24	0.28	0.36	<0.01	0.03	0.02
BDE-47	2.35	<17.94	<14.63	<12.82	<36.15	<31.31	0.55	1.53	1.17
BDE-49	0.14	1.35	0.87	0.47	1.29	1.12	0.04	0.08	0.06
BDE-66	0.02	0.03	0.02	0.02	0.24	0.18	0.02	0.05	0.04
BDE-71	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
BDE-77	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
BDE-85	<0.01	<0.01	<0.01	<0.01	0.07	<0.01	<0.01	<0.01	<0.01
BDE-99	0.43	0.03	0.03	0.02	0.81	0.61	0.11	1.15	0.81
BDE-100	0.51	12.46	8.91	3.40	26.66	25.90	0.09	0.42	0.38
BDE-119	<0.01	0.08	0.05	0.03	0.21	0.19	<0.01	<0.01	<0.01
BDE-126	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
BDE153	0.12	2.32	1.36	0.92	2.15	1.76	0.02	0.12	0.09
BDE138	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
BDE 154	0.15	4.56	2.47	1.27	1.68	3.42	0.03	0.12	0.09
BDE-183	<0.01	<0.01	<0.01	<0.01	0.02	0.02	<0.01	<0.01	<0.01
BB-15	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
BB-49	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
BB-52	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
BB-80	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
BB-101	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
BB-153	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Deca BDE and decaBB									
BDE-209	0.05	0.06	0.09	0.03	0.09	0.06	0.05	0.04	0.02
BB-209	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01

Table 20: Polychlorinated naphthalenes (PCNs) in river fish (Phase 2).

FERA sample No.	17380	17381	17391	17392	17393	17404	17405	17487	17488	17489
Sample Details	Bronze Bream Greengield Heritage Site Holywell	Silver Bream Dog Kennel Pond Rotherham, 10/08/09	Perch, Dog Kennel Pond, Rotherham, 10/08/09	Tench, Chesterfield Canal, 17/08/09	Crucian Carp, Chesterfield Canal, 17/08/09	Perch, Grantham Canal, 28/08/09	Silver Bream, Grantham Canal, 28/08/09	Bronze Bream, R.Mersey (Warrington). Sampled- 20/9/09	Perch, R.Mersey (Warrington). Sampled- 20/9/09	Rudd, R.Mersey (Warrington). Sampled- 20/9/09
Fat %	9.0	1.65	0.54	1.3	0.80	1.08	1.84	5.68	1.24	3.2
ng/kg whole weight										
PCN 52/60	49.99i	5.73i	3.47i	15.14i	23i	0.44	20.27i	596.32i	106.45	186.89i
PCN 53	9.88i	2.05i	0.53i	1.55i	2.95i	<0.25	6.94i	63.05i	47.17	27.48i
PCN 66/67	4.05	0.98	0.56	1.87i	3.75	<0.11	1.93	111.9	20.09	30.85
PCN 68	2.94	0.7	0.61	2.08i	4.36	<0.11	1.73	142.4	19.85	42.18
PCN 69	2.88	0.63	0.4	1.92i	2.8	<0.09	3.96	89.54	16.77	30.64
PCN 71/72	4.52	1.26	0.7	2.99i	4.98	0.07	6.73	161.54	20.88	47.01
PCN 73	0.15	0.07	<0.04	0.28i	0.28	<0.02	0.1	19.15	4.65	13.81
PCN 74	0.13	0.02	0.02	0.12i	0.19	<0.01	0.08	13.16	2.23	10.55
PCN 75	<0.02	<0.02	<0.02	<0.08	<0.08	<0.02	<0.02	0.67	0.13	0.37
Sum PCNs (upper bnd)	74.57	11.46	6.36	26.03	42.4	1.11	41.76	1197.73	238.22	389.79

Table 20: Polychlorinated naphthalenes (PCNs) in river fish (Phase 2) contd.

