THE NATIONAL UNIVERSITY OF IRELAND, CORK

UNIVERSITY COLLEGE CORK

SCHOOL OF FOOD & NUTRITIONAL SCIENCES

Head of School: Professor Yrjo Roos

Supervisor: Professor Albert Flynn

Coláiste na hOllscoile Corcaigh, Éire
University College Cork, Ireland

Assessment of dietary background exposure of the Irish Adult Population to Dioxins and PCBs particularly taking into account additional exposure due to the 2008 Irish dioxin food contamination incident

THESIS

Presented by

Christina Tlustos, MSc

For the degree of

PHD - DOCTOR OF PHILOSOPHY

In Food & Nutritional Sciences

October, 2013

Table of Contents

Table of Tables

Table of Figures

Declaration

The thesis submitted is my own work and has not been submitted for another degree, either at University College Cork or elsewhere.

Signed: ………………………………………………

(Christina Tlustos)

Acknowledgements

Many people have assisted, helped and encouraged me during the last 5 years and I would like to thank you all. In particular, my thanks extend to my supervisors Prof. Albert Flynn (UCC) and Wayne Anderson (FSAI) for their input and support.

I wish to thank the Department of Agriculture, Food and the Marine for its assistance in compiling the data required. In particular I would like to extend my gratitude to Michael Sheridan, who provided me with a lot of his time, patience and knowledge and the data required to facilitate this thesis. I would also like to thank Andrew O'Connor, Dan O'Sullivan, Peter Maher, Michael Gunn, Mary Kavanagh, Pat Brangan, Mary Neenan, Mary T McMahon, Paul Barry Walsh, Carina Campion, Finbarr O'Connell and Liam Hyde for their time and effort. I would also like to thank the Environmental Protection Agency, in particular Ian Marnane, for the provision of data relating to the contamination in oil. I further wish to thank An Bord Bia for the provision of meat balance data, which was kindly provided by Peter Duggan.

I would like to thank the FSAI for funding this work, in particular Alan Reilly for his encouragement, Wayne Anderson for his much valued assistance and supervision, Iona Pratt for her input and support, Carol Heavey and Donal McCoy for helping me track the last few missing slaughter statistics, and Karl McDonald, Elaine Connolly, Vanessa Cooling, Anne Marie Boland and Helen Crowley for their help and moral support during my long journey of recipe disaggregation, my manager Rhodri Evans for his support and Oonagh Eustace for her help with all my administrative needs.

To Iona Pratt,

Sorely missed friend and mentor

Personal contribution

I have personally been involved in the implementation, management, analysis and reporting of the FSAI monitoring programs on POPs, and I have published and presented this work nationally and on an international basis, which provided me with an in-depth knowledge of the data used for the background exposure assessment on dioxins.

I collated all the above information in this thesis together with all other existing data on dioxin contamination in Ireland to provide one single overview of data collected in Ireland. I was also actively involved in the 2008 Irish dioxin food contamination incident, in particular I personally carried out the initial risk assessment and personally submitted all relevant information to the European Commission and the European Food Safety Authority.

For the in-depth re-assessment of additional exposure to dioxins as a result of the 2008 Irish dioxin food contamination incident discussed in this thesis, I extensively liaised with officials from the Department of Agriculture, Food and the Marine (DAFM) and associated laboratories, with the Environmental Protection Agency (EPA) and foreign contract laboratories (i.e FERA, RIKILT and SAL) to collect, collate, scrutinise and quality control all available analytical data and to create one single database capturing all incident related data. This information has also been published since.

I also spent a considerable amount of time with colleagues from DAFM to trace and track all available information on the implicated herds, their movement, slaughter statistics, information on recall numbers, final cull numbers and other related information required to derive the contamination presence probabilities required for the exposure assessment to dioxins.

I have personally carried out all required modifications on the two adult food consumption surveys to facilitate the probabilistic exposure assessments on dioxins carried out as part of this study and I have personally selected, coded and matched all food consumption and contaminant occurrence data, designed the exposure models and performed all data runs using Creme™ probabilistic software and subsequent analysis on the so generated data.

I have published, presented and contributed to work, which has been incorporated into this thesis. These are as follows:

Tlustos C. (2009a) The dioxin contamination incident in Ireland 2008. *Organohalogen Compounds* Vol.71 p. 1155-1159.

Tlustos C. (2009b) The dioxin crisis in Ireland 2008. Challenges in risk management and risk communication. *Organohalogen Compounds* Vol.71 p. 1152-1154.

Tlustos C, Sheridan M, O'Sullivan D, Anderson W, and Flynn A. (2012) The dioxin contamination incident in Ireland, 2008: analytical results and congener patterns. *Food Addit Contam* Vol.29/1 p. 128-138.

Pratt IS, Anderson WA, Crowley D, Daly SF, Evans RI, Fernandes AR, Fitzgerald M, Geary MP, Keane DP, Malisch R, McBride J, Morrison JJ, Reilly A, and Tlustos C. (2012) Polychlorinated dibenzo-p-dioxins (PCDDs), polychlorinated dibenzofurans (PCDFs) and polychlorinated biphenyls (PCBs) in breast milk of first-time Irish mothers: Impact of the 2008 dioxin incident in Ireland. *Chemosphere* Vol.88/7 p. 865-872.

Tlustos C, Anderson W, and Flynn A. (2014) Exposure of the Irish Adult population to dioxins and PCBs from the diet *Food Addit Contam Part A Chem Anal Control Expo Risk Assess. 2014 Mar 19*

Tlustos C, Anderson W, and Flynn A. (2014) Additional exposure of the Irish Adult population to dioxins and PCBs from the diet as a consequence of the 2008 Irish dioxin food contamination incident. *Food Addit Contam Part A Chem Anal Control Expo Risk Assess. 2014 Mar 28*

Abstract

Irish monitoring data on PCDD/Fs, DL-PCBs and Marker PCBs were collated and combined with Irish Adult Food Consumption Data, to estimate dietary background exposure of Irish adults to dioxins and PCBs. Furthermore, all available information on the 2008 Irish pork dioxin food contamination incident was collated and analysed with a view to evaluate any potential impact the incident may have had on general dioxin and PCB background exposure levels estimated for the adult population in Ireland.

The average upperbound daily intake of Irish adults to dioxins Total WHO TEQ (2005) (PCDD/Fs & DL-PCBs) from environmental background contamination, was estimated at 0.3 pg/kg bw/d and at the 95th percentile at 1 pg/kg bw/d. The average upperbound daily intake of Irish adults to the sum of 6 Marker PCBs from environmental background contamination ubiquitous in the environment was estimated at 1.6 ng/kg bw/d and at the 95th percentile at 6.8 ng/kg bw/d.

Dietary background exposure estimates for both dioxins and PCBs indicate that the Irish adult population has exposures below the European average, a finding which is also supported by the levels detected in breast milk of Irish mothers. Exposure levels are below health based guidance values and/or Body Burdens associated with the TWI (for dioxins) or associated with a NOAEL (for PCBs). Given the current toxicological knowledge, based on biomarker data and estimated dietary exposure, general background exposure of the Irish adult population to dioxins and PCBs is of no human health concern.

In 2008, a porcine fat sample taken as part of the national residues monitoring programme led to the detection of a major feed contamination incidence in the Republic of Ireland. The source of the contamination was traced back to the use of contaminated oil in a direct-drying feed operation system. Congener profiles in animal fat and feed samples showed a high level of consistency and pinpointed the likely source of fuel contamination to be a highly chlorinated commercial PCB mixture.

To estimate additional exposure to dioxins and PCBs due to the contamination of pig and cattle herds, collection and a systematic review of all data associated with the contamination incident was conducted. A model was devised that took into account the proportion of contaminated product reaching the final consumer during the 90 day contamination incident window.

For a 90 day period, the total additional exposure to Total TEQ (PCDD/F &DL-PCB) WHO (2005) amounted to 407 pg/kg bw/90d at the 95th percentile and 1911 pg/kg bw/90d at the 99th percentile.

Exposure estimates derived for both dioxins and PCBs showed that the Body Burden of the general population remained largely unaffected by the contamination incident and approximately 10 % of the adult population in Ireland was exposed to elevated levels of dioxins and PCBs.

Whilst people in this 10 % cohort experienced quite a significant additional load to the existing body burden, the estimated exposure values do not indicate approximation of body burdens associated with adverse health effects, based on current knowledge.

The exposure period was also limited in time to approximately 3 months, following the FSAI recall of contaminated meat immediately on detection of the contamination.

A follow up breast milk study on Irish first time mothers conducted in 2009/2010 did not show any increase in concentrations compared to the study conducted in 2002. The latter supports the conclusion that the majority of the Irish adult population was not affected by the contamination incident.

Glossary

Abbreviation	Full Name
Ah receptor	aryl hydrocarbon (Ah) receptor
BB	body burden
half-life	Half-life ($t½$) is the time required for a quantity to fall to half its value as measured at the beginning of the time period
LD50	the amount of a toxic agent that is sufficient to kill 50 percent of the study population of animals
MoBB	Margin of Body Burden
PBPK	Physiological based pharmacokinetic model
Toxicokinetics	Toxicokinetics is the study of five time-dependent processes related to toxicants as they interact with living organisms. Absorption, distribution, storage, biotransformation and elimination
BEL	Belgium
BUL	Bulgaria
HR	Croatia
CZR	Czech Republic
FIN	Finland
DE	Germany
HU	Hungary
IRL	Ireland
ITA	Italy
LUX	Luxembourg
NOR	Norway
ROM	Romania
SVK	Slovakia
ES	Spain
SWE	Sweden
NL	Netherlands
BIM	Sea Fisheries Board (Ireland)
DAFM	Department of Agriculture, Fisheries and the Marine
EC	European Community
EFSA	European Food Safety Authority
EPA	Environmental Protection Agency (for Ireland)
FBO	Food Business Operator
FERA	Food and Environment Research Agency
FSAI	Food Safety Authority of Ireland
HSE	Health Service Executive
JECFA	FAO/WHO Joint Expert Committee Food Additives and Contaminants
MI	Marine Institute
NANS	National Adult Nutritional Survey
NATO	North Atlantic Treaty Organisation
NATO-CCMS	NATO Committee on the Challenges of Modern Society
NSIFCS	North South Food Consumption Survey
PCS	Pesticide Control Service Laboratory
SAL	Scientific Analysis Laboratories
SCF	Scientific Committee on Food
SCOOP	Scientific Cooperation Task of the EC
SPSS	Statistical Product and Service Solutions (software package used for statistical analysis)
Teagasc	National Food Centre (Ireland)
USEPA	United States Environmental Protection Agency
WHO	World Health Organisation
WHO-ECEH	European Centre for Environment and Health of the World Health Organization
POP	Persistent Organic Pollutant
Congener	a chemical substance related to another
NDL-PCB	non-dioxin-like PCB
DL-PCB	dioxin-like PCB
Sum of 6 Marker PCBs	Sum of 6 PCBs (28, 52, 101,138, 153 and 180)

Glossary continued

ICES-6	International Council for the Exploration of the Seas-6 Indicator PCBs
ICES-7	International Council for the Exploration of the Seas-7 Indicator PCBs
DDT	dichlorodiphenyltrichloroethane
HpCB	heptachlorobiphenyl
HpCDD	heptachlorodibenzo-*p*-dioxin
HpCDF	heptachlorodibenzofuran
HxCB	hexachlorobiphenyl
HxCDD	hexachlorodibenzo-*p*-dioxin
HxCDF	hexachlorodibenzofuran
OCDD	octachlorodibenzo-*p*-dioxin
OCDF	octachlorodibenzofuran
PCB	polychlorinated biphenyl
PCBs	polychlorinated biphenyls
PCDD/F	Abbreviation for PCDDs and PCDFs
PCDDs	polychlorinated dibenzo-*p*-dioxins
PCDFs	polychlorinated dibenzofurans
PnCB	pentachlorobiphenyl
PnCDD	pentachlorodibenzo-*p*-dioxin
PnCDF	pentachlorodibenzofuran
TCB	tetrachlorobiphenyl
TCDD	tetrachlorodibenzo-*p*-dioxin
TCDF	tetrachlorodibenzofuran
LOD	Limit of Detection
LOQ	Limit of Quantification/Quantitation
Lower-bound (LB)	Analytical results below the LOQ set at zero for calculation purposes
Upper-bound (UB)	Analytical results below the LOQ set at the LOQ value for calculation purposes
bw	body weight
atm	Unit to measure atmospheric pressure. 1 atmosphere = 101325 Pascal (Pa)
K_{0W}	The octanol-water partition coefficient is the ratio of the concentration of a chemical in octanol and in water at equilibrium and at a specified temperature.
d	day
m	month
90d	90 days
ng	nanogram (0.000000001 g, 10^{-9} g or one billionth of a gram)
ng/g	nanogram per gram
ng/kg	nanogram per kilogram
ng/kg bw	nanogram per kilogram bodyweight
pg	picogram (0.000000000001 g, 10^{-12} g or one trillionth of a gram)
pg/g	picogram per gram
pg/kg	picogram per kilogram
pg/kg bw	picogram per kilogram bodyweight
ww	wet weight or whole weight
µg	microgram (0.000001 g, 10^{-6} g or one millionth of a gram)
µg/g	microgram per gram
µg/kg	microgram per kilogram
µg/kg bw	microgram per kilogram bodyweight
cwe	carcass weight equivalent
PTMI	Provisional Tolerable Monthly Intake
TDI	Tolerable Daily Intake
TEF	toxic equivalency factor
TEQ	toxicity equivalent or toxic equivalency
TWI	Tolerable Weekly Intake
RfD	Oral Reference Dose
Boxplot	Boxplot showing the median, quartiles, and outlier and extreme values for a scale variable. The interquartile range (IQR) is the difference between the 75th and 25th percentiles and corresponds to the length of the box. ○: Outliers are values between 1.5 IQR's and 3 IQR's from the end of a box *: Values more than 3 IQR's from the end of a box are defined as extreme.

1 Introduction

Persistent organic pollutants (POPs) are chemical substances that persist in the environment, bio-accumulate through the food web, and pose a risk of causing adverse effects to human health and the environment. This group of priority pollutants consists of pesticides (e.g. dichlorodiphenyltrichloroethane (DDT)), industrial chemicals (e.g. polychlorinated biphenyls (PCBs)) and unintentional by-products of industrial processes (e.g. dioxins and furans).

POPs are distributed across international boundaries far from their sources, even to regions where they have never been used or produced. Because of the long-range environmental transportation and bio-magnification[1] of these substances, persistent organic pollutants pose a threat to the environment and to human health all over the globe.

Amongst the group of POPs, dioxins and dioxin-like chemicals form a large group of compounds which are structurally related, are environmentally and biologically persistent, induce a common spectrum of responses, and have a common mechanism of action (Van den Berg *et al,* 1998).

1.1 Structure of chlorinated dioxins, furans and biphenyls

Chlorinated dibenzo-p-dioxins (CDDs) and chlorinated dibenzofurans (CDFs) are two series of tricyclic aromatic compounds with similar chemical and physical properties (WHO, 1989b) and chlorinated biphenyls (CBs) are a class of chemical compounds in which 2–10 chlorine atoms are attached to the biphenyl molecule (ATSDR, 2000) (see Figure 1).

For dioxins the basic structure is a dibenzo-p-dioxin (DD) molecule, which is comprised of 2 benzene rings joined at their para carbons by 2 oxygen atoms whereas furans contains two benzene rings fused to a central furan ring (ATSDR, 1994; ATSDR, 1998). For chlorinated biphenyls the basic structure is a biphenyl molecule (Erickson, 2001).

Based on the number of chlorine substituents on the benzene rings, there are eight homologues of chlorinated dioxins and furans (monochlorinated through octachlorinated),

[1] "A process where chemicals are retained in fatty body tissue and increase in concentration over time. Biomagnification is the increase of tissue accumulation in species higher in the natural food chain as contaminated food species are eaten" (US EPA, 2013).

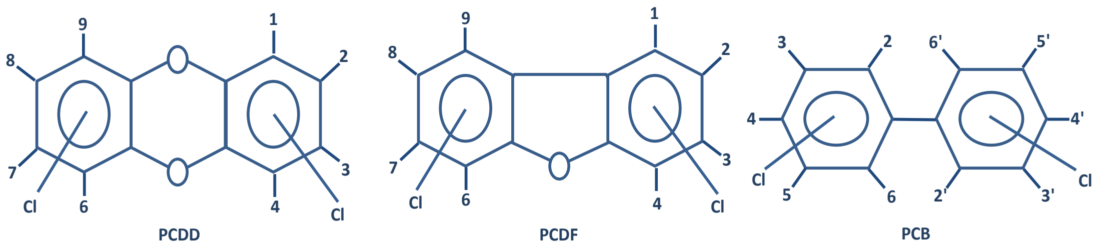
(ATSDR, 1994; ATSDR, 1998) and ten homologues of chlorinated biphenyls (monochlorinated through decachlorinated), each homologue group containing one or more congeners (ATSDR, 2000).

The class of CDDs contains 75 congeners, consisting of 2 monoCDDs, 10 diCDDs, 14 triCDDs, 22 tetraCDDs, 14 pentaCDDs, 10 hexaCDDs, 2 heptaCDDs, and a single octaCDD. Because of molecular asymmetry, PCDFs have 135 congeners, compared to 75 for PCDDs (Ryan *et al,* 1991). These are 4 monoCDFs, 16 diCDFs, 28 triCDFs, 38 tetraCDFs, 28 pentaCDFs, 16 hexaCDFs, 4 heptaCDFs, and one octaCDF (ATSDR, 2000).

PCDDs and PCDFs are commonly referred to as dioxins or PCDD/Fs.

Chlorinated biphenyls comprise 3 monoCBs, 12 diCBs, 24 triCBs, 42 tetraCBs, 46 pentaCBs, 42 hexachlorobiphenysl, 24 heptaCBs, 12 octaCBs, 3 nonaCBs and one decaCB (ATSDR, 2000).

Figure 1 Structure of PCDD/Fs and PCBs



1.2 Sources and Environmental Fate

Polychlorinated biphenyls (PCBs) are industrial chemicals, which were produced as technical mixtures and marketed under various brand names, characterised by their chlorine content, such as 'Aroclor' (produced in the USA), 'Clophen' (produced in Germany), 'Phenoclor' (produced in France), 'Fenclor' (produced in Italy), and 'Kanechlor' (produced in Japan). They were mainly used in electronic appliances, heat-transfer systems, and hydraulic fluids, but also in building materials, lubricants, coatings, plasticizers and inks, although their use has now largely been phased out (ATSDR, 2001; Srogi, 2008).

Dioxins are unwanted contaminants almost exclusively produced by industrial and combustion processes (Bumb *et al,* 1980; Cleverly *et al,* 2007; Fiedler, 2007; Hites, 2011; Olie *et al,* 1977), chlorine bleaching of paper and pulp (Engwall *et al,* 1997), the manufacture of some agro-chemicals (Stone, 2007; Young *et al,* 2004) and as by-products of the chlor-alkali process (Rappe *et al,* 1991) or chlorophenol production (Oeberg and

Rappe, 1992). Natural processes such as forest fires and volcanoes (EFSA, 2010b) can also lead to formation of dioxins.

Deposition of airborne dioxins onto farmland and water, and subsequent ingestion of this contaminated vegetation and soil by food animals, followed by bioaccumulation up terrestrial and aquatic food chains, is considered the primary pathway by which dioxins enter the food chain. Other sources may include contaminated feed, improper application of sewage sludge, flooding of pastures, contaminated soil or industrial waste effluents washed into rivers and lakes and certain types of food processing (Fries, 1995; Van Leeuwen *et al,* 2000).

According to the Environment Protection Agency (EPA) in Ireland, the main sources of dioxin emissions to air in Ireland in 2010 include open burning processes (e.g.: accidental burning of vehicles and buildings, and backyard burning), and emissions from fuel being burned for heat and power generation (residential and commercial). Emissions from controlled waste incineration are comparatively low as a result of environmental protection controls through high temperature combustion, high standards of pollution abatement and strict dioxin emission limits (EPA, 2012).

Many hydrophobic and lipophilic compounds are highly resistant to breakdown processes in the environment and to metabolism in vertebrate species, including humans. Three physical chemical characteristics are important in determining the fate and transport of PCDDs and PCDFs in the environment, namely water-solubility, volatility and the octanol-water partition coefficient (log K_{ow}s). Water-solubility is low, ranging from 317 ng/L for TCCD to 0.074 for OCDD and the log K_{ow}s range from 6.8 for TCDD to 8.2 for OCDD and OCDF (Shiu *et al,* 1988). The PCDDs and PCDFs are characterized as semi-volatile to non-volatile with vapour pressures ranging from 10-8 atm[2] for TCDD to 10-12 atm for OCDD (Eitzer and Hites, 1991). Nearly all PCDD and PCDF congeners with the 2,3,7,8-chlorine substitution pattern are chemically and metabolically stable under normal environmental conditions. As a result, PCDDs and PCDFs persist and concentrate in the lipids of biological systems and bio-magnification occurs through the food chain. Therefore high tissue concentrations can often occur in top predator species (Van den Berg *et al,* 1998; Weber *et al,* 2008).

---

[2] 1 atmosphere (atm) = 101,325 Pascal (Pa)

Humans, as a result, retain a large number of PCDD and PCDF congeners with a 2,3,7,8-chlorine substitution pattern in their tissues, blood, and milk (Van den Berg *et al,* 1994). A wide range of PCB congeners are also strongly retained (Liem *et al,* 2000; Schecter *et al,* 1994) and higher levels of PCDD/Fs and PCBs are commonly found in people living in more industrialised countries (Schecter *et al,* 2006).

1.3 Toxicity

Long term exposure to PCDDs, PCDFs and PCBs can cause serious health effects like cancer, hormone disruption, impaired reproduction, skin toxicity and immune system disorders (IARC, 1997; JECFA, 2002; Kogevinas, 2001; US EPA, 2003). Based on both animal studies and epidemiological evidence, 2,3,7,8-TCDD was classified as a "known human carcinogen" (class 1) by the WHO International Agency for Research on Cancer (IARC) in 1997 (IARC, 1997). PCBs, without distinction into dioxin-like (DL-PCBs) or non dioxin-like congeners (NDL-PCBs), on the other hand, were classified as "probably carcinogenic to humans" (Group 2A) (IARC, 1999). A wide range of toxicity endpoints including reproductive toxicity have been identified and used as critical effects in the risk assessment of PCDDs, PCDFs and PCBs, as discussed further in section 1.3.1.4.

1.3.1 Dioxins and dioxin-like substances (PCDD/Fs and DL-PCBs)

Of a total of 75 possible PCDDs and 135 possible PCDFS and 209 possible PCBs, there are seven PCDDs, ten PCDFs and twelve PCBs which are considered dioxins or dioxin-like compounds by the WHO (Van den Berg *et al,* 2006). The toxic PCDDs and PCDFs have chlorines on the 2, 3, 7, and 8 positions. The 12 specific PCB congeners elicit similar toxicological properties to PCDD/Fs. These include four non-ortho (PCBs 77, 81, 126, 169) and eight mono-ortho congeners (PCBs 105, 114, 118, 123, 156, 157, 167, 189) and are referred to as "dioxin-like", with the remainder being referred to as "non dioxin like" PCBs (NDL-PCBs). Of the latter, the most commonly reported are the sum of six PCB congeners (PCBs 28, 52, 101, 138, 153, 180) often referred to as indicator or marker PCBs or the sum of seven (sum of six indicator PCBs plus PCB 118), because these congeners are appropriate indicators for different PCB patterns in various sample matrices (La Rocca and Mantovani, 2006).

Most, if not all, toxic and biological effects of PCDD/Fs and DL-PCBs are mediated through the aryl hydrocarbon receptor (AhR), a cytosolic receptor protein present in most vertebrate tissues with high affinity for 2,3,7,8–substituted PCDD/Fs and some PCBs (Van den Berg *et al,* 2006). It is believed, that the AhR is a key regulatory protein in normal development and homeostasis (Andersson *et al,* 2002; Andersson *et al,* 2003) aging, hypoxia and circadian rhythms (Carlson and Perdew, 2002) and that dioxins induce toxicity through persistent activation of the receptor (White and Birnbaum, 2009).

Adverse health effects of dioxin exposure in humans may include cardiovascular disease, diabetes, cancer, porphyria, endometriosis, early menopause, reduced testosterone and thyroid hormones, altered immunologic response, skin, tooth, and nail abnormalities, altered growth factor signalling, and altered metabolism (US EPA, 2003).

The effects of dioxin exposure during development are also many, and include altered thyroid and immune status, altered neurobehaviour at the level of hearing, psychomotor function, and gender-related behaviours, altered cognition, dentition, and development of reproductive organs, and delays in breast development, in addition to altered sex ratios among the exposed offspring (White and Birnbaum, 2009).

Recent studies have revealed that thyroid-stimulating hormone was elevated in neonates born from mothers with presently elevated plasma dioxin levels, nearly 30 years after their exposures during the 1976 Seveso dioxin disaster (Baccarelli et al, 2008). Another study on men who were exposed to dioxin in their youth in Seveso, found that those who were exposed prior to puberty exhibited reduced sperm count and motility as adults, 22 years later, while those who were exposed during adolescence exhibited increased sperm counts and motility (Mocarelli et al, 2008).

1.3.1.1 The toxic equivalency system (TEQ system)

Due to their common mechanism of action (AhR receptor activation) and because they occur as mixtures in the environment, in food, and in human tissues, the dioxins and dioxin-like compounds are commonly assessed and regulated as a class (Srogi, 2008; Van den Berg *et al,* 2006).

However, PCDDs, PCDFs and DL-PCB congeners exhibit variable toxic potency, and therefore a relative potency ranking scheme has been devised that assigns a Toxic Equivalency Factor (TEF) (see Table 1) to each compound, representing the relative toxicity of the compound being measured to the most toxic dioxin congener, TCDD. This in turn reflects the relative strength of binding to the Ah receptor (White and Birnbaum, 2009).

TEFs for dioxin-like compounds apply only to AhR mediated responses and cannot be applied to effects that are not AhR-mediated and this concept assumes a model of dose additivity (Van den Berg *et al,* 2000). The criteria for including a compound in the TEF scheme for dioxin like compounds are (Ahlborg *et al,* 1994):

- A compound must show a structural relationship to the PCDDs and PCDFs
- A compound must bind to the Ah receptor
- A compound must elicit Ah receptor-mediated biochemical and toxic responses
- A compound must be persistent and accumulate in the food chain

The concept of toxic equivalency was first developed in New York by the State Health Department in a series of experiments in response to the need for re-entry criteria of an office building contaminated by a mixture of dioxins and PCBs following an electrical transformer fire (Eadon and Kaminsky, 1986).

An arbitrary TEF of 1 is assigned to TCDD, and by multiplying the analytically determined concentrations of each congener in a sample by its corresponding TEF, individual toxicity equivalents (TEQs) are determined.

Summing the contribution from each congener, the Total TEQ value of the sample can be obtained using the following equation:

Equation 1 Calculation of Total Toxic Equivalency

$$TEQ = (PCDD_i \times TEF_i) + (PCDF_i \times TEF_i) + (DL\text{-}PCB_i \times TEF_i)$$

Where i is the specific PCDD/F or PCB congener and congener associated TEF (see Table 1)

Several different TEF schemes have been proposed. For many years the most widely used schemes were that of the NATO Committee on the Challenges of Modern Society (NATO/CCMS) (NATO/CMS, 1988), giving the so-called International TEFs (I-TEFs) for PCDDs and PCDFs and the European Centre for Environment and Health of the WHO (WHO-ECEH) scheme for PCBs. In 1998, WHO-ECEH proposed a new scheme of WHO-TEFs for PCDDs, PCDFs and DL-PCBs, which to date has been the most commonly used scheme (Van den Berg *et al,* 1998). Dioxin TEQ values for food and human samples based on WHO-TEFs are approximately 10-20 % higher than those obtained by using the I-TEFs of NATO/CCMS. WHO has recently re-evaluated the WHO-TEFs proposed in 1998 (Van den Berg *et al,* 2006) and has adjusted the TEFs for a number of compounds (see Table 1). For this re-evaluation process, a refined TEF database (Haws *et al,* 2006) was used as a starting point. Decisions about a TEF value were made based on a combination of un-weighted relative effect potency (REP) distributions from this database, expert judgment, and point estimates. Previous TEFs were assigned in increments of 0.01, 0.05, 0.1, etc., but for this re-evaluation, it was decided to use half order of magnitude increments on a logarithmic scale of 0.03, 0.1, 0.3, etc. Changes were decided by the expert panel for 2,3,4,7,8-pentachlorodibenzofuran (PeCDF) (TEF 0.3), 1,2,3,7,8-pentachlorodibenzofuran (PeCDF) (TEF 0.03), octachlorodibenzo-p-dioxin and octachlorodibenzofuran (TEFs 0.0003), 3,4,4',5-tetrachlorbiphenyl (PCB 81) (TEF 0.0003), 3,3',4,4',5,5'-hexachlorobiphenyl (PCB 169) (TEF 0.03), and a single TEF value (0.00003) for all relevant mono-ortho–substituted PCBs.

The biochemical and toxicological effects of PCDDs, PCDFs and DL-PCBs are directly related to their concentrations in tissues, and not to the daily dose (WHO, 2002). Metabolism and excretion rates for dioxins are highly variable among species, which contributes to the difficulty of developing relevant animal models for toxicological studies (Yakitine *et al,* 2006).

Table 1 Toxic Equivalency Factors for dioxins and DL-PCBs

	Toxic Equivalency Factor (TEF)		
PCDDs and PCDFs	I-TEF (NATO/CMS, 1988)	1998 WHO-TEF (Van den Berg *et al,* 1998)	2005 WHO-TEF (Van den Berg *et al,* 2006)
2,3,7,8-TCDD	1	1	1
1,2,3,7,8-PnCDD	0.5	1	1
1,2,3,4,7,8-HxCDD	0.1	0.1	0.1
1,2,3,6,7,8-HxCDD	0.1	0.1	0.1
1,2,3,7,8,9-HxCDD	0.1	0.1	0.1
1,2,3,4,6,7,8-HpCDD	0.01	0.01	0.01
OCDD	0.001	0.0001	0.0003
2,3,7,8-TCDF	0.1	0.1	0.1
1,2,3,7,8-PnCDF	0.05	0.05	0.03
2,3,4,7,8-PnCDF	0.5	0.5	0.3
1,2,3,4,7,8-HxCDF	0.1	0.1	0.1
1,2,3,6,7,8-HxCDF	0.1	0.1	0.1
1,2,3,7,8,9-HxCDF	0.1	0.1	0.1
2,3,4,6,7,8-HxCDF	0.1	0.1	0.1
1,2,3,4,6,7,8-HpCDF	0.01	0.01	0.01
1,2,3,4,7,8,9-HpCDF	0.01	0.01	0.01
OCDF	0.001	0.0001	0.0003
PCBs (IUPAC No. in parenthesis)			
Non-ortho PCBs			
3,3',4,4'-TCB (77)	0.0005	0.0001	0.0001
3,4,4',5-TCB (81)	-	0.0001	0.0003
3,3',4,4',5-PnCB (126)	0.1	0.1	0.1
3,3',4,4',5,5'-HxCB (169)	0.01	0.01	0.03
Mono-ortho PCBs			
2,3,3',4,4'-PnCB (105)	0.0001	0.0001	0.00003
2,3,4,4',5-PnCB (114)	0.0005	0.0005	0.00003
2,3',4,4',5-PnCB (118)	0.0001	0.0001	0.00003
2,3,4,4'5-PnCB (123)	0.0001	0.0001	0.00003
2,3,3',4,4',5-HxCB (156)	0.0005	0.0005	0.00003
2,3,3',4,4',5'-HxCB (157)	0.0005	0.0005	0.00003
2,3',4,4',5,5'-HxCB (167)	0.00001	0.00001	0.00003
2,3,3',4,4',5,5'-HpCB (189)	0.0001	0.0001	0.00003
Abbreviations: PnCDD, pentachlorodibenzo-p-dioxin; HxCDD, hexachlorodibenzo-p-dioxin; HpCDD, heptachlorodibenzo-p-dioxin; OCDD, octachlorodibenzo-p-dioxin; PnCDF, pentachlorodibenzofuran; HxCDF, hexachlorodibenzofuran; HpCDF, heptachlorodibenzofuran; OCDF, octachlorodibenzofuran. TCB, tetrachlorobiphenyl; PnCB, pentachlorobiphenyl; HxCB, hexachlorobiphenyl; HpCB, heptachlorobiphenyl.			

1.3.1.2 Species Sensitivity

The differences in species sensitivity can vary by a factor of nearly 10000 when looking at the short-term toxicity (LD_{50}) observed in different species (Geyer *et al,* 2002). It has been suggested though, that on average, humans are among the more dioxin-resistant species. However, the human data set is too limited to be conclusive (Harper *et al,* 2002; Okey *et al,* 2005) and further research into REP values in human systems to establish if the present TEFs based on rodent studies are indeed also valid for humans may therefore be warranted (Van den Berg *et al,* 2006).

In his review of half lives, Geyer et al (Geyer *et al,* 2002) stated:

"The adult ''Reference Western Man'' of 70 kg body weight and 21 % body fat with an estimated LD_{50} of 6230 µg TCDD/kg body weight would be relatively resistant to acute toxicity of TCDD, whereas newborns with ca. 13.6 % body fat would be about 10 times more sensitive, LD_{50}: 614 µg/kg, and the human foetus with 2.9 kg body weight and 6.7 % body fat is predicted to be much more sensitive to acute toxicity of TCDD, LD_{50}: ca. 15 µg/kg (Geyer et al., 1990, Geyer et al., 1999, unpublished results)."

In accordance with short term toxicity, half life estimates also vary considerably between species, and have been reported to vary for TCDD from an average of 18.7 days in rats (Geyer *et al,* 2002) to 93 days in cattle (Thorpe *et al,* 2001) to an average of 7.8 years in humans (Geyer *et al,* 2002). Other dioxins may be eliminated more or less rapidly with as little as a 6-month half-life of elimination estimated for some PCDFs, but 20 years for others (Schecter *et al,* 2006).

However, the half-life of a persistent chemical is not constant and depends on many biotic and abiotic factors, such as body weight, total body fat of the organism, age, sex, dose and existing body burden (Geyer *et al,* 2002). Recent pharmacokinetic studies indicate faster elimination at higher concentrations, also varying with body composition, so that higher amounts of body fat lead to increased persistence (Aylward *et al,* 2005; Emond *et al,* 2005). Also, lactating women and infants have much faster clearance rates, due to increased excretion (parturition) and in the case of infants, dilution due to increasing body mass. Kreutzer et al (Kreuzer *et al,* 1997) reported an apparent half-life of 5 months in infants, with a steady increase to approximately 10 years in adults.

In their review of relevant literature, Geyer et al (Geyer *et al,* 2002) also found that it takes between six and seven half-lives to approach steady state (equilibrium) levels of chemicals in an organism, which would be reached between 47 and 55 years in the case of TCDD based on a mean half-life of 7.8 years.

1.3.1.3 Body Burden concept

As mentioned previously, biochemical and toxicological effects of dioxins are directly related to their concentrations in tissues, however, in the absence of information on the latter, body burden data (see section 1.3.1.4) can be used, which were found to show a clear association for a number of effects at similar levels in humans and animals (DeVito *et al,* 1995). Therefore, the body burden is generally considered to be a suitable dose metric to scale dioxin dose-response across species (Van Leeuwen *et al,* 2000) and this approach was used to derive tolerable intake values by the WHO (JECFA, 2002; Van Leeuwen *et al,* 2000) and the Scientific Committee on Food of the European Commission (SCF) (SCF, 2000; SCF, 2001) in their risk assessments of dioxins (see Table 2).

1.3.1.4 Risk assessment of dioxins, furans and DL-PCBs in food

The SCF carried out a risk assessment of dioxins and dioxin-like PCBs (DL-PCBs) in food (SCF, 2000; SCF, 2001), as a consequence of which they concluded that the Tolerable Weekly Intake (TWI) for PCDDs, PCDFs and DL-PCBs should be no more than 14 pg WHO-TEQ/kg body weight (bw). This is very similar to the Provisional Tolerable Monthly Intake (PTMI) of 70 pg/kg bw per month derived by the FAO/WHO Joint Expert Committee on Food Additives and Contaminants (JECFA) (JECFA, 2002) and the Tolerable Daily Intake (TDI) expressed as range of 1-4 TEQ pg/kg bw established by the WHO European Centre for Environment and Health (ECEH) in collaboration with the International Programme on Chemical Safety (IPCS) (Van Leeuwen *et al,* 2000).

In all cases, tolerable intake values were derived using the body burden approach. This is based on the consideration that elimination of low doses of PCDDs follows first-order kinetics, and may be calculated using the following toxicokinetic equation:

Equation 2 Body Burden Equation for PCDDs

Body burden at steady state (ng/kg bw) = [f x intake (ng/kg bw/d) x half-life (days)]/ln(2) *where f is the fraction of dose absorbed from food (assumed to be 50 % in humans) and the estimated half-life of TCDD is 2774 days (7.6 years) (JECFA, 2002)*

Following this approach, tolerable intake levels were derived, based on the key pivotal effects identified in toxicity studies involving exposure to TCDD (see Table 2). Adverse effects seen at low exposures to TCDD include effects on the reproductive system in the male and female offspring of pregnant rats (Faqi *et al,* 1998; Gray *et al,* 1997a; Mably *et al,* 1992) and monkeys (Rier *et al,* 1993), genital malformation in offspring of pregnant rats (Gray *et al,* 1997b; Ohsako *et al,* 2001), immune suppression in offspring of pregnant rats (Gehrs *et al,* 1997; Gehrs and Smialowicz, 1999) and neurobehavioral effects in offspring of pregnant monkeys (Schantz and Bowman, 1989).

WHO ECEH/ICPS derived a TDI by applying an uncertainty factor of 10 to the range of Estimated Human Daily Intakes (EHDIs) of 14-37 pg TCDD/kg bw/d associated with the lowest observable adverse effect levels (LOAELs) (see Table 2), expressed as a range, of 1 - 4 TEQ pg/kg bw (rounded figures) for dioxins and dioxin-like compounds (WHO ECEH/IPCS, 1998) .

JECFA derived a PMTI by applying a safety factor of 3.2 to the Estimated Human Monthly Intake (EHMI) (237/330) associated with the no observable effect level (NOEL), and a total safety factor of 9.6 to the EHMI (423/630) associated with the lowest observable effect level (LOEL), and selecting the mid-point of the calculated range (40–100 pg/kg bw per month), i.e. 70 pg/kg bw per month as PTMI for dioxins and dioxin-like compounds (JECFA, 2002).

SCF derived a TWI by applying a safety factor of 9.6 to the EHDIs ranging from 20-50 pg 2,3,7,8-TCDD/kg bw associated with the LOAELs, and a safety factor of 3.2 to the EHDI of 10 ng/kg bw associated with the NOAEL suggesting a tolerable intake in the range of 2 to 3 pg/kg bw/day. The Committee found it more appropriate to express the tolerable intake on a weekly rather than a daily basis and established a TWI of 14 pg 2,3,7,8-TCDD/kg bw (SCF, 2001).

Table 2 Overview of pivotal studies used in the derivation of tolerable intake levels by WHO ECEH/IPCS, JECFA and SCF

Pivotal study	Evaluating body						Species	Effect	Point of Departure	
	WHO/ECEH (Van Leeuwen *et al,* 2000)		JECFA (JECFA, 2002)		SCF (SCF, 2001)				NOAEL	LOAEL
	BB ng/kg bw (1)	EHDI pg/kg bw/d	BB ng/kg bw (2)	EHMI pg/kg bw/m(d) (3)	BB ng/kg bw (1)	EHDI pg/kg bw/d				
(Mably *et al,* 1992)	28	14	28		100	50	Holtzman Rats	Decreased sperm count in offspring		64 ng/kg bw single bolus dose by gavage
(Gray *et al,* 1997a)			28		80	40	Long Evan rats	Decreased sperm count in offspring, accelerated eye opening		50 ng/kg bw single bolus dose by gavage
(Faqi *et al,* 1998)			25	423/630 (7.9/11)	40	20	Wistar rats	Decreased sperm production and altered sexual behaviour in male offspring		Maintenance of 25 ng/kg bw by subcutaneous injections
(Ohsako *et al,* 2001)			13	237/330 (14.1/21)	20	10	Holtzman Rats	Decreased anogenital distance in male offspring; ventral prostate weight	12.5 ng/kg bw single bolus dose by gavage	
			51		80	40				50 ng/kg bw single bolus dose by gavage
(Gray *et al,* 1997b)	73	37					Long Evan rats	Increased genital malformations in offspring		
(Gehrs *et al,* 1997)	50	25	50				F344 rats	Immune suppression in offspring		Single oral bolus dose by gavage on day 14 of gestation
(Gehrs and Smialowicz, 1999)							F344 rats	Immune suppression in offspring		
(Rier *et al,* 1993)	69	35					Rhesus Monkeys	Endometriosis		
(Schantz and Bowman, 1989)	42	21					Monkeys	Neurobehavioral effects in offspring		

BB = Body Burden, EHDI = Estimated human daily intake EHMI = Estimated human monthly intake

(1) Increment over background body burden (estimated at 4 ng/kg bw)
(2) Excluding background body burden
(3) Liner Model/Power Model derived values; values divided by 30 to approximate daily values

In February 2012 the US EPA released a reanalysis of key issues related to dioxin toxicity in response to comments submitted by the National Academy of Science (NAS) (NAS, 2006) and provided for an oral reference dose (RfD) for TCDD of 7×10^{-10} mg/kg/d (i.e. 0.7 pg/kg bw/d) (US EPA, 2012). Whilst the JECFA, the SCF and WHO/ECEH all based their evaluations of a tolerable intake using the body burden as dose metric, which is based on the consideration that elimination of low doses of PCDDs follows first-order kinetics, the US EPA adopted a different approach. They derived an oral reference dose (RfD) based on a dose metric of concentration in whole blood, modelled as a function of administered dose. The blood concentrations were modelled using a TCDD physiologically based pharmacokinetic (PBPK) model based on the Seveso cohort, whose members were exposed environmentally to high peak concentrations of TCDD as a consequence of an industrial accident. Two epidemiologic studies were used: a study that associated TCDD exposures with decreased sperm concentration and sperm motility in men who were exposed during childhood (Mocarelli *et al,* 2008) and a study that associated increased thyroid-stimulating hormone levels in newborn infants born to mothers who were exposed to TCDD (Baccarelli *et al,* 2008). Because these two studies defined the most sensitive endpoints evaluated in the epidemiologic literature, they were designated as co-principal studies for the RfD. The two points of departure (PODs) based on these studies, were adjusted LOAELs with the same value of 0.020 ng/kg bw/d and designated as co-critical effects. EPA used a composite uncertainty factor (UF) of 30 for the RfD. A factor of 10 for UFL[3] was applied to account for lack of a NOAEL. A factor of 3 for UFH[4] was applied to account for human inter-individual variability because the effects were elicited in sensitive life stages. A UF of 1 was not applied because the sample sizes in these two epidemiologic studies were relatively small, which, combined with uncertainty in exposure estimation, may not fully capture the range of inter-individual variability. In addition, potential chronic effects are not well defined for humans and could possibly be more sensitive (US EPA, 2012).

This so derived safe dose for non-cancer effects of 0.7 pg/kg bw/d is slightly lower than the health based guidance values derived by the other previously mentioned expert bodies. This is due to the agency taking a more conservative view of the margin of exposure needed to ensure safety (Hays and Aylward, 2003). Whilst the US EPA used recent

---

[3] UFL = LOAEL-to-NOAEL UF
[4] UFH = human variability UF

epidemiological studies versus rodent studies used by JECFA, SCF and WHO, and different pharmacokinetic models, the derived estimated human intake values, used as PODs were of similar size to those used by JECFA, SCF and WHO. The major difference in deriving the RfD versus the other health based guidance values (i.e. TDI, TWI, PTMI) was the use of a UF of 30 versus factors ranging from 3.2 - 10 used by the other expert bodies.

1.3.2 NDL-PCBs

Although many toxicity studies on PCBs (mainly technical mixtures) exist, evaluation of toxicity of NDL-PCBs is hampered mainly due to presence of DL-PCB constituents in these mixtures, and hence are not suitable for the separate assessment of NDL-PCBs (EFSA, 2005).

Studies on individual NDL-PCBs are available, however, the effects observed, including thyroid, liver, immune and reproductive toxicity, are not specific for NDL-PCBs, but can also be observed after exposure to PCDD/F and DL-PCBs. Thus, any estimate of a NOAEL for NDL-PCBs is hampered by the uncertainty as to what extent the individual congeners were contaminated with PCDD/F and/or DL-PCB, as even minute concentrations of potent dioxin-like contaminants (in the range of 0.1 %) in the NDL-PCB test preparations might be sufficient to explain the effects observed (EFSA, 2005).

The most sensitive effects seen in studies with NDL-PCBs in experimental animals are liver and thyroid toxicity. The NOAELs in 90-day rat studies were in the range of 30-40 μg/kg bw/d. The effects seen in these studies occurred at considerably lower dose levels than many other effects observed in studies of shorter duration with different NDL-PCBs. However, when a comparison is made on the basis of estimated body burdens it appears that the NOAELs for all these effects are found at rather similar body burdens, ranging from about 400-1200 μg/kg bw or higher (EFSA, 2005).

1.3.2.1 Risk assessment of NDL-PCBs in food

A risk assessment for the NDL-PCBs in food has been carried out at European level by the European Food Safety Authority (EFSA) CONTAM Panel in 2005, to include identification of the most relevant/sensitive toxicological endpoints for the PCB-congener patterns usually found in food (EFSA, 2005). The panel concluded that the current toxicological database on health effects is not suitable for the separate assessment of NDL-PCBs. Also the human data on exposure did not enable a distinction between the effects of NDL-PCBs and

PCDD/Fs to be made, due to co-occurrence of PCDDs and PCDFs, and therefore the assessment was based on individual NDL-PCB congeners. Due to the absence of genotoxicity the establishment of a health-based guidance value for levels of NDL-PCBs in food was considered possible, however, the Panel considered the toxicological database too limited and hence a "Margin of Exposure” (MoE)[5] approach was used. This approach, which can be used to assess the risks to human health of exposure to a substance in absence of a tolerable daily intake or similar guidance value, was endorsed by the Scientific Committee of EFSA (EFSA, 2005) and JECFA (WHO, 2005).

Considering that the LOAEL Body Burden (BB) for the most sensitive effects (liver, thyroid) were 10 times higher than the NOAEL BB (400, 800, and 1200 µg /kg bw for PCBs 28, 128, and 153, respectively), the Panel chose an overall body burden of 500 µg /kg bw as a representative conservative body burden at the NOAEL (NOAEL BB) for all individual NDL-PCBs and for the sum of NDL-PCBs occurring in human tissues.

The Panel noted that the NDL-PCBs found in human milk are the congeners that accumulate in the human body: PCBs 18, 28, 33, 37, 52, 60, 66, 74, 99, 101, 110, 128, 138, 141, 153, 170, 180, 183, 187, 194, 206, and 209. The median total concentration of all the NDL-PCBs measured in human milk was about 240 ng/g fat, which would correspond to an estimated median human body burden of about 48 µg/kg bw, assuming 20 % fat content in the human body. A rather small margin of body burden (MoBB) of 10 was calculated, however, the panel stressed that the endpoints considered in the evaluation of individual NDL-PCB congeners can also be observed with PCDD/Fs and DL-PCBs (EFSA, 2005).

To convert the median human body burden of about 48 µg/kg NDL-PCB/kg bw at steady state into a daily intake, the Panel considered the limited data on bioavailability and the reported half-lives for the most persistent congeners (PCBs 28, 52, 101, 105, 118, 138, 153, 170, 180) and assumed a bioavailability from food of 90 % and an overall biological half-life of 10 years. Using these assumptions, an estimated intake of about 10 ng/kg bw per day of total NDL-PCBs would be needed to achieve steady state at 48 µg/kg bw following the equation below:

---

5 The margin of exposure is defined as the reference point on the dose-response curve (usually based on animal experiments in the absence of human data) divided by the estimated intake by humans. (EFSA 2005b)

Equation 3 Body Burden Equation for PCBs

Body burden at steady state (ng/kg bw) = [f x intake (ng/kg bw/d) x half-life (days)]/ln(2) *where f is the fraction of dose absorbed from food (assumed to be 90 % in humans) and the estimated half-life of PCBs is 3650 days (10 years) (EFSA, 2005)*

This median estimate is in the same order of magnitude as the current estimated average intakes of 10 - 45 ng/kg bw per day and of the median intakes reported for adults by several European countries (EFSA, 2005).

1.4 Reduction Strategies and Legislative Measures

Given the concerns regarding the health effects of these ubiquitous environmental contaminants and their persistence in the environment, international strategies have been adopted to minimise their release into the environment, such as the United Nations Economic Commission for Europe (UNECE) Convention on Long-Range Transboundary Air Pollution on Persistent Organic Pollutants (UNECE, 1979) and the United Nations Environment Program (UNEP) Stockholm POPs Convention (UNEP, 2001). The Stockholm Convention was adopted in 2004 and aims to protect human health and the environment by reducing or eliminating releases of POPs as a result of intentional production and use (UNEP, 2001). Strategies for the reduction of exposure to POPs introduced under the Stockholm Convention and other international measures include the establishment of emission limits for dioxins to air, prohibition of the use of PCBs, and safe collection, storage and environmentally compatible disposal or destruction of dioxin and PCB-contaminated devices and products (UNEP, 2007).

The Stockholm Convention entered into force for Ireland in 2010 and in accordance with Article 7 of the Convention, Ireland has developed a National Implementation Plan on POPs for the implementation of its obligations under the Convention. The Environmental Protection Agency, as competent authority, has prepared the National Implementation Plan in consultation with a number of public authorities, national stakeholders and the public. The National Implementation Plan on POPs includes an assessment of POPs in Ireland and details the measures put in place to protect human health and the environment from the POPs that are listed under the Convention. The Plan also outlines further activities which will be carried out to support the control of POPs (EPA, 2012).

In 2001, the European Commission (EC, 2001a) introduced their reduction strategy aimed at directly or indirectly reducing the release of these compounds into the environment, with the objective of reducing human exposure and protecting human health and the environment .

In accordance with this strategy, a number of legislative measures related to food and feed have been introduced since then, including:

- the introduction of measures to reduce the contamination of feeding stuffs for animal nutrition originally via Council Directive 2001/102/EC amending Directive 1999/29/EC on the undesirable substances and products in animal nutrition (EC, 2001b). The latter has since been replaced by Directive 2002/32/EC, as amended (EC, 2002c).
- The introduction of maximum levels for PCDDs and PCDFs in foodstuffs, originally via Council Regulation (EC) No. 2375/2001 amending Commission Regulation 466/2001 (EC, 2001c) which set maximum levels for certain contaminants in foodstuffs. Maximum levels for dioxin-like PCBs were originally introduced via Commission Regulation 199/2006 (EC, 2006f). All the cited legal instruments above have since been replaced by Regulation 1881/2006/EC (EC, 2006c), as amended. Concerning PCDD/Fs and DL-PCBs maximum levels have been updated in accordance with the 2005 TEF scheme (Van den Berg *et al,* 2006). Maximum limits for the sum of 6 Marker PCBs (PCBs 28, 52, 101, 138, 153, 180) were established in 2012. Currently existing MLs for PCDD/Fs, DL-PCBs and Marker PCBs are shown in Table 3
- The introduction of measures to implement the Community's obligations under the Protocol and the Convention via Regulation 850/2004/EC on persistent organic pollutants (EC, 2004d).

In Ireland, The Food Safety Authority of Ireland (FSAI) is the competent authority for the implementation of Regulation 1881/2006/EC, the Department of Agriculture, Food & the Marine (DAFM) is the competent authority for the implementation of Directive 2002/32/EC and the Environmental Protection Agency (EPA) is the competent authority for the implementation of EC Regulation 850/2004 on persistent organic pollutants.

The above mentioned legislative instruments on food and feed are also accompanied by a recommendation on the reduction of the presence of dioxins, furans and PCBs in feed and food, originally introduced in 2002 (EC, 2002b) and since replaced in 2006 (EC, 2006b), in

2011 (EC, 2011) and 2013 (EC, 2013). The latter introduces action levels, which are intended as a tool for competent authorities and operators as an early warning of higher than expected levels of dioxins in food and feed. They are set at a lower level than the maximum levels to highlight those cases where it is appropriate to identify a source of contamination and to take measures for its reduction or elimination.

Furthermore, recommendations on the monitoring of background levels of dioxins and DL-PCBs, both in foodstuffs (EC, 2004a; EC, 2006a) and feedingstuffs (EC, 2004a) were introduced .

Under this obligation, Ireland has carried out substantial monitoring for a range of POPs in a variety of foodstuffs. Results for monitoring surveys have been published and reports are available on the FSAI website (FSAI, 2001; FSAI, 2002a; FSAI, 2002b; FSAI, 2004; FSAI, 2005a; FSAI, 2005b; FSAI, 2010a; FSAI, 2010b; FSAI, 2010c; Tlustos *et al,* 2007). All these data were submitted to EFSA as part of the review of maximum limits and to gauge the effectiveness of the reduction strategy (EFSA, 2010b).

Table 3 Maximum levels established in Commission Regulation 1881/2006 for PCDD/Fs, and sum of PCDD/Fs and DL-PCBs and Sum of ICES 6 PCBs (EC, 2006c)

Foodstuffs		Maximum levels		
		(WHO-PCDD/F-TEQ) (32)	(WHO-PCDD/F-PCB-TEQ) (32)	Sum ICES – 6 PCBs (32)
		unit/g fat except 5.2-5.6 & 5.13 unit/g wet weight		
5.1	Meat and meat products (excluding edible offal) of the following animals (6) :			
	— bovine animals and sheep	2.5 pg (33)	4.0 pg (33)	40 ng (33)
	— poultry	1.75 pg (33)	3.0 pg (33)	40 ng (33)
	— pigs	1.0 pg (33)	1.25 pg (33)	40 ng (33)
5.2	Liver of terrestrial animals referred to in 5.1 (6), and derived products thereof,	4.5 pg	10.0 pg	40 ng
	Liver of sheep and derived products thereof	1.25 pg/g	2.0 pg/g	3 ng/g
5.3	Muscle meat of fish and fishery products and products thereof (25) (34), with the exemption of: — wild caught eel — wild caught fresh water fish, with the exception of diadromous fish species caught in fresh water — fish liver and derived products — marine oils The ML for crustaceans applies to muscle meat from appendages and abdomen (44). In case of crabs and crab-like crustaceans (Brachyura and Anomura) it applies to muscle meat from appendages.	3.5 pg	6.5 pg	75 ng
5.4	Muscle meat of wild caught fresh water fish, with the exception of diadromous fish species caught in fresh water, and products thereof (25)	3.5 pg	6.5 pg	125 ng
5.5	Muscle meat of wild caught eel (Anguilla anguilla) and products thereof	3.5 pg	10.0 pg	300 ng
5.6	Fish liver and derived products thereof with the exception of marine oils referred to in point 5.7	—	20.0 pg (38)	200 ng (38)
5.7	Marine oils (fish body oil, fish liver oil and oils of other marine organisms intended for human consumption)	1.75 pg	6.0 pg	200 ng
5.8	Raw milk (6) and dairy products (6), incl. butter fat	2.5 pg (33)	5.5 pg (33)	40 ng (33)
5.9	Hen eggs and egg products (6)	2.5 pg (33)	5.0 pg (33)	40 ng (33)
5.10	Fat of the following animals:			
	— bovine animals and sheep	2.5 pg	4.0 pg	40 ng
	— poultry	1.75 pg	3.0 pg	40 ng
	— pigs	1.0 pg	1.25 pg	40 ng
5.11	Mixed animal fats	1.5 pg	2.50 pg	40 ng
5.12	Vegetable oils and fats	0.75 pg	1.25 pg	40 ng
5.13	Foods for infants and young children (4)	0.1 pg	0.2 pg	1.0 ng
(4) The maximum level refers to the products ready to use (marketed as such or after reconstitution as instructed by the manufacturer).				
(6) Foodstuffs listed in this category as defined in Regulation (EC) No 853/2004 of the European Parliament and of the Council of 29 April 2004 laying down specific hygiene rules for food of animal origin (OJ L 226, 25.6.2004, p. 22).				
(25) Where fish are intended to be eaten whole, the maximum level shall apply to the whole fish.				
(31) Dioxins (sum PCDD/Fs, expressed as WHO TEQ using the WHO- TEFs) and sum of PCDD/Fs and DL-PCBs, expressed as WHO TEQ using the WHO-TEFs). WHO-TEFs for human risk assessment based on the conclusions of the IPCS) expert meeting in Geneva in June 2005				
(32) Upperbound concentrations: Upperbound concentrations are calculated on the assumption that all the values of the different congeners below the limit of quantification are equal to the limit of quantification.				
(33) The maximum level expressed on fat is not applicable for foods containing < 2 % fat. For foods containing less than 2 % fat, the maximum level applicable is the level on product basis corresponding to the level on product basis for the food containing 2 % fat, calculated from the maximum level established on fat basis, making use of following formula: Maximum level expressed on product basis for foods containing less than 2 % fat = maximum level expressed on fat for that food x 0.02.				
(34) Foodstuffs listed in this category as defined in categories (a), (b), (c), (e) and (f) of the list in Article 1 of Regulation (EC) No 104/2000, with the exclusion of fish liver referred to in point 5.11.				
(36) Foodstuffs listed in this category as defined in categories (b), (c), and (f) of the list in Article 1 of Regulation (EC) No 104/2000.				
(38) In the case of canned fish liver, the maximum level applies to the whole edible content of the can.				

1.5 Dietary Sources and human exposure

Up to 90 % of human exposure to dioxins results from the consumption of food containing dioxins, mainly foodstuffs of animal origin with a high fat content, since these contaminants are lipophilic and accumulate in fatty tissues (EFSA, 2010b; Fürst *et al,* 1992; Gilman *et al,* 1991; Liem *et al,* 2000; Paepke, 1998). Foodstuffs in which these POPs mainly occur include meat, fish, eggs and milk.

Following the recommendation on background monitoring for dioxins, Member States of the European Union as well as Norway and Iceland collected occurrence data on PCDDs, PCDFs and PCBs. These data were submitted to the Commission, who handed over the entire data collection to EFSA for analysis in 2008. A total of 7270 samples were analysed in detail by EFSA, covering results from 1999 to 2008 (EFSA, 2010b). Since then, EFSA have provided an updated analysis on the latest data received from Member States (EFSA, 2012).

Table 4 provides an overview of average concentrations of Total WHO TEQ (sum of PCDD/F&DL-PCBs) in various food-groups based on the most recent data submitted by European countries. Fish, including liver, show by far the highest concentrations (Total WHO TEQ 2.5 pg/g whole weight in muscle meat of fish, 28.3 pg/g whole weight in fish liver), with much lower levels detected in meat (Total TEQ 0.2-2 pg/g fat), eggs (Total WHO TEQ 1.6 pg/g fat) and dairy products (Total WHO TEQ 1.9 pg/g fat).

Table 4 Food group specific means for Sum of PCDD/F&DL-PCBs (Total WHO TEQ (2005)) using lower and upper bound concentrations (adapted from EFSA (EFSA, 2012))

Food group	N	Unit	TOTAL WHO TEQ (2005) pg/g	
			lower-bound	upper-bound
Meat bovine animals and sheep	412	fat	1.92	2.01
Meat poultry	129	fat	0.89	0.99
Meat pigs	169	fat	0.22	0.31
Liver terrestrial animals	170	fat	10.84	10.98
Muscle meat fish	3821	whole	2.49	2.5
Muscle meat eel	464	whole	9.7	9.76
Raw milk and dairy products	1422	fat	1.81	1.91
Hen eggs and egg products	1154	fat	1.54	1.62
Fat ruminants	370	fat	0.82	0.91
Fat of poultry	149	fat	0.39	0.49
Fat of pig	255	fat	0.09	0.2
Vegetable oils and fats	133	fat	0.1	0.18
Marine oil	91	fat	1.25	1.4
Fish liver and derived products	84	whole	28.25	28.28
Fruits, vegetables and cereals	256	whole	0.03	0.05
Infant and baby foods	414	whole	0.01	0.03

EFSA estimated the exposure of dioxins and DL-PCBs to European adults ≥ 18 years of age at an average exposure of between 0.57 and 1.64 pg/kg bw/d TOTAL WHO TEQ (2005) and a 95th percentile of exposure between 1.2 and 4.6 pg pg/kg bw/d TOTAL WHO TEQ (2005) (EFSA, 2012).

Besides the estimates provided for the general European population by EFSA, many countries have performed national intake evaluations on dioxins and DL-PCBs. Table 5 provides an overview of dietary intake estimates performed in Europe, available in the literature between 2003 and 2011. These estimates are consistent with estimates provided by EFSA.

Comparisons between countries are difficult and are hampered by the use of different survey methodologies, treatment of left censored data (i.e. analytical data below the Limit of Quantification) timeframe of occurrence data used, selection of food-groups and modelling used to derive estimates. However, as a general indication, this overview indicates that average exposure estimates in Europe range from 0.4 – 2.8 pg/kg bw/d TOTAL WHO TEQ.

The estimates derived by EFSA and individual Member States show a lower range than reported in the SCOOP task in 2000 (EC, 2000a) which was based on data collected up to 1999. This is consistent with several reports from Member States indicating a general downward trend in exposure. A reduction of between 60 - 70 % was observed in Belgium between 2000/2001 – 2008 (Windal *et al,* 2010), a 60 % decrease between 2000 and 2005 in France (Tard *et al,* 2007), a decrease of 36 % between 1999 and 2004 in the Netherlands (De Mul *et al,* 2008), a 46 % decrease from 1999 - 2005 in Sweden (Tornkvist *et al,* 2011) and an 88 % decrease from 1982 to 2001 in the UK (Fernandes *et al,* 2004). Consistent with the observed decrease of levels in food and dietary intake, a decline in levels has also been observed in human breast milk (see 1.5.1).

Table 5 Overview of dietary intake of dioxins (pg Total TEQ (1998)/kg bw/d) reported for European countries between 2003 and 2011

Country	Year of occurrence data	Reporting Level	Age of population	Survey method	Total TEQ	% Contribution				
					mean (median)	Dairy	Meat	Fish	Eggs	Reference
Denmark	2000 - 2002		Adults		1.9	30	9	58	3	(Cederberg, 2004)
Denmark	2000 - 2004		Adults		0.8 - 1.1	30-40	13-18			(Cederberg *et al,* 2010)
Denmark	2005 - 2009		Adults		0.7-1					
Finland	1997 - 1999	UB	25 - 64	24HR	1.5	14	5 (6)	72		(Kiviranta *et al,* 2004)
Sweden	1999/2003/2004	MB	17 - 79	7d Dietary Record	1.3 (1.07)	20	14	43		(Ankarberg *et al,* 2007)
Sweden (1)	2005	MB	?	Food Balance (5)	0.7	23	14	40	2	(Tornkvist *et al,* 2011)
Sweden	1999	MB	Adults	Food Balance (5)	1.3	20	15	32	6	(Darnerud *et al,* 2006)
Sweden	1998 - 2004	MB	1 - 24	7d Dietary Record	1.5	10	5	75		(Bergkvist *et al,* 2008)
Netherlands (2)	2001 - 2004	MB	1 - 97	2d Dietary Record	(0.82)	38	17	12		(De Mul *et al,* 2008)
Netherlands	1998/1999	LB	1 - 97	2d Dietary Record	(1.2)	27	23	16	4	(Baars *et al,* 2004)
Belgium (3)	2008	MB	>15	24hR/FFQ	0.72	51	22	18	4.8	(Windal *et al,* 2010)
Italy (4)	1997 - 2003	UB	0 - 94	3 - 7d Dietary Record	2.3	27	7	44	1	(Fattore *et al,* 2006)
Norway	2003	?	Adults	FFQ	(0.78)					(Kvalem *et al,* 2009)
France	2001 - 2004	UB	>15	7d Dietary Record	1.8	31	8	48		(Volatier *et al,* 2006)
Spain	2006 - 2008	UB	>17	3dDietary Record	2.9	12	5	59		(Marin *et al,* 2011)
Spain (Catalonia)	2006	MB	Adults		1.12		6.2	58		(Llobet *et al,* 2008b; Llobet *et al,* 2008a)
UK (7)	1999/2000	UB	Adult males	duplicate diet	1.09					(Harrad *et al,* 2003)
UK	2001	UB	Adults	TDS	0.9					(Fernandes *et al,* 2004)
Ireland	2002 - 2006	UB	18 - 64	7d Dietary Record	0.4					(FSAI, 2010a)

Total TEQ = Sum WHO TEQ PCDD/F+DL-PCB; UB = upperbound (<LOQ=LOQ) ; MB = mediumbound (<LOQ=1/2LOQ) ; LB = lowerbound (<LOQ=0)

1 per capita intake from food balance information
2 Usual intake, 2005 WHO TEQs
3 Usual intake
4 Concentration data from EU Commission Database collection data from all Member States
5 per capita consumption data, derived from Swedish producers and trade statistics
6 includes eggs
7 Not representative for the whole UK population

Data on the sum of 6 marker PCBs collected by European Member States, following the recommendation on background monitoring for dioxins, was first evaluated by EFSA in 2005 (EFSA, 2005), and was reported to range between 4.8 and 18 ng/kg bw/d. In 2012, EFSA provided an update of the monitoring data, which showed consistency with the lower range of the earlier estimates, providing an average exposure between 4.3 and 12.5 ng/kg bw/d and a 95th percentile of exposure between 7.8 and 36.5 ng/kg bw/d for the adult ≥18 year old population (EFSA, 2012). EFSA further undertook a review of national exposure estimates (see Table 6) and observed consistency with estimates derived in their 2012 update.

Table 6 National Exposure estimates available for adults in the European Union

Country	Population group	Survey Type	Mean	P95	Source
			Sum of 6 Marker PCBs		
ITA	Adolescents and adults	Monitoring	10.9	23.8	Fattore *et al*. 2008
F	Adults	Monitoring/TDS	7.7	16	Arnich *et al*., 2009
DE	Adults (Bavaria)	Duplicate diet	*5.6		Fromme *et al*. 2009
F	Adults	TDS	2.7	7.9	Sirot *et al.,* 2012
SVK	General population	Monitoring	**17.0	45	Salgovicova *et al*., 2007
Europe	General population	Monitoring	15	meat consumer: 20, fish consumer: 35	EFSA, 2005
*Median for the sum of the 6 NDL-PCB indicators multiplied by a factor 2; **Median					

Source: adapted from EFSA (EFSA, 2012)

1.5.1 *Breast milk as an indicator of human exposure*

Given the lipophilicity of the POPs, they also accumulate in fatty tissues in the human body following consumption of foodstuffs of animal origin and can be detected in human blood, adipose tissue and, in particular, human breast milk (Furst, 2006; Phillips *et al,* 1989). Measurement of POPs in breast milk is accepted as providing a robust and relatively non-invasive measurement of body burden of these ubiquitous contaminants. Breast milk contains many lipid soluble compounds that are also present in mothers' adipose tissue and can be assumed to be representative for those in plasma, serum lipid and adipose tissue (Malisch *et al,* 2008), which is confirmed by the levels of POPs in breast milk fat generally reflecting the levels found in blood lipids (Aylward *et al,* 2003; Wehler *et al,* 1997). Therefore levels of these contaminants in human milk reflect the body burden and can thus be used as an indicator for the overall exposure of the general population to POPs (Malisch *et al,* 2008).

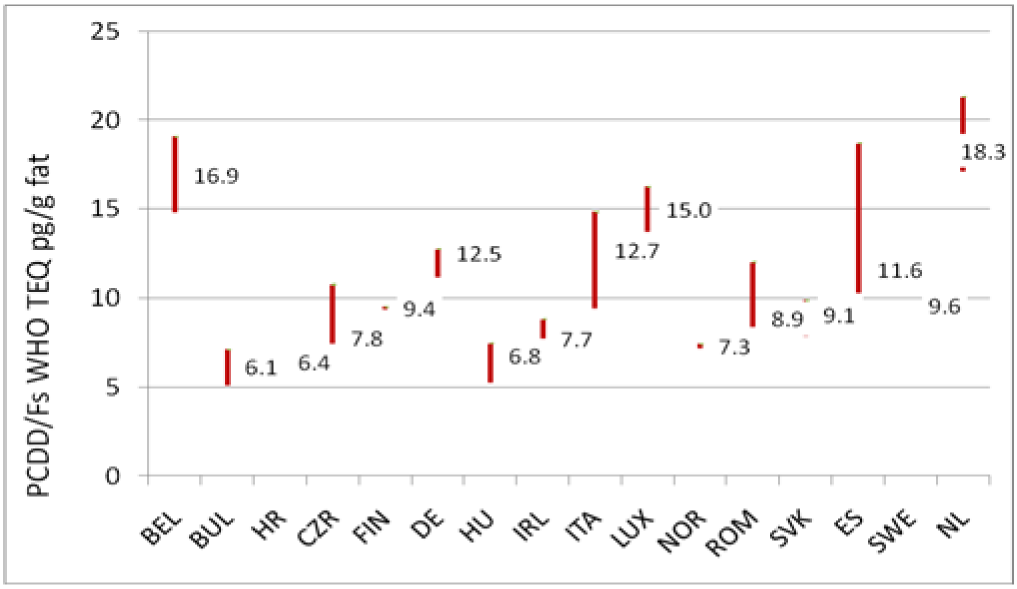
A substantial source of comparable data on dioxins in breast milk relating to the majority of Member States is the WHO co-ordinated study, which since the mid-eighties, in collaboration with other international organisations and national institutions, has coordinated a comprehensive programme on possible health risks of PCBs, dioxins and furans (Van Leeuwen and Malisch, 2002). The first WHO-coordinated exposure study took place in 1987 - 1988 (WHO, 1989a), the second round in 1992 - 1993 (WHO, 1996). Over the period from 1987 to 1993 the average dioxin concentration in breast milk in EU Member States decreased by around 35 % (8.3 % per year), with a slightly higher decrease in rural areas and slightly lower in industrial areas (Buckley-Golder, 1999). This trend continued through to the next round, showing a 40 % decline between the levels found in the second round in 1993 and the third round in 2003 (Van Leeuwen and Malisch, 2002) (see section 1.5.1.1, Figure 2 and Figure 3). During the years 2005 - 2007 and 2008 - 2010, UNEP and the WHO implemented the fourth and fifth round surveys on human milk. Results of these two rounds for WHO-PCDD/F-TEQs show that the median was 6 and 5.9 pg WHO-PCDD/F-TEQ/g fat, and 6.8 and 6.9 pg WHO-PCB-TEQ/g fat, for participating western and eastern European countries, respectively (UNEP, 2011).

1.5.1.1 Human breast milk studies in Ireland

Human breast milk samples from Ireland were analysed in 2002, as part of round 3 of the coordinated WHO study and again in 2009/2010 following the same protocol but with the aim to examine any potential influence of the 2008 dioxin contamination of Irish pork on the overall population exposure. In 2002, pooled breast milk samples from two urban areas (Cork and Dublin) had concentrations of Total WHO TEQs (1998) of 13.3 and 13.7 pg/g fat, respectively, with lower concentrations being observed in two sub-urban and rural samples (Wicklow and Donegal) of 11.6 pg/g fat and 8.9 pg/g fat respectively, giving an overall mean of 11.9 pg/g fat over the 4 samples. In 2009/2010 eleven pools were analysed with results ranging from Total WHO-TEQs (1998) from 7.5–13.7 pg/g fat, the overall pooled sample of milk from 109 mothers in 2010 showing 9.7 pg/g fat. Comparison of results of the two studies revealed generally lower concentrations of PCDD/Fs and dioxin-like PCBs in the 2010 samples, confirming the declining trend (Pratt *et al,* 2012).

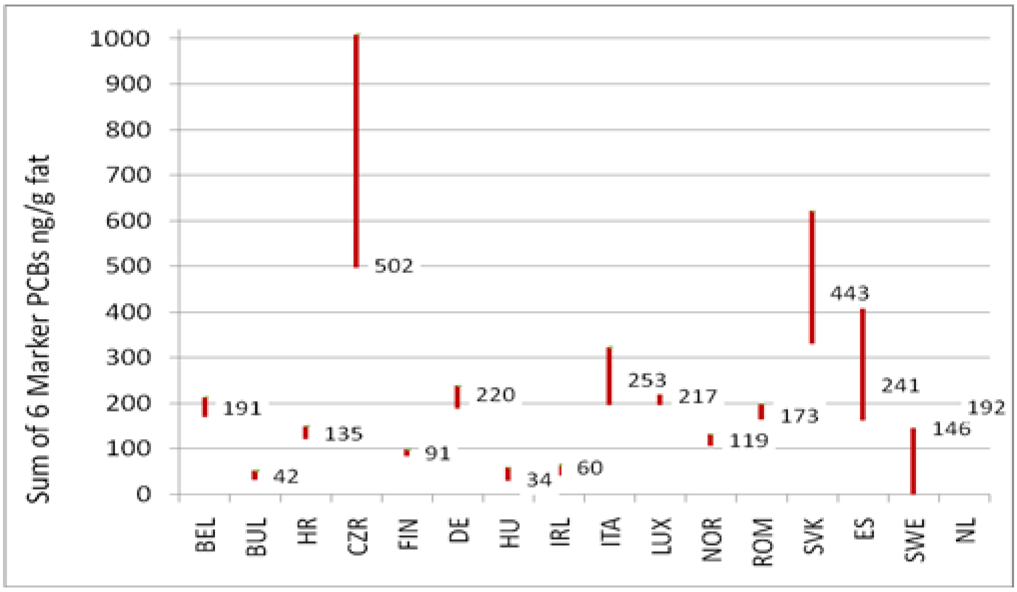
As mentioned previously, Ireland participated in the 3rd round of the WHO-coordinated exposure study, comprising a total of 26 countries from all over the world. Lowest levels of PCDDs/PCDFs and DL-PCBs were found in countries on the southern hemisphere (Fiji, Brazil, Philippines, Australia, New Zealand) and for a number of European countries (Bulgaria, Croatia, Hungary, Ireland) and for the USA, whereas comparatively high levels were found in a number of western European countries (Italy, Spain, Germany, Luxembourg, Belgium and the Netherlands) and in Ukraine (Malisch and Van Leeuwen, 2003). Figure 2 provides an overview of the range of PCDD/Fs found in human breast milk samples submitted by European countries, and shows that results for Ireland are at the lower range of values observed. The same observation also holds for the sum of 6 Marker PCBs (see Figure 3).

Figure 2 Range of PCDD/Fs (pg/g fat) in human breast milk in European countries participating in the 3rd WHO round (number displayed shows the median)



Data Source: (Malisch and Van Leeuwen, 2003)

Figure 3 Range of Sum of 6 Marker PCBs (ng/g fat) in human breast milk in European countries participating in the 3rd WHO round (number displayed shows the median)



Data Source: (Malisch and Van Leeuwen, 2003)

1.6 POPs contamination incidents

While levels of POPs in the human population, as assessed in human breast milk studies, are primarily influenced by environmental levels of these contaminants, including levels in food, which in turn are influenced by the degree of local urbanisation and industrialisation, levels in the human population may also be influenced by specific incidents or accidents leading to high exposure of the environment or the food supply with POPs. One example of industrial accidents is the so-called Seveso incident in 1976, in which an explosion in a chemical manufacturing facility located in the Seveso area in northern Italy led to contamination of humans, animals, food crops and land in the vicinity of the plant with 2,3,7,8-tetrachloro-dibenzo-para-dioxin (TCDD) (Weiss *et al,* 2003). Non-industrial accident related contamination of the food/feed chain occurs more frequently and over the last 15 years a number of food contamination incidents occurred in Europe (see Table 7).

Table 7 Overview of recent dioxin and PCB food/feed contamination incidents

Year	Contamination	Source
1998	Contamination of dairy products and meat by the use of contaminated citrus pulp in feedstuffs in Germany	(Carvalhaes *et al,* 1999; Malisch, 2000)
1999	Contamination of feed fat with PCB containing oil in Belgium	(Bernard *et al,* 1999)
1999	Contamination of feed due to the use of contaminated kaolin as anticoagulant in Switzerland	(Schmid and Uthrich, 2000)
2000	Contamination of animal feed due to contaminated sawdust used as carrier in pre-mixed choline chloride in Germany.	(Llerena *et al,* 2001)
2003	Contamination of bakery waste due to use of waste wood in the drying process in Germany	(Hoogenboom and Traag, 2003)
2004	Contamination of poultry meat and eggs due to PCP contaminated wood shavings as litter in Italy	(Diletti *et al,* 2005)
2004	Contamination of pig feed due to inclusion of waste fat contaminated by a malfunction in gelatine processing in the Netherlands	(Hoogenboom *et al,* 2006)
2004	Contamination of milk by use of potato by-products contaminated by kaolinic clay during sorting in animal feed in the Netherlands	(Hoogenboom *et al,* 2005)
2008	Contamination of pork due to contaminated zinc oxide used as feed ingredient in Chile	(Kim *et al,* 2009)
2008	Contamination of buffalo milk due to illegal waste burning in Italy	(Borrello *et al,* 2008; CRL, 2009; Esposito *et al,* 2010)
2008	Contamination of pork and beef due to contamination of bakery waste via burning of contaminated oil in Ireland	(Tlustos, 2009a; Tlustos *et al,* 2012), see 1.6.1
2010	Contamination of pigs and poultry via dioxin-contaminated oil in animal feed in Germany	(BMELV, 2011)

1.6.1 The 2008 Dioxin Contamination of Irish Pork

In September 2008 a feed contamination incident occurred in Ireland, which subsequently led to contamination of pig herds and cattle herds supplied with this feed.

A porcine fat sample taken as part of the national residues monitoring programme in 2008 led to the detection of a major feed contamination incidence in the Republic of Ireland. The source of the contamination was traced back to the use of contaminated oil in a direct-drying feed operation system. Congener profiles in animal fat and feed samples showed a high level of consistency and pinpointed the likely source of fuel contamination to be a highly chlorinated commercial PCB mixture. Chapter 4 provides in-depth results of the research into source identification and provides the analytical data gathered during the incidence (Tlustos, 2009a; Tlustos *et al,* 2012), which was collated and analysed for the purposes of the exposure assessment for dioxins and PCBs performed in Chapter 5. The following sections provide an overview of additional information related to the incident published in the literature:

1.6.1.1 Critical reviews of the contamination incident

Subsequent to the contamination incident, several government bodies and research institutes performed critical reviews and case studies on the incident. In 2009, an inter-agency review group reviewed what factors contributed to the contamination incident and what policies, and practices, might be put in place to prevent similar incidents from occurring in the future (Wall *et al,* 2009). Similarly, the Joint Oireachtas committee undertook an investigation into the impact and consequences of the dioxin contamination incident, with a view to identifying the causes of the problem and suggesting some lessons for the future. This report particularly focused on the circumstances surrounding the pork recall in terms of the effectiveness of the existing traceability system, the monitoring of licensed feed premises, the proportionality of the response and the way forward for the industry domestically and globally (House of the Oireachtas, 2009).

Two case studies comparing the crisis in Belgium in 1999 with the 2008 crisis in Ireland were published in 2010. Jacob et al (Jacob *et al,* 2010) published an analysis of the management of the two crises by their respective federal governments and highlighted the good crisis management performed by the Irish authorities. The Irish government, due to prompt and detailed communication managed to maintain the trust of the public and other nations throughout their crisis situation, in stark contrast to the Belgian authorities, whose practices resulted in widespread distrust in the government by both consumers and importing nations. Similar to the paper by Jacobs et al, Casey et al (Casey *et al,* 2010) reviewed the strengths and weaknesses in the management of the Belgian and Irish dioxin contamination incidents. They outlined the progress made in terms of scientific risk assessments, EC legislation and non-legally binding monitoring and control mechanisms since the Belgian crisis but highlighted the fact that effective overall EC management and control of a food crisis continues to be heavily reliant on Member States acting in a transparent, communicative and cooperative manner. To that extend the authors further stressed the importance of having science based consumer protection agencies, as demonstrated by the rapid risk assessment of FSAI and EFSA in response to the Irish crisis.

Shan et al (Shan *et al,* 2013) used the Irish dioxin crisis as case study to examine the differences in communication between social and traditional media, highlighting the need of risk managers and risk communicators to be aware of all media channels engaging with the public during a crisis.

1.6.1.2 Environmental Impact and Disposal of contaminated material

Any potential environmental impact the contamination incident may have caused was assessed by the EPA. This involved assessing the impact of emissions from the drying process via dispersion modelling of the stack gas emissions with subsequent sampling of soil from the areas of maximum ground level impact, sampling of groundwater and sediment samples. Results from groundwater analysis indicated no significant levels of contaminants with all results below the laboratory limit of detection, while soil analytical results were in the range 0.88– 2.2 ng/kg TEQ, which were within the normal range for Irish soils, and within the 5 ng/kg threshold used in Germany to describe uncontaminated soils (Marnane, 2012).

Elevated sediment samples (dioxin concentrations greater than 3000 ng/kg TEQ, which is well in excess of the 1000 ng/kg guideline threshold value applied in Germany) indicated limited contamination of the land drainage channel and the FBO was requested to submit a remediation plan for the contaminated area, including decontamination of the associated pipe work (Marnane, 2012).

Remaining feed material in storage at the feed manufacturing facility, including returned materials from farms was sent to the United Kingdom for incineration as a nonhazardous waste (based on analytical data for the feed material) (Marnane, 2012).

The residual contaminated oil from the feed manufacturing site was retained at a secure facility as evidence in the event of legal proceedings, but will eventually be disposed of via an appropriate waste management facility (Marnane, 2012).

The actual processing building and the feed drying equipment itself are also required to be decontaminated, and this work is ongoing. The incineration of the recalled pork, culled animals and contaminated feed was carried out at permitted facilities operating in line with the requirements of the Waste Incineration Directive (2000/76/ EC) (Marnane, 2012).

1.6.1.3 The economic impact

The Irish Government provided €182,000,000 as an industry support measure, however, the total economic burden of the crisis is as yet unknown. As direct economic consequences, pig farmers were facing financial ruin, 1800 pig processors were laid off as a result of the pork recall and another 10000 indirect jobs were at threat. Many companies in Ireland lost their status as sole suppliers of pork to overseas markets and Ireland's reputation as "clean" food supplier came under threat (Tlustos, 2009b).

1.6.1.4 Media Coverage

The crisis was heavily reported by the media, with the FSAI receiving over 700 queries from journalists as follows:

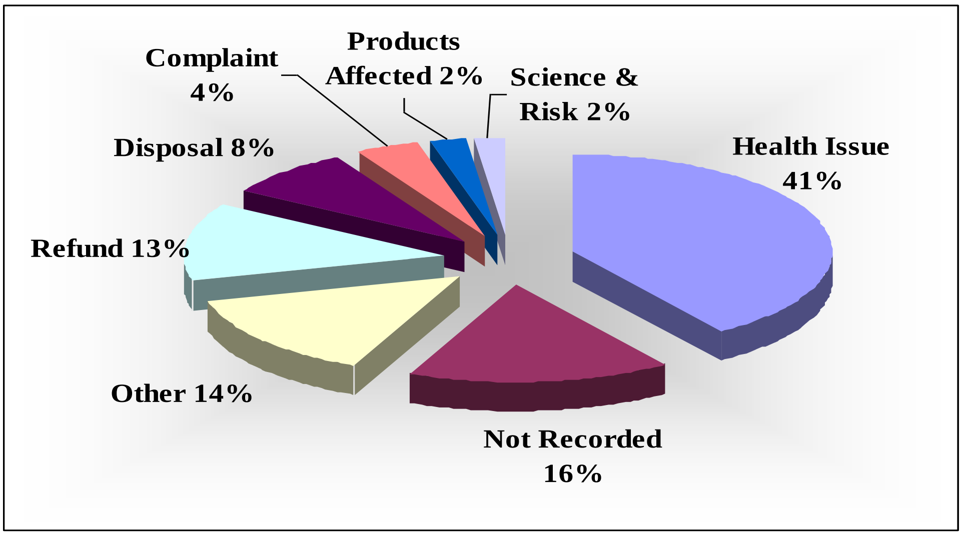
- 385 Articles in National Press
- 200 Articles in Regional Press
- 70 Radio Programs and phone-interviews
- 17 Television Programs
- 200 Internet News Items
- Daily press conferences

For those specifically seeking information on the internet, Google provided 36700 hits when queried about toxins in Irish pork (Tlustos, 2009b).

1.6.1.5 Consumer interest

The FSAI's helpline received a total of 3725 calls between 6th and 12th December 2008 with the majority of queries relating to health issues (see Figure 4). 2660 of these calls were received on Sun 7th 2008, the day after the recall had been issued (Tlustos, 2009b).

Figure 4 Type of queries received by the Food Safety Authority



In the same period, the FSAI Website registered 42400 visitors, half of which visited the website between Sat 6th and Sun 7th December 2008, an increase of 4310 % compared to the previous weekend (Tlustos, 2009b).

2 Collation of occurrence data of dioxins and PCBs in food in Ireland

There are different food monitoring programs for dioxins and PCBs in operation in Ireland. Some of them are rolling programs implemented to test for compliance with legislation whereas others have been implemented to provide time-trends or provide information on environmental contamination, etc. Overall, over the last 20 years, 1038 food samples[6] were analysed for dioxins in Ireland (see Table 8). The majority of samples were taken by the FSAI in collaboration with its agencies, followed by independent studies performed by DAFM, EPA, Teagasc Food Research Centre and Bord Iascaigh Mhara (Irish Sea Fisheries Board, BIM). These data are reported in different formats and in different places by the various organisations. This chapter provides an overview of the various programs in operation in Ireland and a collation of all data on dioxins and PCBs available in Ireland with a view to facilitate exposure assessment to dioxins and PCBs in this study and any further assessments in the future.

[6] Excluding targeted samples taken as part of the 2008 contamination incident

Table 8 Breakdown of routine monitoring samples taken in Ireland between 1991 - 2010 for dioxin analysis

Category	1991	1992	1993	1995	1997	1998	1999	2000	2001	2003	2004	2005	2006	2007	2008	2009	2010	Grand Total
Carcass fat										34			38					72
Carcass fat (Teagasc)								60										60
Liver										7		12	12					31
Dairy										6		9	30					51
Dairy (Teagasc)						90*												90
Milk (Cork County Council)	1	1	1	2	2	2	2	2	2	2	2	10	5	6	7	6	1	54
Milk (EPA)				33*				37			37		37	37	37	37	37	259
Eggs										47			20					67
Fats and Oils										3								3
Fish									45	13	55						52	165
Fish, canned											15							15
Soup										1								1
Vegetables										8								8
Fruit										3								3
Cereals										3								3
Supplements									15			43						58
Infant Formula (DAFM)															6*	6	7	19
Fish (BIM)											52							52
Grand Total	1	1	1	2	2	92	2	99	62	127	161	74	142	43	50	49	97	1038

* PCDD/Fs only
Not included are figures for programs covering Marker PCBs only
Not included are targeted samples taken as a consequence of the 2008 contamination incident

2.1 Methodologies

2.1.1 FSAI Monitoring Programme

2.1.1.1 Monitoring Rationale

The FSAI co-ordinates the collation of food safety surveillance information in Ireland and also conducts targeted food safety surveillance in areas where potential safety issues have been identified and/or on food contaminants for which there are limited facilities in Ireland, such as dioxins. In response to the recommendations on the monitoring of background levels of dioxins and DL-PCBs in foodstuffs (EC, 2004b; EC, 2006a) the FSAI has carried out substantial monitoring for a range of POPs in a variety of foodstuffs.

2.1.1.2 Sampling & Analysis

The FSAI has published numerous surveys on dioxins over the last 10 years (see Table 8), covering a wide range of foodstuffs, in particular foods of lipophilic nature known to accumulate dioxins, such as fish, eggs, meat, offal, fish oils and other oily supplements , fats and oils and dairy products (FSAI, 2001; FSAI, 2002a; FSAI, 2002b; FSAI, 2004; FSAI, 2005a; FSAI, 2005b; FSAI, 2010a; Tlustos *et al,* 2004; Tlustos *et al,* 2005; Tlustos *et al,* 2007).

All surveys conducted by FSAI were designed to follow EC legislation "on the sampling and analysis of sampling methods and the methods of analysis for the official control of dioxins and the determination of dioxin-like PCBs in foodstuffs" in 2002 (EC, 2002a), which has since been replaced by Regulation 252/2012 (EC, 2012).

The latter requires a sample to be representative of the lot from which it was taken and is based on a principle of aggregating incremental samples. Depending on the lot size, the type of sample and homogeneity of contaminant distribution, between 3 - 10 incremental samples are to be taken, the minimum weight of an incremental sample being at least 100 g, however, depending on the particle size in the lot, this number may change requiring the recording of the departure of the standard procedure. The overall aggregate sample should be 1 kg. An exception was made for eggs, for which the aggregate sample should consist of 12 eggs. More specific provisions were also introduced in 2004 for fish, providing for the sampling of fish of different sizes. General exceptions to the above rule also exist for samples taken at retail, or lots were following the above procedure would result in considerable damage to the lot and subsequent economic loss. The latter problem was not encountered in any sampling regime employed for any program described in the following chapters.

Analysis of all samples was carried out by laboratories accredited according to the DIN EN ISO/IEC 17025:2000 standard. The analytical methodology for dioxin and PCB analysis followed international standards, such as EPA 1613 (EPA, 1994), Directive 2002/69/EC laying down the methods of analysis for the determination of dioxin-like PCBs in foodstuffs (EC, 2002a), as amended by Commission Directive 2004/44/EC (EC, 2004c), which was eventually replaced by EU Regulation 1883/2006/EC (EC, 2006d). All analyses were carried out using ^{13}Carbon labelled internal standards and measurement was made using both, high-resolution GC-MS and low-resolution GC-MS as appropriate. The method implemented quality assurance and quality control followed the requirements of international standards for the analysis of Dioxins and PCBs at low concentration levels (e. g. EC Directive 2002/69, EN 1948, EPA 1613). All laboratories provided proof of successful participation in inter-laboratory comparison schemes and proficiency tests, such as FAPAs[7], Quasimeme[8], Folkehelsea[9], etc.

2.1.2 Animal Health Surveillance Scheme (AHSS) in County Cork

2.1.2.1 Monitoring Rationale

Since 1991, the Veterinary Department of Cork County Council has operated an Animal Health Monitoring Scheme (Buckley and Larkin, 1998). The scheme monitors the health of dairy cattle herds in the vicinity of the harbour area (Target herds) and herds in non-industrialised areas (Control herds). As part of this monitoring programme, Cork County Council, in collaboration with FSAI have carried out dioxin analysis on cow's milk samples for the years 1991 – 2010.

2.1.2.2 Sampling & Analysis

The AHSS sampling regime was designed to follow any trends in target versus control dairy herds and employed a sampling regime of 10 pooled milk samples from impact herds versus 2 pooled milk samples of control herds. The latter does not present a huge variation

7 **www.fapas.com**
8 **www.quasimeme.org**
9 **www.fhi.no**

from the EC sampling requirements, which due to the heterogeneity of contaminant distribution generally only requires the taking of a minimum of 3 incremental samples.

Analysis of all samples was carried out by laboratories accredited according to the DIN EN ISO/IEC 17025:2000 standard, as described in 2.1.1.2 .

2.1.3 EPA National milk surveys

2.1.3.1 Monitoring Rationale

The EPA, since 1995 have carried out a dioxin monitoring program in cow's milk samples taken during the grazing season, levels of dioxins in which are used to serve as indicators for the actual average local dioxin exposure by atmospheric deposition (EPA, 2000; EPA, 2004; EPA, 2006; EPA, 2007; EPA, 2008; EPA, 2009).

2.1.3.2 Sampling & Analysis

Milk samples taken by the EPA are pooled regional samples, taken from bulk tankers, which are representative of herds within certain regions. Whilst not in exact agreement with the EC sampling requirements, the sampling methodology complies with the general concept of representativeness of the sample with the lot from which it was taken.

Analysis of all samples was carried out by laboratories accredited according to the DIN EN ISO/IEC 17025:2000 standard, as described in 2.1.1.2.

2.1.4 Teagasc Food Research Centre Monitoring

2.1.4.1 Monitoring Rationale

Teagasc undertook studies in 1998 and 2000 on dioxins and DL-PCBs in dairy products (cheese) and in carcass fat samples (beef, pork, poultry and sheep) which were representative of food in the export market and were supplied by food companies. The aim was to produce a Food Residue Database[10] providing information to be used by the Irish food industry to assist production, processing and marketing of food.

2.1.4.2 Sampling & Analysis

Monitoring undertaken by Teagasc was conducted prior to introduction of EC legislation on sampling and consisted of taking of individual samples. Sampling was in accordance with

---

[10] See here http://nfrd.teagasc.ie/

schedules provided by Teagasc (formerly The National Food Centre) to ensure random geographical and seasonal distribution of samples. Samples were stored frozen or refrigerated at the laboratory prior to analysis (O'Keeffe *et al,* 2001). The study on cheese examined 90 samples from seven dairy companies during the period September 1998 to August 1999. The study on carcass fat was undertaken between January and July 2000 and comprised of 15 samples each of beef, pork, poultry and sheep fat from 13 meat processing companies. Analysis of all samples was carried out by laboratories accredited according to the DIN EN ISO/IEC 17025:2000 standard, as described in 2.1.1.2.

2.1.5 96/23 DAFM Residue Monitoring Program

Directive 96/23/EC (EC, 1996) requires all member states to monitor certain „substances and residues thereof in live animals and animal products". Under this program, DAFM, has coordinated routine analysis on Marker PCBs on samples of animal origin via its agencies. Sampling under this program is matrix specific and deviates from the requirements of sampling associated with Regulation 1881/2006/EC. Monitoring under this program led to the detection of the 2008 dioxin in pork contamination incident.

2.1.6 MI Bivalve Molluscs and Fish Landings Monitoring

The Marine Institute has carried out various monitoring programmes that provide information on PCBs in fish and shellfish, including studies in collaboration with FSAI (see 2.1.1), the 96/23 finfish aquaculture monitoring (see 2.1.5), a bivalve mollusc monitoring program and a monitoring program on fish landed at Irish ports. The latter two programs serve the requirements under EU food safety monitoring obligations and the requirements of the shellfish waters Directive (EC, 2006g) and also provide information on the range of naturally occurring and anthropogenic substances in fish/shellfish (McGovern *et al,* 2011). Sampling and analysis under these programs generally agree with the requirements on sampling associated with Regulation 1881/2006/EC (EC, 2006c).

2.1.7 DAFM Infant Formula and Follow on Formula Monitoring

The dairy section of DAFM has been monitoring infant formula and ingredients of infant formula since 2008. A limited number of samples are taken from the manufacturers in Ireland every year and are tested by an accredited laboratory according to the DIN EN ISO/IEC 17025:2000 standard, as described in 2.1.1.2 for compliance with Regulation 1881/2006 (EC, 2006c).

2.1.8 BIM Ad hoc salmon survey

In 2004, BIM conducted an ad-hoc survey of 52 samples of farmed salmon (homogenates) taken from the West and North coast of Ireland. Analysis was undertaken by an accredited laboratory according to the DIN EN ISO/IEC 17025:2000 standard, as described in 2.1.1.2, with the aim to collect comparative data on fish analysed with and without skin and cooked versus raw fish.

Not included here are data which did not meet the required quality criteria. These were an FSAI survey on cream samples in 2005 and a DAFM survey on milk from 2004. A substantial amount of targeted sampling of bovine and porcine tissue also took place in 2008/2009 related to the feed contamination incidence (Tlustos *et al,* 2012). This data is further described in Chapter 3.3.4.

2.2 Results and Discussion

2.2.1 FSAI Monitoring Programme

Table 8 provides information on the number and sampling location of samples analysed for PCDD/Fs & DL-PCBs. The same number of samples was also analysed for the sum of 6 Marker PCBs. Table 9 and 10 provide average LB and UB results for dioxins and sum of 6 Marker PCBs and Table 44 - 45 in Annex provide the min - max ranges for dioxins and sum of 6 Marker PCBs.

2.2.1.1 Carcass Fat and Liver Samples

Average mean concentrations of Total TEQ (LB - UB) calculated over all years were 0.08 - 0.38, 0.69 - 0.73, 0.53 - 0.56, and 0.12 - 0.22 ng/kg fat for avian, bovine, ovine and porcine carcass fat, respectively. Levels in liver were 0.40 - 0.97, 1.77 - 1.83, 5.05 - 5.17 and 0.63 - 1.67 ng/kg fat for avian, bovine, ovine and porcine liver, respectively (see Table 9 for more detail).

Average mean concentrations for the sum of 6 Marker PCBs (LB - UB) calculated over all years were 1.3 - 1.4, 0.2 - 0.2, 1.1 - 1.2, 1.2 - 1.3 and 0.7 - 0.9 µg/kg fat for avian, bovine, ovine and porcine carcass fat, respectively. Levels in liver were 1.0 - 2.8, 2.8 - 2.9, 4.3 - 4.3, 1.8 - 3.2 and 0.5 - 0.7 µg/kg fat for avian, bovine, ovine and porcine liver, respectively (see Table 10 for more details).

2.2.1.2 Eggs

Average mean concentrations of Total TEQ (LB - UB) calculated over all years were 0.27 - 0.41, 0.35 - 0.57, 0.51 - 0.69 and 2.44 - 2.5 ng/kg fat in barn, battery, free range and organic eggs, respectively. The relatively higher result in organic eggs can be attributed to high results obtained in a sample in 2003, and results excluding this sample are 0.76 - 0.86 ng/kg fat) (see Table 9 for more detail).

Average mean concentrations for the sum of 6 Marker PCBs (LB - UB) calculated over all years were 5.4 - 5.5, 2.2 - 2.4, 1.7 - 1.9 and 51 µg/kg fat in barn, battery, free range and organic eggs, respectively. The relatively higher result in organic eggs can be attributed to high results obtained in a sample in 2003, and results excluding this sample are 4.9 - 5.0 µg/kg fat (see Table 10 for more details).

2.2.1.3 Fish and fish products

Average mean concentrations of Total TEQ (LB - UB) calculated over all years ranged from 0.32 - 25.16 ng/kg fat. Levels in shellfish were 1.20 - 15.55 ng/kg fat in mussels, oysters and prawns, respectively (see Table 9 for more detail).

Average mean concentrations for the sum of 6 Marker PCBs (LB - UB) calculated over all years ranged from 1 - 150 µg/kg fat. Levels in shellfish were 1 - 43 µg/kg fat in mussels, oysters and prawns, respectively (see Table 10 for more details).

2.2.1.4 Milk and Milk products

Average mean concentrations of Total TEQ (LB - UB) calculated over all years were 0.48 - 0.5, 0.16 - 0.23, 0.07 - 0.13 and 0.33 - 0.63 Total TEQ ng/kg fat for butter/cheese, yoghurt, dairy spreads and milk, respectively (see Table 9 for more detail).

Average mean concentrations for the sum of 6 Marker PCBs (LB - UB) calculated over all years were 0.5 - 1.1, 0.2 - 0.7, 0 - 0.8 and 0.4 - 1 µg/kg fat for butter/cheese, yoghurt, dairy spreads and milk, respectively (see Table 10 for more details).

2.2.1.5 Other (Fats/Oils, Cereals, Fruit, Vegetables, Packet Soup)

Average mean concentrations of Total TEQ (LB - UB) calculated over all years were 0.43 - 0.45 and 0.03 - 0.10 ng/kg whole weight for animal/vegetable fat and vegetable oils, respectively. Levels in all other food groups were below the limit of detection and ranged from 0 - 0.06, 0 - 0.05 and 0 - 0.47 ng/kg whole weight in cereals, fruit & vegetables and packet soup, respectively (see Table 9 for more detail).

Average mean concentrations for the sum of 6 Marker PCBs (LB - UB) calculated over all years are 0.6 - 1 and 0.1 - 0.4 µg/kg whole weight for animal/vegetable fat and vegetable oils, respectively. Levels in all other food groups were below the limit of detection and ranged from 0 - 0.1, 0 - 0.06 and 0 - 0.07 µg/kg whole weight in cereals, fruit & vegetables and packet soup, respectively (see Table 10 for more details).

2.2.1.6 Food Supplements

Food Supplements were tested in 2001 and 2005. Monitoring in 2001 was conducted prior to legislative limits being established and relatively high concentrations were found in fish oils (mean Total TEQ of 17 ng/kg whole weight). These levels decreased considerably after regulations were introduced, and levels in 2005 were 2.96 - 3.28 ng/kg whole weight. Other food supplements (plant oils, vitamins, omega 3 formulations) contained on average 0.01 - 1.12 Total TEQ ng/kg whole weight (see Table 9 for more detail).