FERA sample No.	17490	17500	17627	17629	17630	17632	17633	17634	17635	17636
Sample Details	Dace, R.Mersey (Warrington). Sampled-20/9/09	Eels, Lough Neagh Fishermans Cooperative, Sent: 21.09.09	Perch, River Trent Staffordshire	Chub - 2, River Trent Staffordshire	Chub - 3, River Trent Staffordshire	Pike - 1, River Trent Staffordshire	Pike - 2, River Trent Staffordshire	Pike - 3, River Trent Staffordshire	Pike - 4, River Trent Staffordshire	Barbel - 1, River Trent Staffordshire
Fat %	1.8	27.42	2.21	1.75	2.61	1.18	1.7	0.43	1.43	4.8
ng/kg whole weight										
PCN 52/60	21.77	3.01	2.4i	10.77	27.35	46.26	85.71	7.17	13.96	81.97
PCN 53	2.4	0.74	0.3i	1.83	1.99	23.9	13.71	2.27	6.64	2.45
PCN 66/67	3.32	4.2	0.39	0.56	1.99	3.06	6.22	0.64	1.18	5.84
PCN 68	6.22	0.14	<0.12	1.01	1.88	5.57	7.6	0.83	1.83	6.2
PCN 69	5.46	0.89	0.14	2.01	5.63	8.96	8.42	1.22	2.8	21.63
PCN 71/72	10.79	0.2	0.2	4.3	12.75	16.41	13.88	1.95	4.75	38.37
PCN 73	2.15	0.3	<0.02	0.07	0.1	0.57	0.52	0.09	0.23	0.58
PCN 74	2.88	0.07	<0.01	0.04	0.1	0.25	0.21	0.03	0.14	0.59
PCN 75	0.11	<0.03	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02
Sum PCNs (upper bnd)	55.11	9.57	3.58	20.6	51.82	104.99	136.29	14.21	31.54	157.65

Table 20: Polychlorinated naphthalenes (PCNs) in river fish (Phase 2) contd.

FERA sample No.	17637	17638	17639	17640	17930	17931	17932
Sample Details	Barbel - 2, River Trent Staffordshire	Barbel - 3, River Trent Staffordshire	Eel - 1, River Trent Staffordshire	Eel - 2, River Trent Staffordshire	Flounder - 1 Fish, River Gryff	Brown Trout - 17 Fish, River Gryff	Rainbow Trout - 13 Fish, River Gryff
Fat %	4.59	3.54	29.91	24.02	0.8	1.76	2.2
ng/kg whole weight							
PCN 52/60	59.53	51.54	9.98i	8.71	3.07	29.04	16.44
PCN 53	4.55	3.81	1.92i	1.18	<0.67	2.0	1.16
PCN 66/67	4.15	3.05	6.1	6.74	<0.29	1.0	0.7
PCN 68	5.35	4.63	<0.22	<0.2	<0.28	1.83	0.78
PCN 69	15.2	13.03	8.72	8.6	0.49	4.81	2.97
PCN 71/72	32.89	28.49	2.36	2.12	0.65	5.91	2.03
PCN 73	0.4	0.25	2.22	3.05	<0.06	0.12	0.16
PCN 74	0.49	0.34	0.41	0.57	0.03	0.11	0.1
PCN 75	<0.02	<0.02	0.04	0.07	<0.05	<0.02	<0.02
Sum PCNs (upper bnd)	122.57	105.17	31.98	31.25	5.59	44.83	24.36

Table 21: Organofluorine compounds in river fish (Phase 2).

OPHA Sample Number **FERA LIMS No.** **Sample Details:** **(mg/kg)**	17380 S09-012713 Bronze Bream Greengield Heritage Site Holywell	17381 S09-012714 Silver Bream Dog Kennel Pond Rotherham, 10/08/09	17391 S09-013102 Perch, Dog Kennel Pond, Rotherham, 10/08/09	17393 S09-013108 Crucian Carp, Chesterfield Canal, 17/08/09	17404 S09-015105 Perch, Grantham Canal, 28/08/09	17405 S09-015106 Silver Bream, Grantham Canal, 28/08/09	17489 S09-017171 Rudd, R.Mersey (Warrington).Sampled-20/9/09
PFHxA	<5	<5	<5	<5	<5	**5**	<5
PFHpA	<5	<5	<5	<5	<5	<5	**5**
PFOA	<2	<2	<2	<2	<2	<2	<2
PFNA	<2	<2	<2	<2	<2	<2	<2
PFDeA	<5	<5	<5	<5	<5	<5	<5
PFUnA	<5	<5	<5	<5	<5	<5	<5
PFDoA	<5	<5	<5	<5	<5	<5	<5
PFBSH	<2	<2	<2	<2	<2	<2	<2
PFHxSH	<2	<2	<2	<2	<2	<2	<2
PFOS	**6**	**23**	**22**	**12**	**5**	**8**	**43**
PFOSA	<5	<5	<5	<5	<5	<5	<5

Table 21: Organofluorine compounds in river fish (Phase 2) contd.