The average mean concentrations for the sum of 6 Marker PCBs (LB - UB) was 120 µg/kg fat in 2001 and considerable lower in 2005 at 35 µg/kg fat (see Table 10 for more details).

Table 9 Number of samples and results expressed as LB and UB Mean Total TEQ (1998) fat weight covered by FSAI monitoring programs 2001 - 2010

Category	Species	Sampling Stage	2001			2003			2004			2005			2006			2010			2001 - 2010		
			N	Mean		N	Mean		N	Mean		N	Mean		N	Mean		N	Mean		N	Mean	
				LB	UB		LB	UB		LB	UB		LB	UB		LB	UB		LB	UB		LB	UB
Carcass Fat	Avian	Slaughterhouse				7	0.27	0.36							11	0.37	0.39				18	0.34	0.38
	Avian (Duck)	Slaughterhouse				1	0.06	0.17							2	0.10	0.13				3	0.08	0.14
	Bovine	Slaughterhouse				10	0.82	0.88							9	0.54	0.56				19	0.69	0.73
	Ovine	Slaughterhouse				8	0.60	0.64							10	0.48	0.50				18	0.53	0.56
	Porcine	Slaughterhouse				8	0.05	0.17							6	0.23	0.28				14	0.12	0.22
Dairy	Butter	Retail				1	0.48	0.50													1	0.48	0.50
	Cheese	Retail				3	0.41	0.45													3	0.41	0.45
	Milk	Farm										5	0.43	0.58	30	0.31	0.36				35	0.33	0.39
		Retail										4	0.54	0.63							4	0.54	0.63
	Spread	Retail				1	0.07	0.13													1	0.07	0.13
	Yogurt	Retail				1	0.16	0.23													1	0.16	0.23
Eggs	Eggs (Barn)	Packing Station				4	0.33	0.58							5	0.23	0.27				9	0.27	0.41
	Eggs (Battery)	Packing Station				16	0.42	0.65							5	0.14	0.30				21	0.35	0.57
	Eggs (Free Range)	Packing Station				16	0.57	0.79							5	0.30	0.36				21	0.51	0.69
	Eggs (Organic)	Packing Station				11	3.34	3.39							5	0.46	0.55				16	2.44	2.50
	Eggs (Organic) *	Packing Station				3	1.25	1.39							5	0.46	0.55				8	0.76	0.86
Offal	Avian	Slaughterhouse				3	0.40	0.51							3	0.39	0.41				6	0.40	0.46
	Avian (Turkey)	Slaughterhouse				1	0.82	0.97													1	0.82	0.97
	Bovine	Slaughterhouse				1	2.06	2.12							2	1.62	1.68				3	1.77	1.83
	Equine	Slaughterhouse													2	14.23	14.26				2	14.23	14.26
	Ovine	Retail										11	4.10	4.23	2	10.30	10.32				13	5.05	5.17
		Retail**										11	4.10	4.23	1	4.22	4.25				12	4.11	4.24
		Slaughterhouse				1	5.41	5.46							1	5.19	5.20				2	5.30	5.33
	Porcine	Retail										1	0.63	1.67							1	0.63	1.67
		Slaughterhouse				1	1.01	1.23							2	0.91	0.97				3	0.94	1.06

* excluding one extreme value and seven targeted follow up samples ** excluding one extreme value

Table 9 continued Number of samples and results expressed as LB and UB Mean Total TEQ (1998) fat weight covered by FSAI monitoring programs 2001 - 2010

Category	Species	Sampling Stage	2001			2003			2004			2005			2006			2010			2001 - 2010		
			N	Mean		N	Mean		N	Mean		N	Mean		N	Mean		N	Mean		N	Mean	
				LB	UB		LB	UB		LB	UB		LB	UB		LB	UB		LB	UB		LB	UB
Fish	Cod	Port landings																4	3.63	3.77	4	3.63	3.77
	Farmed Salmon	Aquaculture	15	25.52	25.62				15	15.35	15.39							6	10.18	10.18	36	18.73	18.78
	Farmed Trout	Aquaculture	15	24.73	25.16																15	24.73	25.16
	Haddock	Port landings																5	6.63	6.72	5	6.63	6.72
	Hake	Port landings																1	7.24	7.25	1	7.24	7.25
	Herring	Port landings							4	7.86	7.90										4	7.86	7.90
	Lemon Sole	Port landings																4	7.71	7.71	4	7.71	7.71
	Ling	Port landings																2	6.58	6.63	2	6.58	6.63
	Mackerel	Port landings							4	12.75	12.93							5	8.89	8.89	9	10.60	10.68
	Monk Fish	Port landings																4	6.92	6.94	4	6.92	6.94
	Mussels	Aquaculture																5	9.00	9.00	5	9.00	9.00
	Oysters (C.gigas)	Aquaculture							5	11.97	15.55										5	11.97	15.55
	Plaice	Port landings																2	12.61	12.61	2	12.61	12.61
	Prawns	Port landings																1	1.20	1.20	1	1.20	1.20
	Ray	Port landings																1	5.48	5.49	1	5.48	5.49
	Sea Trout	Port landings																2	5.24	5.24	2	5.24	5.24
	Smoked Salmon	Retail							11	12.32	12.36										11	12.32	12.36
	Tinned herring	Retail							2	5.11	5.13										2	5.11	5.13
	Tinned Mackerel	Retail							2	3.33	3.46										2	3.33	3.46
	Tinned pink salmon	Retail							3	1.16	1.43										3	1.16	1.43
	Tinned red salmon	Retail							2	5.90	5.98										2	5.90	5.98
	Tinned sardines	Retail							1	7.09	7.20										1	7.09	7.20
	Tinned tuna	Retail							5	0.32	3.18										5	0.32	3.18
	Tuna	Port landings							5	11.14	11.25							5	5.16	5.16	10	8.15	8.21
	Whiting	Port landings																5	13.22	13.26	5	13.22	13.26
	Wild Salmon	Port landings	15	8.29	8.52				10	8.16	8.21										25	8.24	8.40

Table 9 continued Number of samples and results expressed as LB and UB Mean Total TEQ (1998) whole weight covered by FSAI monitoring programs 2001 - 2010

Category	Species	Sampling Stage	2001			2003			2004			2005			2006			2010			2001 - 2010		
			N	Mean		N	Mean		N	Mean		N	Mean		N	Mean		N	Mean		N	Mean	
				LB	UB		LB	UB		LB	UB		LB	UB		LB	UB		LB	UB		LB	UB
Other	Soup	Retail				1	0.05	0.47													1	0.05	0.47
Fats and Oils	Mixed Fat	Retail				1	0.43	0.45													1	0.43	0.45
	Vegetable Oil	Retail				2	0.03	0.10													2	0.03	0.10
Supplements	Fish oil	Retail	15	16.94	17.01							27	2.96	3.28							42	7.95	8.19
	Oil	Retail										1	0.43	0.85							1	0.43	0.85
	omega FA	Retail										8	0.40	1.12							8	0.40	1.12
	Plant oil	Retail										5	0.01	0.76							5	0.01	0.76
	Vitamin Prep.	Retail										2	0.06	1.07							2	0.06	1.07
Vegetables	Cabbage	Farm				1	0	0.05													1	0	0.05
	Carrots	Farm				1	0	0.05													1	0	0.05
	Lettuce	Farm				1	0	0.05													1	0	0.05
	Mushrooms	Farm				1	0	0.05													1	0	0.05
	Peppers Red	Farm				1	0	0.05													1	0	0.05
	Potato	Farm				1	0	0.05													1	0	0.05
	Spring Onions	Farm				1	0	0.05													1	0	0.05
	Tomatoes	Farm				1	0	0.05													1	0	0.05
Cereals	Cereals	Farm				3	0	0.06													3	0	0.06
Fruit	Apples	Farm				1	0	0.05													1	0	0.05
	Raspberries	Farm				1	0	0.05													1	0	0.05
	Strawberries	Farm				1	0	0.05													1	0	0.05

Table 10 Number of samples and results expressed as LB and UB Mean of Sum of 6 Marker PCBs in µg/kg fat weight covered by FSAI monitoring programs 2001 - 2010

Category	Product	Stage of Marketing	2001			2003			2004			2005			2006			2010			2001 - 2010		
			N	LB	UB	N	LB	UB	N	LB	UB	N	LB	UB	N	LB	UB	N	LB	UB	N	LB	UB
Carcass fat	Avian	Slaughterhouse				7	0.68	0.92							11	1.7	1.7				18	1.3	1.4
	Avian (Duck)	Slaughterhouse				1	0.13	0.22							2	0.3	0.3				3	0.2	0.2
	Bovine	Slaughterhouse				10	1.26	1.42							9	0.9	0.9				19	1.1	1.2
	Ovine	Slaughterhouse				8	1.42	1.70							10	0.9	0.9				18	1.2	1.3
	Porcine	Slaughterhouse				8	0.80	1.07							6	0.6	0.6				14	0.7	0.9
Dairy	Butter	Retail				1	0.66	1.08													1	0.7	1.1
	Cheese	Retail				3	0.54	0.98													3	0.5	1.0
	Milk	Farm										5	0.90	0.91	30	0.4	0.4				35	0.4	0.5
		Retail										4	1.01	1.03							4	1.0	1.0
	Spread	Retail				1	0	0.84													1	0.0	0.8
	Yogurt	Retail				1	0.23	0.73													1	0.2	0.7
Egg, shelled	Eggs (Barn)	Packing Station				4	2.47	2.65							5	7.8	7.8				9	5.4	5.5
	Eggs (Battery)	Packing Station				16	2.67	2.84							5	0.8	0.8				21	2.2	2.4
	Eggs (Free Range)	Packing Station				16	1.94	2.13							5	1.0	1.1				21	1.7	1.9
	Eggs (Organic)	Packing Station				11	73.9	74.2							5	0.9	0.9				16	51	51
	Eggs (Organic)	Packing Station				3	4.9	5.04							5	0.9	0.9				8	0.9	5.04
Offal	Avian	Slaughterhouse				3	0.8	0.9							3	1.1	1.1				6	1.0	1.0
	Avian (Turkey)	Slaughterhouse				1	2.5	2.8													1	2.5	2.8
	Bovine	Slaughterhouse				1	2.3	2.5							2	3.1	3.1				3	2.8	2.9
	Equine	Slaughterhouse													2	4.3	4.3				2	4.3	4.3
	Ovine	Retail										11	1.8	1.8							11	1.8	1.8
		Slaughterhouse				1	3.2	3.25							3	3.1	3.1				4	3.2	3.2
	Porcine	Retail										1	0.6	0.7							1	0.6	0.7
		Slaughterhouse				1	0.36	0.70							2	0.5	0.5				3	0.5	0.6

* excluding one extreme value and seven targeted follow up samples

Table 10 continued Number of samples and results expressed as LB and UB Mean of Sum of 6 Marker PCBs in µg/kg fat weight covered by FSAI monitoring programs 2001 - 2010

Category	Product	Stage of Marketing	2001			2003			2004			2005			2006			2010			2001 - 2010		
			N	LB	UB	N	LB	UB	N	LB	UB	N	LB	UB	N	LB	UB	N	LB	UB	N	LB	UB
Fish	Tinned herring	Retail							2	29	29										2	29	29
	Tinned Mackerel	Retail							2	17	17										2	17	17
	Tinned pink salmon	Retail							3	10	10										3	10	10
	Tinned red salmon	Retail							2	29	29										2	29	29
	Tinned sardines	Retail							1	9	9										1	9	9
	Tinned tuna	Retail							5	0.60	4.3										5	1	4
	Cod	Port landings																4	23	23	4	23	23
	Farmed Salmon	Aquaculture	15	184	184				15	107	107							6	81	81	36	134	134
	Farmed Trout	Aquaculture	15	150	150																15	150	150
	Haddock	Port landings																5	26	26	5	26	26
	Hake	Port landings																1	79	79	1	79	79
	Herring	Port landings							4	52	52										4	52	52
	Lemon Sole	Port landings																4	23	23	4	23	23
	Ling	Port landings																2	49	49	2	49	49
	Mackerel	Port landings							5	58	58							5	61	61	10	60	60
	Monk Fish	Port landings																4	31	31	4	31	31
	Plaice	Port landings																2	61	61	2	61	61
	Ray	Port landings																1	17	17	1	17	17
	Sea Trout	Port landings																2	40	40	2	40	40
	Smoked Salmon	Retail							11	89	89										11	89	89
	Tuna	Port landings							5	103	103							5	56	56	10	79	79
	Whiting	Port landings																5	82	82	5	82	82
	Wild Salmon	Port landings	15	59	59				10	48	48										25	55	55
Shellfish	Mussels	Aquaculture																5	24	24	5	24	24
	Oysters (C.gigas)	Aquaculture							5	41	43										5	41	43
	Prawns	Port landings																1	1	2	1	1	2

Table 10 continued Number of samples and results expressed as LB and UB Mean of Sum of 6 Marker PCBs in µg/kg whole weight covered by FSAI monitoring programs 2001 - 2010

Category	Product	Stage of Marketing	2001			2003			2004			2005			2006			2010			2001 - 2010		
			N	LB	UB	N	LB	UB	N	LB	UB	N	LB	UB	N	LB	UB	N	LB	UB	N	LB	UB
Cereals	Cereals	Farm				3	0	0.10													3	0	0.1
Fruit	Apples	Farm				1	0	0.06													1	0	0.1
	Raspberries	Farm				1	0	0.06													1	0	0.1
	Strawberries	Farm				1	0	0.06													1	0	0.1
Soup	Soup	Retail				1	0	0.07													1	0	0.1
Supplements	Supplements, oil	Retail										1	18	18							1	18	18
	Supplements, Fish oil	Retail	15	120	120							26	35	35							41	66	66
	Supplements, omega fatty acids	Retail										8	2	3							8	2.1	2.7
	Supplements, Plant oil	Retail										5	0	0.94							5	0	0.9
	Supplements, Vitamin preparation	Retail										2	0	0.98							2	0	1.0
Vegetables	Cabbage	Farm				1	0	0.06													1	0	0.1
	Carrots	Farm				1	0	0.06													1	0	0.1
	Lettuce	Farm				1	0	0.06													1	0	0.1
	Mushrooms	Farm				1	0	0.06													1	0	0.1
	Peppers Red	Farm				1	0	0.06													1	0	0.1
	Potato	Farm				1	0	0.06													1	0	0.1
	Spring Onions	Farm				1	0	0.06													1	0	0.1
	Tomatoes	Farm				1	0	0.06													1	0	0.1
Fats and Oils	Animal and Vegetable	Retail				1	0.59	1.03													1	0.6	1.0
	Vegetable Oil	Retail				2	0.07	0.39													2	0.1	0.4

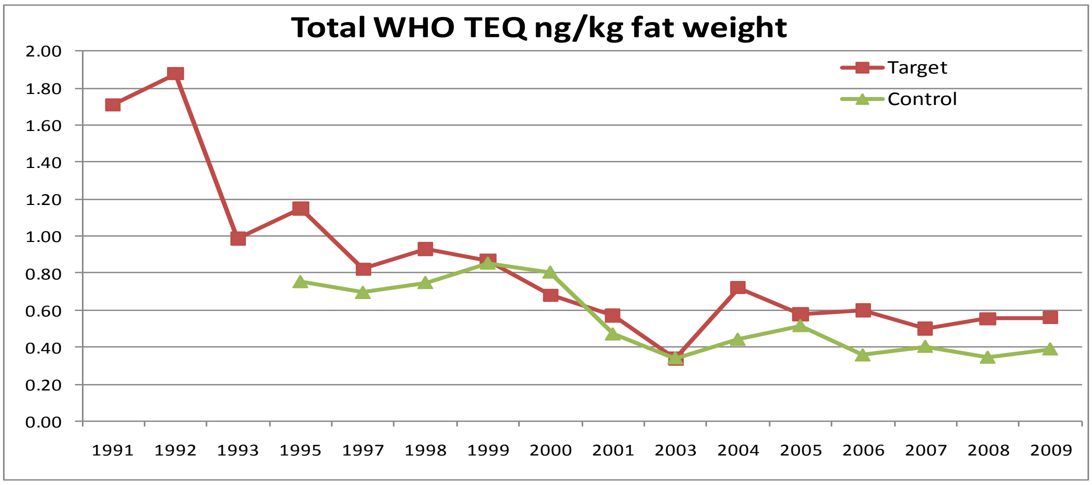
2.2.2 Animal Health Surveillance Scheme (AHSS) in County Cork

Table 8 provides information on the number and sampling location of samples analysed for PCDD/Fs & DL-PCBs under this program. The same number of samples was also analysed for the sum of 6 Marker PCBs.

All samples collected between 1991 and 2001 were sent for analysis in 2001 and are therefore particularly suitable for assessing any trends in concentration, as analysis on all samples was carried out at the same time and by the same laboratory (FSAI, 2001). Levels monitored thereafter have to be interpreted with caution, as these were analysed by different laboratories, and advances in analytical sensitivity has also had an influence on detection limits. However, these data suggest that concentrations of dioxins started to level off from 2001 onwards and the fluctuation that can be observed is most likely due to seasonal variation.

1991 – 2001: Mean levels of PCDD/Fs in milk from herds in the harbour area declined from 0.81 pg WHO-TEQ/g fat in 1991 to 0.31 in 2001. This equated to a decrease of just over 60 %. The reduction was particularly marked in the period 1991 – 1994, coinciding with the introduction of the Environmental Protection Agency's Integrated Pollution Control licensing system. DL-PCB levels in harbour milk were essentially similar to those for the dioxins with a 65 % drop in levels over the ten year period from 1.7 pg WHO-TEQ/g fat to 0.57 pg WHO-TEQ/g fat. In total, levels decreased by 70 % from an average of 1.79 pg WHO-TEQ/g fat for 1991/1992 to an average of 0.55 pg WHO-TEQ/g fat measured between 2001 - 2009. Levels of dioxins in milk from the control herds ranged from 0.75 to 0.47 pg WHO-TEQ/g fat over the period 1995 to 2001. Figure 5 shows the Total TEQ (Sum PCDD/F & DL-PCBs) for all samples analysed between 1991 and 2009. A more in-depth review of these data, covering the years 1991 - 2005 was recently published by Donovan et al (O'Donovan *et al,* 2011). The mean Irish dioxin levels of 0.2 to 0.4 pg WHO-TEQ/g fat reported for 1995 - 2000 from milk in the control herds can be compared with those for Belgium (2.06 pg/g), United Kingdom (1.01 pg/g), Netherlands (0.94 pg/g), France (0.67 pg/g) and Germany (0.57 pg/g) generated between 1995 and 1999 and reported as part of an EU led scientific cooperation task (SCOOP, 2000).

Figure 5 Total TEQ ng/kg fat weight (upperbound) measured in cow's milk samples taken from target and control herds between 1991 – 2009 under the AHSS scheme



Data Source: FSAI

A similar decline could be observed for the sum of 6 Marker PCBs, which decreased from 2.9 µg/kg fat in 1991 to 0.6 µg/kg fat in 2009 in the harbour herds. Concentrations of the sum of 6 Marker PCBs in control herds declined from 1.3 µg/kg fat in 1995 to 0.5 µg/kg fat in 2009.

2.2.3 EPA National milk surveys

Table 8 provides information on the number and sampling location of samples analysed for PCDD/Fs & DL-PCBs. Marker PCBs are not analysed as part of this monitoring program.

In 1995, data was only collected for PCDD/Fs (mean I-TEQ 0.24 pg/g fat medium-bound) and DL-PCBs were only included from 2000 onwards. The mean value for PCDD/F in milk fat in the 2000 survey was 0.20 pg I-TEQ/g compared to a mean value of 0.24 pg I-TEQ/g for the 1995 survey, corresponding to a reduction of around 16 per cent over the 5 year period. Table 11 provides a summary of mean upper-bound concentrations for Total WHO TEQ (1998) ng/kg fat determined by the EPA since 2000, which are in line with the reported findings under the AHSS scheme (see Figure 5).

Table 11 Mean Total WHO TEQ (1998) ng/kg fat weight (upperbound) measured in cow's milk samples taken from sentinel herds between 2000 – 2009

	2000	2004	2006	2007	2008	2009
Mean Total WHO TEQ ng/kg fat upperbound	0.496	0.379	0.468	0.425	0.440	0.385

Source : (EPA, 2000; EPA, 2004; EPA, 2006; EPA, 2007; EPA, 2008; EPA, 2009)

2.2.4 Teagasc Monitoring 1998 and 2000

Table 8 provides information on the number and sampling location of samples analysed for PCDD/Fs & DL-PCBs as part of these surveys. Marker PCBs were not analysed.

The values in cheese sampled in 1998/1999 for dioxins and DL-PCBs combined ranged from 0.15 - 1.2 pg Total TEQ/g fat, with a mean of 0.44 pg Total TEQ/g fat, which is slightly lower than the reported findings by both the EPA and AHSS in milk fat. The study on carcass fat was undertaken between January and July 2000 and comprised of 15 samples each of beef, pork, poultry and sheep fat from 13 meat processing companies. All of the meat samples taken in 2000 contained less than 5 pg TEQ/g fat for dioxins and DL-PCBs combined, using a bio-assay screen. A smaller number of samples analysed using HRGC/MS showed a range of 0.3 – 1.1 pg Total TEQ/g fat in bovine fat, 0.1 - 0.9 pg Total TEQ/g fat in porcine fat, 0.2 - 1.6 pg Total TEQ/g fat in poultry fat and 1.4 - 3.3 pg Total TEQ/g fat in ovine fat.

2.2.5 96/23 DAFM Residue Monitoring Program

Between 1999 and 2010 in excess of 4000 analyses on samples of animal origin (excluding aquaculture) have been carried out by the Pesticides Control Service Laboratory for the presence of marker PCBs. Within this timeframe, 6 samples were found to contain levels above the reporting limit of 0.005 mg/kg fat (see Table 12). Monitoring under this program led to the detection of the 2008 pork dioxin contamination incident in Ireland.

Residue Analysis under the 96/23 monitoring program in finfish aquaculture has been carried out by the Marine Institute. Since 2001, 421 samples of salmon, freshwater and sea trout have been analysed for the presence of PCBs. Source: National Residue Database (O'Keeffe *et al,* 2001), PCS

Table 13 provides an overview of results for samples, for which complete congener information was available (for 60 samples sum of 7 Marker PCBs/6 Marker PCBs could not be calculated and result have been excluded).

Table 12 Number of analyses for 7 Marker PCBs performed under the 96/23 Residue Monitoring program, including information on samples detected above the reporting limit

Year	N *** Analyses	Species	Marker PCBs ≥ 0.005 mg/kg fat			
			N	Species	PCB	mg/kg fat
1999	211	Bovine, Ovine, Porcine	0			
2000	1643	Bovine, Ovine, Porcine, Avian, Venison	1	Bovine	138	0.01
			1	Bovine	180	0.01
2001	2204	Bovine, Ovine, Porcine, Avian, Venison, Milk	1	Poultry	28	0.008
2002	2345	Bovine, Ovine, Porcine, Avian, Venison, Milk, Eggs	0			
2003	2555	Bovine, Ovine, Porcine, Avian, Venison, Milk, Eggs	0			
2004	2527	Bovine, Ovine, Porcine, Avian, Venison, Milk	0			
2005	2561	Bovine, Ovine, Porcine, Avian, Venison, Milk, Eggs	1	Porcine	153	0.012
2006	2499	Bovine, Ovine, Porcine, Avian, Venison, Milk, Eggs	0			
2007	2673	Bovine, Ovine, Porcine, Avian, Venison, Milk, Eggs	1	Ovine	153	0.012
2008**	2733	Bovine, Ovine, Porcine, Avian, Venison, Milk, Eggs	1	Porcine*	138	0.099
			1	Porcine*	153	0.094
			1	Porcine*	180	0.056
			1	Poultry	153	0.0073
2009	3143	Bovine, Ovine, Porcine, Avian, Venison, Horse, Milk, Eggs, Butter, Milk (Goat, Sheep)	0			
2010	2940	Bovine, Ovine, Porcine, Avian, Venison, Horse, Milk, Eggs, Butter, Milk (Goat, Sheep)	0			
* Sample that triggered the dioxin contamination investigation. **Not included in 2008 statistics are all follow up samples taken as part of the contamination incident. *** Analysis of each of the 7 Marker PCBs counts as 7 analysis per sample (typical yearly sample throughput is approximately 300 - 400 samples)						

Source: National Residue Database (O'Keeffe *et al,* 2001), PCS

Table 13 Analyses for 7 Marker PCBs carried out in fish under the 96/23 Residue Monitoring program

Year	Species	N	% Lipid	Sum 7 Marker PCBs	Sum 6 Marker PCBs
				µg/kg fresh weight	
2001	Salmon	108	13.0	26.3	23.5
	Trout (Freshwater)	8	6.6	13.4	12.0
	Trout (Seawater)	6	12.4	23.4	21.0
2002	Salmon	95	12.4	17.2	15.2
	Trout (Freshwater)	7	7.4	9.2	8.0
	Trout (Seawater)	4	10.8	11.2	9.7
2003	Salmon	22	13.8	16.0	13.9
	Trout (Freshwater)	2	6.0	4.4	3.8
	Trout (Seawater)	1	12.5	13.4	11.7
2004	Salmon	20	12.1	18.9	16.8
	Trout (Freshwater)	2	6.3	14.0	12.3
	Trout (Seawater)	2	12.4	18.6	17.2
2006	Salmon	19	n.a.	30.0	25.9
	Trout (Freshwater)	2	n.a.	20.9	18.9
2007	Salmon	17	n.a.	18.3	16.4
	Trout	2	n.a.	18.5	16.3
	Trout (Freshwater)	2	n.a.	17.0	15.2
2008	Salmon	16	14.2	15.8	14.0
	Trout (Freshwater)	2	8.9	8.1	7.2
	Trout (Seawater)	3	13.9	11.8	10.4
2009	Salmon	15	14.7	15.4	13.7
	Trout (Freshwater)	3	7.7	8.7	7.9
	Trout (Seawater)	3	13.0	11.9	10.5

Source: Marine Institute

2.2.6 MI Bivalve Molluscs and Fish Landings Monitoring Program

Since 1993, MI has carried out PCB analysis in excess of 700 (pooled) samples. Table 14 provides mean concentrations for the sum of 7 and sum of 6 Marker PCBs determined under the various monitoring programs.

Table 14 Analyses for Marker PCBs carried out in port landings and shellfish

Programme	Year	N	Mean of Sum 7 Marker PCBs	Mean of Sum 6 Marker PCBs
			µg/kg whole weight	
Fish Port Landings	1995	15	2.6	2.3
	1996	9	4.4	3.9
	2000	15	2.5	2.3
	2001	11	8.8	7.8
	2004	14	1.5	1.4
	2005	13	3.8	3.5
	2006	10	0.4	0.4
	2007	10	0.9	0.8
	2008	10	1.8	1.5
	2009	10	2.1	1.9
	2010	11	3.0	2.6
	2011	11	1.9	1.6
Fish Port Landings Total		139	2.8	2.5
Spatial Shellfish Monitoring*	1993	50	9.8	8.3
	1994	31	26.0	22.7
	1995	9	1.9	1.7
	1996	12	1.7	1.5
	1997	7	4.5	4.0
	1998	5	3.7	3.3
	1999	10	4.1	3.6
	2000	11	2.3	2.1
	2001	27	2.6	2.4
	2002	23	1.1	0.9
	2004	10	1.2	1.0
	2005	17	1.7	1.4
	2006	15	1.3	1.1
	2007	12	1.0	0.9
	2009	9	1.2	1.0
	2010	8	1.2	1.0
	2011	6	1.5	1.2
Spatial Shellfish Monitoring Total		262	6.3	5.5
Shellfish Waters Directive Monitoring	2008	60	0.9	0.7
	2009	113	0.8	0.7
	2010	123	0.8	0.7
	2011	18	1.1	0.9
Shellfish Waters Directive Monitoring Total		314	0.8	0.7
Grand Total		715	3.2	2.8

* spatial shellfish – predominantly taken for the purpose of environmental monitoring and not food safety
Source: Marine Institute

2.2.7 DAFM Infant Formula and Follow on Formula Monitoring Program

Results for WHO TEQ (1998) PCDD/Fs in infant formula and follow on formula samples (N=12) monitored by DAFM between 2008 - 2009 ranged from 0.14 - 0.16 pg/g fat. 50 % of the samples were analysed for Total WHO TEQs (PCDD/Fs & DL-PCBs) which ranged from 0.21 – 0.30 pg/g fat. Ingredients of infant formula (N=103) were monitored between 2010 - 2013. Approximately one third of the samples were screened using a bioassay screening method, which returned 100 % compliant results, results for the remaining samples, which were analysed using full congener analysis ranged from 0.16 - 0.39 pg/g fat for WHO TEQ PCDD/Fs and 0.17 - 0.49 pg/g fat for Total WHO TEQ (PCDD/F & DL-PCBs). All results were found to be below established legislative maximum limits. Marker PCBs are not included under this program.

2.2.8 BIM Ad hoc salmon survey

The 2004 survey conducted by BIM on potential effects of cooking or removal of the skin-fat layer from the sample suggested that cooking did not appear to have an influence, whereas removal of skin generally led to a decrease of contaminant concentration (see Table 15). Results from this survey were in agreement with findings in salmon of an FSAI survey of the same year.

Table 15 Overview of results of 2004 BIM study on the effects of cooking and skin removal on contaminant concentration in farmed salmon, expressed as Total WHO TEQ pg/g whole weight and Sum of 6 marker PCBs in ng/g whole weight(ww)

Farmed salmon		WHO TEQ (1998) PCDD/F & DL-PCBs pg/g whole weight			Sum of 6 Marker PCBs ng/g whole weight		
		Min	Max	Mean	Min	Max	Mean
Skin off	cooked	0.8	1.9	1.2	5.6	13.2	8.1
	uncooked	0.7	1.6	1.1	4.6	10.7	7.4
Skin off Total		0.7	1.9	1.1	4.6	13.2	7.7
Skin on	cooked	1.2	3.2	1.9	7.8	22.4	12.7
	uncooked	1.0	3.2	1.7	6.6	21.5	11.8
Skin on Total		1.0	3.2	1.8	6.6	22.4	12.3
Overall Total (ww)		0.7	3.2	1.5	4.6	22.4	10.0
Overall Total (fat weight)		7.5	27.2	14.0	209	756	400

Data Source: BIM

3 Dietary Background Exposure of the Irish Population to Dioxins and PCBs

In general, exposure to contaminants present in food cannot be measured directly and therefore indirect approaches, such as combining consumption data with contaminant concentration data are used to estimate exposure. The following chapter provides the results of an exposure assessment based on historic food consumption data and in the following describes in detail the updated exposure assessment, based on more recent food consumption and occurrence data.

3.1 Overview of exposure estimate based on North/South Ireland Food Consumption Survey (NSIFCS) 1997 - 1999

A first estimate of dietary intake to dioxins was conducted in 2006, which utilised available food consumption data and occurrence data at the time.

3.1.1 Food Consumption Database

The North/South Ireland Food Consumption Survey (NSIFCS) was carried out by the Irish Universities Nutrition Alliance (IUNA) and investigated habitual food and beverage consumption, lifestyle, health indicators and attitudes to food and health in a representative sample (n=1379) of the 18 - 64 year old adult population in the Republic of Ireland and Northern Ireland during 1997 - 1999. Food intake was determined using a 7-day estimated food record (IUNA, 2001). All data collected was stored in relational Statistical Package for the Social Sciences (SPSS) databases.

The modifications applied to the food consumption database for the exposure assessment included disaggregation of recipes into their constituent ingredients, application of weight loss factors and application of fat fraction factors. These mirror the methodologies described in detail in section 3.2.1.

3.1.2 Concentration Data

Background exposure was estimated using occurrence data available for each food group collected between 2002 and 2006, and was estimated for intake from foods of animal origin and vegetable oils/fats. For the purpose of probabilistic modelling, all data points for each food group were used as inputs in the model when available (i.e. for some food groups only single values were available).

3.1.3 Exposure Model

Exposure assessments were conducted using a Monte Carlo simulation (McNamara *et al,* 2003) using the web-based software application Creme™ (Creme Software Ltd., 2006) which performs exposure assessments using probabilistic modelling. Estimated intake was based on the combination of distributions of concentration data collected between 2002 and 2006 and food consumption data collected as part of the NSIFCS (IUNA, 2001). Exposure to dioxins was estimated based on consumption of eggs, dairy products, meat, offal, vegetable oil and fish recorded in the NSIFCS.

Left censored data (data falling below the Limit of Quantification (LOQ)) was treated in two ways, either computed as <LOQ=LOQ (upperbound (UB)) or <LOQ=0 (lowerbound (LB)) and results are reported as LB and UB estimates.

3.1.4 Results and Discussion

Table 16 provides the mean and 97.5th percentile exposure estimate for the Total TEQ (PCDD/F & DL-PCB), using both the 1998 and 2005 TEF schemes. All results are provided as lowerbound and upperbound concentrations.

Table 16 Estimated exposure of the Irish adult population to Total WHO TEQ in pg/kg bw per month for PCDD/Fs & DL-PCBs from intake of fish, meat, offal, dairy products, vegetable oils, bivalve molluscs and eggs produced in Ireland

	Average intake		P97.5 intake	
	pg/kg bw/month			
	LB	UB	LB	UB
Total WHO TEQ (1998)	10	12	47	49
Total WHO TEQ (2005)	9	10	39	41

Exposure of the average adult consumer to upperbound Total WHO TEQ (PCDD/Fs & DL-PCBs) (2005) was estimated at 10 pg/kg bw, which compared to the WHO PMTI of 70 pg/kg bw falls within 14 % of the tolerable monthly intake, and exposure of the above average consumer (P97.5) is estimated at 41 pg/kg bw per month, falling within 59 % of the tolerable monthly intake.

Comparing the Total WHO TEQ (1998) estimates with exposure values reported in Table 5 suggests that the exposure of the Irish population to dioxins in food is less than the European average.

Since then, more recent occurrence data has become available for some of the food groups, and also more recent food consumption data has been published (IUNA, 2011). The exposure calculated in the following chapters is based on this newly available data.

3.2 Exposure estimate based on National Adult Nutrition Survey (NANS) 2008 - 2010

3.2.1 Food Consumption Database

The NANS was conducted between 2008 and 2010 by IUNA (IUNA, 2011). The survey collected provides data for 1500 adults (including elderly) on food, beverage and nutritional supplement intake along with habitual physical activity levels, attitudes to food and health and factors influencing food choice. Physical measurements including weight, height, body fat and blood pressure were also taken. Four day, semi-weighed food diaries were used to record the food and drink intake of the participants. Each time food/drink was consumed, it was recorded as well as the location, amount, cooking method and quantity of each food item/drink consumed.

All data collected was stored in relational SPSS databases. The primary food consumption file (food file) provides food intake on an individual level, with each individual line in the file representing one single eating occasion recorded by the participant. In total, the database comprises 133068 rows of data. Food items are coded following the food classification system as described in Mc Cance and Widdowson's (MCW) Composition of Food and supplementary editions (Chan *et al,* 1994; Chan, 1995; Chan, 1996; Holland *et al,* 1989; Holland *et al,* 1991; Holland *et al,* 1992a; Holland *et al,* 1992b; McCance *et al,* 1988; McCance and Widdowson, 2002) and supplemented with additional national codes developed by IUNA for foods for which no suitable MCW code was available. In total, 2552 different foodcodes were used to classify food recorded in this survey. In tandem with this survey, also information on recipes and food ingredients were collected when available and entered into two databases as follows:

3.2.1.1 Recipe Database

The recipe database contains information on constituent ingredients of composite foods recorded in the consumption surveys. Contribution to the total weight of the composite food is recorded for each Ingredient based either on recipes as recorded by the survey participants or standard recipe information available from MCW Composition of Food and supplementary editions (Chan *et al,* 1994; Chan, 1995; Chan, 1996; Holland *et al,* 1989; Holland *et al,* 1991; Holland *et al,* 1992a; Holland *et al,* 1992b; McCance *et al,* 1988; McCance and Widdowson, 2002). Of the 2552 foodcodes used in the database, recipe information was available for 26 % (15 % IUNA recipes, 11 % McCance and Widdowson recipes).

3.2.1.2 National Food Ingredients Database (INFID)

The Irish National Food Ingredients Database (INFID) was first established by researchers at UCD and UCC and includes data on food additives, packaging type and ingredient data for brand foods consumed by food consumption survey participants. Since then, updated versions accompanying each new food consumption survey have become available and are to be used in tandem with the survey for which they were collected (IUNA, 1999; IUNA, 2006; IUNA, 2010; IUNA, 2012).

3.2.2 Modification of the Food Consumption Database

For the purposes of estimating exposure to dioxins, the NANS foodfile was manipulated to convert the food consumption data as described in sections 3.2.2.1 to 3.2.2.4. The final foodfile used in the exposure assessment model comprised fat intake from food disaggregated into ingredients and converted back to raw as appropriate. The final database therefore presents a convenient tool to estimate exposure to lipophilic substances, such as dioxins and other POPs.

3.2.2.1 Disaggregation of recipes/composite foods into ingredients

Recipes or composite dishes were disaggregated into single ingredients using the recipe database (see 3.2.1.1). This allowed for the conversion of 26 % of foodcodes into ingredients. Where no recipe was available for a particular composite food, recipe fractions were either derived based on comparable composite foods for which information was available, extrapolated from the list of ingredients using INFID (see 3.2.1.2) or derived from ingredient information available on the labels of pre-packaged food sold in Ireland. These approaches were used for another 20 % of foodcodes contained in the database. The remainder, i.e. 54 % of foodcodes did not require further disaggregation.

In order to retain subject specific information and to create a new SPSS database containing information on the final ingredient, the original database was re-coded into a multitude of sub-files, each containing different ingredient information. These were subsequently merged back into one file. For a number of foodcodes, an additional step had to be applied as some of the ingredients required further disaggregation into sub-ingredients. Table 17 provides an example for the composite food "Apple Slices/Lattice", which contains 7 ingredients, of which ingredient 1 contains a further 6 sub-ingredients.

Table 17 Example of disaggregated composite food

Foodcode	Ingredient number	Sub-ingredient number	Ingredient	Sub-Ingredient
Apple Slices/Lattice	1	1	Flaky pastry, raw	Wheat flour, white, plain
Apple Slices/Lattice	1	2	Flaky pastry, raw	Margarine
Apple Slices/Lattice	1	3	Flaky pastry, raw	Butter
Apple Slices/Lattice	1	4	Flaky pastry, raw	Salt
Apple Slices/Lattice	1	5	Flaky pastry, raw	Water, distilled
Apple Slices/Lattice	1	6	Flaky pastry, raw	Lemon juice, fresh
Apple Slices/Lattice	2	0	Wheat flour, white, plain	Wheat flour, white, plain
Apple Slices/Lattice	3	0	Cooking apples, raw peeled	Cooking apples, raw peeled
Apple Slices/Lattice	4	0	Sugar, white	Sugar, white
Apple Slices/Lattice	5	0	Cinnamon, ground	Cinnamon, ground
Apple Slices/Lattice	6	0	Lemon juice, fresh	Lemon juice, fresh
Apple Slices/Lattice	7	0	Eggs, chicken, whole, raw	Eggs, chicken, whole, raw

This procedure was applied to 46 % of all foodcodes contained in the database, which varied in the number of final ingredients from between 2 to 37 ingredients. Overall, this procedure resulted in the addition of 105609 rows to the original database (133068 rows), creating a new database of 238677 rows of information. The number of foodcodes used for classifying the disaggregated final ingredients was 1759, compared to the original number of 2552 required to classify the original foodfile. The observed reduction is due to less foodcodes being required to describe single ingredients than foodcodes required to describe all composite foods and recipes.

On finalisation of this procedure, rigorous quality checks were performed on all data to test against coding and weight conversion errors. This included re-aggregation of the entire database to compare aggregated weight for each foodcode (addition of recipe ingredient weights) against the weight recorded in the original database and checking of aggregated recipe information (foodcodes and ingredient fractions) against information held in the recipe databases.

3.2.2.2 Conversion of cooked weight into raw weight

Heat treatment of food, such as frying, baking, boiling, etc may result in the change of composition, in particular gain or loss of water and gain or loss of fat. The change in water status is usually covered by weight loss or weight gain factors to be applied in tandem with recipe fractions and recipe ingredients are typically recorded in their raw state (see Table 18).

For foods, which were prepared and were not part of a recipe, weight loss factors were applied separately, based on information contained in MCW Composition of Food and supplementary editions (Chan *et al,* 1994; Chan, 1995; Chan, 1996; Holland *et al,* 1989; Holland *et al,* 1991; Holland *et al,* 1992a; Holland *et al,* 1992b; McCance *et al,* 1988; McCance and Widdowson, 2002) and weight loss and yield factors published by the Bundesforschungsanstalt für Ernährung (Bognár, 2002). Application of these factors typically results in an increase of the originally recorded weight (due to the correction for loss of water and/or fat) but in some cases can also result in a decrease of the original weight (due to the correction for gain of water, i.e. rice, spaghetti, etc).

Table 18 Example of recipe with recorded weight loss factor

Composite food	Raw ingredients	Ingredient portion (g)	Raw ingredient weight (g)	Ingredient fraction	Weight loss after cooking (%)
Homemade Lentil, Onion & Carrot Soup	Lentils, red, split, dried, raw	250	1720	0.145	0.28
	Onions, raw	250	1720	0.145	0.28
	Carrots, old, raw	420	1720	0.244	0.28
	Stock cubes, chicken	5	1720	0.003	0.28
	Water, distilled	795	1720	0.462	0.28

3.2.2.3 Conversion of weight of food consumed into fat from food consumed

Since POPs are associated with the fat compartment of foods, the weight of food consumed was converted into fat intake from foods consumed via the application of fat fractions. The latter were derived from compositional information contained in MCW Composition of Food and supplementary editions (Chan *et al,* 1994; Chan, 1995; Chan, 1996; Holland *et al,* 1989; Holland *et al,* 1991; Holland *et al,* 1992a; Holland *et al,* 1992b; McCance *et al,* 1988; McCance and Widdowson, 2002), compositional information recorded by IUNA for foodcodes derived by IUNA, or in absence of the former two options, derived from nutritional information available from pre-packaged foods sold at retail.

3.2.2.4 Assignment of a purpose built food classification system

In order to facilitate the exposure assessment, MCW and IUNA foodcodes were converted into a purpose built 3 tiered food classification system (Category I, II and III), which groups fat intake from related foods into food groups and food categories (see Annex 7.1). The introduction of this system considerably reduced the amount of coding required to combine dioxin concentration data with food consumption data.

3.2.3 Exposure assessment methodology

When separate data sets are available for food consumption, as measured in food consumption surveys, and for chemical concentration, one of three approaches is usually applied to combine or integrate the data to provide an estimate of exposure: (i) point estimates; (ii) simple distributions; and (iii) probabilistic analyses. The method chosen will usually depend on a number of factors, including the purpose of the assessment (target chemical, population group, degree of accuracy required) and the availability of data. (Kroes *et al,* 2002).

For the purposes of this assessment, a probabilistic model was chosen to facilitate an as accurate as possible exposure of the adult population to general background concentration. This type model allows for usage of all data points collected. Furthermore, using full data distributions better takes into account variability of both the survey population and the presence of dioxins in the environment. Exposure assessments were conducted using a Monte Carlo simulation (McNamara *et al,* 2003) using the web-based software application Creme™ (Creme Software Ltd., 2013a), which performs exposure assessments using probabilistic modelling.

For all exposure scenarios calculated here, distributions of data have been used for both occurrence data (see section 3.3.2) and food consumption data (see section 3.2.1), and for each scenario, intake for a population of 30000 people was simulated (i.e. 20 iterations of 1500 people, i.e. the number of NANS survey participants, see 3.3.1).

Typically, chronic exposure estimates are calculated for mean and high percentile consumers of the total population, the latter typically expressed as the 95th percentile (EFSA, 2011b). In addition, to facilitate comparison with modelling of the 2008 incident concentration data (see chapter 4.4.4), also the median and additional percentiles (P97.5, P98 and P99) were included in this model

Since PCDD/Fs and DL-PCBs persist and concentrate in the lipids of biological systems, foods of animal origin (see section 1.2), which naturally contain a considerable portion of fat, and vegetable oils and fats are considered the major foods of interest with regard to dioxin exposure. Therefore, of the eleven Category I food categories contained in the converted foodfile (see Annex 7.1), the following six were included in the model: Dairy, Eggs, Fats & Oils, Fish & Fish Products, Meat & Meat Products and Oil based supplements. As consumption of food in the foodfile has been converted into intake of fat from these food groups a direct match with concentration data, which is expressed on a fat weight basis, was possible. The matching of concentration data and food data was done at Category level I, II or level III, depending on the amount of detail available (see Annex 7.3).

Left censored data was treated in two ways, computed as UB and LB and results are reported as ranges. This approach was chosen as very few data points were below the LOQ and the range between LB and UB was hence expected to be very small. This approach is in line with recent recommendations issued by EFSA (EFSA, 2010a).

For this exposure scenario six output models were developed:

- Total WHO TEQ (1998) PCDD/F&DL-PCBs – LB
- Total WHO TEQ (1998) PCDD/F&DL-PCBs – UB
- Total WHO TEQ (2005) PCDD/F&DL-PCBs - LB
- Total WHO TEQ (2005) PCDD/F&DL-PCBs - UB
- Sum of 6 Marker PCBs - LB
- Sum of 6 Marker PCBs - UB

For each model, intake for the total population was calculated, expressed as intake per kilogram bodyweight per day (kg/bw/d) to facilitate comparison with health based guidance values which are expressed on a kg bw basis. Exposure estimates were calculated based on average daily intakes, however, since averages over a small number of days may not adequately represent individual usual long term intake due to the large amount of random error, calculation of "usual" or "lifetime" was also added to the model, based on the methodologies developed by Nusser (Nusser et al, 1996). However, the technique of estimating usual intakes relies on the ability to transform the input data to normality and this requirement is tested using the Anderson-Darling test statistic (Creme Software Ltd., 2013b). Several food groups included in the models failed this requirement and therefore usual intake estimates could not be calculated for these food groups. Also, overall total intake figures could not be expressed on a lifetime basis, as the aggregated data failed the Anderson-Darling test. Therefore, overall assessment of total intake from all food groups could only be based on statistics derived from average daily intakes. However, the availability of lifetime estimates for some food groups provides some indication of the potential over-estimation of higher percentiles based on average daily intakes due to presence of inter-individual variation.

3.2.4 Concentration Data

Background exposure was estimated using the most recent occurrence data available for each food group and was derived from occurrence data available for Ireland (see Chapter 2). For the purpose of probabilistic modelling, all data points for each food group were used as inputs for data distributions in the model, where available (i.e. for some food groups only single values were available).

3.2.5 Presence Probability

Occurrence of POPs in the modelled food groups is generally ubiquitous and therefore a presence probability of 100 % was assigned in order to estimate general background exposure to the Irish population from dietary intake. This means that it was assumed that all food in the food groups was contaminated.

3.3 Results and Discussion

3.3.1 Number of Iterations required

To determine the number of iterations required to produce robust statistical outcomes, the 99^{th} percentile and change in % of Error were chosen as performance indicators. The model was run repeatedly with an increasing number of iterations until the error of the 99^{th} percentile stabilised.

Figure 6 Change of P99+/- Error and 95 % confidence interval over increasing iterations

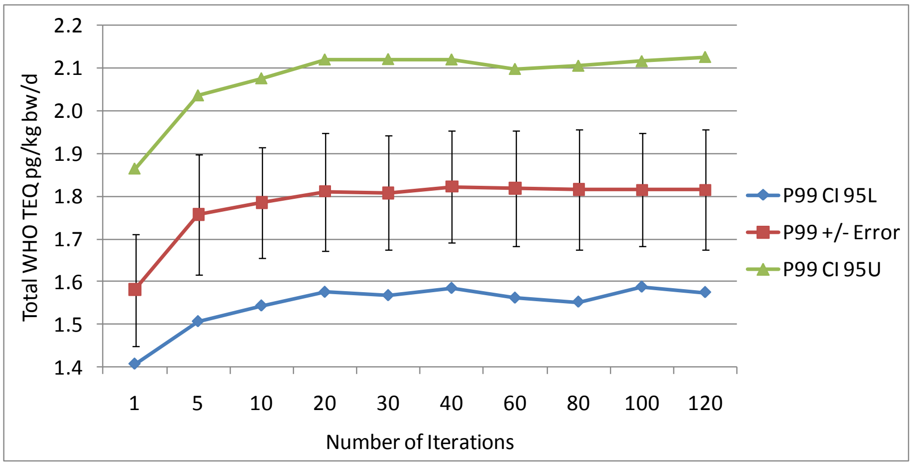


Figure 7 Change of Error of Mean, Median, P95 and P99 over increasing iterations

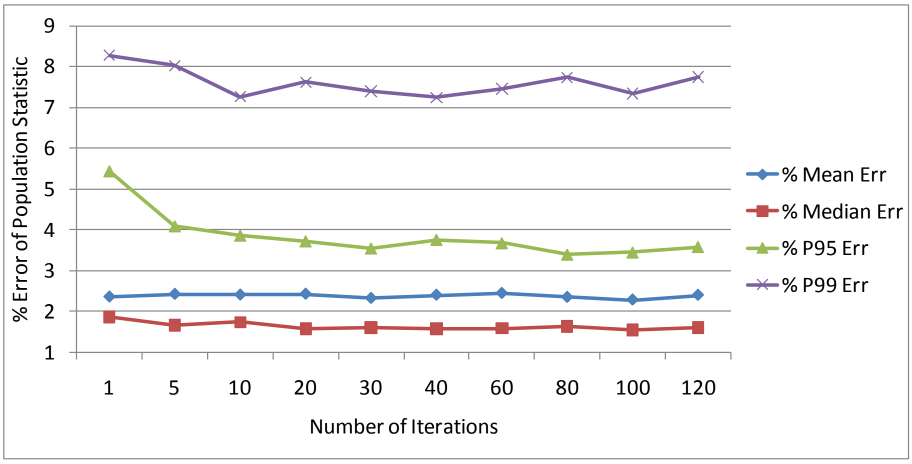


Figure 6 shows that stabilisation of the 99th percentile value occurs from 20 iteration onwards, whereas Figure 7 shows that the % Error of the 99th percentile fluctuates between 7 - 8 % with no significant improvement over increasing iterations. Therefore, the model was run over 20 iterations.

3.3.2 Concentration Data

Table 19 provides an overview of data used in the exposure assessment providing the minimum, average and maximum for the Total TEQ (PCDD/F & DL-PCB), using both the 1998 and 2005 TEF schemes and for the sum of 6 Marker PCBs. All results are provided as LB and UB concentrations. The distributions of data used for each food group is shown as tables in the Annex (see Annex 7.3)

3.3.2.1 Bovine, porcine, avian and ovine fat, bovine and porcine liver and eggs

General background concentration of dioxins and PCBs in animal fat and liver were derived from routine monitoring programmes conducted by FSAI, the latest available data having been collected in 2006 (see Table 19). Meat and liver results are based on composite samples (N=10 - 40) collected from slaughterhouses all over Ireland and egg results are based on composite samples (N=24) collected from packing stations all over Ireland, in accordance with Directive 1883/2006/EC (EC, 2006e).

3.3.2.2 Dairy Fat

General background concentration of dioxins and PCBs in milk were derived from routine monitoring programmes conducted by FSAI, the latest available data for milk having been collected in 2006 - 2009 (see Table 19). Results comprise individual and composite samples (N=2) collected from bulk tankers all over Ireland, in accordance with Directive 1883/2006/EC (EC, 2006e). Information on dairy spreads is available from 2003 based on a composite sample of ten subsamples.

3.3.2.3 Fish

General background concentrations of dioxins and PCBs in fish were derived from routine monitoring programmes conducted by FSAI, the latest available data for fresh fish and shellfish having been collected in 2010 and for canned fish in 2004 (see Table 19). Results are based on individual fish and composite samples (N=1 - 200) collected from aquaculture, ports and/or retail, in accordance with Directive 1883/2006/EC (EC, 2006e).

3.3.2.4 Fats and Oils, excl butter

General background concentration of dioxins and PCBs in fats, oils and dairy spreads were derived from routine monitoring programmes conducted by FSAI, the latest available data having been collected in 2003 (see Table 19). Results are based on individual samples collected at retail, in accordance with Directive 1883/2006/EC (EC, 2006e).

3.3.2.5 Food Supplements

General background concentration of dioxins and PCBs in food supplements were derived from routine monitoring programmes conducted by FSAI, the latest available data having been collected in 2005 (see Table 19). Results are based on individual samples collected at retail, in accordance with Directive 1883/2006/EC (EC, 2006e).

Table 19 Overview of concentration data used to estimate background exposure expressed in ng/kg fat for Total WHO TEQ and µg/kg for the sum of 6 Marker PCBs

Year	Food Category	Species	N	Sub N	TOTTEQ1998 (LB)			TOTTEQ1998 (UB)			TOTTEQ2005 (LB)			TOTTEQ2005 (UB)			6 Marker PCBs (LB)			6 Marker PCBs (UB)		
				Range	min	mean	max	min	mean	max	min	mean	max	min	mean	max	min	mean	max	min	mean	max
2006	Carcass Fat	Avian	11	10-40	0.16	0.37	0.83	0.18	0.39	0.83	0.14	0.32	0.69	0.15	0.33	0.69	0.48	1.69	4.25	0.48	1.69	4.25
2006		Avian (Duck)	2	20	0.08	0.1	0.11	0.12	0.13	0.14	0.07	0.09	0.1	0.09	0.1	0.11	0.25	0.26	0.26	0.25	0.26	0.26
2006		Bovine	9	10	0.17	0.54	0.77	0.2	0.56	0.78	0.14	0.49	0.71	0.16	0.5	0.71	0.68	0.92	1.34	0.68	0.92	1.34
2006		Ovine	10	10	0.35	0.48	0.71	0.37	0.5	0.73	0.33	0.45	0.66	0.34	0.45	0.66	0.71	0.94	1.13	0.71	0.94	1.13
2006		Porcine	6	20	0.06	0.23	0.86	0.13	0.28	0.88	0.07	0.22	0.81	0.11	0.26	0.81	0.34	0.62	0.95	0.34	0.62	0.95
2006-2009	Dairy	Milk	39	1-2	0.16	0.32	0.62	0.22	0.37	0.66	0.15	0.3	0.6	0.19	0.32	0.6	0.21	0.41	0.95	0.26	0.47	1.04
2006	Eggs	Barn, Battery, F. Range	15	24	0.06	0.22	0.37	0.2	0.31	0.42	0.06	0.21	0.33	0.17	0.27	0.36	0.23	3.21	30.62	0.37	3.25	30.62
2003	Fats and Oils	Mixed Fat	1	7	0.43	0.43	0.43	0.45	0.45	0.45	0.39	0.39	0.39	0.4	0.4	0.4	0.59	0.59	0.59	1.03	1.03	1.03
2003		Vegetable Oil	2	3	0.01	0.03	0.05	0.09	0.1	0.1	0.01	0.03	0.04	0.06	0.07	0.07	0.02	0.07	0.11	0.35	0.39	0.42
2003		Dairy Spread	1	10	0.07	0.07	0.07	0.13	0.13	0.13	0.06	0.06	0.06	0.11	0.11	0.11	0	0	0	0.84	0.84	0.84
2010	Fish	Cod	4	4-44	2.14	3.63	6.72	2.35	3.77	6.73	2.21	3.71	6.86	2.4	3.84	6.87	13.12	23.27	48.47	13.12	23.38	48.47
2010		Farmed Salmon	6	5-6	7.32	10.18	12.51	7.32	10.18	12.51	7.25	10.07	12.4	7.25	10.07	12.4	59.05	80.74	102.15	59.05	80.74	102.15
2010		Haddock	5	4-10	1.08	6.63	15.9	1.46	6.72	15.92	1.12	6.62	16.03	1.4	6.7	16.04	7	26.49	74	7	26.49	74
2010		Hake	1	5	7.24	7.24	7.24	7.25	7.25	7.25	7.35	7.35	7.35	7.36	7.36	7.36	78.98	78.98	78.98	78.98	78.98	78.98
2010		Lemon Sole	4	7-34	3.14	7.7	11.37	3.15	7.71	11.37	2.94	7.2	10.64	2.95	7.2	10.64	12.59	22.63	35.21	12.59	22.63	35.21
2010		Ling	2	3-5	4.3	6.58	8.86	4.36	6.63	8.89	4.32	6.64	8.96	4.39	6.69	8.99	35.27	49.43	63.58	35.27	49.43	63.58
2010		Mackerel	5	11-30	3.96	8.89	15.53	3.96	8.89	15.53	3.9	8.71	15.29	3.9	8.71	15.29	25.08	61.38	127.54	25.08	61.38	127.54
2010		Monk Fish	4	3-15	2.44	6.92	18.96	2.46	6.94	18.98	2.33	6.62	18.14	2.35	6.64	18.15	11.06	31.35	84.58	11.06	31.35	84.58
2010		Mussels	5	122-200	2.15	9	17.13	2.15	9	17.14	2.1	8.73	16.46	2.1	8.74	16.47	7.17	24.22	47.83	7.41	24.48	47.83
2010		Plaice	2	10-29	7.94	12.61	17.27	7.95	12.61	17.27	7.5	12	16.49	7.5	12	16.49	33.98	61.29	88.6	33.98	61.29	88.6
2010		Prawns	1	141	1.2	1.2	1.2	1.2	1.2	1.2	1.1	1.1	1.1	1.11	1.11	1.11	1.49	1.49	1.49	1.58	1.58	1.58
2010		Ray	1	10	5.48	5.48	5.48	5.49	5.49	5.49	5.23	5.23	5.23	5.24	5.24	5.24	17.47	17.47	17.47	17.47	17.47	17.47
2010		Sea Trout	2	5	5.04	5.23	5.43	5.04	5.23	5.43	4.94	5.14	5.34	4.94	5.14	5.34	39.14	40.19	41.23	39.14	40.19	41.23
2004		Tinned herring	2	5	4.79	5.11	5.42	4.81	5.13	5.44	3.93	4.15	4.36	3.94	4.16	4.38	26.71	28.63	30.54	26.71	28.63	30.54
2004		Tinned Mackerel	2	5	3.23	3.33	3.43	3.34	3.46	3.57	2.78	2.87	2.96	3	3.12	3.23	16.93	17.47	18.01	16.93	17.47	18.01

N= number of composite samples; Sub-N = Number of subsamples in the composite; UB = upperbound; LB = lowerbound, TOTEQ1998 = Total WHO TEQ (1998) Sum of PCDD/F & DL-PCBs based on 1998 TEF system; TOTEQ2005 = Total WHO TEQ (2005) Sum of PCDD/F & DL-PCBs based on 2005 TEF system

Table 19 continued Summary statistics concentration data used to estimate background exposure expressed in ng/kg fat for Total WHO TEQ (TOTEQ) and µg/kg for the sum of 6 Marker PCBs

Year	Food Category	Species	N	Sub N	TOTTEQ1998 (LB)			TOTTEQ1998 (UB)			TOTTEQ2005 (LB)			TOTTEQ2005 (UB)			6 Marker PCBs (LB)			6 Marker PCBs (UB)		
				Range	min	mean	max	min	mean	max	min	mean	max	min	mean	max	min	mean	max	min	mean	max
2004		Tinned pink salmon	3	5	0.99	1.16	1.29	1.25	1.43	1.62	0.76	0.91	1.03	1.15	1.36	1.56	8.88	10.48	12.13	8.88	10.48	12.13
2004		Tinned red salmon	2	5	4.14	5.9	7.66	4.27	5.98	7.69	3.37	4.84	6.31	3.67	5.01	6.34	21.4	28.66	35.92	21.4	28.66	35.92
2004	Fish	Tinned sardines	1	5	7.09	7.09	7.09	7.2	7.2	7.2	6.74	6.74	6.74	6.95	6.95	6.95	8.89	8.89	8.89	8.89	8.89	8.89
2004		Tinned tuna	5	5	0	0.32	1.56	0.49	3.18	7.1	0	0.31	1.56	0.56	3.58	7.93	0	0.6	2.14	0.63	4.34	9.83
2010		Tuna	5	1	4.48	5.16	6.71	4.49	5.16	6.71	4.54	5.24	6.73	4.54	5.24	6.73	43.86	55.76	78	43.86	55.76	78
2010		Whiting	5	7-35	1.25	13.22	27.16	1.29	13.26	27.16	1.21	13.02	27.21	1.25	13.07	27.22	9.77	82.25	173.73	9.77	82.25	173.73
2006		Avian	3	10-40	0.24	0.39	0.62	0.25	0.41	0.65	0.21	0.37	0.6	0.22	0.37	0.6	0.38	1.13	1.95	0.38	1.13	1.95
2006		Bovine	2	10	1.56	1.62	1.68	1.64	1.68	1.72	1.39	1.46	1.54	1.44	1.5	1.55	2.94	3.06	3.18	2.94	3.06	3.18
2006	Offal	Equine	2	10	6.04	14.23	22.42	6.08	14.25	22.43	5.11	11.99	18.86	5.12	11.99	18.86	2.9	4.33	5.75	2.9	4.33	5.75
2006		Ovine	2	10	4.22	4.71	5.19	4.25	4.73	5.2	3.34	3.72	4.1	3.35	3.72	4.1	2.13	3.49	4.85	2.13	3.49	4.85
2006		Porcine	2	10	0.68	0.91	1.14	0.74	0.97	1.2	0.58	0.77	0.97	0.61	0.8	1	0.46	0.52	0.57	0.46	0.52	0.57
2005		Fish oil	27	1-6	0	2.96	10.11	0.45	3.28	10.15	0	2.11	8.2	0.46	2.54	8.24	0.11	37.87	131.79	0.24	37.97	131.79
2005		Oil	1	2	0.43	0.43	0.43	0.85	0.85	0.85	0.12	0.12	0.12	0.63	0.63	0.63	17.95	17.95	17.95	17.95	17.95	17.95
2005	Supplements	omega FA	8	1-4	0	0.4	1.4	0.69	1.12	1.55	0	0.38	1.69	0.78	1.22	1.8	0	2.11	8.32	0.86	2.9	8.32
2005		Plant oil	5	1	0	0.01	0.05	0.68	0.76	0.86	0	0.01	0.05	0.77	0.86	0.98	0	0	0	0.85	0.94	1.09
2005		Vitamin prep.	2	1	0.03	0.06	0.08	0.81	1.07	1.32	0.03	0.06	0.08	0.91	1.21	1.5	0	0	0	0.96	1.32	1.68

N= number of composite samples; Sub-N = Number of subsamples in the composite; UB = upperbound; LB = lowerbound; TOTEQ1998 = Total WHO TEQ (1998) Sum of PCDD/F & DL-PCBs based on 1998 TEF system; TOTEQ2005 = Total WHO TEQ (2005) Sum of PCDD/F & DL-PCBs based on 2005 TEF system

3.3.3 Exposure Estimates

3.3.3.1 Food consumption

<u>Survey Population Count</u>

Table 20 provides the number of consumers within the overall NANS survey population of N= 1500 that consumed food within the food categories of interest.

Table 20 Amount of consumers of total population (N=1500) in each food group selected

Category Name	Group Name	Total Population	Food Consumers	
		N	N	%
DAIRY	DAIRY, MILKS	1500	1463	97.5
	DAIRY, CREAMS	1500	779	51.9
	DAIRY, CHEESE	1500	1151	76.7
	DAIRY, BUTTER	1500	1083	72.2
	DAIRY, YOGHURTS	1500	708	47.2
	TOTAL	1500	1498	99.9
EGGS	EGGS, CHICKEN	1500	1254	83.6
	EGGS, DUCK	1500	4	0.27
	TOTAL	1500	1254	83.6
MEAT AND MEAT PRODUCTS	MEAT AND MEAT PRODUCTS, BEEF	1500	1062	70.8
	MEAT AND MEAT PRODUCTS, PORK	1500	1295	86.3
	MEAT AND MEAT PRODUCTS, POULTRY	1500	1218	81.2
	MEAT AND MEAT PRODUCTS, LAMB	1500	260	17.3
	MEAT AND MEAT PRODUCTS, MIXED MEAT	1500	7	0.47
	MEAT AND MEAT PRODUCTS, OTHER	1500	4	0.27
	OFFAL, PORK	1500	23	1.5
	OFFAL, POULTRY	1500	6	0.40
	OFFAL, LAMB	1500	19	1.3
	OFFAL, BEEF	1500	12	0.80
	TOTAL	1500	1476	98.4
FISH AND FISH PRODUCTS	FISH AND FISH PRODUCTS, OILY FISH	1500	481	32.1
	FISH AND FISH PRODUCTS, WHITE FISH	1500	409	27.3
	FISH AND FISH PRODUCTS, SHELLFISH	1500	116	7.7
	FISH AND FISH PRODUCTS, OTHER	1500	6	0.40
	FISH AND FISH PRODUCTS, MIXED FISH	1500	2	0.13
	TOTAL	1500	798	53.2
FATS AND OILS EXCL BUTTER	FAT/DAIRY SPREADS EXCL BUTTER	1500	1385	92.3
	OILS	1500	1464	97.6
	TOTAL	1500	1493	99.5
SUPPLEMENTS	SUPPLEMENTS, OILS/FATTY ACIDS	1500	200	13.3
	TOTAL	1500	200	13.3

For several food groups, namely, "Eggs, Duck", "Offal, Pork", "Offal, Poultry", "Meat and Meat Products, Mixed Meat", "Offal, Lamb", "Offal, Beef", "Meat and Meat Products, Other", "Fish and Fish Products, Other" and "Fish and Fish Products, Mixed", the number of consumers was very low, ranging from 2 - 23 consumers, which indicates that these foods are rarely consumed by Irish adults in comparison to other foods. The latter is important when calculating high percentiles, as these are used to identify consumers with above average consumption. The issue of reliability of high percentiles has recently been addressed by EFSA (EFSA, 2011a) who proposed guidelines for the minimum number of samples for which (extreme) percentiles can be computed, namely at $n \geq 59$ and $n \geq 298$ for the 95th or 99th percentiles, respectively. All of the above-mentioned food groups have considerably less than 59 consumers, therefore, the higher percentiles calculated for the estimate of dioxin exposure for these food groups are not statistically robust and consequently have a very wide uncertainty associated with them. However, estimates derived on category basis, with the exception of food supplements, which only shows 200 consumers, have sufficient consumer numbers to calculate robust extreme percentiles.

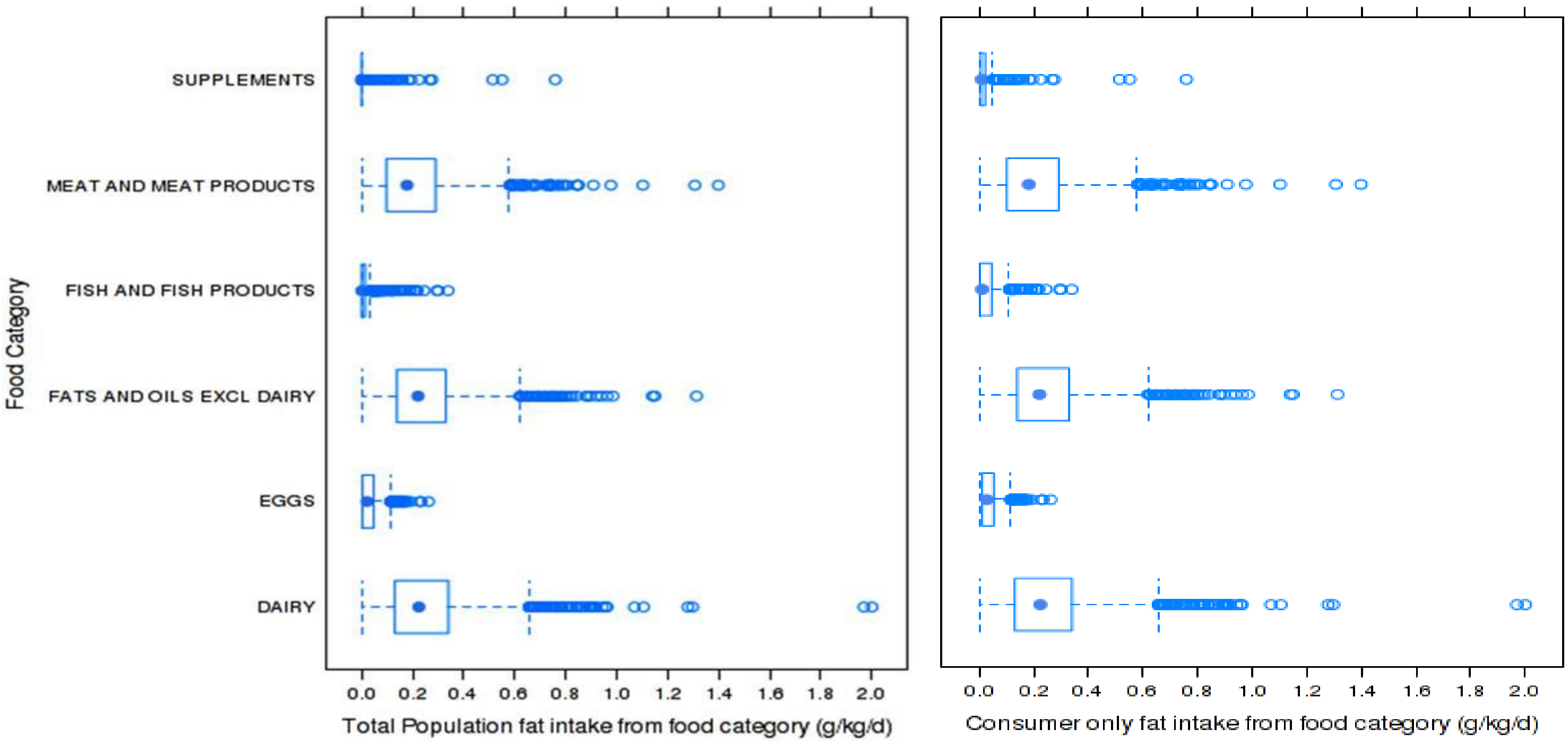
Also, for these rarely consumed foods, calculation of lifetime values was not possible, due to the low consumer count. To enable calculation of the latter, information on frequency of consumption is needed, which was not collected as part of the NANS.

Intake of fat from food groups

Table 21 provides an overview of fat intake from the six food categories of interest. The overall fat intake of the total population was on average 0.8 g fat/kg bw/d with a 95th percentile intake of 1.4 g fat/kg bw/d. The 99th percentile intake of fat was estimated at 1.9 g fat/kg bw/d. The food categories "Dairy", "Meat and meat products" and "Fats and Oils" contributed to 93 % of average daily fat intake. The major individual food group contributors were "Fats/dairy spreads excluding butter" and "oils" contributing on average 16.7 % and 15.5 %, respectively, followed by "Meat and meat products, pork" and "Dairy, milks", contributing on average 13 % and 11 %, respectively. The categories, "Fish and fish products", "Eggs" and "Supplements" were found to be minor contributors to total average fat intake, contributing 2.1 %, 3.9 % and 0.6 %, respectively.

Figure 8 provides a comparison of total population intake versus consumers only intake per food category. With the exception of "Fish and fish products" and "Supplements", the distributions are in good agreement, which can be attributed to the high number of consumers in the food groups displayed. The boxplots further indicate that the distributions are skewed to the right.

Figure 8 Boxplot of Total Population and Consumer only fat intake from food categories included in the exposure assessment, expressed as g fat/kg bw/



To account for inter-individual variation in food consumption, a lifetime model was also run on the same data. For a number of food groups, this was not possible due to insufficient data or violation of the lifetime model requirement of normality of the transformed distribution. For the following groups no lifetime intake could be calculated: "Eggs, Duck", "Meat and meat products, Other", Meat and Meat Products, Mixed Meat", "Offal, Beef", "Offal, Lamb", "Offal, Pork", "Offal, Poultry", "Fish and Fish products, Mixed Fish" and "Fish and Fish Products, Other". For the remaining food groups, for which lifetime estimates could be calculated, a number of warnings were received however (see Table 22) and results are to be interpreted with caution.

Mean average daily and mean lifetime values, where available, are generally in good agreement, whereas for higher percentiles, lifetime values are generally lower than average daily values (see Figure 9), which is expected due to the reduction of variance within the distribution by the model applied (Creme Software Ltd., 2013b). The latter ("tightening of the distribution") also leads to an increase in the median values for lifetime estimates for some food groups.

However, since lifetime values could not be calculated for all food groups of interest, average daily intakes have been used for the assessment of total intake and note has been taken that higher percentile intakes are likely to present an overestimate of lifelong high percentile exposure. At the 95th percentile, lifetime estimates for the categories "Dairy", "Eggs", "Meat", "Fish" and "Fats & Oils" were 15, 28, 28, 43 and 13 % lower than estimates derived based on average daily intakes, respectively.

Figure 9 Comparison of summary statistics for consumption of g fat/kg bw/d derived using average daily intake (DA) versus lifetime estimates (LIFE)

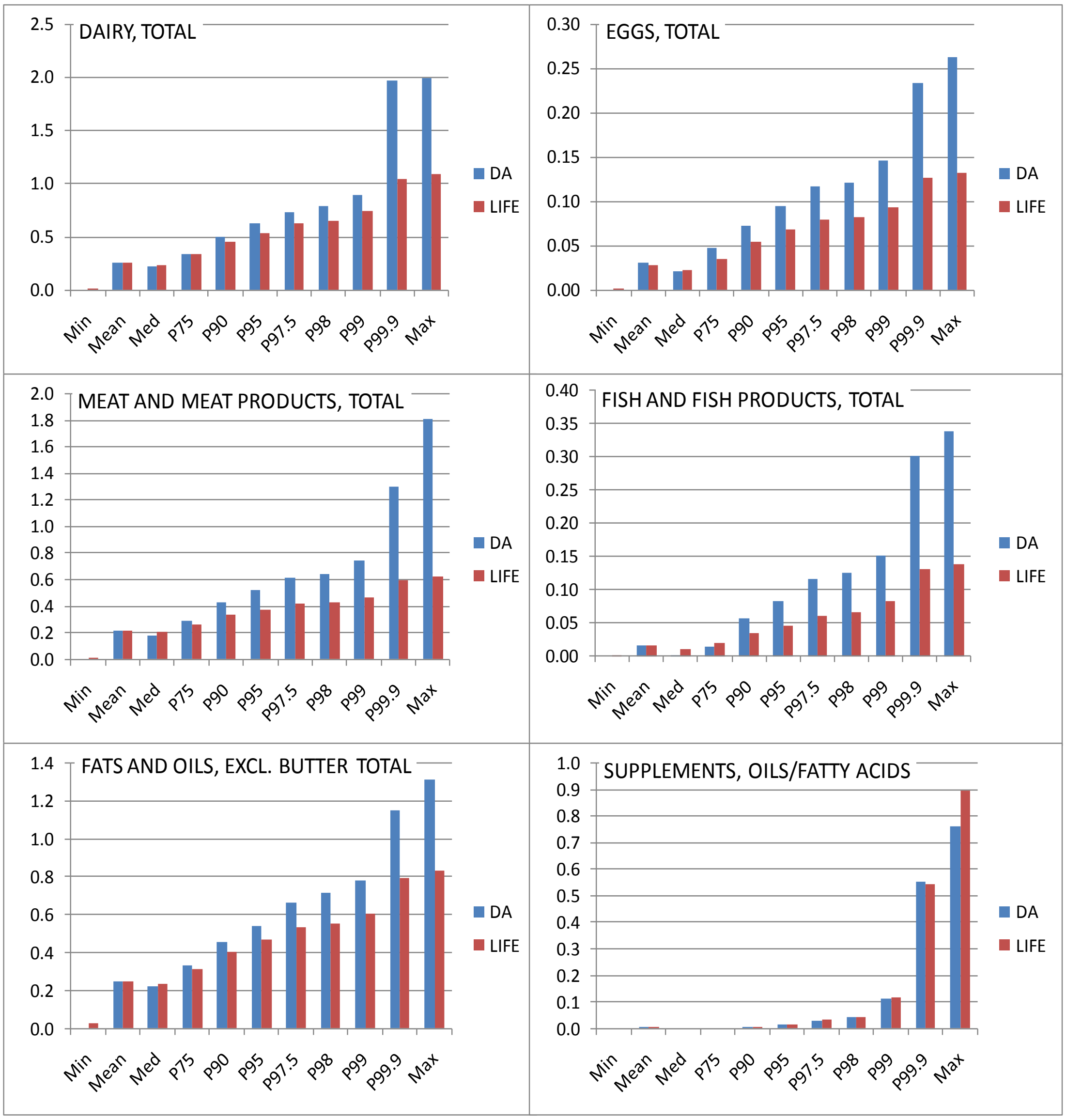


Table 21 Mean and high percentile Intakes of fat from six food groups, expressed as g/kg bw/d

Group Name	% Contribution to mean of		Total population fat intake from food groups (g fat/kg bw/d)									
	Category	Total	Min	Mean	Med	P75	P90	P95	P97.5	P98	P99	Max
DAIRY, MILKS	33.3	11.2	0	0.09	0.06	0.1	0.2	0.2	0.3	0.3	0.4	0.8
DAIRY, CREAMS	10.4	3.5	0	0.03	0.004	0.04	0.08	0.1	0.2	0.2	0.2	0.4
DAIRY, YOGHURTS	3.7	1.3	0	0.010	0	0.01	0.03	0.05	0.06	0.06	0.08	0.2
DAIRY, CHEESE	27.8	9.4	0	0.07	0.05	0.1	0.2	0.2	0.3	0.3	0.4	0.7
DAIRY, BUTTER	24.8	8.4	0	0.07	0.03	0.08	0.2	0.2	0.3	0.4	0.5	1.8
DAIRY TOTAL	100	33.7	0	0.3	0.2	0.3	0.5	0.6	0.7	0.8	0.9	2.0
EGGS, CHICKEN	99.6	3.9	0	0.03	0.02	0.05	0.07	0.10	0.1	0.1	0.1	0.3
EGGS, DUCK	0.4	0.02	0	0.0001	0	0	0	0	0	0	0	0.06
EGGS TOTAL	100	3.9	0	0.03	0.02	0.05	0.07	0.10	0.1	0.1	0.1	0.3
MEAT AND MEAT PRODUCTS, BEEF	32.7	9.0	0	0.07	0.05	0.1	0.2	0.2	0.3	0.3	0.4	0.6
MEAT AND MEAT PRODUCTS, LAMB	9.5	2.6	0	0.02	0	0	0.08	0.1	0.2	0.2	0.3	0.9
MEAT AND MEAT PRODUCTS, PORK	47.0	12.9	0	0.1	0.07	0.1	0.2	0.3	0.4	0.4	0.5	0.9
MEAT AND MEAT PRODUCTS, POULTRY	10.4	2.9	0	0.02	0.010	0.02	0.05	0.10	0.2	0.2	0.3	0.7
MEAT AND MEAT PRODUCTS, OTHER	0.04	0.01	0	0.00008	0	0	0	0	0	0	0	0.06
MEAT AND MEAT PRODUCTS, MIXED MEAT	0.10	0.03	0	0.0002	0	0	0	0	0	0	0	0.2
OFFAL, BEEF	0.02	0.00	0	0.00004	0	0	0	0	0	0	0	0.02
OFFAL, LAMB	0.13	0.03	0	0.0003	0	0	0	0	0	0	0.003	0.06
OFFAL, PORK	0.07	0.02	0	0.0001	0	0	0	0	0	0	0.002	0.07
OFFAL, POULTRY	0.01	0.002	0	0.00001	0	0	0	0	0	0	0	0.01
MEAT AND OFFAL TOTAL	100	27.5	0	0.2	0.2	0.3	0.4	0.5	0.6	0.6	0.7	1.8

Table 21 continued, Mean and high percentile Intakes of fat from six food groups, expressed as g/kg bw/d

Group Name	% Contribution to mean of		Total population fat intake from food groups (g fat/kg bw/d)									
	Category	Total	Min	Mean	Med	P75	P90	P95	P97.5	P98	P99	Max
FISH AND FISH PRODUCTS, WHITE FISH	8.3	0.17	0	0.001	0	0.001	0.004	0.007	0.01	0.01	0.02	0.06
FISH AND FISH PRODUCTS, OILY FISH	89.9	1.9	0	0.01	0	0.009	0.05	0.08	0.1	0.1	0.1	0.3
FISH AND FISH PRODUCTS, MIXED FISH	0.01	0.0002	0	0.000001	0	0	0	0	0	0	0	0.001
FISH AND FISH PRODUCTS, SHELLFISH	1.8	0.04	0	0.0003	0	0	0	0.001	0.003	0.004	0.007	0.04
FISH AND FISH PRODUCTS, OTHER	0.07	0.002	0	0.00001	0	0	0	0	0	0	0	0.005
FISH AND FISH PRODUCTS, TOTAL	100	2.1	0	0.02	0.001	0.01	0.06	0.08	0.1	0.1	0.2	0.3
FAT/DAIRY SPREADS EXCL BUTTER	51.8	16.7	0	0.1	0.10	0.2	0.3	0.4	0.5	0.5	0.6	1.3
OILS	48.2	15.5	0	0.1	0.1	0.2	0.2	0.3	0.4	0.4	0.4	1.1
FATS&OILS EXCL BUTTER TOTAL	100	32.2	0	0.3	0.2	0.3	0.5	0.5	0.7	0.7	0.8	1.3
SUPPLEMENTS, OILS/FATTY ACIDS	100	0.6	0	0.005	0	0	0.006	0.01	0.03	0.05	0.1	0.8
SUPPLEMENTS TOTAL	100	0.6	0	0.005	0	0	0.006	0.01	0.03	0.05	0.1	0.8
ALL FOODGROUPS TOTAL	100	100	0.05	0.8	0.7	1.0	1.2	1.4	1.6	1.6	1.9	3.2

Table 22 Lifetime estimate of mean and high percentile Intakes of fat from six food groups, expressed as g/kg bw/d

Group Name	% Contribution to mean of		Total population fat intake from food groups (g fat/kg bw/d) (based on lifetime estimates)										Lifetime Notes
	Category	Total	Min	Mean	Med	P75	P90	P95	P97.5	P98	P99	Max	
DAIRY, MILKS	35	12	0.0005	0.09	0.07	0.1	0.2	0.2	0.3	0.3	0.4	0.7	-6
DAIRY, CREAMS	9.9	3.3	0	0.03	0.02	0.04	0.05	0.07	0.09	0.09	0.1	0.2	-2
DAIRY, YOGHURTS	3.9	1.3	0	0.01	0.004	0.01	0.03	0.04	0.06	0.06	0.07	0.1	-6
DAIRY, CHEESE	27	9.1	0.002	0.07	0.06	0.10	0.1	0.2	0.2	0.2	0.2	0.3	-6
DAIRY, BUTTER	25	8.4	0	0.07	0.05	0.09	0.1	0.2	0.2	0.3	0.3	0.6	-4
DAIRY TOTAL	100	34	0.02	0.3	0.2	0.3	0.5	0.5	0.6	0.7	0.7	1.1	-6
EGGS, CHICKEN	100	3.5	0.002	0.03	0.02	0.04	0.06	0.07	0.08	0.08	0.09	0.1	-6
EGGS, DUCK	0.4	0.02											3
EGGS TOTAL	100	3.6	0.002	0.03	0.02	0.04	0.06	0.07	0.08	0.08	0.09	0.1	-6
MEAT AND MEAT PRODUCTS, BEEF	31	8.6	0	0.07	0.06	0.09	0.1	0.1	0.1	0.2	0.2	0.4	-6
MEAT AND MEAT PRODUCTS, LAMB	13	3.4	0	0.03	0	0.05	0.08	0.10	0.1	0.1	0.1	0.2	-2
MEAT AND MEAT PRODUCTS, PORK	46	13	0	0.10	0.09	0.1	0.2	0.2	0.2	0.3	0.3	0.4	-2
MEAT AND MEAT PRODUCTS, POULTRY	12	3.2	0.002	0.03	0.02	0.03	0.05	0.06	0.07	0.08	0.09	0.2	-6
MEAT AND MEAT PRODUCTS, OTHER	0.04	0.010											3
MEAT AND MEAT PRODUCTS, MIXED MEAT	0.1	0.03											3
OFFAL, BEEF	0.02	0.005											3
OFFAL, LAMB	0.1	0.03											3
OFFAL, PORK	0.07	0.02											12
OFFAL, POULTRY	0.001	0.0004	0	0.000003	0	0	0	0	0	0.00002	0.00006	0.004	-36
MEAT AND OFFAL TOTAL	100	28	0.01	0.2	0.2	0.3	0.3	0.4	0.4	0.4	0.5	0.6	-2

Table 22 continued Lifetime estimate of mean and high percentile Intakes of fat from six food groups, expressed as g/kg bw/d

Group Name	% Contribution to mean of		Total population fat intake from food groups (g fat/kg bw/d) based on lifetime estimates										Lifetime Notes
	Category	Total	Min	Mean	Med	P75	P90	P95	P97.5	P98	P99	Max	
FISH AND FISH PRODUCTS, WHITE FISH	8.2	0.2	0	0.001	0.001	0.002	0.002	0.003	0.003	0.003	0.004	0.005	-6
FISH AND FISH PRODUCTS, OILY FISH	94	1.9	0	0.02	0.007	0.02	0.04	0.06	0.08	0.09	0.1	0.2	-6
FISH AND FISH PRODUCTS, MIXED FISH	0.008	0.0002											3
FISH AND FISH PRODUCTS, SHELLFISH	1.0	0.02	0	0.0002	0	0.0001	0.0006	0.0009	0.001	0.001	0.002	0.004	-38
FISH AND FISH PRODUCTS, OTHER	0.07	0.002											3
FISH TOTAL	100	2.1	0.0005	0.02	0.01	0.02	0.03	0.05	0.06	0.07	0.08	0.1	-6
FAT/DAIRY SPREADS EXCL BUTTER	51	17	0.002	0.1	0.1	0.2	0.3	0.3	0.4	0.4	0.4	0.7	-6
OILS	48	15	0.008	0.1	0.1	0.2	0.2	0.2	0.3	0.3	0.3	0.4	-2
FATS&OILS EXCL BUTTER TOTAL	100	32	0.03	0.3	0.2	0.3	0.4	0.5	0.5	0.6	0.6	0.8	-2
SUPPLEMENTS, OILS/FATTY ACIDS	100	0.6	0	0.005	0	0	0.006	0.01	0.03	0.05	0.1	0.9	-20
SUPPLEMENTS TOTAL	100	0.6	0	0.005	0	0	0.006	0.01	0.03	0.05	0.1	0.9	-20
ALL FOODGROUPS TOTAL		100											3

Lifetime return values:-2: Added extra lower endpoints to curve fit; 3: Usual Intake could not be calculated due to insufficient or unsuitable data; -4: Added extra upper endpoints to curve fit; -6: Added extra lower endpoints to curve fit & Added extra upper endpoints to curve fit; 12: Negative variance of Usual Intakes [too few people with multiple observations]; -36: Added extra upper endpoints to curve fit & Fourth moment of Usual intakes less than 3.0; -38: Added extra lower endpoints to curve fit & Added extra upper endpoints to curve fit & Fourth moment of Usual intakes less than 3.0

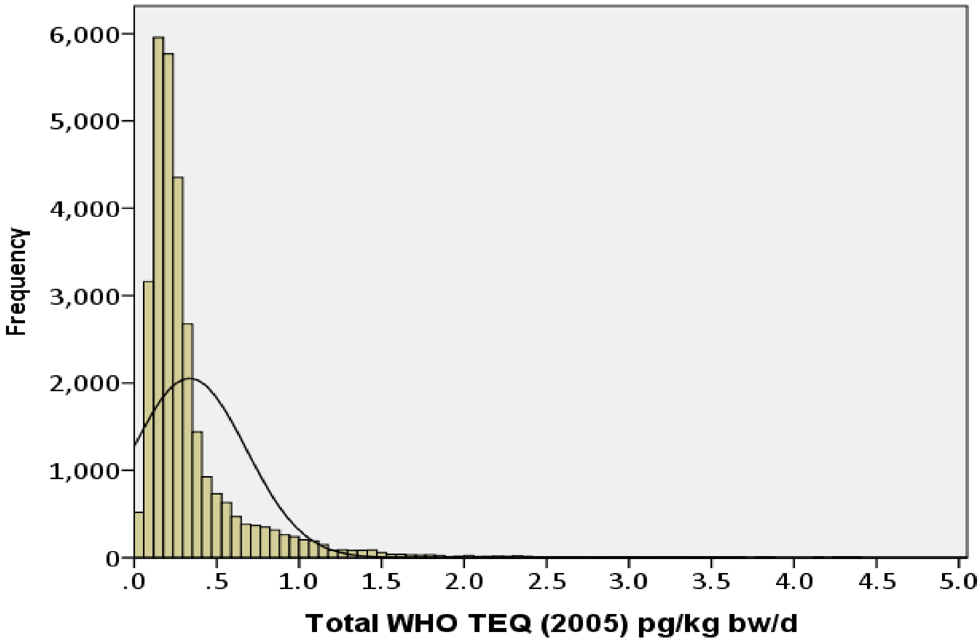
3.3.3.2 Background exposure to TOTAL WHO TEQ (PCDD/F&DL-PCBs)

Table 23 shows summary statistics for total exposure to Total WHO TEQ (2005), reported as LB - UB range for mean, median and higher percentile intake, expressed as pg/kg bw/d and Table 24 provides summary statistics for all food groups. Figure 10 displays the exposure distribution for total intake from the six food groups considered. Results expressed using the 1998 TEF scheme are provided in the Annex (see Annex 7.4) to facilitate comparison with previous results.

Table 23 Overall total exposure to Total TEQ (PCDD/F&DL-PCB) WHO (2005) pg/kg bw/d

	LB - UB Total TEQ (PCDD/F&DL-PCB) WHO (2005) pg/kg bw/d				
	Mean	Med	P95	P97.5	P99
TOTAL	0.3 - 0.3	0.2 - 0.2	0.9 - 1	1.2 - 1.3	1.7 - 1.8

Figure 10 Total Population Distribution of exposure to Total WHO TEQ from six food groups



Total mean average daily intake to Total WHO TEQ (2005) was estimated at 0.3 pg/kg bw/d and 95th percentile intake at 0.9 - 1 pg/kg bw/d, which translates into a monthly (30 day) intake of 9 pg/kg bw/m at the mean and 27 - 30 pg/kg bw/m at the 95th percentile. At the 99th percentile intake was estimated at 1.7 - 1.8 pg/kg bw/d, which translates into a monthly intake of 51 - 54 pg/kg bw/m.

The most important contributor to the mean average daily exposure comes from the category "Fish and fish products", contributing up to 41 % to the total exposure, followed by "Meat and meat products" and "Dairy", each contributing up to 25 % to the total exposure.

These exposure figures can be compared to the WHO PMTI of 70 pg/kg bw indicating a mean exposure of 13 % of the tolerable monthly intake, and exposure of the 95th percentile consumer falling within 39 - 43 % of the tolerable monthly intake. Estimated intake at the 99th percentile falls within 73 - 77 % of the PMTI.

As observed for fat intake from the food groups of interest, lifetime exposure values, where available (see Table 25), are lower for high percentile consumers, which suggests that high percentile long-term exposure may be lower than estimated based on average daily intake values. Consequently, the median values increase with also the mean values for food categories "Fish and fish products" and "Supplements", which are not consumed as frequently as the other food groups, increasing due to the removal of variance in the distribution.

Table 24 Range of LB - UB summary statistics of exposure to Total WHO TEQ (2005) expressed as pg/kg bw/d and % contribution to the total mean average daily intake

Group Names	LB - UB Total TEQ (PCDD/F&DL-PCB) WHO (2005) pg/kg bw/d (Statistics derived based on average daily intake)								
	% Contribution	Mean	Med	P75	P90	P95	P97.5	P98	P99
DAIRY, MILKS	8.7-8.5	0.03-0.03	0.02-0.02	0.04-0.04	0.06-0.06	0.08-0.08	0.1-0.1	0.1-0.1	0.1-0.1
DAIRY, CREAMS	2.7-2.6	0.008-0.009	0.0009-0.001	0.01-0.01	0.02-0.03	0.03-0.04	0.05-0.05	0.06-0.06	0.08-0.08
DAIRY, YOGHURTS	1-1	0.003-0.003	-	0.004-0.004	0.01-0.01	0.01-0.02	0.02-0.02	0.02-0.02	0.02-0.03
DAIRY, CHEESE	7.3-7.1	0.02-0.02	0.01-0.02	0.03-0.03	0.05-0.06	0.07-0.08	0.09-0.1	0.1-0.1	0.1-0.1
DAIRY, BUTTER	6.5-6.3	0.02-0.02	0.009-0.01	0.02-0.03	0.05-0.06	0.08-0.08	0.1-0.1	0.1-0.1	0.1-0.2
DAIRY	26-25	0.08-0.09	0.07-0.07	0.1-0.1	0.1-0.2	0.2-0.2	0.2-0.2	0.2-0.3	0.3-0.3
EGGS, CHICKEN	2.1-2.4	0.006-0.008	0.004-0.006	0.01-0.01	0.02-0.02	0.02-0.03	0.03-0.03	0.03-0.03	0.03-0.04
EGGS, DUCK	0.008-0.009	0.00002-0.00003	-	-	-	-	-	-	-
EGGS	2.1-2.4	0.006-0.008	0.004-0.006	0.01-0.01	0.02-0.02	0.02-0.03	0.03-0.03	0.03-0.03	0.03-0.04
MEAT AND MEAT PRODUCTS, BEEF	11-11	0.03-0.04	0.02-0.02	0.05-0.05	0.09-0.09	0.1-0.1	0.2-0.2	0.2-0.2	0.2-0.2
MEAT AND MEAT PRODUCTS, LAMB	3-2.8	0.009-0.009	-	-	0.04-0.04	0.06-0.06	0.09-0.09	0.1-0.1	0.1-0.1
MEAT AND MEAT PRODUCTS, PORK	7.2-7.7	0.02-0.03	0.009-0.01	0.03-0.03	0.06-0.07	0.09-0.09	0.1-0.1	0.1-0.1	0.2-0.2
MEAT AND MEAT PRODUCTS, POULTRY	2.4-2.2	0.007-0.007	0.003-0.003	0.007-0.007	0.02-0.02	0.03-0.03	0.05-0.05	0.06-0.06	0.08-0.08
MEAT AND MEAT PRODUCTS, OTHER	0.009-0.008	0.00003-0.00003	-	-	-	-	-	-	-
MEAT AND MEAT PRODUCTS, MIXED MEAT	0.03-0.03	0.0001-0.0001	-	-	-	-	-	-	-
OFFAL, BEEF	0.01-0.01	0.00003-0.00003	-	-	-	-	-	-	-
OFFAL, LAMB	0.3-0.3	0.0009-0.0009	-	-	-	-	-	-	0.002-0.002
OFFAL, PORK	0.03-0.03	0.00009-0.0001	-	-	-	-	-	-	0.001-0.002
OFFAL, POULTRY	0.002-0.002	0.000005-	-	-	-	-	-	-	-
MEAT AND MEAT PRODUCTS	24-24	0.07-0.08	0.06-0.06	0.1-0.1	0.2-0.2	0.2-0.2	0.2-0.3	0.3-0.3	0.3-0.3

Table 24 continued Range of LB - UB summary statistics of exposure to Total WHO TEQ (2005) expressed as pg/kg bw/d and % contribution to the total mean average daily intake

Group Names	LB - UB Total TEQ (PCDD/F&DL-PCB) WHO (2005) pg/kg bw/d (Statistics derived based on average daily intake)								
	% Contribution	Mean	Med	P75	P90	P95	P97.5	P98	P99
FISH AND FISH PRODUCTS, WHITE FISH	2.6-2.4	0.008-0.008	-	0.003-0.004	0.02-0.02	0.05-0.05	0.09-0.09	0.09-0.09	0.1-0.1
FISH AND FISH PRODUCTS, OILY FISH	38-36	0.1-0.1	-	0.001-0.03	0.5-0.5	0.7-0.7	1-1.1	1.1-1.2	1.5-1.5
FISH AND FISH PRODUCTS, MIXED FISH	0.002-0.002	0.000006-	-	-	-	-	-	-	-
FISH AND FISH PRODUCTS, SHELLFISH	0.4-0.3	0.001-0.001	-	-	-	0.001-0.001	0.004-0.004	0.006-0.006	0.04-0.04
FISH AND FISH PRODUCTS, OTHER	0.02-0.02	0.00006-0.00006	-	-	-	-	-	-	-
FISH AND FISH PRODUCTS	41-39	0.1-0.1	0-0.002	0.05-0.08	0.5-0.5	0.7-0.8	1.1-1.1	1.2-1.2	1.5-1.5
FAT/DAIRY SPREADS EXCL BUTTER	2.6-4.3	0.008-0.01	0.006-0.01	0.01-0.02	0.02-0.03	0.02-0.04	0.03-0.05	0.03-0.06	0.04-0.07
OILS	1-2.4	0.003-0.008	0.002-0.007	0.004-0.01	0.006-0.02	0.008-0.02	0.01-0.02	0.01-0.03	0.01-0.03
FATS AND OILS EXCL BUTTER	3.6-6.6	0.01-0.02	0.009-0.02	0.01-0.03	0.02-0.04	0.03-0.05	0.03-0.06	0.03-0.07	0.04-0.08
SUPPLEMENTS, OILS/FATTY ACIDS	2.2-2.8	0.007-0.009	-	-	0.005-0.01	0.02-0.03	0.04-0.06	0.05-0.08	0.1-0.2
SUPPLEMENTS	2.2-2.8	0.007-0.009	0-0	0-0	0.005-0.01	0.02-0.03	0.04-0.06	0.05-0.08	0.1-0.2
TOTAL	100-100	0.3-0.3	0.2-0.2	0.3-0.4	0.7-0.7	0.9-1	1.2-1.3	1.4-1.4	1.7-1.8

Table 25 Lifetime estimate of UB summary statistics of exposure to Total WHO TEQ (2005) expressed as pg/kg bw/d

Group Name	Lifetime statistic UB Total TEQ (PCDD/F&DL-PCB) WHO (2005) pg/kg bw/d								Lifetime return value
	Mean	Med	P75	P90	P95	P97.5	P98	P99	
DAIRY, MILKS	0.03	0.02	0.04	0.06	0.08	0.10	0.1	0.1	0.00*
DAIRY, CREAMS	0.008	0.007	0.01	0.02	0.02	0.03	0.03	0.04	-6.00
DAIRY, YOGHURTS	0.003	0.001	0.004	0.010	0.01	0.02	0.02	0.02	0.00*
DAIRY, CHEESE	0.02	0.02	0.03	0.05	0.06	0.07	0.07	0.08	-2.00
DAIRY, BUTTER	0.02	0.01	0.03	0.05	0.06	0.08	0.09	0.1	0.00
DAIRY	0.08	0.08	0.1	0.1	0.2	0.2	0.2	0.2	0.00*
EGGS, CHICKEN	0.007	0.006	0.009	0.01	0.02	0.02	0.02	0.03	-2.00
EGGS, DUCK									3.00
EGGS	0.007	0.006	0.010	0.01	0.02	0.02	0.02	0.03	-2.00
MEAT AND MEAT PRODUCTS, BEEF	0.03	0.03	0.04	0.06	0.06	0.07	0.08	0.09	-4.00
MEAT AND MEAT PRODUCTS, LAMB	0.01	0	0.02	0.04	0.05	0.05	0.05	0.06	0.00
MEAT AND MEAT PRODUCTS, PORK	0.02	0.02	0.03	0.04	0.05	0.06	0.07	0.07	-2.00
MEAT AND MEAT PRODUCTS, POULTRY	0.008	0.006	0.01	0.02	0.02	0.02	0.02	0.03	-6.00
MEAT AND MEAT PRODUCTS, OTHER									3.00
MEAT AND MEAT PRODUCTS, MIXED MEAT									3.00
OFFAL, BEEF									3.00
OFFAL, LAMB									3.00
OFFAL, PORK									12.00
OFFAL, POULTRY	0.000001	0	0	0	0	0	0.000008	0.00003	-36.00
MEAT AND MEAT PRODUCTS	0.08	0.08	0.10	0.1	0.1	0.2	0.2	0.2	-6.00

Table 25 continued Lifetime estimate of UB summary statistics of exposure to Total WHO TEQ (2005) expressed as pg/kg bw/d

Group Name	Lifetime statistic UB Total TEQ (PCDD/F&DL-PCB) WHO (2005) pg/kg bw/d								Lifetime return value
	Mean	Med	P75	P90	P95	P97.5	P98	P99	
FISH AND FISH PRODUCTS, WHITE FISH	0.008	0.008	0.01	0.01	0.02	0.02	0.02	0.02	-6.00
FISH AND FISH PRODUCTS, OILY FISH	0.1	0.05	0.2	0.4	0.5	0.7	0.8	1.0	-6.00
FISH AND FISH PRODUCTS, MIXED FISH									3.00
FISH AND FISH PRODUCTS, SHELLFISH	0.001	0	0.0004	0.003	0.006	0.010	0.01	0.02	-38.00
FISH AND FISH PRODUCTS, OTHER									3.00
FISH AND FISH PRODUCTS	0.2	0.10	0.2	0.4	0.6	0.8	0.9	1.2	-6.00
FAT/DAIRY SPREADS EXCL BUTTER	0.01	0.01	0.02	0.03	0.03	0.04	0.04	0.05	-6.00
OILS	0.008	0.007	0.010	0.01	0.01	0.02	0.02	0.02	-2.00
FATS AND OILS EXCL BUTTER	0.02	0.02	0.03	0.04	0.04	0.05	0.05	0.06	-2.00
SUPPLEMENTS, OILS/FATTY ACIDS	0.01	0	0	0.01	0.05	0.1	0.1	0.2	0.00*
SUPPLEMENTS	0.01	0	0	0.01	0.05	0.1	0.1	0.2	0.00*
TOTAL									3.00

Lifetime return values:-2: Added extra lower endpoints to curve fit; 3: Usual Intake could not be calculated due to insufficient or unsuitable data; -4: Added extra upper endpoints to curve fit; -6: Added extra lower endpoints to curve fit & Added extra upper endpoints to curve fit; 12: Negative variance of Usual Intakes [too few people with multiple observations]; -36: Added extra upper endpoints to curve fit & Fourth moment of Usual intakes less than 3.0; -38: Added extra lower endpoints to curve fit & Added extra upper endpoints to curve fit & Fourth moment of Usual intakes less than 3.0
*Requirement of normality not met

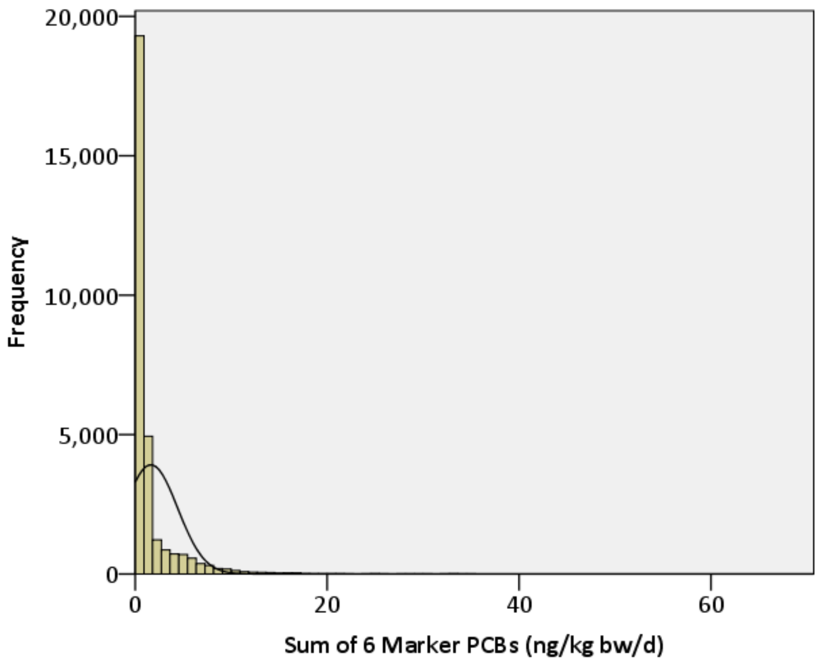
3.3.3.3 Background exposure to Sum of 6 Marker PCBs

Table 26 shows summary statistics for total exposure to sum of 6 Marker PCBs, reported as LB - UB range for mean, median and high percentile intake, expressed as ng/kg bw/d and Table 28 provides summary statistics for all food groups. Figure 11 displays the exposure distribution for total intake from the six food groups considered.