OPHA Sample Number	17500	17628	17629	17630	17632	17633	17634
FERA LIMS No.	S09-017192	S09-020925	S09-020926	S09-020927	S09-020929	S09-020930	S09-020931
Sample Details: **(mg/kg)**	Eels, Lough Neagh Fishermans Cooperative, Sent: 21.09.09	Chub - 1, River Trent Staffordshire, 7/10/09	Chub - 2, River Trent Staffordshire, 7/10/09	Chub - 3, River Trent Staffordshire, 7/10/09	Pike - 1, River Trent Staffordshire, 7/10/09	Pike - 2, River Trent Staffordshire, 7/10/09	Pike - 3, River Trent Staffordshire, 7/10/09
PFHxA	<5	<5	<5	<5	<5	**23**	**5**
PFHpA	<5	<5	**8**	<5	<5	<5	<5
PFOA	<2	<2	<2	<2	<2	<2	<2
PFNA	<2	<2	<2	<2	<2	<2	<2
PFDeA	<5	<5	**7**	**5**	<5	<5	<5
PFUnA	<5	<5	<5	<5	<5	<5	<5
PFDoA	<5	**5**	**16**	**11**	<5	<5	<5
PFBSH	<2	<2	3	<2	<2	<2	<2
PFHxSH	<2	<2	<2	<2	<2	<2	<2
PFOS	**9**	**69**	**37**	**106**	**24**	**77**	**32**
PFOSA	<5	<5	<5	<5	<5	<5	<5

Table 21: Organofluorine compounds in river fish (Phase 2) contd.

OPHA Sample Number	17635	17636	17637	17638	17639	17931	17932
FERA LIMS No.	S09-020932	S09-020933	S09-020934	S09-020935	S09-020936	S09-022055	S09-022056
Sample Details:	Pike - 4, River Trent Staffordshire, 7/10/09	Barbel - 1, River Trent Staffordshire, 7/10/09	Barbel - 2, River Trent Staffordshire, 7/10/09	Barbel - 3, River Trent Staffordshire, 7/10/09	Eel - 1, River Trent Staffordshire, 7/10/09	Brown Trout - 17 Fish, River Gryff, 21/10/09	Rainbow Trout - 13 Fish, River Gryff, 21/10/09
(mg/kg)							
PFHxA	<5	<5	<5	<5	<5	<5	<5
PFHpA	<5	<5	<5	<5	<5	<5	<5
PFOA	<2	<2	<2	<2	<2	<2	<2
PFNA	<2	<2	<2	<2	<2	<2	<2
PFDeA	<5	**5**	**7**	<5	<5	<5	<5
PFUnA	<5	<5	<5	<5	<5	<5	<5
PFDoA	**5**	**6**	**7**	**5**	**5**	<5	<5
PFBSH	<2	<2	<2	<2	<2	<2	<2
PFHxSH	<2	<2	<2	<2	<2	<2	<2
PFOS	**28**	**146**	**153**	**72**	**85**	**8**	**6**
PFOSA	<5	<5	<5	<5	<5	<5	<5

Table 22: Summary of contaminant concentrations (upper bound whole weight basis)

Principal contaminants: Summary of concentrations						
	PCDD/F WHO-TEQ (upper)	**PCB WHO-TEQ**	**PCDD/F & PCB WHO-TEQ**	**PBDD/F TEQ (phase 1 only)**	**Σ PCNs**	**PFOS**
			ng/kg			**mg/kg**
Min	0.037	0.063	0.103	0.030	1.11	2
Median	0.33	0.966	1.762	0.033	43.78	43
Mean	2.547	1.82	4.418	0.034	109.75	50.21
Max	26.319	6.543	32.304	0.051	1197.73	153
	Σ PBDEs	**Deca-BDE**	**As**	**Cd**	**Hg**	**Pb**
	µg/kg	**µg/kg**	**mg/kg**	**mg/kg**	**mg/kg**	**mg/kg**
Min	0.20	0.01	0.01	0.005	0.027	0.005
Median	10.90	0.04	0.08	0.005	0.12	0.01
Mean	20.43	0.05	0.15	0.008	0.140	0.014
Max	129.55	0.22	0.97	0.053	0.402	0.063

Appendix 1

Environmental contaminants in fish and shellfish from unmanaged inland UK waterways – Identification of high pollutant pressure sites

Appendix 2

Environmental Contaminants in Fish and Shellfish from Unmanaged Inland UK Waterways: Socio-economic Study