Table 26 Overall total exposure to sum of 6 Marker PCBs ng/kg bw/d

	LB - UB Sum of 6 Marker PCBs ng/kg bw/d (Statistics derived based on average daily intake)				
	Mean	Med	P95	P97.5	P99
TOTAL	1.4 - 1.6	0.5 - 0.7	6.4 - 6.8	9 - 9.3	13 - 13

Figure 11 Total Population Distribution of exposure to sum of 6 Marker PCBs from six food groups



Mean average daily intake of sum of 6 Marker PCBs was estimated at 1.4 - 1.6 ng/kg bw/d and 95th percentile intake at 6.4 - 6.8 ng/kg bw/d. The 99th percentile was estimated at 13 ng/kg bw/d.

The most important contributor to this exposure comes from the category "Fish and Fish Products", contributing up to 64 % to the total exposure, followed by "Meat and Meat Products" contributing up to 13 % to the total exposure.

As observed for dioxins and fat intake, lifetime exposure values, where available (see Table 29), are lower for high percentile consumers, which suggests that high percentile long-term exposure may be lower than estimated based on average daily intake values. Consequently, the median values increase with also the mean values for food categories "Fish and Fish Products" and "Supplements", which are not consumed as frequently as the other food groups, increasing due to the removal of variance in the distribution.

No health based guidance value has been adopted for NDL-PCBs by any scientific body. In absence of the latter, a Margin of Exposure (MoE), or in this case a Margin of Body Burden (MoBB) can be used. In 2005 the EFSA CONTAM Panel (EFSA, 2005), chose an overall body burden of 500 µg/kg bw as a representative conservative body burden at the NOAEL (NOAEL BB) for all individual NDL-PCBs and for the sum of NDL-PCBs occurring in human tissues (see 1.3.2.1)[11].

The UB mean average daily intake of sum of 6 Marker PCBs of 1.6 ng/kg bw/d derived in this study may be converted into an estimate of the body burden (see 1.3.2.1, Equation 3). To account for total NDL-PCB intake, a correction factor of 2[12], as proposed by EFSA (EFSA, 2005), has been applied. The calculated body burden was estimated at 15 µg/kg bw, giving a MoBB at the NOAEL of 33 which is 3 times larger than the MoBB at the NOAEL of 10 estimated by EFSA for the average European population (see 1.3.2.1). However, data from the latest Irish breast milk survey suggest that the ratio between sum of 6 Marker PCBs and total PCBs (as identified by EFSA) is 1.5, which results in a lower estimated body burden of 11.4 µg/kg bw/ with an associated MoBB at the NOAEL of 44.

However, a better indicator of the PCB body burden can be derived from breast milk data. NDL-PCBs were analysed in human breast milk in Ireland in 2002 and in 2009/2010. Average sum of 6 Marker PCBs and sum of all PCBs measured in 2002 were 54 µg/g fat and 74 µg/g fat and in 2010, 41 µg/g fat and 68 µg/g fat, respectively. In the 2010 survey, more PCB congeners were included than in the 2002 study, and the sum of the PCBs for 2010, which were included in the 2002 survey was 61 µg/g fat (see Table 27).

---

[11] The EFSA Panel noted that the NDL-PCB found in human milk are the congeners that accumulate in the human body: PCBs 18, 28, 33, 37, 52, 60, 66, 74, 99, 101, 110, 128, 138, 141, 153, 170, 180, 183, 187, 194, 206, and 209 (EFSA, 2005)

[12] Sum of Marker PCBs can be converted into total NDL-PCB by multiplying the "sum of the three" by 3, the "sum of the six" by 2 and the "sum of the seven" by 2 x 0.85 (the latter factor is a correction for the contribution of PCB 118) (EFSA, 2005)

The average bodyweight recorded in the 2010 breast milk study was 65 kg, which is in line with the average body weight of 67.4 kg reported in the NANS for women 18 - 35 years old. The NANS further reported a mean body fat percent of 31 % for this population group and the latter has been used in the estimation of the body burden (see 1.3.2.1, Equation 3).

Based on a body weight of 65 kg and 30 % body fat the average 2002 levels of 54 and 74 µg/g fat NDL-PCBs in human breast milk correspond to body burdens of 16 µg/kg bw and 22 ng/kg bw for sum of 6 Marker PCBs and sum Total NDL-PCBs, respectively. The average 2010 levels of 41 and 68 µg/g fat NDL-PCBs in human breast milk correspond to body burdens of 12 µg/kg bw and 20 µg/kg bw for sum 6 Marker PCBs and sum Total NDL-PCBs, respectively (see Table 27). Adding up the concentrations of the PCBs identified by EFSA to be present in human milk (see footnote 11) provides a slightly smaller estimate of 19 µg/kg bw.

Table 27 Estimated Body Burden based on NDL-PCBs in breast milk

	Irish Breast milk content		Associated Body Burden	
	2002	2010	2002	2010
	µg/g breast milk fat		µg/kg bw	
Sum 6 Marker PCBs	54	41	16	12
Sum Total PCBs included in both surveys*	73	61	22	18
Sum Total PCBs included in survey	74	68	22	20
Sum Total EFSA-PCBs **	-	62	-	19

* 2004: PCBs 28, 33, 37, 52, 55, 56/60 , 61/74, 66, 101, 122, 124, 128, 138, 141, 153, 170, 180, 183, 187, 194, 206, 209

* 2010: PCBs 18, 28, 31, 33, 37, 41, 44, 47, 49, 51, 52, 56/60 , 61/74, 66, 87, 99, 101, 110, 128, 129, 138, 141, 149, 151, 153, 170, 180, 183, 185, 187, 191, 193, 194, 201 , 202, 203, 206, 208, 209

** PCBs identified by EFSA to be present in human milk: PCBs 18, 28, 33, 37, 52, 60, 66, 74, 99, 101, 110, 128, 138, 141, 153, 170, 180, 183, 187, 194, 206, 209

The BB associated with the total NDL-PCB content of the 2010 breast milk survey of 20 µg/kg bw (19 µg/kg bw when based on PCBs selected by EFSA) is less than the BB of 50 µg/kg bw based on reports from European Member States used by EFSA in their risk assessment. Therefore the MoBB, compared with a NOAEL BB of 500 µg/kg bw calculates at 25 (26 based on EFSA PCBs) for the Irish adult population, compared to a MoBB at the NOAEL of 10 calculated for the European adult population by EFSA.

The MoBBs at the NOAEL of 44 and 25, derived via the two different methods above indicate that the current body burden status of the population is below the NOAEL BB of 500 µg/kg bw and that current intakes are also not of concern. Whereas the average dietary exposure estimate reflects recent eating behaviour and recent occurrence data in food, the breast milk concentration reflects lifetime exposure, which for most of the mothers participating in the breast milk surveys would be in excess of 30 years.

Table 28 Range of LB - UB summary statistics of exposure to sum of 6 Marker PCBs expressed as ng/kg bw/d and % contribution to the total mean average daily intake

Group Names	LB - UB Sum of 6 Marker PCBs ng/kg bw/d (Statistics derived based on average daily intake)								
	% Contribution	Mean	Med	P75	P90	P95	P97.5	P98	P99
DAIRY, MILKS	2.5-2.5	0.04-0.04	0.03-0.03	0.05-0.05	0.08-0.09	0.1-0.1	0.1-0.2	0.1-0.2	0.2-0.2
DAIRY, CREAMS	0.8-0.8	0.01-0.01	0.001-0.001	0.01-0.02	0.03-0.04	0.05-0.05	0.07-0.08	0.08-0.09	0.1-0.1
DAIRY, YOGHURTS	0.3-0.3	0.004-0.005		0.005-0.006	0.01-0.02	0.02-0.02	0.03-0.03	0.03-0.03	0.03-0.04
DAIRY, CHEESE	2.1-2.1	0.03-0.03	0.02-0.02	0.04-0.05	0.07-0.08	0.1-0.1	0.1-0.1	0.1-0.2	0.2-0.2
DAIRY, BUTTER	1.9-1.9	0.03-0.03	0.01-0.01	0.03-0.04	0.07-0.08	0.1-0.1	0.1-0.2	0.2-0.2	0.2-0.2
DAIRY	7.5-7.6	0.1-0.1	0.09-0.1	0.1-0.2	0.2-0.2	0.3-0.3	0.3-0.4	0.3-0.4	0.4-0.4
EGGS, CHICKEN	6.6-6	0.1-0.1	0.02-0.03	0.08-0.08	0.2-0.2	0.5-0.5	0.8-0.8	0.9-0.9	1.2-1.2
EGGS, DUCK	0.03-0.02	0.0005-0.0004							
EGGS	6.7-6.1	0.1-0.1	0.02-0.03	0.08-0.08	0.2-0.2	0.5-0.5	0.8-0.8	0.9-0.9	1.2-1.2
MEAT AND MEAT PRODUCTS, BEEF	4.5-4	0.06-0.06	0.04-0.04	0.09-0.09	0.2-0.2	0.2-0.2	0.3-0.3	0.3-0.3	0.4-0.4
MEAT AND MEAT PRODUCTS, LAMB	1.3-1.2	0.02-0.02			0.08-0.08	0.1-0.1	0.2-0.2	0.2-0.2	0.3-0.3
MEAT AND MEAT PRODUCTS, PORK	4.4-3.9	0.06-0.06	0.04-0.04	0.09-0.09	0.2-0.2	0.2-0.2	0.3-0.3	0.3-0.3	0.3-0.3
MEAT AND MEAT PRODUCTS, POULTRY	2.7-2.3	0.04-0.04	0.01-0.01	0.03-0.03	0.08-0.08	0.1-0.1	0.3-0.3	0.3-0.3	0.5-0.5
MEAT AND MEAT PRODUCTS, OTHER	0.004-0.003	0.00005-0.00005							
MEAT AND MEAT PRODUCTS, MIXED MEAT	0.01-0.01	0.0002-0.0002							
OFFAL, BEEF	0.005-0.004	0.00007-0.00007							
OFFAL, LAMB	0.06-0.05	0.0008-0.0008							0.004-0.004
OFFAL, PORK	0.005-0.005	0.00008-0.00008							0.0009-0.0009
OFFAL, POULTRY	0.001-0.001	0.00002-0.00002							
MEAT AND MEAT PRODUCTS	13-11	0.2-0.2	0.2-0.2	0.2-0.2	0.4-0.4	0.5-0.5	0.6-0.6	0.6-0.6	0.7-0.7

Table 28 continued Range of LB - UB summary statistics of exposure to sum of 6 Marker PCBs expressed as ng/kg bw/d and % contribution to the total mean average daily intake

Group Names	LB - UB Sum of 6 Marker PCBs ng/kg bw/d (Statistics derived based on average daily intake)								
	% Contribution	Mean	Med	P75	P90	P95	P97.5	P98	P99
FISH AND FISH PRODUCTS, WHITE FISH	3.2-2.8	0.05-0.05		0.02-0.02	0.1-0.1	0.2-0.2	0.4-0.5	0.5-0.6	0.8-0.8
FISH AND FISH PRODUCTS, OILY FISH	61-55	0.9-0.9		0.005-0.07	3.5-3.5	5.6-5.8	7.8-8	8.7-8.8	12-12
FISH AND FISH PRODUCTS, MIXED FISH	0.003-0.002	0.00004-0.00004							
FISH AND FISH PRODUCTS, SHELLFISH	0.4-0.3	0.005-0.005				0.002-0.002	0.006-0.006	0.01-0.01	0.1-0.1
FISH AND FISH PRODUCTS, OTHER	0.03-0.02	0.0004-0.0004							
FISH AND FISH PRODUCTS	65-58	0.9-0.9	0.0007-0.004	0.3-0.3	3.6-3.6	5.7-5.8	7.9-8.1	8.8-8.9	12-12
FAT/DAIRY SPREADS EXCL BUTTER	0-6.7	0-0.1	- -0.08	- -0.2	- -0.2	- -0.3	- -0.4	- -0.4	- -0.5
OILS	0.5-2.9	0.008-0.05	0.006-0.04	0.01-0.06	0.02-0.09	0.02-0.1	0.03-0.1	0.03-0.1	0.03-0.2
FATS AND OILS EXCL BUTTER	0.5-9.6	0.008-0.2	0.006-0.1	0.01-0.2	0.02-0.3	0.02-0.4	0.03-0.5	0.03-0.5	0.03-0.6
SUPPLEMENTS, OILS/FATTY ACIDS	7.7-7.5	0.1-0.1			0.08-0.09	0.3-0.4	0.7-0.7	0.9-0.9	2.4-2.4
SUPPLEMENTS	7.7-7.5	0.1-0.1	0-0	0-0	0.08-0.09	0.3-0.4	0.7-0.7	0.9-0.9	2.4-2.4
TOTAL	100-100	1.4-1.6	0.5-0.7	1.1-1.3	4.3-4.5	6.4-6.8	9-9.3	9.7-10	13-13

Table 29 Lifetime estimate of UB summary statistics of exposure to sum of 6 Marker PCBs expressed as ng/kg bw/d

Group Name	Lifetime statistic UB Sum of 6 Marker PCBs ng/kg bw/d								Lifetime return value
	Mean	Med	P75	P90	P95	P97.5	P98	P99	
DAIRY, MILKS	0.04	0.03	0.06	0.09	0.1	0.1	0.2	0.2	0.00*
DAIRY, CREAMS	0.01	0.010	0.02	0.03	0.03	0.04	0.04	0.05	-4.00
DAIRY, YOGHURTS	0.005	0.002	0.006	0.01	0.02	0.03	0.03	0.03	-2.00
DAIRY, CHEESE	0.03	0.03	0.05	0.07	0.08	0.10	0.1	0.1	0.00
DAIRY, BUTTER	0.03	0.02	0.04	0.07	0.09	0.1	0.1	0.2	-2.00
DAIRY	0.1	0.1	0.2	0.2	0.3	0.3	0.3	0.3	-2.00
EGGS, CHICKEN	0.1	0.08	0.2	0.3	0.4	0.5	0.5	0.6	-6.00
EGGS, DUCK									3.00
EGGS	0.1	0.08	0.2	0.3	0.4	0.5	0.5	0.6	-6.00
MEAT AND MEAT PRODUCTS, BEEF	0.06	0.06	0.08	0.1	0.1	0.1	0.1	0.2	-4.00
MEAT AND MEAT PRODUCTS, LAMB	0.03	0	0.05	0.08	0.09	0.1	0.1	0.1	0.00
MEAT AND MEAT PRODUCTS, PORK	0.06	0.06	0.08	0.1	0.1	0.1	0.2	0.2	-2.00
MEAT AND MEAT PRODUCTS, POULTRY	0.05	0.03	0.06	0.10	0.1	0.1	0.2	0.2	-6.00
MEAT AND MEAT PRODUCTS, OTHER									3.00
MEAT AND MEAT PRODUCTS, MIXED MEAT									3.00
OFFAL, BEEF									3.00
OFFAL, LAMB									3.00
OFFAL, PORK									12.00
OFFAL, POULTRY	0.000004	0	0	0	0	0	0.00003	0.0001	-38.00
MEAT AND MEAT PRODUCTS	0.2	0.2	0.2	0.3	0.3	0.4	0.4	0.4	-6.00

Table 29 continued Lifetime estimate of UB summary statistics of exposure to sum of 6 Marker PCBs expressed as ng/kg bw/d

Group Name	Lifetime statistic UB Sum of 6 Marker PCBs ng/kg bw/d								Lifetime return value
	Mean	Med	P75	P90	P95	P97.5	P98	P99	
FISH AND FISH PRODUCTS, WHITE FISH	0.05	0.04	0.06	0.1	0.1	0.2	0.2	0.2	-6.00
FISH AND FISH PRODUCTS, OILY FISH	1.0	0.4	1.2	2.7	4.1	5.6	6.1	7.9	-6.00
FISH AND FISH PRODUCTS, MIXED FISH									3.00
FISH AND FISH PRODUCTS, SHELLFISH	0.005	0	0.0006	0.02	0.03	0.05	0.06	0.08	-38.00
FISH AND FISH PRODUCTS, OTHER									3.00
FISH AND FISH PRODUCTS	1.2	0.9	1.5	2.5	3.4	4.3	4.6	5.6	-6.00
FAT/DAIRY SPREADS EXCL BUTTER	0.1	0.09	0.1	0.2	0.3	0.3	0.3	0.4	-6.00
OILS	0.05	0.04	0.06	0.07	0.09	0.10	0.1	0.1	-2.00
FATS AND OILS EXCL BUTTER	0.2	0.1	0.2	0.3	0.3	0.4	0.4	0.4	-6.00
SUPPLEMENTS, OILS/FATTY ACIDS	0.1	0	0	0.2	0.7	1.5	1.9	3.2	-4.00
SUPPLEMENTS	0.1	0	0	0.2	0.7	1.5	1.9	3.2	-4.00
TOTAL									3.00

Lifetime return value: -2: Added extra lower endpoints to curve fit; 3: Usual Intake could not be calculated due to insufficient or unsuitable data; -4: Added extra upper endpoints to curve fit; -6: Added extra lower endpoints to curve fit & Added extra upper endpoints to curve fit; 12: Negative variance of Usual Intakes [too few people with multiple observations]; -36: Added extra upper endpoints to curve fit & Fourth moment of Usual intakes less than 3.0; -38: Added extra lower endpoints to curve fit & Added extra upper endpoints to curve fit & Fourth moment of Usual intakes less than 3.0
*Requirement of normality not met

3.3.4 Uncertainty Analysis

A review of each step was performed and uncertainties are considered qualitatively, using a tabular format (see Table 30), as recommended by EFSA for refined assessments (EFSA, 2006).

Table 30 Qualitative evaluation of influence of uncertainties on the exposure estimate of dioxin from background contamination of the Irish Adult Population

Source of uncertainty	Direction & magnitude*
Consumption data:	
Representativeness/under-reporting/misreporting/portion size estimation	++/--
Extrapolation from food consumption survey of few days to estimate chronic exposure, especially at high percentiles	++
Modification of (NANS) food consumption database:	
Application of standard recipes, application of extrapolated recipes, application of recipes derived from ingredient information	+/-
Application of conversion factors from cooked to raw food :	+/-
Consumption data applies to the general population and does not consider regions with potential higher consumption due to particular consumption patterns (e.g. fishermen)	--
Food intake has been converted from cooked to raw and does not take into account loss of contaminants due to processing/cooking of the food	+
Occurrence data used in models:	
Exclusion of foods with potentially very low contamination (fruit, vegetable)	-
For some food categories older concentration data was used (data used was collected between 2003-2010)	+
Occurrence data is predominantly based on national food production only and does not take into consideration imported food (with the exception of canned fish)	-
Linkage of food consumption data and occurrence data:	
For some food groups concentration data was extrapolated from other related food groups	+/-
Body Burden Calculations:	
Extrapolations from breast milk concentration data to body burden	+/-
* Key to direction and magnitude: +, ++, +++ = uncertainty likely to cause small, medium or large over-estimation of exposure; -, - -, - - - = uncertainty likely to cause small, medium or large under-estimation of exposure.	

Several sources of potential under- and/or overestimation of exposure were identified. Whilst certain sources of error are difficult to minimise, such as those associated with collecting food consumption information from individuals, for other errors generating additional data would lead to a decrease in uncertainty. In this particular study, additional information on frequency of food consumption via for example a food frequency questionnaire could have assisted in the estimate of long term intake of foods. Surveys targeting specific areas, such as coastal areas would improve knowledge on of specific consumption patterns and collection of up up-to to-date contaminant concentration data for a wider group of foods (thereby decreasing the need for extrapolation from one food type to another), and inclusion of imported foods for all food categories would provide a more precise estimate of exposure. For example, the exclusion of fruit, vegetables and cereals from the exposure assessment was a likely source of under-estimation, but due to generally low occurrence levels in these foodstuffs, exposure estimates are typically driven by the analytical method sensitivity, i.e. where methods have a high LOQ and POPs are not detected, the requirement to estimate upperbound concentrations can greatly overestimate the contribution of these foodstuffs to the overall intake. For this reason, data generated in Ireland in 2003 for fruit, vegetables and cereals (FSAI, 2005b) were not included in the exposure assessment due to the relatively high LOQs reported for these foodstuffs (LOQ of 0.04 pg/g fresh weight).

A study specifically targeted at estimating dioxin exposure from vegetables was conducted in the Netherlands in 2004 (Hoogerbrugge *et al,* 2004), which arrived at a most likely estimated average intake of 0.014 pg TEQ (1998)/kg bw /day (Sum PCDD/F & non-ortho PCBs), contributing to less than 2 % of the mean total daily dioxin intake in the Netherlands, which was deemed negligible by the authors. A recent study undertaken in Spain in 2010 (Perello *et al,* 2012) reported mean medium-bound (MB: <LOD=½LOD) concentrations of TEQ (2005) PCDD/F 0.002 and 0.003 ng/kg fresh weight (fw) in vegetables & tubers and pulses, TEQ (2005) DL-PCBs of 0.003 ng/kg fw in all vegetables including tubers and pulses. Levels reported for fruit and cereals were similar at 0.003 and 0.006 ng/kg fw TEQ (2005) PCDD/F and 0.004 and 0.006 ng/kg fw for TEQ (2005) DL-PCBs, respectively. Summed exposure values reported by Perello et al (2012) indicate an intake of Total WHO TEQ (2005) 2.6 pg/d (0.04 pg/kg bw/d for a 70 kg adult) from fruit and vegetables, presenting approximately 6.8% of total exposure to dioxins. For cereals, the reported figure of 2.7 pg/d represent 7% of total exposure to dioxins.

In an attempt to estimate potential additional exposure of adults resident in Ireland to dioxins from fruit and vegetables, the concentration data reported for Spain (Perello *et al,* 2012) have been combined with consumption data available for Ireland. The so derived exposure estimates indicate a potential 10% contribution from fruit and vegetables, and a 6% contribution from cereals to the total dioxin intake. The latter derived estimates would increase the mean exposure estimate derived in this study to Total WHO TEQ (2005) 0.35 pg/kg bw/d, however, due to all concentration data for fruit, vegetables and cereals being reported as <LOD, and data being derived from a study conducted in Spain, there is considerable uncertainty associated with these estimates.

4 The 2008 Dioxin Contamination of Irish Pork

4.1 Introduction

In September 2008 a feed contamination incident occurred in Ireland, which subsequently led to contamination of pig herds and cattle herds supplied with this feed.

4.1.1 Discovery of the contamination

The incident was discovered in November 2008, when a pork fat sample, taken as part of a routine monitoring programme under Commission Directive 96/23/EC (EC, 1996) was found by the PCS to contain elevated levels of three Marker PCBs (NDL- PCBs 153, 138, 180). Under this program, an average of 300 animal kidney fat samples are analysed for the 7 Marker PCBS (PCBs 28, 52, 101, 118, 138, 153, 180) per year. Following on from this discovery, further porcine fat tissue samples and also animal feed ingredients were analysed from the identified pig farm and tested for the presence of Marker PCBs. Simultaneously, the same samples were also sent to the Food and Environment Research Agency (FERA) in the United Kingdom for High Resolution Gas Chromatography/Mass Spectrometry (GC/MS) analysis of dioxins.

4.1.2 Source of contamination

Feed ingredients taken from the implicated farm comprised of Pot Ale Syrup, Soya Oil, Soya Meal, Soya Hulls, Feed Minerals, Barley, Dried Breadcrumbs and Wheat.

Analysis of these samples by PCS, using Gas Chromatography/Electron Capture Detector (GC/ECD) and Gas Chromatography/Mass Selective Detector (GC/MSD), confirmed the presence of elevated levels of Marker PCBs in the porcine fat samples and found elevated levels of Marker PCBs in the dried breadcrumb feed components. All other feed components did not contain detectable levels of PCBs.

The source of the breadcrumb ingredient was traced back to a feed recycling plant, and a full investigation into the manufacture and distribution of this feed was undertaken. The plant produced feed via recycling of waste bread and waste dough delivered to the site from various bread factories.

The process was based on a convection drying system, in which combustion gas was used as a drying gas, thereby coming in direct contact with the material to be dried. The reported gas temperature in the fire tube was on average 425°C, whereas the temperature of the exhaust gas at the end of the dryer was on average 80°C. In this system, feed material was conveyed through the dryer entrained in the flue gas/air stream assisted by the rotary motion of the dryer, reducing the moisture content of the ingoing material from on average 40 % down to on average 8 %. This system was capable of processing approximately 7 tonnes of raw material per hour.

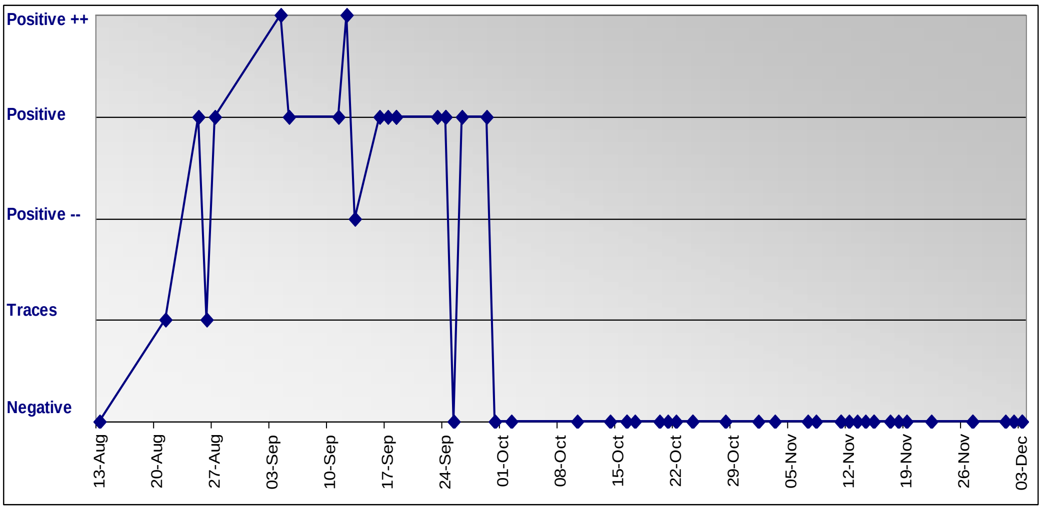
Examination of the production process revealed that the fuel oil used to produce the drying gas was the cause of the contamination. Analysis of individual samples of raw material sampled prior to the drying process confirmed this conclusion, as none of these samples were found to be contaminated. It was therefore concluded, that contamination must have taken place during the drying process and was due to airborne deposition and consequent adsorption of contaminants contained in the exhaust gas onto the surface of the feed material. Subsequent analysis of the fuel oil confirmed a very high contamination with PCBs.

4.1.3 Tracing of contaminated produce and onset of contamination

A list of farms which had received feed material from the premises was compiled and feed samples, both current and archive samples from late July 2008, were submitted to the PCS for analysis for presence of Marker PCBs. All animal herds which had received feed from the implicated feed mill were identified and immediately put under restriction by DAFM pending further investigation. In total, 12 pig farms and 49 cattle farms were restricted. Two animals from each affected herd and known to have been fed contaminated feed from the implicated feed mill were slaughtered and renal fat was analysed for the presence of marker PCBs and dioxins. As a consequence, nine of the restricted pig herds and 27 of the restricted cattle herds were fully depopulated and 8 cattle herds were partially depopulated (due to farm to farm animal movement). In total, 5707 cattle and 170605 pigs were culled as a result, representing 0.09 % of the entire live cattle herd population and 10 % of the entire live pig herd population in 2008

Analysis of archive feed samples from the implicated feed mill indicated that the contamination incident began 25th August and ended on 26th September, which correlates with an on-farm contamination window from 1st September through to approximately the 10th of October (see Figure 12).

Figure 12 Results of Analysis of Archive Feed Samples (13Aug – 3 Dec)



Data Source: PCS

This window was further supported by the presence of certain congeners in the pork fat which are usually metabolised quickly and information received from the feed mill operator regarding the use of the oil.

A simultaneous investigation by the Dutch authorities into elevated levels of dioxins found in a deboned pork loin sample detected in a French processing plant identified the origin of pork to be from Ireland.

This was based on tracking and tracing of origin of the meat supply and subsequent testing of batches received. Full confirmatory results for samples taken from meat of Irish origin became available shortly after the issue had already been identified in Ireland, and the congener patterns in samples analysed in the Netherlands matched results for samples taken in Ireland. The contamination had also been picked up by a gelatine processing plant in Belgium, which observed a steady increase in dioxin concentrations from mid September onwards, further supporting the estimated onset of contamination identified from analysis of archive feed samples. The congener profile showed a comparable distribution of congeners with the meat sample taken from the French processing plant, which was a strong argument for one source of contamination (Heres L *et al,* 2010). A full review of the tracing and identification of the contamination source in the Netherlands was published by Heres et al (Heres L *et al,* 2010).

4.1.4 The Recall

Final confirmation and full extent of the scale of contamination became apparent when full congener profile analysis for the first lot of pork fat samples became available on Dec 6th 2008. These indicated a Total TEQ ranging from 80 - 200 pg/g fat in the pork fat samples.

An Inter Departmental/Agency group chaired by the Minister for Agriculture, Food and the Marine, and attended by the Irish Prime Minister, the Minister for Health and Children, the Minister of State for Food Safety, the Minister of State for Food Promotion, the Chief Medical Officer, the FSAI, and officials from the Department of Agriculture, Food and the Marine and Department of Health and Children met on 6th December 2008 to discuss the emerging situation. At least 10 pig farms were implicated in the feed incident, representing 8 % of total pig production in Ireland. However products from a wider range of farms were supplied to major processing plants and it was impossible to trace back final consumer products to the individual farms. As a consequence all pork products manufactured from pigs slaughtered in Ireland between 1st Sep and 6th December were withdrawn and a consumer recall was initiated. Cattle farms were less implicated, with only 0.02 % of the total beef production affected and implicated products were traced and withdrawn from trade.

A recall is generally viewed as a public process in which unsafe food must be removed from the market whilst informing consumers. Withdrawal, on the other hand, is viewed as a business to business communication process to remove unsafe food from the distribution chain before it has reached the consumer (FSAI, 2007).

4.1.5 Initial Risk Assessment

From all the information available at the time, it was possible to determine that consumers were exposed to contaminated pork and beef products for a period of approximately 3 months, starting September 1st and ending December 6th 2008 when the recall of pork produce was issued.

The initial calculated additional body burden to Irish consumers from the incident was estimated at 10 % from pork products. EFSA (EFSA, 2008) considered this increase in body burden of no concern for this single event. An additional increase to the body burden of 0.035 % from beef products was also derived at the time. However, the actual span of contamination was found to be wider after the initial risk assessments were performed.

Since then, more recent food consumption data, collected between 2008 - 2010 has become available and more time to review the incidence in depth has allowed for a reanalysis of this initial risk assessment (see chapter 4.4.4)

4.2 Materials and Methods

A total of 427 samples of bovine and porcine fat and animal feed from the feed plant and farms that had received feed from the implicated feed mill were taken and analysed by 4 different laboratories (see Table 31). Animal fat samples (kidney fat) were collected by Veterinary Inspectors at designated slaughterhouses in accordance with sampling provisions issued under the national residues monitoring program. For each restricted herd, 2 animals known to have consumed feed supplied by the implicated mill were sacrificed. Analysis of samples for Marker PCBs was carried out by PCS and PCDD/F, DL-PCB and NDL-PCB analysis was carried out by FERA, RIKILT Institute for Food Safety, Netherlands and Scientific Analytical Services, UK (SAL).

Table 31 Number of bovine and porcine fat samples and animal feed samples analysed

	Total Sample Number	PCS		FERA	RIKILT		SAL
		H2SO4 Acid Screen (positives)	GC-MSD	GC/MS	GC/MS	CALUX	GC/MS
Bovine Fat	107	39 (2)	88	16	10	7	19
Porcine Fat	103	24 (0)	39	29	10	26	
Feed	217	178 (28)	21	24	1	0	7
Overall total	427	241 (30)	148	69	21	33	26

The PCS, to identify contaminated material, initially employed a rapid screening analytical method that used a sulphuric acid (H_2SO_4) clean up step for the detection of the major PCBs congeners 138, 153 and 180. Positive samples were confirmed and quantified using conventional analytical methods with gel permeation clean up and analysis using GC-MSD. However, upon receipt of full congener analysis of the first samples dispatched to FERA it became clear that in this particular situation, where polychlorinated dibenzofurans (PCDFs) were formed during the burning of contaminated heating oil, the analysis of samples for Marker PCBs with an LOQ of 5 µg/kg was not sufficiently sensitive to detect illegal dioxin residues. This was due to the very low ratio between sum of 6 Marker PCBs and Total TEQ levels present in the samples (ratios ranging from 300 - 7600). Therefore it was necessary to have all animal fat samples previously found to contain PCB levels < 5 µg/kg fat (GC-MSD) sent for full HR-GC/HR-MS dioxin analysis to confirm presence or absence of contamination. A number of samples were also pre-screened by RIKILT using the Dr CALUX Bioassay.

Animal samples found to contain levels of individual Marker PCBs > LOQ (5 µg/kg fat**)** were treated as confirmative of contamination and the relevant herds were subsequently depopulated without further testing.

4.3 Results

4.3.1 Feed

HRGC/HRMS results in raw feed ingredient material (20 samples), pre-drying, were found to contain up to 0.95 pg/g whole weight Total TEQ (1998) (upperbound). Six of these 20 samples were dough and bakery waste samples used in the production of the breadcrumb and biscuit feed material. This indicated that the dough and bakery waste was not contaminated prior to its arrival at the feed processing plant.

HRGC/HRMS results in the final, dried product, i.e. contaminated breadcrumb/biscuit feed (12 samples) ranged from 25 to 18870 Total TEQ (1998) pg/g whole weight, of which between 92 - 99 % was attributable to PCDFs. 2,3,4,7,8 Penta-Chloro-Dibenzo-Furan (2,3,4,7,8 PeCDF) was found to be the major congener, contributing between 73 - 75 % to the Total TEQ (1998), followed by Tetra-Chloro-Dibenzo-Furan (TCDF) which on average contributed 16 % to the Total TEQ (1998). DL-PCBs contributed between 0.6 - 3 % to the Total TEQ (1998), PCB 126 contributing between 42 and 50 % to the DL-PCB-TEQ (1998).

In terms of total mass, TCDF and 2,3,4,7,8 PeCDF were the dominant congeners, contributing on average 35 % each to the total mass of PCDD/Fs in the products. For DL-PCBs, PCBs 118 and 156 were the top contributors, each contributing on average 41 and 22 % respectively (see Figure 13).

The concentration of sum of 6 Marker PCBs (Marker PCBs 28, 52, 101, 138, 153, 180) ranged from 0.47 – 3615 µg/kg whole weight with contributions of PCB 138 > PCB 153 > PCB 180 > PCB 101 > PCB 52 ≥ PCB 28 (see Figure 14).

4.3.2 Porcine Fat

Results in pork fat taken from 12 implicated herds (Herds A - L) ranged from 0.21 – 1430 Total TEQ (1998) pg/g fat weight. Of the 12 herds tested, 9 herds (Herds A – I) showed the characteristic contamination pattern (see Figure 13), whereas the remaining 3 herds indicated only traces (Herd J) or absence (Herds K and L) of contamination (see Table 32).

Concentration in Herds A – I ranged from 12 – 1430 Total TEQ (1998) pg/g fat weight, of which between 91 – 97 % was attributable to PCDFs. 2,3,4,7,8 PeCDF contributed between 76 – 87 % to the Total TEQ (1998). DL-PCBs contributed between 4 – 8 % to the Total TEQ (1998), PCB 156 being the major contributor to DL-PCB-TEQ (1998).

In terms of total mass, 2,3,4,7,8 PeCDF was the dominant congener in 8 herds (Herds A, C - I), contributing on average 51 % to the total mass of PCDD/Fs in the samples. In one herd (Herd B) OCDD was the dominant congener, contributing on average 51 % to total PCDD/F mass. For DL-PCBs, PCB 156 was the top contributor, contributing on average 54 % to total DL-PCB mass (see Figure 13).

The sum of 6 Marker PCBs ranged from 10 to 5364 µg kg/fat, with congeners 180, 153 and 138 being the major contributors in contaminated samples (Herds A - I), contributing a total of between 98 - 99 % to the total in the contaminated herds (see Figure 14).

4.3.3 Bovine Fat

Of a total of 49 restricted herds, 12 showed levels of Sum 3 Marker PCBs (138, 153, 180) > LOQ (5 µg/kg fat), ranging from 46 to 1650 µg kg/fat, and no further confirmatory testing was performed. Of the remainder, HRGC/HRMS results in bovine fat taken from 30 restricted herds (Herds 1 - 30, see Table 33) ranged from 0.5 – 1403 Total TEQ (1998) pg/g fat weight. Of these 30 herds tested, 17 herds contained levels below the legal limit (3 pg/g fat PCDD/F and 4.5 pg/g fat Total WHO TEQ (1998)). The remaining 13 herds showed Total TEQ (1998) levels ranging from 11.6 – 1403 pg/g fat. 2,3,4,7,8 PeCDF was found to positively correlate to Total TEQ (1998) (0.99), contributing between 77 – 91 % to the Total TEQ (1998) in non-compliant samples (see Figure 13), and between 7.6 - 64 % in compliant samples.

DL-PCBs contributed between 1.4 – 7.1 % to the Total TEQ (1998) in non-compliant samples, PCB 126 being the major contributor to DL-PCB-TEQ (1998) (see Figure 13).

The concentration of sum of 6 Marker PCBs ranged from 7.8 - 913 µg kg/fat weight with contributions of PCB 138/PCB 153 > PCB 180 > PCB 101 > PCB 52/PCB 28 (see Figure 14).

4.3.4 Fuel Oil

Fuel oil samples were initially analysed by the PCS for Marker PCBs and further samples were taken from the feed plant by the Environmental Protection Agency (EPA) and sent for full dioxin analysis as part of their investigation into potentially illegal disposal of PCBs. The latter samples were found to contain high levels of PCBs (on average 364 mg/kg 7 Marker PCBs and 29 mg/kg DL-PCBs) and also some PCDD/Fs (on average 10 µg/kg, 75 % PCDFs).

Table 32 Dioxin and PCB Distribution in porcine fat taken from 12 Pig Herds

	Herd A	Herd B	Herd C	Herd D	Herd E	Herd F	Herd G	Herd H	Herd I	Herd J	Herd K	Herd L
Number of samples*	3	10	2	3	3	4	1	1	1	7	2	2
PCDD TEQ (1998) (ng g/fat)	0.65 - 1.22	0.49 - 3.33	3.68 - 3.91	0.22 - 0.39	0.19 - 0.47	0.31 - 0.78	0.6	0.3	0.6	0.02 - 0.1	0.12 - 0.12	0.12 - 0.12
PCDF TEQ (1998) (ng g/fat)	158 - 249	79 - 423	1131 - 1362	26 - 35	12 - 66	114 - 288	163.5	62.9	302.8	0.3 - 1.7	0.1 - 0.1	0.1 - 0.1
non ortho-PCBs (ng g/fat)	0.4 - 0.7	0.3 - 1.1	2.6 - 3.4	0.1 - 0.1	0.1 - 0.2	0.2 - 0.7	0.29	0.15	0.51	0.01 - 0.1	0.01 - 0.02	0.01 - 0.01
ortho-PCBs (ng g/fat)	13.3 - 20.3	6 - 26.5	53.9 - 61.2	0.5 - 0.6	0.2 - 3.1	5.6 - 10.8	4.72	4.34	16.21	0.03 - 0.1	0.02 - 0.03	0.02 - 0.02
Total WHO TEQ (1998) (ng g/fat)	172 - 271	87 - 440	1192 - 1429	27 - 37	12 - 70	121 - 301	169.05	67.69	320.19	0.4 - 2	0.3 - 0.3	0.2 - 0.2
% PCDD of Total TEQ	0.4 - 0.5	0.2 - 0.8	0.3 - 0.3	0.8 - 1.1	0.7 - 1.5	0.3 - 0.5	0.3	0.5	0.2	3.4 - 14	40.8 - 43.3	48.8 - 54
% PCDF of Total TEQ	92 - 92	91 - 96	95 - 95	97 - 97	95 - 96	94 - 96	96.7	92.9	94.6	73 - 91	43 - 44	34 - 40
% 23478 PeCDF of Total TEQ	76 - 77	78 - 85	83 - 85	85 - 86	83 - 84	81 - 85	86.6	82.7	83.1	60 - 81	31 - 31	20 - 26
% DL-PCBs of Total TEQ	7.2 - 8	3.5 - 8.4	4.5 - 4.8	2.1 - 2.2	2.6 - 4.7	3.8 - 5.9	3.0	6.6	5.2	5.3 - 13.4	12.7 - 15.8	10.9 - 12.2
Marker6 (µg kg/fat) **	1101 - 1550	520 - 2568	3896 - 5364	32 - 41	10 - 256	496 - 780	404	477	1787	0.7 - 4	0.7 - 0.8	0.6 - 0.6
% PCB 138 of Marker 6	27 - 29	26 - 39	38 - 38	34 - 38	35 - 38	36 - 37	37.7	38.2	37.6	28 - 35	18 - 20	16 - 16
% PCB 153 of Marker 6	39 - 40	33 - 36	36 - 36	34 - 35	35 - 36	36 - 36	35.3	35.3	35.8	28 - 37	26 - 29	20 - 21
% PCB 180 of Marker 6	31 - 33	24 - 38	24 - 24	25 - 27	22 - 26	25 - 27	26.1	26.2	26.1	11 - 22	14 - 15	15 - 16
Ratio Marker 6/Total TEQ (1998)	4871 - 6345	2179 - 7639	3269 - 3753	1133 - 1255	769 - 3678	2595 - 5103	2389	7044	5581	1263 - 2762	2572 - 3090	2686 - 2902

* Number of samples refers to samples analysed using HRGC/HRMS or HRGC/LRMS as appropriate. **Marker 6 (Sum of PCBs 28, 52, 101, 138, 153 and 180)

Table 33 Dioxin and PCB Distribution in bovine fat taken from 30 Cattle Herds

	Herd 1	Herd 2	Herd 3	Herd 4	Herd 5	Herd 6	Herd 7	Herd 8	Herd 9	Herd 10
Number of samples*	1	1	1	3	1	1	1	1	1	5
PCDD TEQ (1998) (ng g/fat)	11	7	10	0.5-3	3	0.71	0.88	0.43	0.47	0.21 - 0.42
PCDF TEQ (1998) (ng g/fat)	1372	700	943	1-332	228	79	81	36	23	11 - 30
non ortho-PCBs (ng g/fat)	6	3	4	0.44-2	2	0.43	0.74	0.38	0.55	0.31 - 0.42
ortho-PCBs (ng g/fat)	14	17	14	0.07-2.8	2.2	0.52	0.69	0.28	0.27	0.24 - 0.34
Total WHO TEQ (1998) (ng g/fat)	1403	727	971	2-340	235	80	84	37	25	12 - 31
% PCDD of Total TEQ	0.8	1.0	1.0	0.9-21	1.1	0.9	1.0	1.2	1.9	1.3 - 1.9
% PCDF of Total TEQ	98	96	97	57-98	97	98	97	97	95	93 - 96
% 23478 PeCDF of Total TEQ	90	83	86	51-91	91	91	90	91	91	87 - 88
% DL-PCBs of Total TEQ	1.4	2.7	1.9	1.4-24	1.8	1.2	1.7	1.8	3.3	2.2 - 5.3
Marker6 (µg kg/fat) **	710.6	912.6	737.6	2-147.2	107.5	23.7	31.5	12.3	12.0	5.7 - 13.24
% PCB 138 of Marker 6	39	38	36	25-38	35	37	37	37	37	27 - 42
% PCB 153 of Marker 6	36	38	37	37-46	35	36	37	37	37	39 - 40
% PCB 180 of Marker 6	25	24	26	16-24	29	25	25	24	25	19 - 30
Ratio Marker 6/Total TEQ (1998)	506	1255	760	432-821	457	294	376	335	485	373 - 493
	Herd 11	Herd 12	Herd 13	Herd 14	Herd 15	Herd 16	Herd 17	Herd 18	Herd 19	Herd 20
Number of samples	1	1	3	2	2	2	1	1	2	1
PCDD TEQ (1998) (ng g/fat)	0	0.14	0.12 - 0.21	0.25 - 1.2	0.12 - 0.53	0.36 - 0.43	0.51	0.35	0.36 - 0.42	0.70
PCDF TEQ (1998) (ng g/fat)	16	11	0 - 1	2 - 12	0 - 1	0.3 - 0.3	0.3	0.65	0 - 1	0.42
non ortho-PCBs (ng g/fat)	0.35	0.58	0.18 - 0.33	0.23 - 0.29	0.12 - 0.57	0.4 - 0.5	0.17	0.28	0.2 - 0.35	0.25
ortho-PCBs (ng g/fat)	0.19	0.25	0.04 - 0.1	0.2 - 0.24	0.05 - 0.05	0.05 - 0.07	0.08	0.06	0.04 - 0.13	0.05
Total WHO TEQ (1998) (ng g/fat)	17	12	1 - 2	3 - 14	1 - 2	1 - 1	1.06	1.35	1 - 2	1.4
% PCDD of Total TEQ	2.0	1.2	13 - 23	8.5 - 9	11 - 35	33 - 34	48	26	24 - 35	49
% PCDF of Total TEQ	95	92	31 - 69	77 - 87	25 - 74	24 - 24	28	49	42 - 48	30
% 23478 PeCDF of Total TEQ	88	86	25 - 59	74 - 77	17 - 64	19 - 20	13	41	24 - 32	18
% DL-PCBs of Total TEQ	3.2	7.1	18 - 47	3.9 - 14.7	15.4 - 40	42 - 43	24	25	23 - 28	21
Marker6 (µg kg/fat) **	7.8	Not analysed	1 - 2	4 - 6	1 - 1	1 - 2	1.3	0.90	1 - 2	0.50
% PCB 138 of Marker 6	37		21 - 37	36 - 39	25 - 33	30 - 33	38	44	32 - 38	40
% PCB 153 of Marker 6	38		32 - 44	37 - 37	37 - 50	44 - 46	46	44	38 - 41	40
% PCB 180 of Marker 6	23		12 - 21	24 - 27	14 - 17	15 - 16	15	11	25 - 27	20
Ratio Marker 6/Total TEQ (1998)	467		1323 - 1550	432 - 1304	389 - 1088	1286 - 1612	5205	669	766 - 1284	352

Table 33 continued Dioxin and PCB Distribution in bovine fat taken from 30 Cattle Herds

	Herd 21	Herd 22	Herd 23	Herd 24	Herd 25	Herd 26	Herd 27	Herd 28	Herd 29	Herd 30
Number of samples	1	2	2	1	2	1	1	1	1	1
PCDD TEQ (1998) (ng g/fat)	0.30	0.14 - 0.27	0.32 - 0.57	0.24	0.34 - 0.36	0.37	0.32	0.11	0.19	0.35
PCDF TEQ (1998) (ng g/fat)	0.49	1 - 1	0 - 1	0.35	0 - 0	0.32	0.38	0.19	0.12	0.24
non ortho-PCBs (ng g/fat)	0.4	0.21 - 0.34	0.23 - 0.41	0.35	0.13 - 0.15	0.37	0.22	0.15	0.27	0.23
ortho-PCBs (ng g/fat)	0.06	0.04 - 0.04	0.05 - 0.19	0.05	0.06 - 0.09	0.07	0.05	0.05	0.05	0.03
Total WHO TEQ (1998) (ng g/fat)	1.2	1 - 1	1 - 1	0.98	1 - 1	1.1	0.97	0.50	0.63	0.85
% PCDD of Total TEQ	24	14 - 21	24 - 39	24	34 - 44	33	33	23	30	41
% PCDF of Total TEQ	39	50 - 58	19 - 54	35	33 - 41	29	39	38	19	28
% 23478 PeCDF of Total TEQ	33	42 - 53	8 - 42	28	26 - 26	20	25	32	8	10
% DL-PCBs of Total TEQ	36	28 - 29	21 - 41	41	23 - 25	39	28	39	51	31
Marker6 (µg kg/fat) **	1.3	1 - 1	1 - 3	1.02	1 - 1	1.1	1.0	0.97	0.80	0.50
% PCB 138 of Marker 6	37	23 - 43	33 - 37	35	40 - 46	36	40	35	38	40
% PCB 153 of Marker 6	43	36 - 43	40 - 44	44	38 - 40	45	40	40	50	40
% PCB 180 of Marker 6	15	14 - 14	22 - 23	15	15 - 20	18	20	19	13	20
Ratio Marker 6/Total TEQ (1998)	1042	538 - 1181	686 - 2077	1036	1218 - 1310	975	1029	1928	1268	587

* Number of samples refer to samples analysed using HRGC/HRMS or HRGC/LRMS as appropriate. **Marker 6 (Sum of PCBs 28, 52, 101, 138, 153 and 180)

4.4 Discussion

4.4.1 Feed

Following the discovery of the contamination in pigs, all individual feed components in herd F were analysed for dioxins and PCBs. Full congener analysis of cereals, minerals, oils and raw feed ingredients (waste bread and waste dough prior to drying) showed levels of total upper bound TEQ (1998) of 51 pg/g whole weight and were found consistent with normal background concentrations in these substrates (EFSA, 2010b). A very wide range of elevated concentrations of dioxins and PCBs was observed in the final product (dried breadcrumb/biscuit), with concentrations differing in up to three orders of magnitude. The sum of six marker PCBs were found to be present in very high concentrations ranging from 0.4 to 3615 mg/kg whole weight. PCDD/F and DL-PCB TEQ (1998)s ranged from 2 to 18756 pg/g and from 0.04 to 112 pg/g, respectively, with TCDF and 2,3,4,7,8-PeCDF on average contributing 16 % and 72 % to the Total TEQ (1998), respectively. The average ratio between the sum of six marker PCBs and Total TEQ (1998) was 200. The wide span of contamination levels can be attributed to a number of factors. The samples were sourced from the feed manufacturer and farms/feed mills that had obtained material from the feed manufacturer, suggesting that samples taken came from different production batches. Contaminant uptake in the feed is also dependent on the amount of fat in the raw feed material, the surface area exposed to the exhaust gases, the absorptive/adsorptive capacity of the feed material, the level of contamination in the fuel oil used in the production line, the burning temperature in the firing unit and the time of exposure to the exhaust gases during drying. A high level of consistency between the relative concentrations of specific congeners to the overall total (mass and TEQ (1998), as shown in Figure 13 and Figure 14) can be seen for all samples, confirming that all samples were most likely to have been exposed to the same source of contamination.

4.4.2 Porcine fat

Of the 12 pig herds tested, nine primary pig herd producers were found to hold contaminated livestock, and these nine herds and all associated secondary or tertiary herds were depopulated (12 full depopulations and six partial depopulations). The congener profiles found in the fat samples taken from the affected pig herds (Figure 13 and Figure 14) were all in agreement and confirmed that contamination was likely to have originated from the same source. 2,3,4,7,8-PCDF was the major congener, contributing between 76 % and 86 % to the Total TEQ (1998). The overall congener profile found was in agreement with the pattern found in feed, taking into account the selective metabolism of 2,3,7,8-TCDF and 1,2,3,7,8-PCDF in pigs (Hoogenboom *et al,* 2004). As in feed samples, a wide range of contamination across samples from the pig herds was observed, which can be explained by the variation found in the feed in combination with differing feed inclusion rates, age and size of the pigs at slaughter.

4.4.3 Bovine fat

Of the initially 49 restricted cattle herds, 27 were fully depopulated, eight were partially depopulated and the remaining 14 were found to be free of contamination. Depopulation took place in accordance with a Veterinary Procedures Notice, requiring the disposal of animals at a category I animal by-products rendering plant. The congener profile again compared well with the profile found in feed and in porcine fat samples (Figure 13 and Figure 14). As with samples taken from pig herds, the low levels of TCDF and 1,2,3,7,8-PCDF may be attributed to their selective metabolism, which was also observed in other studies on dairy cows (Fries *et al,* 1999; McLachlan *et al,* 1990; Slobs *et al,* 1995). The wide range of contamination across samples from bovine herds can be explained by the variation in feed contamination combined with differing feed inclusion rates, age and size of the cattle at slaughter.

Figure 13 Congener Pattern for PCDD/Fs and DL-PCBS, expressed on a % of mass and % of TEQ (1998) basis

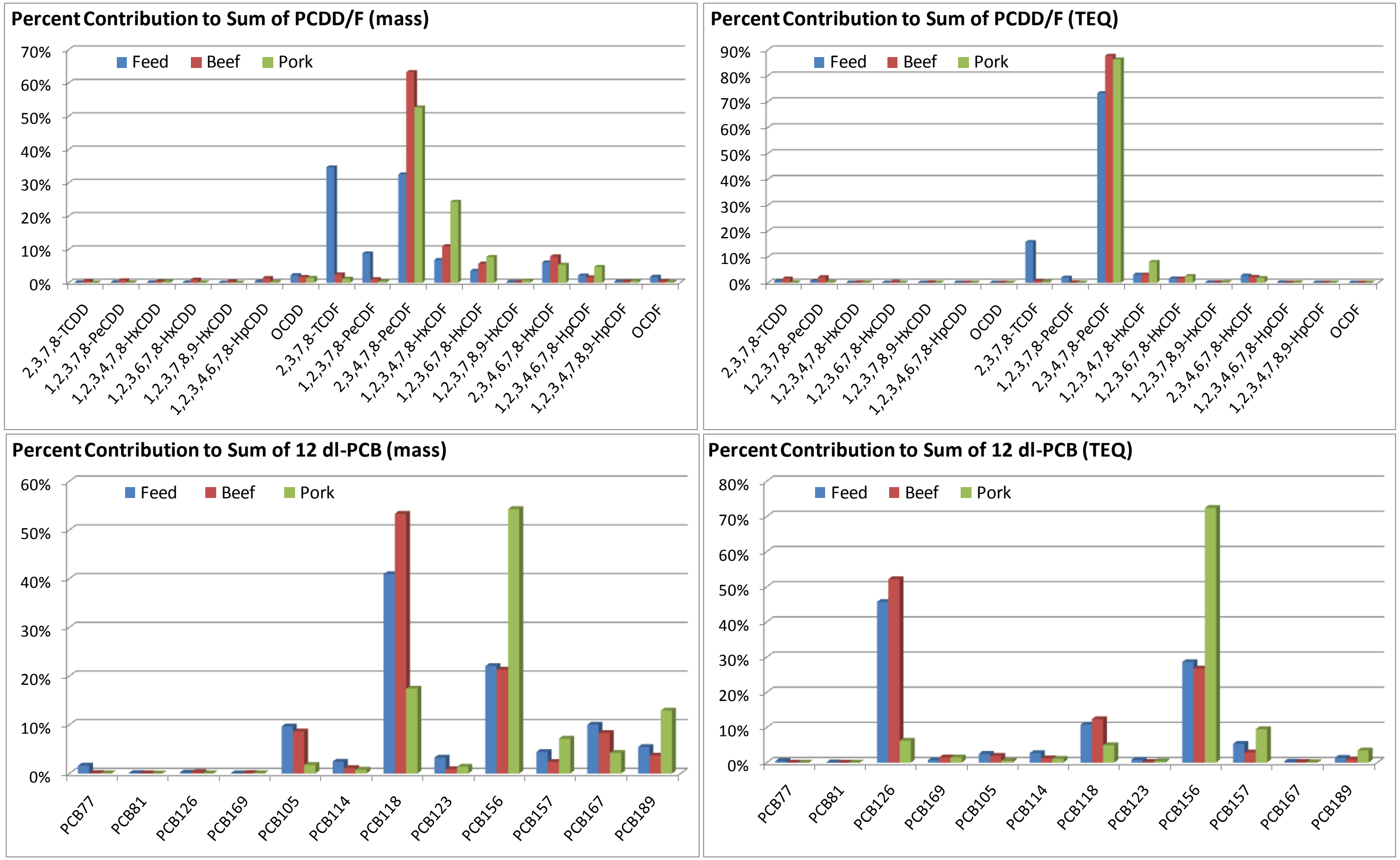
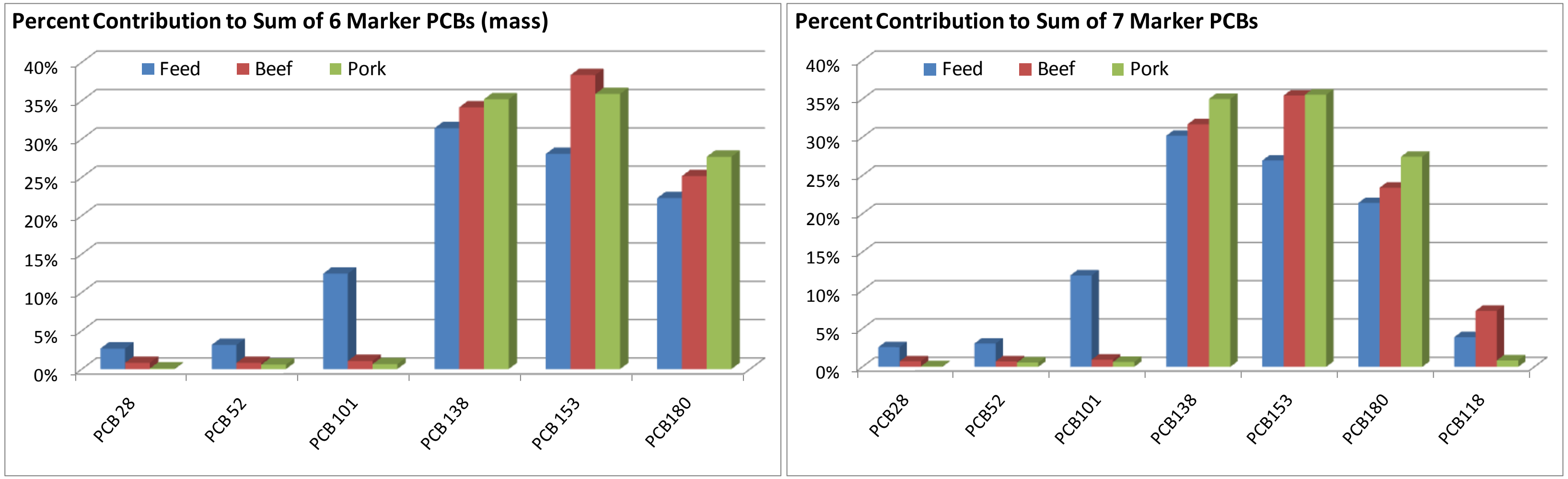


Figure 14 Congener Pattern for Sum of 6 and Sum of 7 Marker PCBs, expressed on a % of mass basis

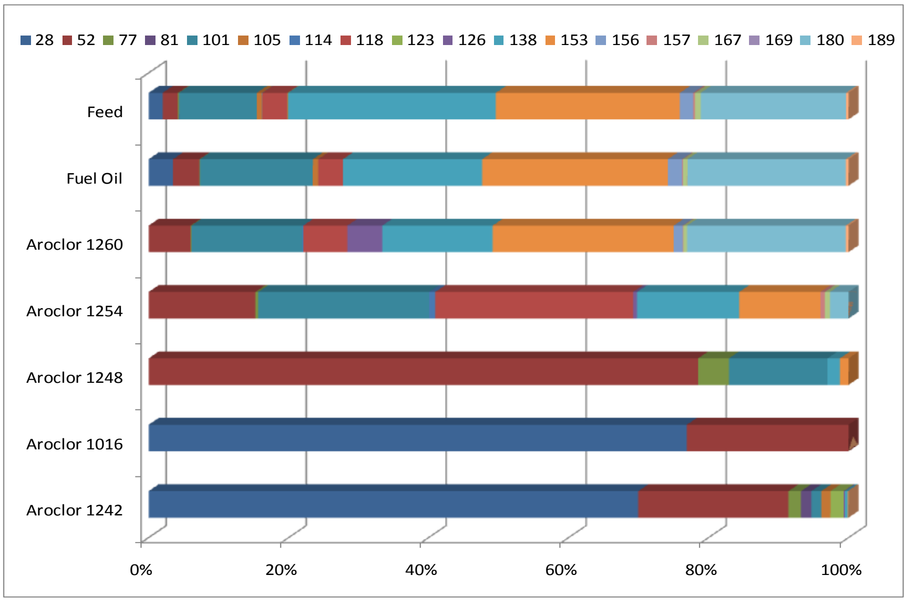


4.4.4 Fuel oil

In order to identify the potential source of the contamination, the average congener pattern of the measured PCBs (7 Marker PCBs and 12 DL-PCBs) in the fuel oil sampled by the EPA was compared to congener patterns available for several commercial PCB mixtures (WHO, 1993) and was found to be highly correlated (R = 0.975) with an Aroclor 1260 mixture (see Figure 15 and Figure 16).

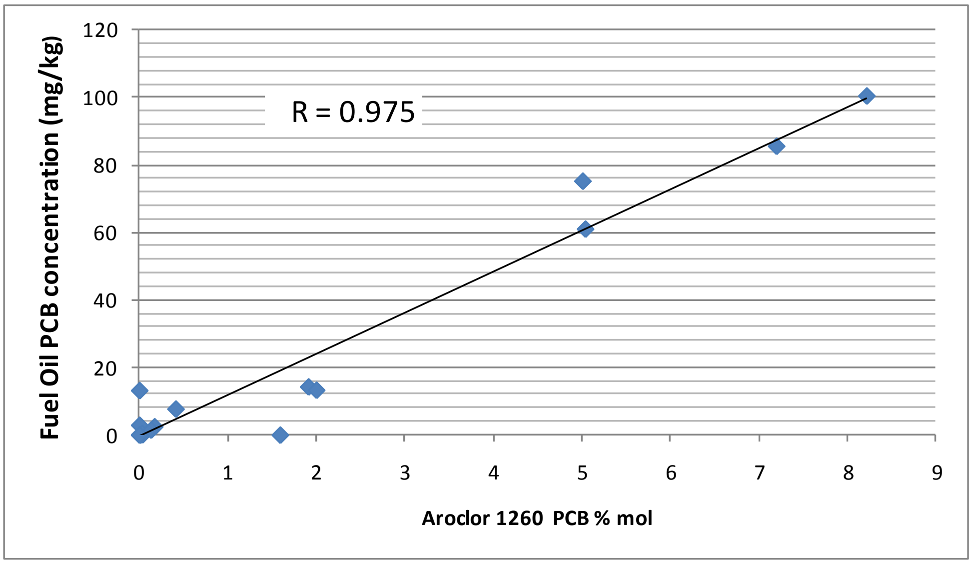
Figure 15 shows the average relative levels of analysed PCB congeners in the oil and their equivalent % in several Aroclor mixtures and Figure 16 displays the correlation between the PCB concentration found in the fuel oil and the % mol of the same congeners in the Aroclor 1260 mixture. This association strongly suggested that the source of the PCBs in the fuel oil was a highly chlorinated technical mixture such as Aroclor 1260. Highly chlorinated mixtures such as Aroclor 1260 and Aroclor 1254 were most commonly used in transformers (WHO, 1993), pinpointing the possible origin of the PCB mixture. Also the presence of PCDFs in the fuel oil is consistent with reports of their presence in PCB mixtures in the literature (WHO, 1993), however, the presence of PCDDs was unexpected, and might be due to a different source.

Figure 15 Percent contribution of DL-PCBs and 7 Marker PCBs to total mass in commercial Aroclor mixtures and in fuel oil



Source of Aroclor composition: EHC 141 (WHO, 1993)

Figure 16 Correlation of PCB composition (mg/kg) in fuel oil and PCB composition (% mol) in Aroclor 1260 commercial PCB mixture



Source of Aroclor composition: EHC 141 (WHO, 1993); R = Pearson Correlation coefficient

The very high concentration of PCDFs found in the feed, could be explained by the incomplete combustion of the PCBs during burning and subsequent formation of PCDFs during pyrolysis, as demonstrated by several researchers (Hutzinger *et al,* 1985). Production of up to 10 % of PCDFs calculated on the amount of PCBs decomposed under optimal conditions (temperature range of 550 - 700°C) has been reported by Bentley (Bentley, 1983). The additional formation of PCDFs during combustion therefore could explain the very poor correlation of the two PCDD/F datasets for the fuel oil and feed (R=0.12), whilst for the PCBs, correlation was found to be excellent (R=0.96), further providing evidence of a contaminant carry-over from the oil onto the feed material. The fuel oil originated in the UK (Northern Ireland) but it is still unclear how the oil became contaminated.

4.5 Conclusion

Elevated levels of PCDD/Fs and PCBs were found in bovine and porcine fat samples, which were in agreement with levels found in feed samples traced back to the contamination site and resulting from the use of contaminated oil used in a direct-heat feed-drying system. Strong consistencies in the congener profiles confirmed that contamination most likely stemmed from the same source, which is strongly indicated to be a commercial highly chlorinated PCB mixture, such as Aroclor 1260 or similar. Although the manufacture, processing and distribution of PCBs has been prohibited in almost all industrial countries since the 1980s, their entry into the environment still occurs, especially due to leaks in electrical equipment and hydraulic systems still in use or improper disposal practices (EFSA, 2005). Whilst general background levels of dioxins and PCBs in food are low in Ireland (FSAI, 2010a), this contamination incident underlines the importance of continued monitoring of the food and feed supply and it gave rise to new guidelines being issued by the European Commission Directorate General for Health and Consumers on the use of convection drying by business operators in the animal feed sector.

5 Impact of the 2008 dioxin contamination of Irish pork on exposure of the Irish Population to Dioxins and PCBs

In 2008 a feed contamination incident (see Chapter 3.3.4) led to contamination of beef and pork products, which by the time the incident was detected had been available on the Irish market for approximately 3 months. The following exposure assessment provides an estimate of the impact of this additional exposure to dioxins and PCBs on top of the general background exposure estimates to dioxins and PCBs derived in chapter 3.

5.1 Food Consumption Database

The NANS was used to estimate the impact of the 2008 dioxin contamination incident on dioxin body burden and was modified to facilitate the exposure model as detailed in section 3.2.1.

5.2 Exposure assessment methodology

Similarly to the estimate of background exposure (see 3.1.3), exposure assessments were conducted using a Monte Carlo simulation (McNamara *et al,* 2003) using the web-based software application Creme^{TM} (Creme Software Ltd., 2013a), which performs exposure assessments using probabilistic modelling.

For all exposure scenarios calculated here, data has been used for both occurrence data (see section 5.3.2) and food consumption data (see section 3.2.1), and for each scenario, intake for a population of 210000 people was simulated (140 iterations of the 1500 NANS survey population, see 5.3.1).

Of the eleven Category I food categories contained in the converted foodfile (see Annex 7.1), the following six were included in the model: Dairy, Eggs, Fats & Oils, Fish & Fish Products, Meat & Meat Products, Oil based supplements. With the exception of beef and pork products for which contamination incident concentration data was used, general background concentration data was matched to the food groups as described in chapter 3. As consumption in the foodfile is expressed as intake of fat from these food groups a direct match with concentration data was possible. The matching of concentration data and food data was done at Category level I, II or level III, depending on the amount of detail available (see Annex 7.3).

Left censored data was treated as UB. This approach was chosen as the range of results for the background concentration between LB and UB was very small (see section 3.3.3.2), and the model was designed to take a conservative approach.

For this exposure scenario three outputs were modelled:

- Post-incident Total WHO TEQ (1998) PCDD/F&DL-PCBs – UB
- Post-incident Total WHO TEQ (2005) PCDD/F&DL-PCBs - UB
- Post incident Sum of 6 Marker PCBs - UB

For each model, intake for the total population was calculated, expressed as intake per kilogram bodyweight per day (kg/bw/d). Exposure estimates were calculated based on average daily intakes only, since the additional short term exposure to elevated levels due to the contamination incident introduced a huge bias in the dataset violating the requirement for normality for the calculation of usual exposure estimates.

It was assumed that all animals from farms that had received contaminated feed from the feed mill during the timeframe identified were contaminated, which is a conservative assumption, since not all farms received feed at the beginning of the contamination time-frame, and feed inclusion rates and exposure time-frame would have varied widely from farm to farm. Therefore, this assumption is likely to result in an over-estimate of exposure.

5.2.1 Concentration Data

For the purpose of estimating additional exposure from consumption of contaminated beef and/or pork, concentration data generated during the crisis in 2008 had to be collated from several different laboratories and/or state departments, scrutinised in collaboration with officials from DAFM and was subsequently presented to the public in a recent publication (Tlustos *et al,* 2012) (see Chapter 4). Suitable incidence concentration data for beef and pork were selected from this pool of data and incorporated into the model. As the presence of the contaminated food needed to be taken into account *in addition* to the existing background contamination, a discrete function (background contamination/incident contamination probability) was used based on the derived presence probabilities (see 5.2.2) to apportion occurrence.

5.2.2 Presence Probability

Only a small amount of beef and pork products were placed on the market during the contamination incidence and presence probabilities of 5 % for pork and 1.1 % for beef were incorporated into the discrete function (see 5.3.3).

5.3 Results and Discussion

5.3.1 Number of Iterations

As the presence probabilities derived for both pork and beef were quite small (5 % and 1.1 %, respectively, see section 5.3.3), the model needed to be run a sufficient number of times to produce robust outcomes, especially in the higher percentiles, which are of the greatest interest in this model, due to the low presence of contaminated produce.

To determine the number of iterations required, the model was run repeatedly with an increasing number of iterations and outcome was judged using the higher percentiles of the food group with the lowest presence probability (i.e. beef at 1.1 %) and their associated errors as performance measure for each simulation.

Figure 17 Change of P99 +/- Error and 95 % confidence interval over increasing iterations

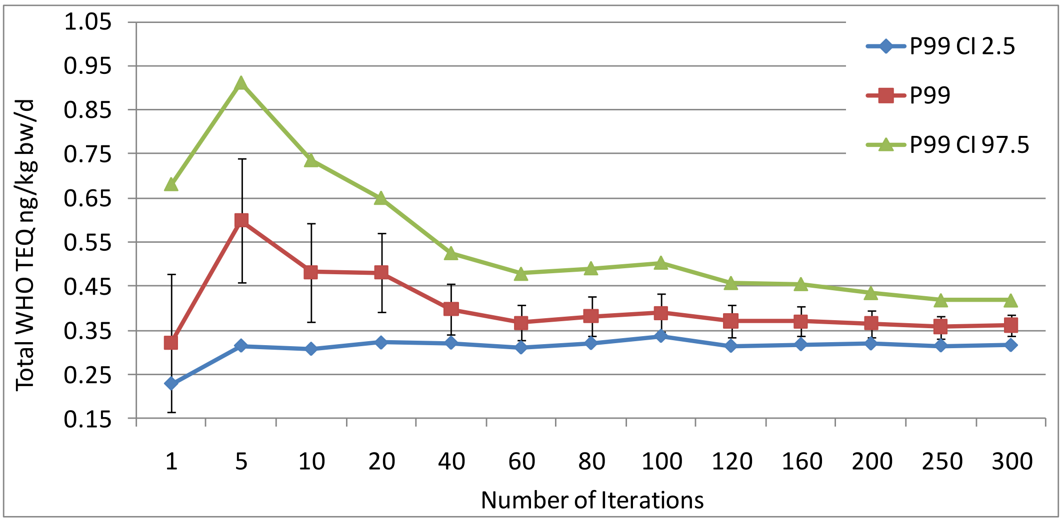


Figure 18 Change % Error of P98.9, P99 and P99.9 over increasing iterations

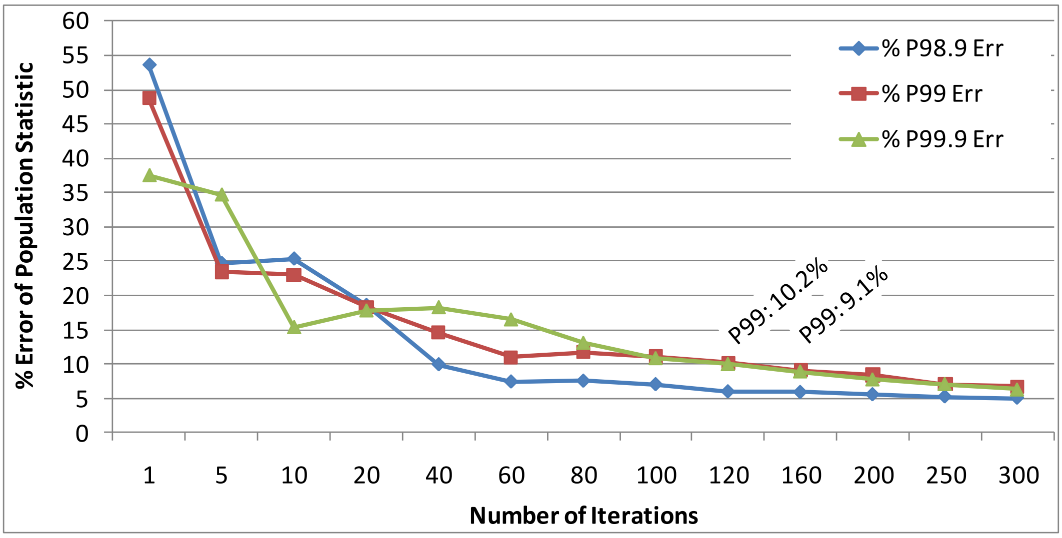


Figure 17 shows that stabilisation of the 99th percentile occurs from 120 iterations onwards. Figure 18 displays the change in % Error of the higher percentiles with increasing iterations, showing a decreasing change at the higher end of the scale. A cut-off point of 10 % Error for the 99th percentile was chosen to determine the number of iterations required, which occurred somewhere between 120 - 160 iterations, therefore 140 iterations were chosen for the model.

5.3.2 Incident Concentration data used in the exposure model

5.3.2.1 Beef

In total, 45 full congener analyses were carried out on bovine fat samples taken during the crisis. For the purposes of this exposure assessment, results which confirmed absence of contamination were not included (N=25). Similar to pork (see following section 5.3.3.2), the results had a very wide span, ranging from Total WHO TEQ (1998) 3 – 1403 pg/g fat (see Figure 19) with a mean of 204 and a median of 27 pg/g fat, and 75 % of results below 84 pg/g fat. Whilst theoretically, due to better traceability in beef production, it may have been possible to attribute specific weighting factors to results from specific herds and derive a distribution for the input model, the latter was hampered by the absence of specific congener data for all herds implicated. The latter is due to some herds not requiring confirmatory analysis as the Marker PCB screen already indicated contamination and the herd was subsequently culled. Therefore, for some herds no congener data is available. Furthermore, similar to pork, wide inter herd variation could be observed, therefore individual results cannot be assumed to be valid for an entire herd. The latter variation is assumed to be due to the heterogeneity of the contamination of the feed, feed inclusion rate, duration of exposure and inter animal variation.

Therefore, for the purpose of estimating additional exposure to the Irish adult population from consumption of contaminated beef products, a distribution of all selected concentration data were included for random selection in the model (see Table 34).

5.3.2.2 Pork

In total, 39 full congener analyses were carried out on pork fat samples taken during the crisis. For the purposes of the exposure assessment, samples taken from sows (N=12) were excluded, as these were not representative of the product that typically reached the market. The latter is due to the different physiological condition of the animal, potential differences in body burden due to repeated pregnancies and lactation and also differences in feeding regime. Results for these excluded animals were typically found to be at the lower end of results obtained for animals deemed representative of the final market product, i.e. weaners/fattening pigs. Also excluded were results which indicated absence of contamination in the samples tested (N=4) (these farms were subsequently de-restricted by DAFM). After the exclusions, 23 samples were deemed suitable and results for Total WHO TEQ (1998) ranged from 37 – 1429 pg/g fat, with a mean of 300 pg/g fat and a median of 213 pg/g fat. Figure 19 displays a box plot of the available results, which indicates that the two highest results are statistical extremes[13]. These samples were taken from the herds belonging to the feed mill operator, which, possibly due to direct and longer access to the contaminated feed, may have contributed to the higher concentrations found in those samples, compared to samples obtained from herds which obtained feed from the mill.

Any attempt to assign a specific distribution or weighting factors in accordance with slaughter figures to results associated with specific herds was hampered by the fact that samples were not taken for the purposes of an exposure assessment, but rather as a contamination presence/absence indicator to facilitate the recall. Therefore, results obtained can only be regarded as spot samples and cannot be used to derive any

---

[13] A boxplot shows the five statistics (minimum, first quartile, median, third quartile, and maximum). The points are outliers. These are defined as values that do not fall in the inner fences. The asterisks or stars are extreme outliers. These represent cases/rows that have values more than three times the height of the boxes.

conclusions on potential contamination of other samples, even from the same herd. The latter is due to the very heterogeneous nature of the contaminated feed (adsorption of contaminant onto feed material in a tumble drier), which would have resulted in considerable inter- as well as intra-batch variation of feed. In addition, different feed inclusion rates, different life stages of the animals exposed, natural variation within the animal population of interest and absence of information on the age and weight of the animals slaughtered further adds to the uncertainties already outlined. However, given the short life span of pigs (e.g. 6 months), it was assumed that the available results provided a reasonable estimate of the contamination span that may have occurred over the 3 months exposure period.

Therefore, for the purpose of estimating additional exposure to the Irish adult population from consumption of contaminated pork products, a distribution of all concentration data, which were deemed representative of a pig ready for slaughter for human consumption were included for random selection in the model (see Table 34)

Figure 19 Boxplot of 23 porcine fat and 20 bovine fat results for Total WHO TEQ (1998) used in the exposure assessment

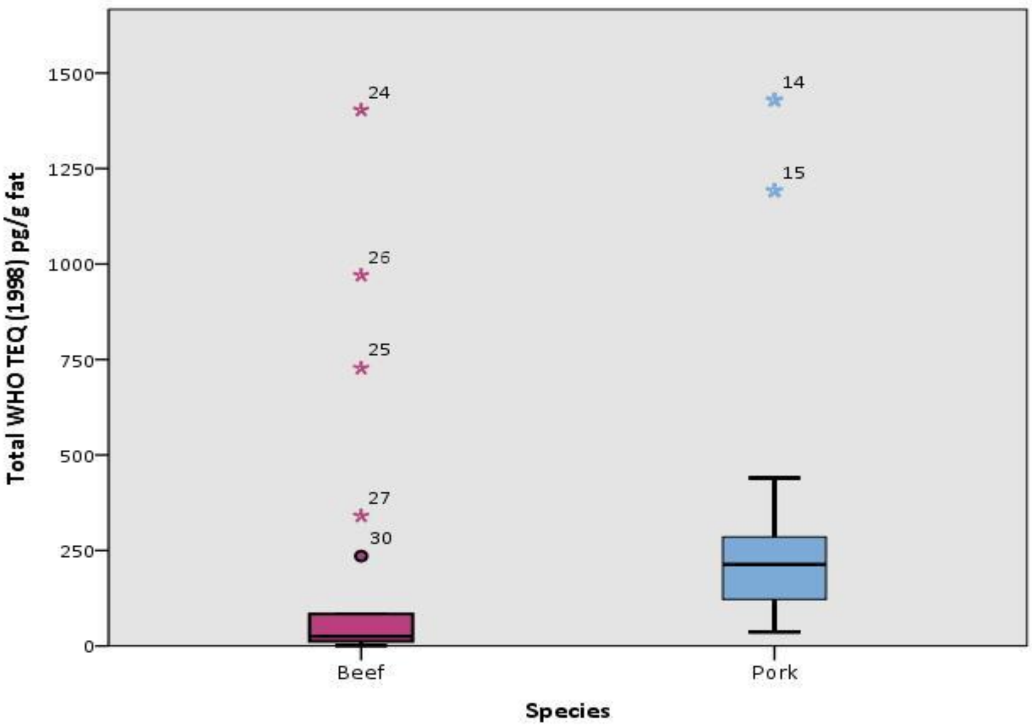


Table 34 Summary statistics of incident concentration data used for exposure assessment

		Bovine Fat	Porcine Fat
	N	20	23
TOTAL WHO TEQ (2005) (UB) ng/kg fat	min	1.89	23.4
	med	17.2	136
	mean	130	188
	P75	76.8	180
	P90	488	279
	max	884	890
TOTAL WHO TEQ (1998) (UB) ng/kg fat	min	2.40	36.6
	med	26.9	213
	mean	204	300
	P75	122	285
	P90	752	439
	max	1403	1429
Sum of 6 Marker PCBs (UB) µg/kg fat	min	2	41
	med	12	958
	mean	146	1236
	P75	70	1287
	P90	716	2364
	max	913	5364

5.3.2.3 Additional considerations

No data was collected for offal during the incident and exposure from liver consumption has been modelled using concentration data collected from fat tissue. Monitoring data collected in Ireland shows that levels in liver are generally higher than in carcass fat and there is evidence of sequestration in the liver during high exposure (Hoogenboom *et al,* 2004; Marchand *et al,* 2010; Schulz *et al,* 2005; Spitaler *et al,* 2005; Thorpe *et al,* 2001). This higher accumulation of contamination in the liver has been observed in experimental studies in pig, cattle and sheep, with levels between 2 - 10 times higher being reported. However, the accumulation depends on the contamination profile and varies much with exposure followed by non-exposure (Marchand *et al,* 2010; Thorpe *et al,* 2001). Whilst the chosen approach is likely to present an underestimation of exposure, it is likely to be of low impact, as consumption of pork and beef liver is extremely rare in Ireland. Of a survey population of 1500 only 23 (1.5 %) and 12 (0.8 %) consumers recorded intake of pork liver or beef liver, respectively. Due to these very low consumption figures, calculation of reliable higher percentiles is also not possible or appropriate. However, to test any potential impact consumption of highly contaminated liver may have had, a ten-fold concentration of occurrence data observed in carcass fat was incorporated into a separate model for liver to test for this hypothetical exposure. The outcomes of this hypothetical sensitivity model are discussed in the Chapter "Summary and Conclusion".

5.3.3 Presence Probability

To estimate additional burden from the contamination incident in 2008, specific presence probabilities were derived to account for the percentage of contaminated beef and pork of total beef and pork reaching the Irish consumer during the incident window (September – December 2008).

5.3.3.1 Beef

To determine the amount of contaminated beef that reached the Irish consumer, cattle balance statistics (see Figure 20) and cattle movement data (see Figure 22) available for 2008 were used.

In 2008 the total output of beef from Irish slaughterhouses was 536554 tonnes carcass weight equivalents (cwe)[14] (DAFM, 2008) and 33939 cwe were imported (CSO, 2013), giving a total domestic production including imports of 570493 cwe. Of these 87842 went onto the domestic Irish market ('domestic consumption') (CSO, 2013). The latter comprises 27 % of production from local abattoirs and 73 % from factories and imports. The exact contribution from each factories and imports to domestic consumption is unknown but can be approximated (see Table 35). Two scenarios have been created to calculate the range of contribution, namely A) all imported meat remains on the market and B) all imported meat is re-exported. The true value will fall in-between these two scenarios. For scenario A, the contribution from imports and factories was calculated at 34 % and 39 %, respectively and for scenario B at zero and 73 %, respectively. In terms of overall total factory output (512463 tonnes cwe), potential supply to the domestic market from factories translates into between 6 - 12 % (see Figure 20).

This range was used to estimate the amount of contaminated cattle slaughtered in factories that reached the domestic market during the incident timeframe (Sept - Mid December). Within this timeframe, a total of 2742 cattle from the affected herds were moved (see Figure 22) (DAFM, 2011). Of those, 2564 went for slaughter for human consumption. 652 animals were slaughtered in local abattoirs destined for the domestic market and 1912 were slaughtered in larger factories, mainly for export purposes (DAFM, 2011). As calculated above, of the latter, between 6 - 12 % was assumed to have reached

---

[14] 536,554 tonnes cwe ≈ 1,7 Mio animals (cattle carcase weight = 322 kg)

the domestic market, equating to 115 - 230 animals. Therefore, a total of 767 - 882 (652 contaminated animals from local abattoirs and between 115 - 230 contaminated animals from export factories) reached the domestic market between September and mid December, which represents 0.96 - 1.11 % of the total amount of cattle (contaminated + uncontaminated) being placed onto the domestic market in that timeframe (approx. 80000 (DAFM, 2008)).

Whilst a considerable amount of beef would have been consumed already by the time the contamination incident was discovered, beef from the contaminated herds was traced and withdrawn from the market on discovery of the contamination. In total 208.5 tonnes of meat were withdrawn, however, the actual amount of carcasses coming from contaminated herds is unknown, as the total amount of withdrawn meat also contained meat from uncontaminated herds (DAFM, 2011). Based on individual daily slaughter records, it has been estimated that approximately 10 % (DAFM, 2011) of withdrawn meat originated from contaminated herds. For the purposes of estimating exposure of the population from consumption of contaminated beef, the amount of withdrawn beef was not taken into account, which may have resulted in a slight overestimate of exposure.

The presence probability used in the model therefore was 0.011 (1.1 %), which reflects the upper estimate of percent contaminated beef of total beef being placed onto the market during the contamination time period.

5.3.3.2 Pork

In 2008 200500 tonnes cwe[15] of pig meat were slaughtered in Ireland and 75500 tonnes were imported, giving a total domestic production including imports of 276000 tonnes cwe. Of these, 138000 tonnes cwe went onto the domestic Irish market (‘domestic consumption’) and 138000 tonnes cwe went for export (see

Figure 21) (Bord Bia, 2008).

Total Domestic Consumption comprises 4000 tonnes cwe from abattoirs slaughtering exclusively for the domestic market and 134000 tonnes from both imports and factories, slaughtering predominantly for export but also for the domestic market. The exact

[15] 201,000 tonnes cwe ≈ 2.5 Mio animals (pig carcase weight = 81 kg)

contribution from each factories and imports to domestic consumption is unknown but can be approximated (see Table 35). Three scenarios were created to calculate the potential percent contribution from both imports and factory output to domestic consumption, namely A) all imported meat remained on the market and B) all imported meat was re-exported. The true value falls in-between these two scenarios. For scenario A, the contribution from imports and factories was calculated at 55 % and 42 %, respectively and for scenario B at zero and 97 %, respectively. However, neither of these two scenarios occur in reality, rather, only a certain amount of imported pig meat is likely to be re-exported, therefore, a third, scenario, based on expert opinion, was added, namely C) only imported carcasses and primal cuts were re-exported (after further processing), whereas imported value added processed product largely remained on the market. The latter assumption results in a contribution of 31 % from imports and 66 % from factories to the total of 134000 tonnes cwe from factories and imports. Compared to the total factory output (196500 tonnes cwe for export and domestic supply), the potential supply to the domestic market from factories calculates at 47 % .

This percentage can be used to estimate the amount of contaminated pigs slaughtered in factories that reached the domestic market during the incident timeframe (Sept - Mid December) (see Figure 22). Within this timeframe, a total of 51734 pigs (DAFM, 2013) from the affected herds went for slaughter for human consumption. 12 animals were slaughtered in local authority abattoirs destined for the domestic market (FSAI, 2013) and 51722 pigs were slaughtered in larger export factories, also supplying the domestic market (DAFM, 2013). As calculated above, of the latter, 47 % was assumed to have reached the domestic market, equating to 24309 animals. Therefore, a total of 24321 (12 contaminated animals from local abattoirs and 24309 contaminated animals from export factories) reached the domestic market between September and mid December, which represents 4.86 % of the total amount of pigs (contaminated + uncontaminated) being placed on the market in that timeframe (approximately 500000).

Whilst a considerable amount of pork would have been consumed already by the time the contamination incident was discovered, pork from the contaminated herds was traced and withdrawn from the market on discovery of the contamination. In total 30000 tonnes of meat were destroyed (DAFM, 2013), however, the actual amount of carcasses from contaminated herds is unknown, as the total amount of withdrawn meat also contained meat from uncontaminated herds. For the purposes of estimating exposure of the population from consumption of contaminated pork, the amount of withdrawn pork was not taken into account, which may have resulted in a slight overestimate of exposure.

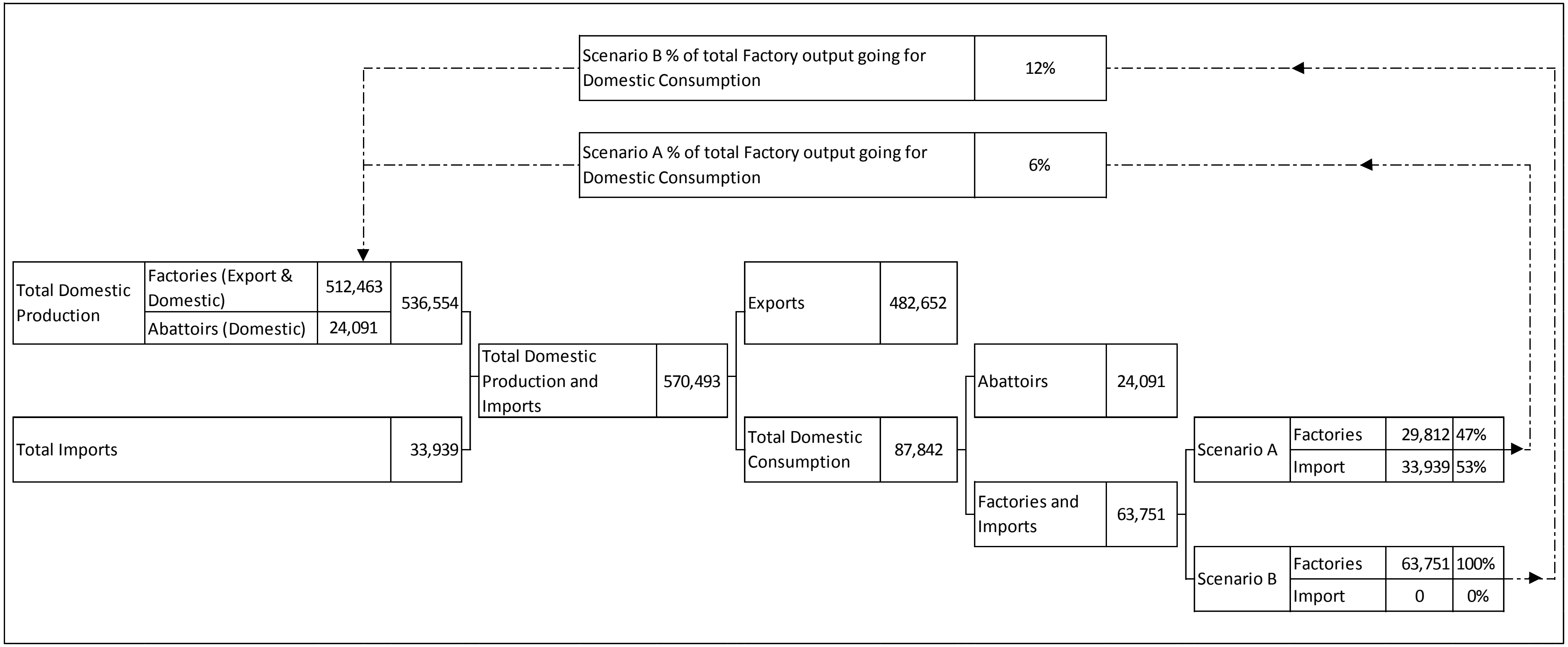
The presence probability used in the model was 0.05 (5 %), rounded up from 4.86 %, which reflects the medium bound estimate of percent contaminated pork of total pork being placed onto the market during the contamination time period, based on expert opinion incorporated in scenario C.

Table 35 Estimation of contribution of factory slaughter and imports to total domestic consumption

Estimation of Contribution of Factory Slaughter and Import to Total Domestic Consumption (TDC)							
	Pig (tonnes cwe)	% of TDC (138000)	% of total factory slaughter (196500)		Beef (tonnes cwe)	% of TDC (87842)	% of total factory slaughter (512463)
Scenario A) All imports remain on market							
Abattoirs (domestic)	4000	3			24091	27	
Imports	75500	55			33939	39	
Contribution from Factories	58500	42	30		29812	34	6
Total Domestic Consumption	138000	100			87842	100	
Scenario B) All imports are re-exported							
Abattoirs (domestic)	4000	3			24091	27	
Imports	0	0			0	0	
Contribution from Factories	134000	97	68		63751	73	12
Total Domestic Consumption	138000	100			87842	100	
Scenario C) A proportion of imports is re-exported							
Abattoirs (domestic)	4000	3					
Imports*	42591	31					
Contribution from Factories	91409	66	47				
Total Domestic Consumption	138000	100					

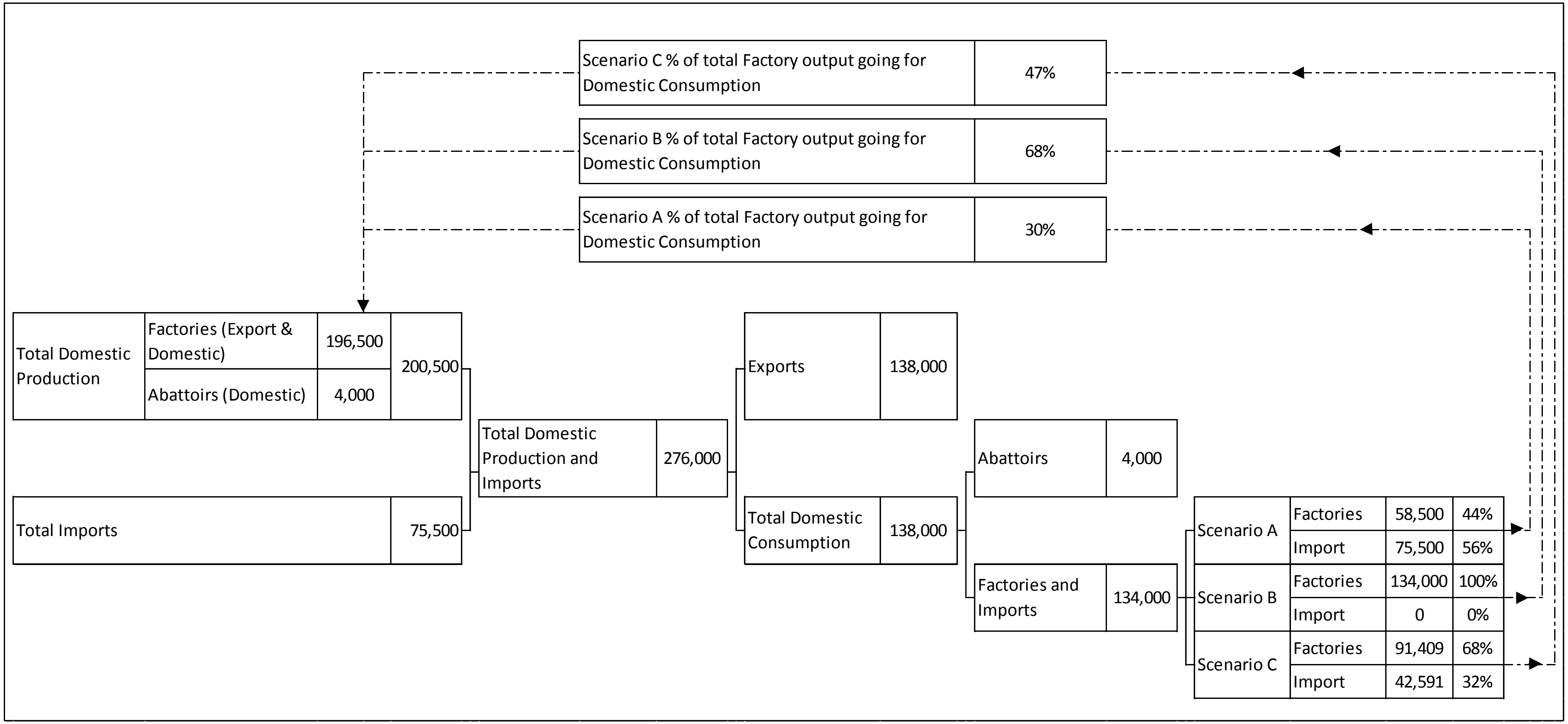
Data Sources: (Bord Bia, 2008; CSO, 2012; DAFM, 2008; DAFM, 2012)
Cwe = carcass weight equivalent
* In 2008, 75500 cwe of pork were imported, comprising 43.6 % of pork carcasses, cuts and offal and 56.4 % of added value products (bacon, ham, sausages, etc)

Figure 20 Beef production statistics 2008 (tonnes carcase weight equivalents (cwe))



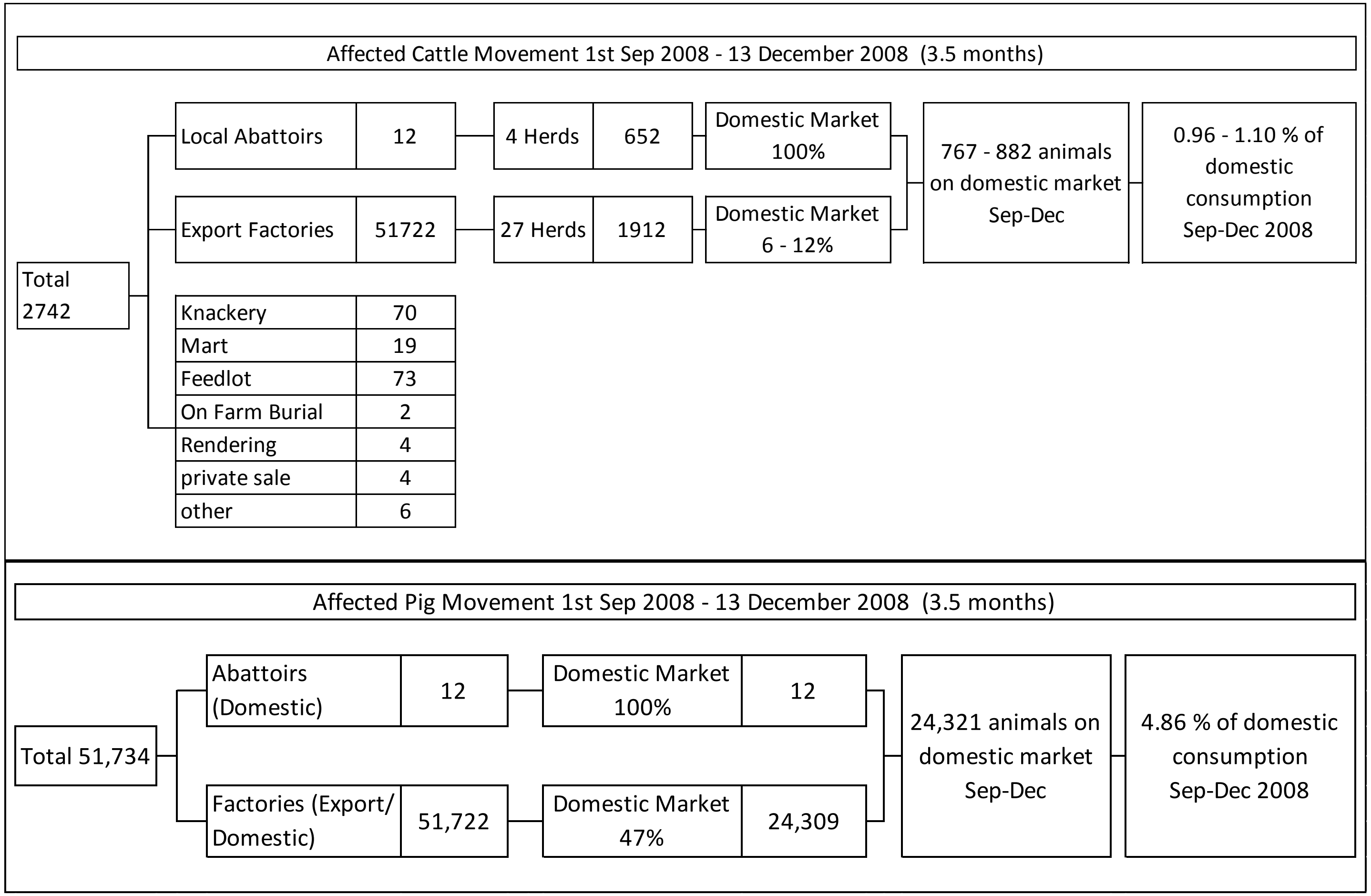
Data Sources: (Bord Bia, 2008; CSO, 2012; DAFM, 2008; DAFM, 2012)

Figure 21 Pork production statistics 2008 (tonnes carcase weight equivalents (cwe))



Data Sources: (Bord Bia, 2008; CSO, 2012; DAFM, 2008; DAFM, 2012)

Figure 22 Movement of contaminated cattle and pigs during the incident time-frame (Sept – mid Dec), expressed in Number of animals



Data Sources: (Bord Bia, 2008; CSO, 2012; DAFM, 2012; FSAI, 2013)

5.3.4 Exposure Estimates

5.3.4.1 Food consumption

Survey Population Count and Intake of fat from food groups are as described in section 3.3.3.1

5.3.4.2 Post Incidence exposure to Total WHO TEQ (2005) (Sum PCDD/F & DL-PCBS)

Table 36 shows summary statistics of the total population exposure to Total WHO TEQ (2005) for the total exposure from all food groups following the 2008 contamination incident, the same data is also displayed graphically in Figure 23. Table 38 provides an overview of estimated UB exposure to Total WHO TEQ per food group. Results expressed using the 1998 TEF scheme are provided in the Annex (see Annex 7.4) to facilitate comparison with previous results.

Table 36 UB Summary statistics of post incident exposure to Total WHO TEQ (2005) from all food groups (pg/kg bw/d)

Group Names	Total WHO TEQ (2005) pg/kg bw/d post incident							
	Mean	Med	P75	P90	P95	P97.5	P98	P99
TOTAL	1.4	0.27	0.6	2.0	5.5	11	13	23

Figure 23 Total Population Distribution of exposure to Total WHO TEQ from six food groups (Chart truncated at P99)

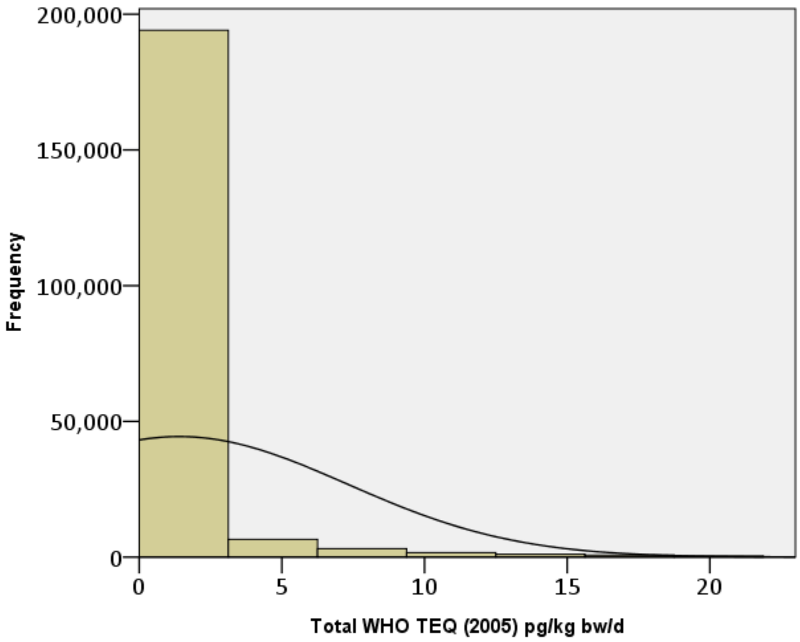
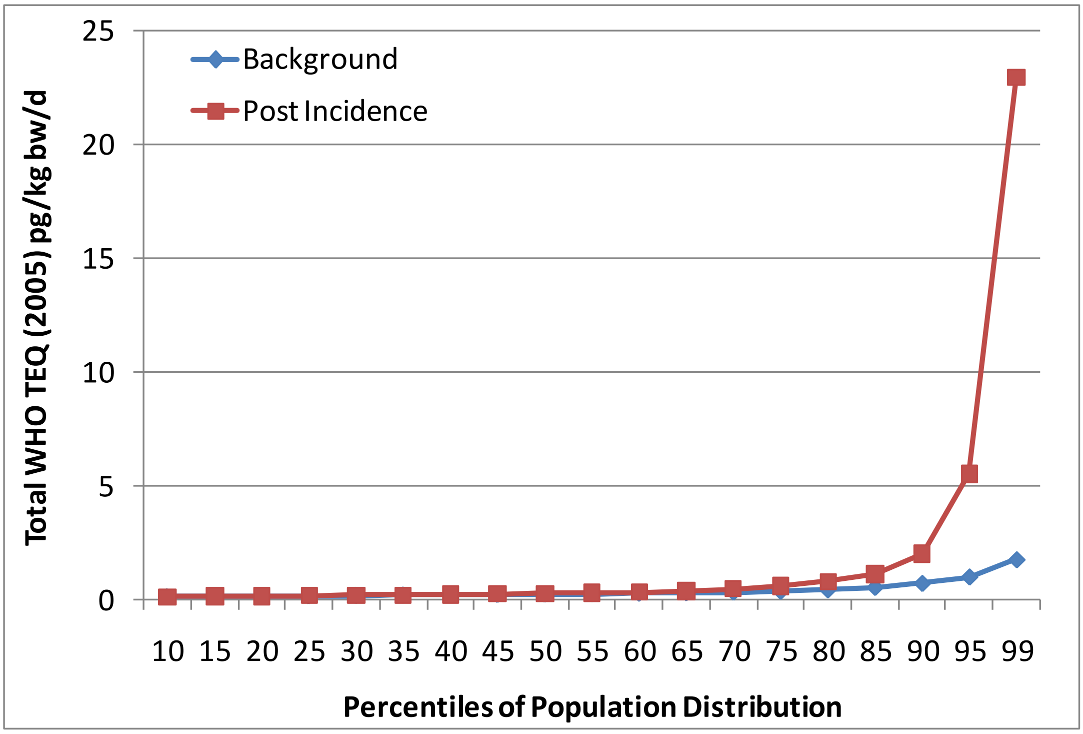


Figure 24 Plotting of background versus post incident distribution for Total WHO TEQ (2005)



As can be seen from Figure 24, the vast majority of the population were not particularly impacted by the contamination incident, and only higher percentile consumers of the population had elevated intakes. Table 36 shows that the mean exposure is higher than the 75th percentile, being situated at the 87.4th percentile. This is due to the mean being "dragged" to the right by the extreme skewness of the distribution, as can be seen in Figure 23. The latter is due to the very low presence of contaminated product (1.1 % and 5 % for beef and pork, respectively), the effects of which can only be observed in the higher percentiles of the exposure distribution. The mean therefore does not serve as a good indicator of the population exposure in this case, and the median, which describes the 50th percentile is a better statistic.

The median daily intake to Total WHO TEQ (2005) was estimated at 0.3 pg/kg bw/d and 95th percentile intake at 5.5 pg/kg bw/d, which translates into a monthly (30 day) intake of 8 pg/kg bw/m at the median and 165 pg/kg bw/m at the 95th percentile.

The most important contributor to the mean exposure, as expected, came from the category "Meat and Meat Products, Pork", contributing to 70 % to the total exposure, followed by "Meat and Meat Products, Beef" and "Fish and Fish Products, Oily Fish", contributing up to 10 and 9 % to the total exposure, respectively. Again the latter percentages were based on the population mean, which as discussed above, sits at the 87.4th percentile, therefore the contribution of food groups to total intake reflects consumption patterns observed at the higher percentiles.

These exposure figures may be compared to the WHO PMTI of 70 pg/kg bw indicating a median exposure of 11 % of the tolerable monthly intake. 90.9 % of consumers had intakes at or below the PTMI, the remaining 9.1 % of the population exceeding the PMTI with an exposure of the 95th percentile consumer at 244 % of the tolerable monthly intake. The 99th percentile consumer would have been exposed to almost ten times the PTMI, practically eroding the safety factor built into the PTMI derived by JECFA (see 1.3.1.4).

However, considering the long biological half-life of dioxins, the impact of an additional exposure on the body burden is a more relevant indicator of the potential health risk rather than the daily dose (EFSA, 2008; JECFA, 2002), and therefore comparisons were made using human milk dioxin data as biomarker of body burden in Ireland.

Human breast milk samples from Ireland were analysed in 2002 and 2009/2010. In 2002, pooled breast milk samples from the industrialised/urban areas of Cork and Dublin had concentrations of Total WHO TEQs (1998) of 13.3 and 13.7 pg/g fat, respectively, with lower concentrations being observed in the sub-urban and rural samples from Wicklow and Donegal of 11.6 pg/g fat and 8.9 pg/g fat respectively, giving an overall mean of 11.9 pg/g fat over the 4 samples. In 2009/2010 eleven pools were analysed with results ranging from Total WHO-TEQs (1998) from 7.5 - 13.7 pg/g fat, the overall pooled sample of milk from 109 mothers in 2010 showing 9.7 pg/g fat (Pratt *et al,* 2012). These figures were converted into 2005 WHO TEQs, giving a mean Total WHO TEQ (2005) for the 2002 study of 9.5 pg/g fat and 8.1 pg/g fat for the overall pooled milk in 2010, respectively.

An average concentration of 9.5 pg/g fat Total WHO TEQ (2005) was used to derive an estimate of the body burden prior to the contamination incident. No information on body weight was recorded in the 2002 study, however available information on the body mass index (BMI) is consistent with BMIs recorded in the 2010 study, which reported an average bodyweight of 65 kg, which is in line with the average body weight of 67.4 kg reported in the NANS for women 18-35 years old. The NANS further reported a mean body fat percent of 31% for this population group and the latter has been used in the estimation of the body burden.

Therefore, based on a (rounded) body weight of 65 kg and 30 % body fat the average level of 9.5 pg/g fat Total WHO TEQ (2005) in human breast milk corresponds to a body burden of 2850 pg/ kg bw[16].

The contamination incident window was identified as having occurred between the start of September and beginning of December, when the contamination was detected. Therefore, the additional exposure will have occurred over a period of approximately 90 days.

The estimated additional exposure due to the contamination incident can be derived by comparing the background exposure results with the results obtained from the incident exposure model. Table 37 provides a comparison of summary statistics derived from background concentration with summary statistics derived from the contamination incident and calculated percentages of the PTMI.

There was no perceptible difference at the population median (see Figure 24). The difference amounts to 4.5 pg/kg bw/d at the 95th percentile up to 21 pg/kg bw/d at the 99th percentile. For a 90 day period, the total additional exposure was 407 pg/kg bw/90d at the 95th percentile and 1911 pg/kg bw/90d at the 99th percentile. Compared with an estimated body burden of 2850 pg/kg bw, the additional exposure amounts to 14 % at the 95th percentile and 1 % of the population would have had an additional exposure of greater than 67 % to the body burden.

However, the body burden of 2850 pg/kg bw derived for Ireland, based on recent breast milk data, is comparably lower than the tolerable body burden at steady state of 4000 pg WHO TEQ/kg bw, which can be extrapolated from the TWI of 14 pg WHO TEQ/kg bw per week established by the SCF, corresponding with a daily dose of 2 pg WHO TEQ/kg bw (EFSA, 2008). Therefore, by following a conservative approach, addition of the 90 day exposure of 1911 pg/kg bw to the established body burden of 2850 pg/kg bw, would result in a slight exceedance of the tolerable body burden at 4761 pg/kg bw at the 99th percentile.

---

[16] (9.5 pg/g = 9500 pg/kg = 2,850 pg/kg bw based on 30% body fat)

Table 37 Difference in summary statistics between background concentration and post incident concentration in Total WHO TEQ (2005) pg/kg bw

BACKGROUND Total WHO TEQ (2005) pg/kg bw					
Population statistics	Median	Mean	P95	P98	P99
TOTAL Exposure	0.23	0.34	0.99	1.40	1.76
TOTAL Exposure (30 days)	7	10	30	42	53
% of PTMI (70 pg/kg bw/m)	10	14	42	60	75

INCIDENT Total WHO TEQ (2005) pg/kg bw					
Population statistics	Median	Mean	P95	P98	P99
TOTAL Exposure (per day)	0.27	1.39	5.5	13	23
TOTAL Exposure (30 days)	8.0	42	166	401	690
% of PTMI (70 pg/kg bw/m)	11	60	236	573	985

ADDITIONAL EXPOSURE (INCIDENCE DATA - BACKGROUND DATA) Total WHO TEQ (2005) pg/kg bw					
Population statistics	Median	Mean	P95	P98	P99
TOTAL Exposure (per day) excl background	0.03	-	4.5	12	21
TOTAL Exposure (90 days) excl background	3.1	-	407	1077	1911
% of Body Burden = 2850 pg/kg bw	0.1	-	14	38	67

The derived estimates are likely to present an overestimation, as it is assumed that all of the contaminants present in the food were absorbed at 100 %, which is unlikely. Absorption rates for the top two contributing congeners to the Total WHO TEQ in the contaminated food, namely 2,3,4,7,8 Penta CDF and 1,2,3,4,7,8 Hexa CDF (≈90 % contribution, see Figure 13), are reported to be around 70 % (US EPA, 2003).

Additional sources of overestimates include the conservative approach taken by incorporating the higher end of the presence probability range in the model and the calculation of exposure based on average daily intakes, rather than usual intakes, which is likely to overestimate exposure in the higher percentiles (see Figure 9).

Table 38 Contamination impact - UB Mean, Median and higher percentile exposure to Total WHO TEQ (2005) expressed as pg/kg bw/d and % contribution to the total mean average daily intake

Group Names	Total WHO TEQ (2005) pg/kg bw/d post incident								
	% Contribution	Mean	Med	P75	P90	P95	P97.5	P98	P99
DAIRY, MILKS	2.0	0.03	0.02	0.04	0.06	0.08	0.1	0.1	0.1
DAIRY, CREAMS	0.6	0.009	0.001	0.01	0.03	0.04	0.05	0.06	0.08
DAIRY, YOGHURTS	0.2	0.003	0	0.004	0.01	0.02	0.02	0.02	0.03
DAIRY, CHEESE	1.7	0.02	0.02	0.03	0.06	0.08	0.10	0.1	0.1
DAIRY, BUTTER	1.5	0.02	0.010	0.03	0.06	0.08	0.1	0.1	0.2
DAIRY	6.1	0.09	0.07	0.1	0.2	0.2	0.2	0.3	0.3
EGGS, CHICKEN	0.6	0.008	0.006	0.01	0.02	0.03	0.03	0.03	0.04
EGGS, DUCK	0.002	0.00003	0	-	-	-	-	-	-
EGGS	0.6	0.008	0.006	0.01	0.02	0.03	0.03	0.03	0.04
MEAT AND MEAT PRODUCTS, BEEF	9.6	0.1	0.02	0.05	0.10	0.1	0.2	0.2	0.4
MEAT AND MEAT PRODUCTS, LAMB	0.7	0.009	0	-	0.04	0.06	0.09	0.1	0.1
MEAT AND MEAT PRODUCTS, PORK	70	1.0	0.02	0.06	1.2	4.8	9.9	12	20
MEAT AND MEAT PRODUCTS, POULTRY	0.5	0.007	0.003	0.007	0.02	0.03	0.05	0.06	0.08
MEAT AND MEAT PRODUCTS, OTHER	0.002	0.00003	0	-	-	-	-	-	-
MEAT AND MEAT PRODUCTS, MIXED MEAT	0.2	0.003	0	-	-	-	-	-	-
OFFAL, BEEF	0.006	0.00008	0	-	-	-	-	-	-
OFFAL, LAMB	0.06	0.0009	0	-	-	-	-	-	0.002
OFFAL, PORK	0.1	0.002	0	-	-	-	-	-	0.002
OFFAL, POULTRY	0.0004	0.000005	0	-	-	-	-	-	-
MEAT AND MEAT PRODUCTS	82	1.1	0.07	0.2	1.5	5.3	11	13	23

Table 38 continued Contamination impact – UB Mean, Median and higher percentile exposure to Total WHO TEQ (2005) expressed as pg/kg bw/d and % contribution to the total mean average daily intake

Group Names	Total WHO TEQ (2005) pg/kg bw/d post incident								
	% Contribution	Mean	Med	P75	P90	P95	P97.5	P98	P99
FISH AND FISH PRODUCTS, WHITE FISH	0.6	0.008	0	0.004	0.02	0.05	0.09	0.09	0.1
FISH AND FISH PRODUCTS, OILY FISH	8.7	0.1	0	0.03	0.5	0.7	1.0	1.1	1.5
FISH AND FISH PRODUCTS, MIXED FISH	0.0005	0.000006	0	-	-	-	-	-	-
FISH AND FISH PRODUCTS, SHELLFISH	0.08	0.001	0	-	-	0.001	0.004	0.006	0.04
FISH AND FISH PRODUCTS, OTHER	0.004	0.00006	0	-	-	-	-	-	-
FISH AND FISH PRODUCTS	9.4	0.1	0.002	0.08	0.5	0.8	1.1	1.2	1.5
FAT/DAIRY SPREADS EXCL BUTTER	1.0	0.01	0.01	0.02	0.03	0.04	0.05	0.06	0.07
OILS	0.6	0.008	0.007	0.01	0.02	0.02	0.02	0.03	0.03
FATS AND OILS EXCL BUTTER	1.6	0.02	0.02	0.03	0.04	0.05	0.06	0.07	0.08
SUPPLEMENTS, OILS/FATTY ACIDS	0.7	0.009	0	-	0.01	0.03	0.06	0.08	0.2
SUPPLEMENTS	0.7	0.009	0	0	0.01	0.03	0.06	0.08	0.2
TOTAL	100	1.4	0.3	0.6	2.0	5.5	11	13	23

5.3.4.3 Post Incidence exposure to Sum of 6 Marker PCBs

Table 39 shows summary statistics of the total population exposure to the sum of 6 Marker PCBs for the total exposure from all food groups following the 2008 contamination incident, the same data is also displayed graphically in Figure 25. Table 41 provides an overview of estimated UB exposure to Total WHO TEQ per food group.

Table 39 UB Summary statistics of post incident exposure to sum of 6 Marker PCBs from all food groups (ng/kg bw/d)

Group	Sum of 6 Marker PCBs (ng/kg bw/d) post incident							
	Mean	Med	P75	P90	P95	P97.5	P98	P99
TOTAL	8.0	0.8	3.3	13	36	70	84	136

Figure 25 Total Population Distribution of exposure to sum of 6 Marker PCBs from six food groups (Chart truncated at P99)

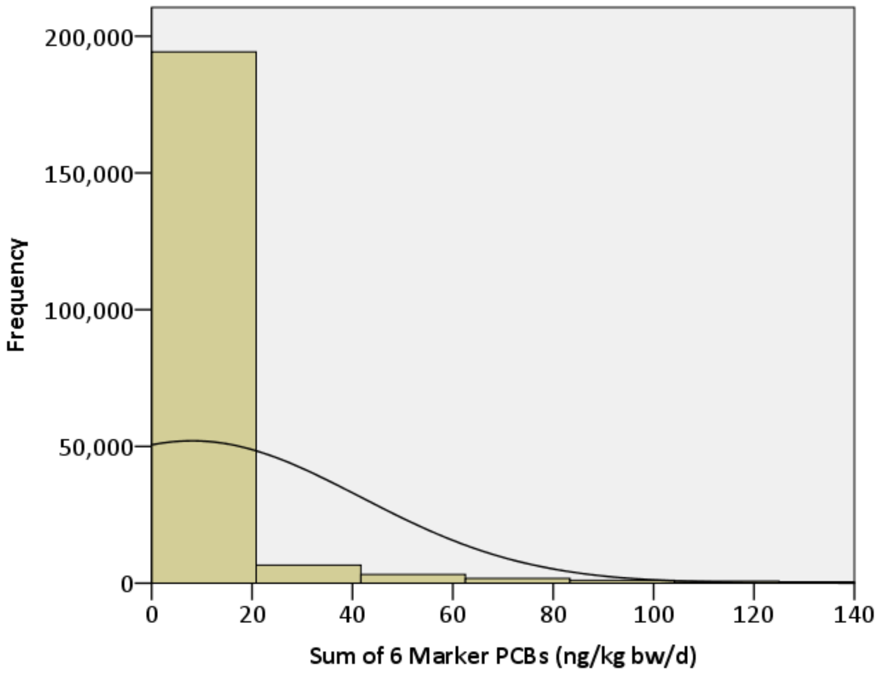
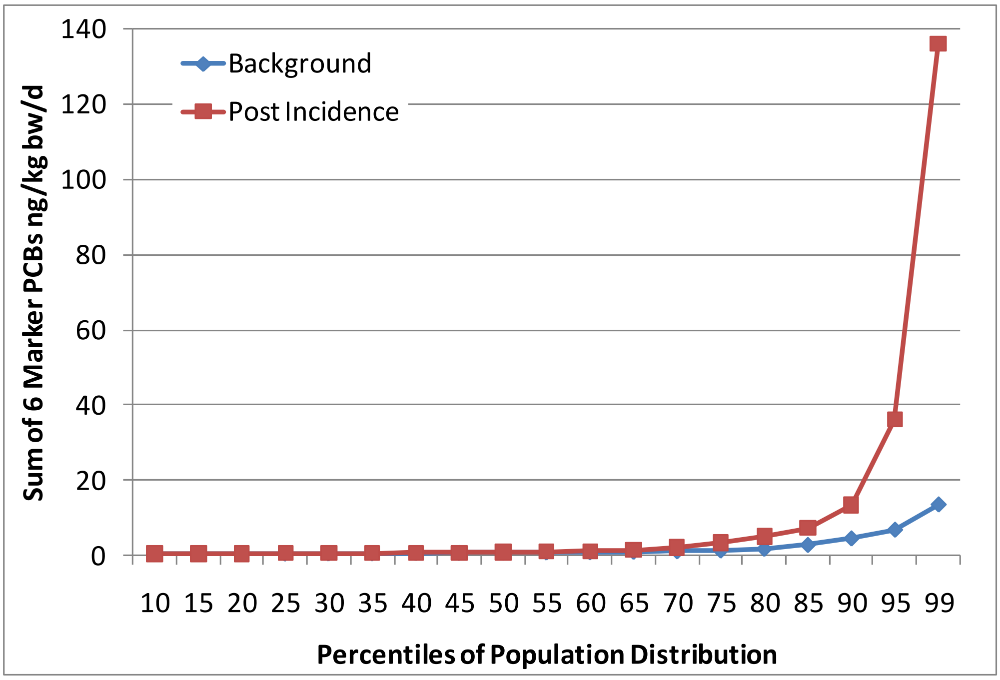


Figure 26 Plotting of background versus post incident distribution for sum of 6 Marker PCBs



Similar to the Total WHO TEQ (2005) (see 5.3.4.2) and as can be seen from Figure 26 the vast majority of the population were not particularly impacted by the contamination incident, only higher percentile consumers of the population had elevated intakes. Table 39 shows that the mean exposure is higher than the 75^{th} percentile, being situated at the 86.1^{th} percentile. This is due to the mean being "dragged" to the right by the extreme skewness of the distribution (see Figure 25). The latter is due to the very low presence of contaminated product (1.1 and 5 % for beef and pork, respectively), the effects of which can only be observed in the higher percentiles of the exposure distribution. The mean therefore does not serve as a good indicator of the population average in this case, and the median, which describes the 50^{th} percentile may provide a better measure.

The median daily intake of sum of 6 Marker PCBs was estimated at 0.8 pg/kg bw/d and 95^{th} percentile intake at 36 pg/kg bw/d, which translates into a monthly (30 day) intake of 240 pg/kg bw/m at the median and 1080 pg/kg bw/m at the 95^{th} percentile. The most important contributor to this exposure comes from the category "Meat and Meat Products, Pork", contributing up to 79 % to the total exposure, followed by "Fish and Fish Products" contributing up to 12 % to the total exposure. Again the latter percentages are based on the population mean, which as discussed above, sits at the 86.1^{th} percentile, therefore the contribution of food groups to total intake reflects consumption patterns observed at the higher percentiles.

The estimated additional exposure due to the contamination incident can be derived by comparing the background exposure results with the results obtained from the incident exposure model.

Again, as for the Total WHO TEQ, there was no perceptible difference at the population median (see Figure 26). Comparing the means is not practical in this case, as the shapes of the two distributions are very different and the means subsequently describe different positions of the exposure distribution. Therefore it is more meaningful to compare results for the different higher percentiles.

Table 40 provides a comparison of summary statistics derived from background concentration with summary statistics derived from the contamination incident.

Table 40 Estimated additional exposure to sum of 6 Marker PCBs (ng/kg bw/d) due to the contamination incident

	Sum of 6 Marker PCBs (ng/kg bw/d)						
Percentile	P50	P75	P90	P95	P97.5	P98	P99
Background	0.67	1.30	4.50	6.80	9.30	10.10	13.50
Post Incidence	0.81	3.30	13.30	36.10	70.30	83.50	136.10
Difference Incident - Background	0.14	2.10	8.80	29.30	61.00	73.40	122.60
TOTAL Exposure excl background ng/kg bw/90 days	12.6	189	792	2637	5490	6606	11034
90 day exposure expressed as % of Body Burden (22 µg/kg bw)	0.06	0.86	3.6	12	25	30	50

The contamination incident window was identified as having occurred between the start of September and beginning of December, when the contamination was detected. Therefore, the additional exposure would have occurred over a period of approximately 90 days. The difference amounts to 29.3 ng/kg bw/d at the 95th percentile up to 122.6 ng/kg bw/d at the 99th percentile. Therefore, for a 90 day period, the total additional exposure amounts to 2637 ng/kg bw/90d at the 95th percentile and 11034 ng/kg bw/90d at the 99th percentile.

This data may be put into context against an estimate of the existing body burden for NDL-PCBs, which is available from recent breast milk studies (see 3.3.3.2). As the contamination profile showed that 95 % of the PCBs present consisted of 3 of the 6 Marker PCBs (PCBs 138, 153 and 180) (see section 4.1.2), this additional exposure can be compared against the estimated body burden for all NDL-PCBs of 22 µg/kg bw (see Table 27). The additional exposure amounts to 12 % at the 95^{th} percentile and 1 % of the population would have had an additional exposure of in excess of 50 % to the body burden.

Again, the derived intake estimates are likely to present an overestimation, as it is assumed that all of the contaminants present in the food were absorbed at 100 %, which is unlikely. Bioavailability for PCBs has been reported to vary from 66 - 96 % with increasing absorption efficiency with increasing level of chlorination (Tanabe *et al,* 1981).

However, assuming a worst case scenario of 100 % absorption and tissue distribution, an increase of the existing body burden of 22 µg/kg bw by 50 % would result in a body burden of 33 µg/kg bw, which compared against the NOAEL BB of 500 µg/kg bw identified by EFSA (EFSA, 2005) would result in a MoBB at the NOAEL of 15, which is still larger than the MoBB at the NOAEL of 10 calculated for the European adult population by EFSA.

Table 41 Contamination Impact: Range of LB - UB Mean, Median and higher percentile exposure to sum of 6 Marker PCBs expressed as ng/kg bw/d and % contribution to the total mean average daily intake

	Sum of 6 marker PCBs (ng/kg bw/d) post incident								
Food Group	% Contribution	Mean	Median	P75	P90	P95	P97.5	P98	P99
DAIRY, MILKS	0.5	0.04	0.03	0.05	0.09	0.1	0.2	0.2	0.2
DAIRY, CREAMS	0.2	0.01	0.001	0.02	0.04	0.06	0.08	0.09	0.1
DAIRY, YOGHURTS	0.06	0.005	0	0.006	0.02	0.02	0.03	0.03	0.04
DAIRY, CHEESE	0.4	0.03	0.02	0.05	0.08	0.1	0.1	0.2	0.2
DAIRY, BUTTER	0.4	0.03	0.01	0.04	0.08	0.1	0.2	0.2	0.2
DAIRY	1.5	0.1	0.1	0.2	0.2	0.3	0.4	0.4	0.4
EGGS, CHICKEN	1.2	0.1	0.03	0.08	0.2	0.5	0.9	1.0	1.3
EGGS, DUCK	0.005	0.0004	0	0	0	0	0	0	0
EGGS	1.3	0.1	0.03	0.08	0.2	0.5	0.9	1.0	1.3
MEAT AND MEAT PRODUCTS, BEEF	2.2	0.2	0.04	0.10	0.2	0.2	0.3	0.4	0.5
MEAT AND MEAT PRODUCTS, LAMB	0.2	0.02	0	0	0.08	0.1	0.2	0.2	0.3
MEAT AND MEAT PRODUCTS, PORK	79	6.3	0.05	0.1	8.2	33	67	81	133
MEAT AND MEAT PRODUCTS, POULTRY	0.5	0.04	0.01	0.03	0.08	0.1	0.3	0.3	0.5
MEAT AND MEAT PRODUCTS, OTHER	0.0006	0.00005	0	0	0	0	0	0	0
MEAT AND MEAT PRODUCTS, MIXED MEAT	0.2	0.02	0	0	0	0	0	0	0
OFFAL, BEEF	0.001	0.0001	0	0	0	0	0	0	0
OFFAL, LAMB	0.01	0.0009	0	0	0	0	0	0	0.004
OFFAL, PORK	0.1	0.01	0	0	0	0	0	0	0.0009
OFFAL, POULTRY	0.0002	0.00002	0	0	0	0	0	0	0
MEAT AND MEAT PRODUCTS	82	6.6	0.2	0.3	9.0	35	69	82	135

Table 41 continued Contamination Impact: Range of LB - UB Mean, Median and higher percentile exposure to sum of 6 Marker PCBs expressed as ng/kg bw/d and % contribution to the total mean average daily intake

Food Group	Sum of 6 marker PCBs (ng/kg bw/d) post incident								
	% Contribution	Mean	Median	P75	P90	P95	P97.5	P98	P99
FISH AND FISH PRODUCTS, WHITE FISH	1	0.05	0	0.02	0.1	0.2	0.5	0.5	0.8
FISH AND FISH PRODUCTS, OILY FISH	11	0.9	0	0.07	3.5	5.7	7.9	8.8	12
FISH AND FISH PRODUCTS, MIXED FISH	0	0.00004	0	0	0	0	0	0	0
FISH AND FISH PRODUCTS, SHELLFISH	0	0.005	0	0	0	0.002	0.006	0.01	0.1
FISH AND FISH PRODUCTS, OTHER	0	0.0004	0	0	0	0	0	0	0
FISH AND FISH PRODUCTS	12	0.9	0.004	0.3	3.6	5.8	8.0	8.9	12
FAT/DAIRY SPREADS EXCL BUTTER	1	0.1	0.08	0.2	0.2	0.3	0.4	0.4	0.5
OILS	1	0.05	0.04	0.06	0.09	0.1	0.1	0.1	0.2
FATS AND OILS EXCL BUTTER	2	0.2	0.1	0.2	0.3	0.4	0.5	0.5	0.6
SUPPLEMENTS, OILS/FATTY ACIDS	1	0.1	0	0	0.09	0.4	0.7	0.9	2.3
SUPPLEMENTS	1	0.1	0	0	0.09	0.4	0.7	0.9	2.3
TOTAL	100	8.0	0.8	3.3	13	36	70	84	136

5.3.5 Uncertainty Analysis

The method applied in any dietary exposure assessment should be clearly stated and reproducible and the need to discuss the uncertainties affecting exposure assessment has repeatedly been highlighted by various scientific and regulatory bodies over recent times (EC, 2000b; EC, 2003; EFSA, 2006; EFSA, 2009; WHO, 2009)

A systematic review of each step has been performed and uncertainties are considered qualitatively, using a tabular format (see Table 42), as recommended by EFSA for refined assessments (EFSA, 2006).

Table 42 Qualitative evaluation of influence of uncertainties on the exposure estimate of dioxin contamination of the Irish Adult Population

Source of uncertainty	Direction & magnitude*
Consumption data:	
Representativeness/under-reporting/misreporting/portion size estimation	++/--
Extrapolation from food consumption survey of few days to estimate chronic exposure, especially at high percentiles	++
Modification of (NANS) food consumption database	
Application of standard recipes, application of extrapolated recipes, application of recipes derived from ingredient information	+/-
Application of conversion factors from cooked to raw food	+/-
Application of fat fractions to amount of food consumed	+/-
Consumption data applies to the general population and does not consider regions with potential higher consumption due to particular consumption patterns (e.g. fishermen)	--
Food intake has been converted from cooked to raw and does not take into account loss of contaminants due to processing/cooking of the food	+
Occurrence data used in models	
Exclusion of foods with potentially very low contamination (fruit, vegetable)	-
For some food categories older concentration data was used,	+
Occurrence data is based on national food production only and does not take into consideration imported food	-
Incident data was not collected for the purposes of exposure assessment and may not fully be representative of the contaminant occurrence	+/-
It was assumed that all animals from affected herds were contaminated at the same time and to the same extent	+
Linkage of food consumption data and occurrence data	
For some food groups concentration data was extrapolated from other food groups	+/-
Presence Probability	
The presence probabilities derived are based on conservative assumptions and do not take into account any potential meat recalled from the market	++
Body Burden Calculations	
Extrapolations from human biomarkers to body burden	+/-
Extrapolations from estimated intake data to body burden	++/--
* Key to direction and magnitude: +, ++, +++ = uncertainty likely to cause small, medium or large over-estimation of exposure; -, - -, - - - = uncertainty likely to cause small, medium or large under-estimation of exposure.	

6 Summary and Conclusion

PCDD/Fs and DL-PCBs have long half-lives in the body and therefore accumulate during continuous exposure and reach a pseudo-steady state only after decades (JECFA, 2002). The biochemical and toxicological effects of PCDDs, PCDFs and DL-PCBs are directly related to their concentrations in tissues, and not to the daily dose (WHO, 2002). In the absence of information on tissue concentration data, body burden data (see section 1.3.1.3) has been used to derive tolerable intake values by the various expert bodies (JECFA, 2002; SCF, 2000; SCF, 2001; Van Leeuwen *et al,* 2000) in their risk assessments of dioxins (see Table 2). To that extent, measurement of POPs in breast milk is accepted as providing a robust and relatively non-invasive measurement of body burden of these ubiquitous contaminants , and can thus be used as an indicator for the overall exposure of the general population (Malisch *et al,* 2008).

However, the breast milk concentration data does not reveal much about the contributing sources, and for regulatory and risk assessment purposes different means of assessing dietary exposure are needed. Furthermore, due to ethical considerations, only pooled samples containing milk from several mothers are typically analysed, which are not likely to pick up any extreme consumer behaviour due to dilution in the pool.

One aim of this particular study was to provide an estimate of background exposure to the Irish adult population with a view to characterise major contributors and compare intake estimates with established health based guidance values. Another aim was to estimate the impact of the 2008 dioxin contamination incident in Ireland on this background exposure, and lastly, the latter intake estimates provided a means to assess the validity of the exposure assessment performed during the crisis, which had been performed subject to extreme time limitations and which had lacked a lot of the information which became available later and which was subsequently utilised in the refined assessment performed here.

In order to fulfil the above aims, a rather resource intensive model was chosen, which provided a full distribution of dietary exposure and utilised individual food consumption data and the full range of chemical concentration data available for Ireland.

6.1 Estimated background exposure

6.1.1 Background exposure to Total WHO TEQ PCDD/Fs & DL-PCBs

The average daily intake of Irish adults to dioxins Total WHO TEQ (2005) (PCDD/Fs & DL-PCBs) from background contamination ubiquitous in the environment, was estimated at 0.3 pg/kg bw/d and at the 95th percentile at 0.9 - 1 pg/kg bw/d. Upperbound and lowerbound results at the mean were equal with a difference of 10 % at the 95th percentile. Comparing the upperbound values to the health based guidance value of WHO PMTI of 70 pg/kg bw indicating a mean exposure of 13 % of the tolerable monthly intake, and exposure of the 95th percentile consumer falling within 39 - 43 % of the tolerable monthly intake. The most important contributor to this exposure comes from the category "Fish and Fish Products", contributing up to 41 % to the total exposure, followed by "Meat and Meat Products" and "Dairy", each contributing up to 25 % to the total exposure.

As described earlier, lifetime estimates could not be computed for all food groups due to violation of the requirement for normality in the data distribution and hence, total estimates could only be calculated based on average daily intakes. However, with the exception of food supplements, lifetime estimates could be derived on a food category basis and comparisons could be made with estimates derived based on average daily intakes. At the 95th percentile, lifetime estimates were lower than average daily estimates as follows: 12 % for dairy, 39 % for eggs, 29 % for meat and meat products, 24 % for fish and fish products and 13 % for fats and oils, giving an overall average of 24 %. For the 99th percentile this overall average increases to 29 %, indicating that long term high percentile chronic intake is likely to be lower.

Concerning the mean exposure to Total WHO TEQ PCDD/F &DL-PCBs, the majority of food groups gave similar results for daily average and lifetime estimates, however, for the food group "Fish and Fish Products", the highest contributor to the total mean intake, lifetime values returned higher mean results, with a difference of 5 - 33 % in comparison to the daily average derived mean. This suggests that the calculated mean might slightly underestimate long term mean chronic intake.

Compared to reported findings in other EU Member States (see Table 5) the results of this study suggest that exposure of Irish adults to dioxins is lower than the reported European average. The UB mean of 0.4 pg/kg bw/d Total WHO TEQ (1998) derived in this study is below the range of means of 0.9 – 2.9 pg/kg bw/d reported for other Member States. However, direct comparisons cannot be made, due to the different methodologies employed by the various countries and also due to the different points of time of the studies undertaken.

6.1.2 Background exposure to Sum of 6 Marker PCBs

The average daily intake of Irish adults to sum of 6 Marker PCBs from background contamination ubiquitous in the environment was estimated at 1.4 - 1.6 ng/kg bw/d and at the 95th percentile at 6.4 - 6.8 ng/kg bw/d.

The most important contributor to this exposure comes from the category "Fish and Fish Products", contributing up to 64 % to the total exposure, followed by "Meat and Meat Products" contributing up to 13 % to the total exposure.

As observed for dioxins, lifetime exposure values, where available, are lower for high percentile consumers, which suggests that high percentile long-term exposure may be lower than estimated based on average daily intake values. Consequently, the median values increase with also the mean values for food categories "Fish and Fish Products" and "Supplements", which are not consumed as frequently as the other food groups, increasing due to the removal of variance in the distribution.

No health based guidance value has been adopted for NDL-PCBs by any scientific body. In the absence of the latter, a MoBB at the NOAEL of 44 was calculated based on the UB mean dietary intake of 1.6 ng/kg bw/d, which is larger than the European average MoBB at the NOAEL of 10 as estimated by EFSA (EFSA, 2005). Dietary exposure estimates derived for Ireland were also lower than recently reported national estimates for other Member States, which ranged from 2.7 - 11 ng/kg bw/d at the mean and 7.9 - 24 and the 95th percentile (see Table 6).

6.1.3 Use of breast milk data as biomarker for exposure to dioxins and PCBs

A better indicator of the average dioxin and PCB body burden can be derived from breast milk data. Human breast milk samples from Ireland were analysed in 2002, as part of round 3 of the coordinated WHO study and again in 2009/2010 following the same protocol, to examine any potential influence of the 2008 dioxin contamination of Irish pork on the overall population exposure (Pratt *et al,* 2012).

The mean Total WHO TEQ (2005) for the 2002 study was 9.5 pg/g fat and 8.1 pg/g fat for the overall pooled milk in 2010, respectively. Based on these data and anthropometric data available in the NANS a body burden of 2850 pg/ kg bw was calculated for the Irish adult population. This body burden is generally lower than the average body burden of 4000 reported for Europe, which corresponds to the TWI of 14 pg WHO-TEQ/kg bw per week established by the SCF (SCF, 2001). These findings are in line with generally lower concentrations of dioxins found in breast milk in Ireland compared with other more industrialised European Member States (see Figure 2).

Average sum of 6 Marker PCBs and sum of all NDL-PCBs measured in 2002 were 54 μg/g fat and 74 μg/g fat and in 2010, 41 μg/g fat and 68 μg/g fat, respectively. The average 2010 levels of 41 and 68 μg/g fat NDL-PCBs in human breast milk correspond to body burdens of 12 μg/kg bw and 20 μg/kg bw for sum 6 Marker PCBs and sum Total NDL-PCBs, respectively. The BB associated with total NDL-PCB content of the 2010 breast milk survey of 20 μg/kg bw is less than the BB of 50 μg/kg bw based on reports from European Member States used by EFSA in their risk assessment. Therefore the MoBB, compared with a NOAEL BB of 500 μg/kg bw amounts to 25 for the Irish adult population, compared to a MoBB at the NOAEL of 10 calculated for the European adult population by EFSA. These findings are in line with generally lower concentrations of PCBs found in breast milk in Ireland compared with other more industrialised European Member States (see Figure 3).

6.1.4 Overall conclusions on background exposure of the Irish adult population to dioxins and PCBs

Dietary exposure estimates for both dioxins and PCBs indicate that the Irish adult population has exposures below the European average, a finding which is also supported by the levels detected in breast milk of Irish mothers. Exposure levels are below health based guidance values and/or Body Burdens associated with the TWI (for dioxins) or associated with a NOAEL (for PCBs). Given the current toxicological knowledge, based on biomarker data and estimated dietary exposure, general background exposure of the Irish adult population to dioxins and PCBs is unlikely to be of human health concern.

6.2 Estimated additional post incident exposure

6.2.1 The exposure model

To estimate additional exposure to dioxins and PCBs due to the contamination incident, a model was devised that took into account the proportion of contaminated product reaching the final consumer during the contamination incident window, which was determined to have occurred between September and December 2008. After collating all available data on animal movement, slaughter, import and export and home consumption statistics, and all available traceability data on the implicated herds the dioxins and PCBs presence probabilities for both pork and beef were derived. These estimates were reported as ranges, and were 4.86 % for pork and 0.96 - 1.1 % for beef, respectively. As a conservative approach, the upper end estimated presence probabilities were incorporated into the model, which will have led to an overestimation of exposure. Due to the very low presence probability, the impact on population exposure could only be observed in the higher percentiles, given the very low probability of consuming a contaminated product. The resulting exposure distributions were extremely skewed, which made using the mean level of contamination as population exposure indicator meaningless. Therefore, the model was run over sufficient amount of iterations to fully capture and produce robust statistics for the upper percentiles, which were deemed the critical indicators of additional exposure.

A conservative approach was also taken in assigning contamination concentrations, by assuming that all animals from all implicated herds were contaminated and that no meat from the affected animals was removed from the market. Whilst a considerable amount of product was recalled from the market, the exact proportion of contaminated meat withdrawn could not be reliably determined, as recalled product was a mixture of uncontaminated and contaminated food. Therefore, not excluding the fraction of removed product would have led to an overestimation of exposure. All concentration data gathered from contaminated herds was included in the model. The latter assumes that all animals from implicated herds that went for slaughter for human consumption were exposed to the contaminated feed. Whether this was indeed the case or not was difficult to establish, as feed supply from the implicated mill was not always directly delivered to the implicated farms, but often via indirect sources. Therefore, not all implicated herds would have been exposed to the contaminated feed for the entire contamination window identified, and depending on feeding rates and feed inclusion ratios large intra as well as inter herd variations were likely. However, the wide span of contamination data gathered during the incident suggests that this variation was captured to a certain extent.

No data, however, was collected for offal during the incident and exposure from liver consumption has been modelled using concentration data collected from fat tissue. However, to test any impact consumption of contaminated liver may have had, a hypothetical model using a ten-fold concentration observed in carcass fat was used to model potentially higher exposure from liver (see 3.2.4. additional considerations).

Exposure statistics were derived based on average daily intakes, which is likely to provide an overestimate in the upper percentiles and an underestimate of the population mean. The latter is due to inter-individual variation in food consumption. The latter can be reduced via mathematical modelling following the principles developed by Nusser et al (Nusser *et al,* 1996), however, due to the extremely skewed data, the requirement for normality in the dataset was violated and the required transformation of the dataset was not possible. However, lifetime estimates were derived for food intake and background exposure estimates and the so derived estimates indicate that lifetime estimates in the higher percentiles are on average 24 % and 29 % lower at the 95th and 99th percentile, respectively.

Comparisons with body burden data also assumed a 100 % absorption rate of the contaminants, which has been reported to be lower in the literature (Schlummer *et al,* 1998; Tanabe *et al,* 1981; US EPA, 2003).

In conclusion, the model employed to estimate additional exposure as a consequence of the 2008 dioxin contamination of Irish pork errs on the conservative side and is likely to over-estimate exposure.

6.2.2 Additional post incident exposure to Total WHO TEQ PCDD/F & DL-PCBs

The median daily intake of Total WHO TEQ (PCDD/F & DL-PCBs) (2005) was estimated at 0.3 pg/kg bw/d and 95th percentile intake at 5.5 pg/kg bw/d, which translates into a monthly (30 day) intake of 8 pg/kg bw/m at the median and 165 pg/kg bw/m at the 95th percentile. The most important contributor to the mean exposure, as expected, comes from the category "Meat and Meat Products, Pork", contributing to 70 % to the total exposure, followed by "Meat and Meat Products, Beef" and "Fish and Fish Products, Oily Fish", contributing up to 10 % and 9 % to the total exposure, respectively.

These exposure figures may be compared to the WHO PMTI of 70 pg/kg bw indicating a median exposure of 11 % of the tolerable monthly intake. 90.9 % of consumers were exposed to levels equal or less than the PTMI, the remaining 9.1 % of the population exceeded the PMTI with an exposure at the 95th percentile of 244 % of the PTMI. The 99th percentile consumer would have been exposed to almost ten times the PTMI, practically eroding the safety factor built into the PTMI derived by JECFA (see 1.3.1.4).

However, considering the long biological half-life of dioxins, the impact of an additional exposure on the body burden is a more relevant indicator of the potential health risk rather than the daily dose (EFSA, 2008; JECFA, 2002), and therefore comparisons have been made using human milk dioxin data as biomarker of body burden in Ireland.

The estimated additional exposure due to the contamination incident can be derived by comparing the background exposure results with the results obtained from the incident exposure model. For a 90 day period, the total additional exposure amounts to 407 pg/kg bw/90d at the 95th percentile and 1911 pg/kg bw/90d at the 99th percentile. Compared with an estimated body burden of 2850 pg/kg bw, the additional exposure amounts to 15 % at the 95th percentile and 1 % of the population would have had an additional exposure of greater than 71 % to the body burden.

However, the body burden of 2850 pg/kg bw derived for Ireland, based on recent breast milk data, is comparably lower than the tolerable body burden at steady state of 4000 pg WHO TEQ/kg bw, which can be extrapolated from the TWI of 14 pg WHO TEQ/kg bw per week established by the SCF, corresponding with a daily dose of 2 pg WHO TEQ/kg bw (EFSA, 2008). Therefore, by following a conservative approach, straight addition of the 90 day exposure of 1911 pg/kg bw to the established body burden of 2850 pg/kg bw, would result in a slight exceedance of the tolerable body burden at 4761 pg/kg bw at the 99th percentile intake.

6.2.3 Additional post incident exposure to Sum of 6 Marker PCBs

The median daily intake of sum of 6 Marker PCBs was estimated at 0.8 pg/kg bw/d and 95th percentile intake at 36 pg/kg bw/d. The most important contributor to this exposure comes from the category "Meat and Meat Products, Pork", contributing up to 79 % to the total exposure, followed by "Fish and Fish Products" contributing up to 12 % to the total exposure.

The additional exposure to Marker PCBs due to the contamination incident was estimated at 2637 ng/kg bw/90d at the 95^{th} percentile and 11034 ng/kg bw/90d at the 99^{th} percentile.

This additional exposure was compared against the estimated body burden for all NDL-PCBs of 22 µg/kg bw. The additional exposure to the existing BB of marker PCBs amounts to 12 % at the 95^{th} percentile and 1 % of the population would have had an additional exposure to the existing BB of marker PCBs in excess of 50 % .

Again, the latter is also likely to present an overestimation, as it is assumed that all of the contaminants present in the food were absorbed at 100 %, which is unlikely. Bioavailability for PCBs has been reported to vary from 66 - 96 % with increasing absorption efficiency with increasing level of chlorination (Tanabe *et al,* 1981).

However, assuming a worst case scenario of 100 % absorption and tissue distribution, an increase of the existing body burden of 22 µg/kg bw by 50 % would result in a body burden of 33 µg/kg bw, which compared against the NOAEL BB of 500 µg/kg bw identified by EFSA (EFSA, 2005) would result in a MoBB at the NOAEL of 15, which is larger than the MoBB at the NOAEL of 10 calculated for the European adult population by EFSA.

6.2.4 Additional considerations

In the absence of real occurrence data for liver from contaminated animals, potential impact of consumption of contaminated liver was estimated based on a hypothetical model using a ten-fold concentration of carcass fat concentrations for liver (see 3.2.4. additional considerations). Due to the very rare consumption of pork and beef liver in Ireland compared to other foodstuffs (1.5 % and 0.8 % consumers of pork liver or beef liver, respectively) and the very low contamination presence in the food supply, no difference could be observed for exposure on a total population basis for dioxins or PCBs. Due to the very low number of consumers, however, this can be expected. Therefore, statistics have been derived for the very low number of consumers of offal. For consumers of offal product, for the Total WHO TEQ (2005) an increase of 0.3 pg/kg bw/d at the 95^{th} percentile and an increase of 1 pg/kg bw/d at the 99^{th} percentile was estimated. The latter would lead to an additional increase of 2 % to the body burden assuming a regular eating pattern of offal. For the sum of 6 Marker PCBs, an increase of 3 ng/kg bw/d and 7 ng/kg bw/d for the 95^{th} and 99^{th} percentile consumer, respectively, was estimated. This would lead to additional increase of 1.5 % and 3 % to the body burden at the 95^{th} and 99^{th} percentile, respectively, again assuming a regular consumption pattern of offal.

6.2.5 Overall conclusions on additional post incident exposure of the Irish adult population to dioxins and PCBs

Exposure estimates derived for both dioxins and PCBs showed that the BB of the general population remained largely unaffected by the contamination incident and only a small percentage of approximately 10 % were exposed to elevated levels of dioxins and PCBs.

Whilst this small percent of the population experienced quite a significant additional load to the existing body burden, the estimated exposure values do not indicate approximation of body burdens associated with adverse health effects.

The exposure period was also limited in time to approximately 3 months, following the FSAI recall of contaminated meat immediately on detection of the contamination.

The follow up breast milk study conducted in 2009/2010 did also not show any increase in concentrations compared to the study conducted in 2002. The latter supports the conclusion that the majority of the Irish adult population was not affected by the contamination incident.

7 Annex I

7.1 Food Categorisation used to estimate exposure to dioxins from the diet

CATEGORY I	CATEGORY II	CATEGORY III
DAIRY	BUTTER	BUTTER
	CHEESE	CHEESE, BLUE CHEESE, BRIE AND SIMILAR CHEESE, CHEDDAR AND SIMILAR CHEESE, COTTAGE CHEESE, CREAM AND SPREADABLE TYPE CHEESE, EDAM, EMMENTAL AND SIMILAR CHEESE, FETA CHEESE, GOAT CHEESE, GRUYERE AND SIMILAR CHEESE, HARD, UNDEFINED CHEESE, MOZZARELLA CHEESE, PARMESAN AND SIMILAR CHEESE, PORT DE SALUT AND SIMILAR CHEESE, PROCESSED CHEESE, SOYA
	CREAMS	CREAM DOUBLE CREAM HALF FAT CREAM SINGLE CREAM SOUR CREAM UHT CREAM WHIPPING CRÈME FRAICHE CRÈME FRAICHE HALF FAT ICECREAM LOLLIES ICECREAM, DAIRY ICECREAM, NON DAIRY
	IMITATION AND OTHER	GOATS MILK OAT MILK (MILK SUBSTITUTE) RICE MILK (MILK SUBSTITUTE) SOYA MILK (MILK SUBSTITUTE)
	MILKS	BUTTERMILK CONDENSED MILK DRIED MILK DRIED WHEY EVAPORATED MILK FLAVOURED MILK SEMI SKIMMED MILK SKIMMED MILK WHOLE MILK
	YOGHURTS	YOGHURT, CEREAL YOGHURT, CHOCOLATE YOGHURT, DRINKING, CEREAL YOGHURT, DRINKING, FRUIT YOGHURT, DRINKING, PLAIN YOGHURT, FRUIT YOGHURT, NUT YOGHURT, PLAIN YOGHURT, SEEDS YOGHURT, SOYA YOGHURT, TOFFEE YOGHURT, VANILLA

CATEGORY I	CATEGORY II	CATEGORY III
EGGS	EGGS, CHICKEN	EGG WHITE EGG WHOLE EGG YOLK
	EGGS, DUCK	DUCK EGG
FATS AND OILS EXCL BUTTER	FAT/DAIRY SPREADS EXCL BUTTER	SPREADS, DAIRY <2 % SPREADS, DAIRY 10 % SPREADS, DAIRY 30 % SPREADS, DAIRY 50 % SPREADS, DAIRY FREE
	OILS	OILS, NUT OILS, SEED OILS, VEGETABLE
FISH AND FISH PRODUCTS	MIXED FISH	PROCESSED FISH, MIXED FISH
	OILY FISH	ANCHOVIES BRISLING Fish ROE HERRING HERRING, CANNED MACKEREL MACKEREL, CANNED MACKEREL, PATE SALMON SALMON, CANNED SARDINES SARDINES, CANNED SWORDFISH TROUT TUNA TUNA, CANNED
	OTHER	SQUID
	SHELLFISH	COCKLES CRAB LOBSTER MUSSELS OYSTERS PRAWNS SCALLOPS SHRIMPS
	WHITE FISH	COD COLEY HADDOCK HAKE HALIBUT HOKI JOHN DORY MONKFISH PLAICE POLLACK SEA BASS SEA BREAM SOLE WHITE FISH, DRIED WHITE FISH, PROCESSED WHITE FISH, UNSPECIFIED WHITING

CATEGORY I	CATEGORY II	CATEGORY III
MEAT AND MEAT PRODUCTS	BEEF	BEEF BEEF MINCE BEEF, FAT BEEF, PROCESSED
	LAMB	LAMB LAMB MINCE
	MIXED MEAT	PORK/BEEF, PROCESSED PORK/BEEF, SAUSAGES
	OTHER	PHEASANT RABBIT VENISON
	PORK	PORK PORK, BACON PORK, FAT PORK, HAM PORK, PROCESSED PORK, PUDDINGS PORK, SAUSAGES, BREAKFAST PORK, SAUSAGES, OTHER
	POULTRY	CHICKEN CHICKEN, PROCESSED DUCK TURKEY TURKEY, PROCESSED
	OFFAL, BEEF	OFFAL, BOVINE KIDNEY OFFAL, CALF LIVER
	OFFAL, LAMB	OFFAL, LAMB KIDNEY OFFAL, LAMB LIVER
	OFFAL, PORK	OFFAL, PORK KIDNEY OFFAL, PORK LIVER OFFAL, PORK LIVER, PROCESSED OFFAL, PORK TROTTERS AND TAILS
	OFFAL, POULTRY	OFFAL, CHICKEN LIVER OFFAL, DUCK LIVER
SUPPLEMENTS	OILS/FATTY ACIDS	SUPPLEMENTS, CONTAINING SPECIAL FATTY ACIDS SUPPLEMENTS, EVENING PRIMROSE AND/OR STARFLOWER SUPPLEMENTS, FISH OILS SUPPLEMENTS, FLAXSEED OIL

7.2 FSAI Monitoring Data (2000 - 2010) for sum of 6 Marker PCBs and Total TEQ (PCDD/F & DL-PCBs) (1998 & 2005) expressed as N (number of samples) and range (min - max)

Table 43 Number of samples for the analysis of 6 Marker PCBs, Total TEQ (1998) and Total TEQ (2005) covered by FSAI monitoring programs 2001 - 2010

	2000	2001	2003	2004	2005	2006	2007	2008	2009	2010	ALL
	Number of Samples										
Carcass Fat			34			38.0					72
Cereals			3								3
Dairy	1	1	7	1	20	33.0	2	2	2		69
Eggs			40								60
Fats and Oils			3								3
Fish		45	13	70						52	180
Fruit			3								3
Offal			7		12	20.0					31
Other			1								1
Supplements		15			43						58
Vegetables			8								8
Dairy	1	1	1	1	5	12.0	4	4	4		23
Eggs			7								7

Table 44 Range of sum of 6 Marker PCBs covered by FSAI monitoring programs 2001 - 2010

	SUM 6 MARKER PCBs (ng/g)									
	2000		2001		2003		2004		2005	
	Min - Max									
	LB	UB	LB	UB	LB	UB	LB	UB	LB	UB
Carcass Fat					0.08-2.5	0.2-2.6				
Cereals					0-0	0.1-0.1				
Dairy	0.7-0.7	1.0-1.0	0-0	0.6-0.6	0-0.7	0.6-1.2	0.5-0.5	0.5-0.5	0.4-2.3	0.4-2.3
Eggs					0.8-271	1.02-271				
Fats and Oils					0.02-0.6	0.4-1.03				
Fish			39.6-303	39.6-303	51.3-152	51.3-152	0-193	0-193		
Fruit					0-0	0.06-0.06				
Offal					0.4-3.2	0.6-3.3			0.5-3.4	0.5-3.4
Other					0-0	0.6-0.6				
Supplements			0-372	1.4-372					0-131.8	0.2-131.8
Vegetables					0-0	0.06-0.06				
Dairy	0.4-0.4	0.8-0.8	0.2-0.2	0.6-0.6	0.6-0.6	0.6-0.6	0.7-0.7	0.8-0.8	0.6-1.08	0.6-1.08
Eggs					17.06-302	17.5-303				

Table 44 continued Range of sum of 6 Marker PCBs covered by FSAI monitoring programs 2001 - 2010

	SUM 6 MARKER PCBs (ng/g)											
	2006		2007		2008		2009		2010		2001 - 2010	
	Min - Max											
	LB	UB	LB	UB	LB	UB	LB	UB	LB	UB	LB	UB
Carcass Fat	0.3-4.3	0.3-4.3									0.08-4.3	0.2-4.3
Cereals											0-0	0.1-0.1
Dairy	0.2-1	0.3-1.04	0.7-0.7	0.7-0.7	0.2-0.4	0.4-0.5	0.3-0.6	0.3-0.6			0-2.3	0.3-2.3
Eggs	0.2-31	0.4-32									0.2-271	0.4-271
Fats and Oils											0.02-0.6	0.4-1.03
Fish									1.5-174	1.6-174	0-303	0-303
Fruit											0-0	0.06-0.06
Offal	0.4-5.8	0.4-5.8									0.4-5.8	0.4-5.8
Other											0-0	0.6-0.6
Supplements											0-372	0.2-371
Vegetables											0-0	0.06-0.06
Dairy	0.6-2.6	0.7-2.6	0.5-1.3	0.5-1.3	0.3-0.6	0.4-0.7	0.3-0.6	0.4-0.7	0.4-0.4	0.4-0.4	0.2-2.6	0.4-2.6
Eggs											17.1-302	17.5-303

Table 45 LB and UB Range of Total TEQ (1998) covered by FSAI monitoring programs 2001 - 2010

	WHO TEQ (1998) (pg/g)									
	2000		2001		2003		2004		2005	
	Min - Max									
	LB	UB	LB	UB	LB	UB	LB	UB	LB	UB
Carcass Fat					0.02-1.2	0.1-1.2				
Cereals					0-0	0.05-0.06				
Dairy	0.8-0.8	0.8-0.8	0.3-0.3	0.5-0.5	0.07-0.5	0.1-0.5	0.3-0.3	0.4-0.4	0.2-0.7	0.3-0.9
Eggs					0.1-6.6	0.4-6.6				
Fats and Oils					0.01-0.4	0.09-0.5				
Fish			41-43	5.2-43	7.7-22.3	7.8-22.3	0-28	0-31		
Fruit					0-0	0.05-0.05				
Offal					0.3-5.4	0.4-5.5			0.4-8.3	0.8-8.3
Other					0.05-0.05	0.5-0.5				
Supplements			0.2-37.5	0.6-38					0-10	0.5-10
Vegetables					0-0	0.05-0.05				
Dairy	0.6-0.6	0.7-0.7	0.4-0.4	0.6-0.6	0.3-0.3	0.3-0.3	0.7-0.7	0.7-0.7	0.3-0.7	0.3-0.7
Eggs					2.1-7.8	2.1-7.8				

Table 45 continued LB and UB Range of Total TEQ (1998) covered by FSAI monitoring programs 2001 - 2010

	WHO TEQ (1998) (pg/g)											
	2006		2007		2008		2009		2010		2001 - 2010	
	Min - Max											
	LB	UB	LB	UB	LB	UB	LB	UB	LB	UB	LB	UB
Carcass Fat	0.06-0.9	0.1-0.9									0.02-1.2	0.1-1.2
Cereals											0-0	0.05-0.06
Dairy	0.2-0.6	0.2-0.7	0.3-0.4	0.4-0.5	0.3-0.4	0.3-0.4	0.4-0.4	0.4-0.4			0.07-0.8	0.1-0.9
Eggs	0.06-0.7	0.2-0.7									0.06-6.6	0.2-6.6
Fats and Oils											0.01-0.4	0.09-0.5
Fish									1.1-27	1.2-27	0-42.7	0-43.04
Fruit											0-0	0.05-0.05
Offal	0.2-22	0.3-22									0.2-22.4	0.3-22.4
Other											0.05-0.05	0.5-0.5
Supplements											0-37.5	0.5-37.5
Vegetables											0-0	0.05-0.05
Dairy	0.5-0.7	0.5-0.7	0.3-0.7	0.4-0.7	0.3-0.7	0.3-0.7	0.3-0.7	0.3-0.7			0.3-0.7	0.3-0.7
Eggs											2.05-7.8	2.05-7.8

Table 46 LB and UB Range of Total TEQ (2005) covered by FSAI monitoring programs 2001 - 2010

	WHO TEQ (2005) (pg/g)									
	2000		2001		2003		2004		2005	
	Min - Max									
	LB	UB	LB	UB	LB	UB	LB	UB	LB	UB
Carcass Fat					0.02-1.07	0.09-1.08				
Cereals					0-0	0.04-0.04				
Dairy	0.7-0.7	0.7-0.7	0.2-0.2	0.4-0.4	0.06-0.4	0.1-0.5	0.3-0.3	0.4-0.4	0.1-0.6	0.3-0.8
Eggs					0.1-31	0.2-31				
Fats and Oils					0.01-0.4	0.06-0.4				
Fish			4.06-37	4.2-38	6.2-18.5	6.5-19	0-26	0-31		
Fruit					0-0	0.04-0.04				
Offal					0.2-4.4	0.4-4.4			0.3-6.5	0.7-6.6
Other					0.05-0.05	0.3-0.3				
Supplements			0.2-32	0.6-32					0-8.2	0.5-8.2
Vegetables					0-0	0.04-0.04				
Dairy	0.6-0.6	0.6-0.6	0.3-0.3	0.5-0.5	0.2-0.2	0.3-0.3	0.5-0.5	0.6-0.6	0.2-0.6	0.3-0.7
Eggs					1.7-5.1	1.7-5.1				

Table 46 continued LB and UB Range of Total TEQ (2005) covered by FSAI monitoring programs 2001 - 2010

	WHO TEQ (2005) (pg/g)											
	2006		2007		2008		2009		2010		2001 - 2010	
	Min - Max											
	LB	UB	LB	UB	LB	UB	LB	UB	LB	UB	LB	UB
Carcass Fat	0.07-0.8	0.09-0.8									0.02-1.07	0.09-1.08
Cereals											0-0	0.04-0.04
Dairy	0.2-0.6	0.2-0.6	0.3-0.4	0.3-0.4	0.2-0.3	0.2-0.4	0.3-0.4	0.3-0.4			0.06-0.7	0.1-0.8
Eggs	0.06-0.7	0.2-0.7									0.06-31	0.2-31
Fats and Oils											0.01-0.4	0.06-0.4
Fish									1.1-27.2	1.1-27.2	0-37.2	0-37.6
Fruit											0-0	0.04-0.04
Offal	0.2-18.9	0.2-18.9									0.2-18.9	0.2-18.9
Other											0.05-0.05	0.3-0.3
Supplements											0-31.9	0.5-31.9
Vegetables											0-0	0.04-0.04
Dairy	0.4-0.6	0.4-0.6	0.3-0.6	0.3-0.6	0.3-0.6	0.3-0.6	0.3-0.6	0.3-0.6			0.2-0.6	0.3-0.7
Eggs											1.7-5.1	1.7-5.1

7.3 Chemical Concentration Data used in probabilistic modelling

- TTOLB = Total WHO TEQ (1998) PCDD/F&DL-PCBs – LB
- TTOUB =Total WHO TEQ (1998) PCDD/F&DL-PCBs – UB
- TTNLB = Total WHO TEQ (2005) PCDD/F&DL-PCBs - LB
- TTNUB = Total WHO TEQ (2005) PCDD/F&DL-PCBs - UB
- M6LB = Sum of 6 Marker PCBs - LB
- M6UB = Sum of 6 Marker PCBs - UB

Table 47 Creme Data Entry Background Concentration

Chemical Code	Food Code Name	Presence Probability	Concentration ng/kg (Marker PCBs in µg/kg)
M6LB	DAIRY	1	Data(0.54, 0.21, 0.29, 0.25, 0.41, 0.3, 0.35, 0.43, 0.8, 0.38, 0.42, 0.29, 0.35, 0.22, 0.34, 0.22, 0.35, 0.28, 0.32, 0.31, 0.22, 0.25, 0.35, 0.51, 0.27, 0.54, 0.46, 0.32, 0.28, 0.47, 0.8, 0.52, 0.95, 0.65, 0.66, 0.44, 0.23, 0.57, 0.34)
M6LB	CHICKEN EGG	1	Data(0.62, 1.08, 2.99, 3.74, 30.62, 0.23, 0.51, 2.37, 0.41, 0.36, 1.72, 0.82, 0.88, 0.67, 1.08)
M6LB	DUCK EGG	1	Data(0.62, 1.08, 2.99, 3.74, 30.62, 0.23, 0.51, 2.37, 0.41, 0.36, 1.72, 0.82, 0.88, 0.67, 1.08)
M6LB	BEEF	1	Data(0.93, 0.78, 0.84, 1.34, 0.85, 1.13, 0.97, 0.76, 0.68)
M6LB	LAMB	1	Data(0.97, 1.1, 1.05, 0.95, 0.71, 1.13, 0.86, 0.99, 0.76, 0.85)
M6LB	PORK	1	Data(0.66, 0.95, 0.34, 0.62, 0.38, 0.79)
M6LB	POULTRY	1	Data(2.19, 3.58, 0.87, 0.69, 0.85, 0.54, 0.67, 0.65, 0.48, 3.83, 4.25)
M6LB	PHEASANT	1	Data(0.25, 0.26)
M6LB	RABBIT	1	0.79
M6LB	VENISON	1	Data(0.97, 1.1, 1.05, 0.95, 0.71, 1.13, 0.86, 0.99, 0.76, 0.85)
M6LB	PORK/BEEF	1	0.79
M6LB	OFFAL, CALF LIVER	1	Data(3.18, 2.94)
M6LB	OFFAL, LAMB KIDNEY	1	Data(0.97, 1.1, 1.05, 0.95, 0.71, 1.13, 0.86, 0.99, 0.76, 0.85)
M6LB	OFFAL, LAMB LIVER	1	Data(4.85, 2.13)
M6LB	OFFAL, PORK KIDNEY	1	Data(0.66, 0.95, 0.34, 0.62, 0.38, 0.79)
M6LB	OFFAL, PORK LIVER	1	Data(0.46, 0.57)
M6LB	OFFAL, CHICKEN LIVER	1	Data(1.95, 0.38, 1.07)
M6LB	OFFAL, DUCK LIVER	1	Data(1.95, 0.38, 1.07)
M6LB	COD	1	Data(17.92, 13.56, 13.12, 48.47)
M6LB	COLEY	1	31.68
M6LB	HADDOCK	1	Data(74, 7, 34.96, 8.85, 7.62)
M6LB	HAKE	1	78.98
M6LB	HALIBUT	1	31.68
M6LB	HOKI	1	31.68
M6LB	JOHN DORY	1	31.68
M6LB	MONKFISH	1	Data(15.23, 11.06, 84.58, 14.54)
M6LB	PLAICE	1	Data(88.6, 33.98)
M6LB	POLLACK	1	31.68
M6LB	SEA BASS	1	31.68

Table 47 continued Creme Data Entry Background Concentration

Chemical Code	Food Code Name	Presence Probability	Concentration ng/kg (Marker PCBs in µg/kg)
M6LB	SEA BREAM	1	31.68
M6LB	SOLE	1	Data(35.21, 29.38, 13.34, 12.59)
M6LB	WHITE FISH, DRIED	1	31.68
M6LB	WHITE FISH, PROCESSED	1	31.68
M6LB	WHITE FISH, UNSPECIFIED	1	31.68
M6LB	WHITING	1	Data(78.69, 34.98, 114.07, 173.73, 9.77)
M6LB	SALMON	1	Data(75.38, 93.4, 102.15, 59.05, 94.49, 59.94)
M6LB	TUNA	1	Data(50.58, 52.69, 53.66, 78, 43.86)
M6LB	TROUT	1	Data(39.14, 41.23)
M6LB	HERRING	1	Data(44.96, 51.54, 53.5, 59.73)
M6LB	MACKEREL	1	Data(25.08, 47.23, 127.54, 67.37, 39.67)
M6LB	MACKEREL, PATE	1	Data(25.08, 47.23, 127.54, 67.37, 39.67)
M6LB	SARDINES	1	8.89
M6LB	BRISLING	1	Data(25.08, 47.23, 127.54, 67.37, 39.67)
M6LB	ANCHOVIES	1	8.89
M6LB	SWORDFISH	1	31.68
M6LB	Fish ROE	1	31.68
M6LB	SALMON, CANNED	1	Data(10.43, 12.13, 8.88, 21.4, 35.92)
M6LB	TUNA, CANNED	1	Data(0, 0.12, 0.73, 0, 2.14)
M6LB	HERRING, CANNED	1	Data(30.54, 26.71)
M6LB	MACKEREL, CANNED	1	Data(18.01, 16.93)
M6LB	SARDINES, CANNED	1	8.89
M6LB	PROCESSED FISH, MIXED FISH	1	31.68
M6LB	MUSSELS	1	Data(47.83, 7.17, 38.87, 13.94, 13.29)
M6LB	OYSTERS	1	Data(51.21, 39.43, 75.84, 16.3, 21.13)
M6LB	PRAWNS	1	1.49
M6LB	SHRIMPS	1	1.49
M6LB	SCALLOPS	1	Data(47.83, 7.17, 38.87, 13.94, 13.29)
M6LB	CRAB	1	31.68
M6LB	LOBSTER	1	1.49
M6LB	COCKLES	1	Data(47.83, 7.17, 38.87, 13.94, 13.29)
M6LB	SQUID	1	31.68
M6LB	SPREADS, EXCL. BUTTER	1	0
M6LB	OILS	1	Data(0.11, 0.02)
M6LB	CONTAINING SPECIAL FATTY ACIDS	1	Data(8.32, 1.33, 4.54, 0, 0, 0.17, 0.32, 2.2, 17.95)
M6LB	EVENING PRIMROSE AND/OR STARFLOWER	1	0
M6LB	FISH OILS	1	Data(19.38, 62.06, 53.14, 23.82, 46.47, 69.89, 131.79, 4.38, 91.02, 25.03, 106.89, 94.23, 50.92, 50.95, 16.66, 11.27, 11.32, 40.62, 0.66, 18.91, 2.03, 3.22, 32.02, 7.36, 0.11, 46.19, 2.05)
M6LB	FLAXSEED OIL	1	Data(8.32, 1.33, 4.54, 0, 0, 0.17, 0.32, 2.2, 17.95)
M6UB	DAIRY	1	Data(0.6, 0.41, 0.36, 0.34, 0.47, 0.35, 0.4, 0.46, 0.8, 0.42, 0.46, 0.33, 0.41, 0.29, 0.43, 0.28, 0.39, 0.32, 0.38, 0.37, 0.26, 0.29, 0.39, 0.56, 0.31, 0.59, 0.51, 0.37, 0.36, 0.54, 0.8, 0.81, 1.04, 0.65, 0.66, 0.54, 0.38, 0.57, 0.34)

Table 47 continued Creme Data Entry Background Concentration

Chemical Code	Food Code Name	Presence Probability	Concentration ng/kg (Marker PCBs in µg/kg)
M6UB	CHICKEN EGG	1	Data(0.62, 1.09, 2.99, 3.74, 30.62, 0.37, 0.53, 2.38, 0.53, 0.43, 1.72, 0.82, 0.9, 0.87, 1.08)
M6UB	DUCK EGG	1	Data(0.62, 1.09, 2.99, 3.74, 30.62, 0.37, 0.53, 2.38, 0.53, 0.43, 1.72, 0.82, 0.9, 0.87, 1.08)
M6UB	BEEF	1	Data(0.93, 0.78, 0.84, 1.34, 0.85, 1.13, 0.97, 0.76, 0.68)
M6UB	LAMB	1	Data(0.97, 1.1, 1.05, 0.95, 0.71, 1.13, 0.86, 0.99, 0.76, 0.85)
M6UB	PORK	1	Data(0.66, 0.95, 0.34, 0.62, 0.38, 0.79)
M6UB	POULTRY	1	Data(2.19, 3.58, 0.87, 0.69, 0.85, 0.54, 0.67, 0.65, 0.48, 3.83, 4.25)
M6UB	PHEASANT	1	Data(0.25, 0.26)
M6UB	RABBIT	1	0.79
M6UB	VENISON	1	Data(0.97, 1.1, 1.05, 0.95, 0.71, 1.13, 0.86, 0.99, 0.76, 0.85)
M6UB	PORK/BEEF	1	0.79
M6UB	OFFAL, CALF LIVER	1	Data(3.18, 2.94)
M6UB	OFFAL, LAMB KIDNEY	1	Data(0.97, 1.1, 1.05, 0.95, 0.71, 1.13, 0.86, 0.99, 0.76, 0.85)
M6UB	OFFAL, LAMB LIVER	1	Data(4.85, 2.13)
M6UB	OFFAL, PORK KIDNEY	1	Data(0.66, 0.95, 0.34, 0.62, 0.38, 0.79)
M6UB	OFFAL, PORK LIVER	1	Data(0.46, 0.57)
M6UB	OFFAL, CHICKEN LIVER	1	Data(1.95, 0.38, 1.07)
M6UB	OFFAL, DUCK LIVER	1	Data(1.95, 0.38, 1.07)
M6UB	COD	1	Data(18.39, 13.56, 13.12, 48.47)
M6UB	COLEY	1	31.68
M6UB	HADDOCK	1	Data(74, 7, 34.96, 8.85, 7.62)
M6UB	HAKE	1	78.98
M6UB	HALIBUT	1	31.68
M6UB	HOKI	1	31.68
M6UB	JOHN DORY	1	31.68
M6UB	MONKFISH	1	Data(15.23, 11.06, 84.58, 14.54)
M6UB	PLAICE	1	Data(88.6, 33.98)
M6UB	POLLACK	1	31.68
M6UB	SEA BASS	1	31.68
M6UB	SEA BREAM	1	31.68
M6UB	SOLE	1	Data(35.21, 29.38, 13.34, 12.59)
M6UB	WHITE FISH, DRIED	1	31.68
M6UB	WHITE FISH, PROCESSED	1	31.68
M6UB	WHITE FISH, UNSPECIFIED	1	31.68
M6UB	WHITING	1	Data(78.69, 34.98, 114.07, 173.73, 9.77)
M6UB	SALMON	1	Data(75.38, 93.4, 102.15, 59.05, 94.49, 59.94)
M6UB	TUNA	1	Data(50.58, 52.69, 53.66, 78, 43.86)
M6UB	TROUT	1	Data(39.14, 41.23)
M6UB	HERRING	1	Data(44.96, 51.54, 53.5, 59.73)
M6UB	MACKEREL	1	Data(25.08, 47.23, 127.54, 67.37, 39.67)
M6UB	MACKEREL, PATE	1	Data(25.08, 47.23, 127.54, 67.37, 39.67)
M6UB	SARDINES	1	8.89
M6UB	BRISLING	1	Data(25.08, 47.23, 127.54, 67.37, 39.67)
M6UB	ANCHOVIES	1	8.89
M6UB	SWORDFISH	1	31.68
M6UB	Fish ROE	1	31.68

Table 47 continued Creme Data Entry Background Concentration

c	Food Code Name	Presence Probability	Concentration ng/kg (Marker PCBs in µg/kg)
M6UB	SALMON, CANNED	1	Data(10.43, 12.13, 8.88, 21.4, 35.92)
M6UB	TUNA, CANNED	1	Data(9.83, 0.63, 0.95, 6.49, 3.79)
M6UB	HERRING, CANNED	1	Data(30.54, 26.71)
M6UB	MACKEREL, CANNED	1	Data(18.01, 16.93)
M6UB	SARDINES, CANNED	1	8.89
M6UB	PROCESSED FISH, MIXED FISH	1	31.68
M6UB	MUSSELS	1	Data(47.83, 7.41, 38.87, 15.01, 13.29)
M6UB	OYSTERS	1	Data(56.46, 39.43, 77.32, 18.01, 24.02)
M6UB	PRAWNS	1	1.58
M6UB	SHRIMPS	1	1.58
M6UB	SCALLOPS	1	Data(47.83, 7.41, 38.87, 15.01, 13.29)
M6UB	CRAB	1	31.68
M6UB	LOBSTER	1	1.58
M6UB	COCKLES	1	Data(47.83, 7.41, 38.87, 15.01, 13.29)
M6UB	SQUID	1	31.68
M6UB	SPREADS, EXCL. BUTTER	1	0.84
M6UB	OILS	1	Data(0.35, 0.42)
M6UB	CONTAINING SPECIAL FATTY ACIDS	1	Data(8.32, 1.94, 4.82, 1.78, 0.86, 0.87, 1.8, 2.8, 17.95)
M6UB	EVENING PRIMROSE AND/OR STARFLOWER	1	Data(0.85, 1.09, 0.86, 0.91, 1.01)
M6UB	FISH OILS	1	Data(19.67, 62.06, 53.28, 23.96, 46.61, 69.89, 131.79, 4.61, 91.02, 25.03, 106.89, 94.23, 51.06, 51.09, 16.66, 11.41, 11.32, 40.77, 1.16, 18.91, 2.33, 3.36, 32.02, 7.52, 0.24, 46.19, 2.08)
M6UB	FLAXSEED OIL	1	Data(8.32, 1.94, 4.82, 1.78, 0.86, 0.87, 1.8, 2.8, 17.95)
TTNLB	DAIRY	1	Data(0.37, 0.4, 0.26, 0.16, 0.4, 0.32, 0.23, 0.31, 0.6, 0.42, 0.41, 0.17, 0.23, 0.16, 0.15, 0.17, 0.22, 0.24, 0.22, 0.32, 0.23, 0.17, 0.26, 0.41, 0.22, 0.35, 0.47, 0.32, 0.27, 0.35, 0.33, 0.38, 0.24, 0.29, 0.38, 0.34, 0.23, 0.35, 0.31)
TTNLB	CHICKEN EGG	1	Data(0.25, 0.17, 0.19, 0.2, 0.25, 0.11, 0.23, 0.25, 0.06, 0.07, 0.33, 0.23, 0.18, 0.3, 0.28)
TTNLB	DUCK EGG	1	Data(0.25, 0.17, 0.19, 0.2, 0.25, 0.11, 0.23, 0.25, 0.06, 0.07, 0.33, 0.23, 0.18, 0.3, 0.28)
TTNLB	BEEF	1	Data(0.5, 0.44, 0.14, 0.66, 0.58, 0.53, 0.71, 0.45, 0.39)
TTNLB	LAMB	1	Data(0.66, 0.46, 0.41, 0.44, 0.42, 0.56, 0.33, 0.44, 0.38, 0.39)
TTNLB	PORK	1	Data(0.81, 0.1, 0.07, 0.11, 0.13, 0.07)
TTNLB	POULTRY	1	Data(0.38, 0.54, 0.24, 0.24, 0.2, 0.15, 0.15, 0.18, 0.14, 0.63, 0.69)
TTNLB	PHEASANT	1	Data(0.1, 0.07)
TTNLB	RABBIT	1	0.44
TTNLB	VENISON	1	Data(0.66, 0.46, 0.41, 0.44, 0.42, 0.56, 0.33, 0.44, 0.38, 0.39)
TTNLB	PORK/BEEF	1	0.44
TTNLB	OFFAL, CALF LIVER	1	Data(1.39, 1.54)
TTNLB	OFFAL, LAMB KIDNEY	1	Data(0.66, 0.46, 0.41, 0.44, 0.42, 0.56, 0.33, 0.44, 0.38, 0.39)
TTNLB	OFFAL, LAMB LIVER	1	Data(4.1, 3.34)
TTNLB	OFFAL, PORK KIDNEY	1	Data(0.81, 0.1, 0.07, 0.11, 0.13, 0.07)
TTNLB	OFFAL, PORK LIVER	1	Data(0.58, 0.97)
TTNLB	OFFAL, CHICKEN LIVER	1	Data(0.6, 0.3, 0.21)
TTNLB	OFFAL, DUCK LIVER	1	Data(0.6, 0.3, 0.21)

Table 47 continued Creme Data Entry Background Concentration

c	Food Code Name	Presence Probability	Concentration ng/kg (Marker PCBs in µg/kg)
TTNLB	COD	1	Data(3.4, 2.38, 2.21, 6.86)
TTNLB	COLEY	1	5.1
TTNLB	HADDOCK	1	Data(16.03, 2.04, 11.57, 1.12, 2.36)
TTNLB	HAKE	1	7.35
TTNLB	HALIBUT	1	5.1
TTNLB	HOKI	1	5.1
TTNLB	JOHN DORY	1	5.1
TTNLB	MONKFISH	1	Data(2.65, 2.33, 18.14, 3.37)
TTNLB	PLAICE	1	Data(16.49, 7.5)
TTNLB	POLLACK	1	5.1
TTNLB	SEA BASS	1	5.1
TTNLB	SEA BREAM	1	5.1
TTNLB	SOLE	1	Data(10.64, 10.25, 2.94, 4.96)
TTNLB	WHITE FISH, DRIED	1	5.1
TTNLB	WHITE FISH, PROCESSED	1	5.1
TTNLB	WHITE FISH, UNSPECIFIED	1	5.1
TTNLB	WHITING	1	Data(17.57, 1.94, 17.19, 27.21, 1.21)
TTNLB	SALMON	1	Data(9.56, 12.15, 12.4, 7.25, 11.78, 7.28)
TTNLB	TUNA	1	Data(4.86, 4.74, 5.31, 6.73, 4.54)
TTNLB	TROUT	1	Data(4.94, 5.34)
TTNLB	HERRING	1	Data(5.55, 5.86, 6.89, 6.21)
TTNLB	MACKEREL	1	Data(3.9, 6.82, 15.29, 11.77, 5.79)
TTNLB	MACKEREL, PATE	1	Data(3.9, 6.82, 15.29, 11.77, 5.79)
TTNLB	SARDINES	1	6.74
TTNLB	BRISLING	1	Data(3.9, 6.82, 15.29, 11.77, 5.79)
TTNLB	ANCHOVIES	1	6.74
TTNLB	SWORDFISH	1	5.1
TTNLB	Fish ROE	1	5.1
TTNLB	SALMON, CANNED	1	Data(0.95, 1.03, 0.76, 3.37, 6.31)
TTNLB	TUNA, CANNED	1	Data(1.56, 0, 0.01, 0, 0)
TTNLB	HERRING, CANNED	1	Data(4.36, 3.93)
TTNLB	MACKEREL, CANNED	1	Data(2.96, 2.78)
TTNLB	SARDINES, CANNED	1	6.74
TTNLB	PROCESSED FISH, MIXED FISH	1	5.1
TTNLB	MUSSELS	1	Data(16.46, 2.1, 15.97, 3.17, 5.96)
TTNLB	OYSTERS	1	Data(25.67, 14.43, 3.56, 2.77, 4.87)
TTNLB	PRAWNS	1	1.1
TTNLB	SHRIMPS	1	1.1
TTNLB	SCALLOPS	1	Data(16.46, 2.1, 15.97, 3.17, 5.96)
TTNLB	CRAB	1	5.1
TTNLB	LOBSTER	1	1.1
TTNLB	COCKLES	1	Data(16.46, 2.1, 15.97, 3.17, 5.96)
TTNLB	SQUID	1	5.1
TTNLB	SPREADS, EXCL. BUTTER	1	0.06
TTNLB	OILS	1	Data(0.04, 0.01)
TTNLB	CONTAINING SPECIAL FATTY ACIDS	1	Data(0.04, 0.76, 0.47, 0, 0, 0, 0.1, 1.69, 0.12)
TTNLB	EVENING PRIMROSE AND/OR STARFLOWER	1	Data(0, 0, 0, 0, 0.05)

Table 47 continued Creme Data Entry Background Concentration

Chemical Code	Food Code Name	Presence Probability	Concentration ng/kg (Marker PCBs in µg/kg)
TTNLB	FISH OILS	1	Data(0.09, 3.81, 1.1, 0.89, 0.95, 8.2, 2.74, 0.53, 5.05, 0.44, 6.53, 2.91, 1.05, 1.19, 1.08, 1.94, 3.23, 4.14, 0.04, 2.14, 0.01, 0.02, 1.34, 1.83, 0, 3.58, 2.15)
TTNLB	FLAXSEED OIL	1	Data(0.04, 0.76, 0.47, 0, 0, 0, 0.1, 1.69, 0.12)
TTNUB	DAIRY	1	Data(0.38, 0.41, 0.3, 0.19, 0.41, 0.32, 0.27, 0.34, 0.6, 0.42, 0.43, 0.21, 0.28, 0.2, 0.26, 0.21, 0.26, 0.28, 0.3, 0.35, 0.24, 0.2, 0.27, 0.42, 0.22, 0.36, 0.48, 0.33, 0.28, 0.36, 0.34, 0.43, 0.28, 0.31, 0.39, 0.35, 0.24, 0.35, 0.32)
TTNUB	CHICKEN EGG	1	Data(0.25, 0.17, 0.24, 0.24, 0.26, 0.24, 0.3, 0.34, 0.21, 0.21, 0.36, 0.28, 0.25, 0.36, 0.29)
TTNUB	DUCK EGG	1	Data(0.25, 0.17, 0.24, 0.24, 0.26, 0.24, 0.3, 0.34, 0.21, 0.21, 0.36, 0.28, 0.25, 0.36, 0.29)
TTNUB	BEEF	1	Data(0.51, 0.46, 0.16, 0.67, 0.59, 0.55, 0.71, 0.45, 0.4)
TTNUB	LAMB	1	Data(0.66, 0.47, 0.41, 0.44, 0.43, 0.57, 0.34, 0.44, 0.38, 0.4)
TTNUB	PORK	1	Data(0.81, 0.13, 0.13, 0.2, 0.15, 0.11)
TTNUB	POULTRY	1	Data(0.39, 0.56, 0.25, 0.24, 0.2, 0.21, 0.15, 0.19, 0.15, 0.63, 0.69)
TTNUB	PHEASANT	1	Data(0.11, 0.09)
TTNUB	RABBIT	1	0.45
TTNUB	VENISON	1	Data(0.66, 0.47, 0.41, 0.44, 0.43, 0.57, 0.34, 0.44, 0.38, 0.4)
TTNUB	PORK/BEEF	1	0.45
TTNUB	OFFAL, CALF LIVER	1	Data(1.44, 1.55)
TTNUB	OFFAL, LAMB KIDNEY	1	Data(0.66, 0.47, 0.41, 0.44, 0.43, 0.57, 0.34, 0.44, 0.38, 0.4)
TTNUB	OFFAL, LAMB LIVER	1	Data(4.1, 3.35)
TTNUB	OFFAL, PORK KIDNEY	1	Data(0.81, 0.13, 0.13, 0.2, 0.15, 0.11)
TTNUB	OFFAL, PORK LIVER	1	Data(0.61, 1)
TTNUB	OFFAL, CHICKEN LIVER	1	Data(0.6, 0.3, 0.22)
TTNUB	OFFAL, DUCK LIVER	1	Data(0.6, 0.3, 0.22)
TTNUB	COD	1	Data(3.43, 2.4, 2.65, 6.87)
TTNUB	COLEY	1	5.1
TTNUB	HADDOCK	1	Data(16.04, 2.09, 11.58, 1.4, 2.37)
TTNUB	HAKE	1	7.36
TTNUB	HALIBUT	1	5.1
TTNUB	HOKI	1	5.1
TTNUB	JOHN DORY	1	5.1
TTNUB	MONKFISH	1	Data(2.66, 2.35, 18.15, 3.4)
TTNUB	PLAICE	1	Data(16.49, 7.5)
TTNUB	POLLACK	1	5.1
TTNUB	SEA BASS	1	5.1
TTNUB	SEA BREAM	1	5.1
TTNUB	SOLE	1	Data(10.64, 10.25, 2.95, 4.96)
TTNUB	WHITE FISH, DRIED	1	5.1
TTNUB	WHITE FISH, PROCESSED	1	5.1
TTNUB	WHITE FISH, UNSPECIFIED	1	5.1
TTNUB	WHITING	1	Data(17.59, 2.08, 17.2, 27.22, 1.25)
TTNUB	SALMON	1	Data(9.57, 12.15, 12.4, 7.25, 11.78, 7.28)
TTNUB	TUNA	1	Data(4.86, 4.74, 5.31, 6.73, 4.54)
TTNUB	TROUT	1	Data(4.94, 5.34)
TTNUB	HERRING	1	Data(5.8, 5.89, 6.93, 6.24)
TTNUB	MACKEREL	1	Data(3.9, 6.82, 15.29, 11.77, 5.79)

Table 47 continued Creme Data Entry Background Concentration

Chemical Code	Food Code Name	Presence Probability	Concentration ng/kg (Marker PCBs in µg/kg)
TTNUB	MACKEREL, PATE	1	Data(3.9, 6.82, 15.29, 11.77, 5.79)
TTNUB	SARDINES	1	6.95
TTNUB	BRISLING	1	Data(3.9, 6.82, 15.29, 11.77, 5.79)
TTNUB	ANCHOVIES	1	6.95
TTNUB	SWORDFISH	1	5.1
TTNUB	Fish ROE	1	5.1
TTNUB	SALMON, CANNED	1	Data(1.38, 1.56, 1.15, 3.67, 6.34)
TTNUB	TUNA, CANNED	1	Data(7.93, 0.56, 0.6, 5.86, 2.97)
TTNUB	HERRING, CANNED	1	Data(4.38, 3.94)
TTNUB	MACKEREL, CANNED	1	Data(3.23, 3)
TTNUB	SARDINES, CANNED	1	6.95
TTNUB	PROCESSED FISH, MIXED FISH	1	5.1
TTNUB	MUSSELS	1	Data(16.47, 2.1, 15.98, 3.17, 5.97)
TTNUB	OYSTERS	1	Data(30.53, 16.56, 10.35, 6.63, 11.64)
TTNUB	PRAWNS	1	1.11
TTNUB	SHRIMPS	1	1.11
TTNUB	SCALLOPS	1	Data(16.47, 2.1, 15.98, 3.17, 5.97)
TTNUB	CRAB	1	5.1
TTNUB	LOBSTER	1	1.11
TTNUB	COCKLES	1	Data(16.47, 2.1, 15.98, 3.17, 5.97)
TTNUB	SQUID	1	5.1
TTNUB	SPREADS, EXCL. BUTTER	1	0.11
TTNUB	OILS	1	Data(0.07, 0.06)
TTNUB	CONTAINING SPECIAL FATTY ACIDS	1	Data(1.01, 1.16, 0.86, 1.59, 0.78, 0.79, 1.73, 1.8, 0.63)
TTNUB	EVENING PRIMROSE AND/OR STARFLOWER	1	Data(0.77, 0.98, 0.83, 0.81, 0.91)
TTNUB	FISH OILS	1	Data(0.85, 4.11, 1.49, 1.23, 1.32, 8.24, 2.98, 0.78, 5.13, 0.81, 6.57, 3.27, 1.19, 1.34, 1.48, 2.34, 3.32, 4.87, 0.94, 2.79, 0.81, 0.81, 2.74, 2.37, 0.46, 3.99, 2.24)
TTNUB	FLAXSEED OIL	1	Data(1.01, 1.16, 0.86, 1.59, 0.78, 0.79, 1.73, 1.8, 0.63)
TTOLB	DAIRY	1	Data(0.39, 0.43, 0.28, 0.17, 0.42, 0.34, 0.24, 0.32, 0.62, 0.46, 0.44, 0.18, 0.24, 0.17, 0.16, 0.18, 0.24, 0.25, 0.24, 0.32, 0.25, 0.18, 0.27, 0.42, 0.23, 0.36, 0.48, 0.32, 0.29, 0.37, 0.37, 0.44, 0.26, 0.33, 0.42, 0.39, 0.26, 0.39, 0.35)
TTOLB	CHICKEN EGG	1	Data(0.27, 0.18, 0.21, 0.22, 0.28, 0.11, 0.23, 0.26, 0.06, 0.06, 0.37, 0.26, 0.19, 0.34, 0.32)
TTOLB	DUCK EGG	1	Data(0.27, 0.18, 0.21, 0.22, 0.28, 0.11, 0.23, 0.26, 0.06, 0.06, 0.37, 0.26, 0.19, 0.34, 0.32)
TTOLB	BEEF	1	Data(0.55, 0.49, 0.17, 0.73, 0.63, 0.59, 0.77, 0.49, 0.44)
TTOLB	LAMB	1	Data(0.71, 0.49, 0.42, 0.47, 0.45, 0.6, 0.35, 0.47, 0.39, 0.42)
TTOLB	PORK	1	Data(0.86, 0.11, 0.06, 0.11, 0.13, 0.08)
TTOLB	POULTRY	1	Data(0.44, 0.64, 0.27, 0.26, 0.23, 0.17, 0.17, 0.21, 0.16, 0.73, 0.83)
TTOLB	PHEASANT	1	Data(0.11, 0.08)
TTOLB	RABBIT	1	0.49
TTOLB	VENISON	1	Data(0.71, 0.49, 0.42, 0.47, 0.45, 0.6, 0.35, 0.47, 0.39, 0.42)
TTOLB	PORK/BEEF	1	0.49
TTOLB	OFFAL, CALF LIVER	1	Data(1.56, 1.68)
TTOLB	OFFAL, LAMB KIDNEY	1	Data(0.71, 0.49, 0.42, 0.47, 0.45, 0.6, 0.35, 0.47, 0.39, 0.42)

Table 47 continued Creme Data Entry Background Concentration

Chemical Code	Food Code Name	Presence Probability	Concentration ng/kg (Marker PCBs in µg/kg)
TTOLB	OFFAL, LAMB LIVER	1	Data(5.19, 4.22)
TTOLB	OFFAL, PORK KIDNEY	1	Data(0.86, 0.11, 0.06, 0.11, 0.13, 0.08)
TTOLB	OFFAL, PORK LIVER	1	Data(0.68, 1.14)
TTOLB	OFFAL, CHICKEN LIVER	1	Data(0.62, 0.31, 0.24)
TTOLB	OFFAL, DUCK LIVER	1	Data(0.62, 0.31, 0.24)
TTOLB	COD	1	Data(3.31, 2.33, 2.14, 6.72)
TTOLB	COLEY	1	5.43
TTOLB	HADDOCK	1	Data(15.9, 2.04, 11.69, 1.08, 2.43)
TTOLB	HAKE	1	7.24
TTOLB	HALIBUT	1	5.43
TTOLB	HOKI	1	5.43
TTOLB	JOHN DORY	1	5.43
TTOLB	MONKFISH	1	Data(2.79, 2.44, 18.96, 3.5)
TTOLB	PLAICE	1	Data(17.27, 7.94)
TTOLB	POLLACK	1	5.43
TTOLB	SEA BASS	1	5.43
TTOLB	SEA BREAM	1	5.43
TTOLB	SOLE	1	Data(11.37, 10.93, 3.14, 5.38)
TTOLB	WHITE FISH, DRIED	1	5.43
TTOLB	WHITE FISH, PROCESSED	1	5.43
TTOLB	WHITE FISH, UNSPECIFIED	1	5.43
TTOLB	WHITING	1	Data(18.13, 1.95, 17.62, 27.16, 1.25)
TTOLB	SALMON	1	Data(9.77, 12.23, 12.51, 7.32, 11.85, 7.39)
TTOLB	TUNA	1	Data(4.77, 4.65, 5.19, 6.71, 4.48)
TTOLB	TROUT	1	Data(5.04, 5.43)
TTOLB	HERRING	1	Data(7.13, 7.49, 8.72, 8.08)
TTOLB	MACKEREL	1	Data(3.96, 6.93, 15.53, 12.11, 5.9)
TTOLB	MACKEREL, PATE	1	Data(3.96, 6.93, 15.53, 12.11, 5.9)
TTOLB	SARDINES	1	7.09
TTOLB	BRISLING	1	Data(3.96, 6.93, 15.53, 12.11, 5.9)
TTOLB	ANCHOVIES	1	7.09
TTOLB	SWORDFISH	1	5.43
TTOLB	Fish ROE	1	5.43
TTOLB	SALMON, CANNED	1	Data(1.19, 1.29, 0.99, 4.14, 7.66)
TTOLB	TUNA, CANNED	1	Data(1.56, 0, 0.02, 0, 0)
TTOLB	HERRING, CANNED	1	Data(5.42, 4.79)
TTOLB	MACKEREL, CANNED	1	Data(3.43, 3.23)
TTOLB	SARDINES, CANNED	1	7.09
TTOLB	PROCESSED FISH, MIXED FISH	1	5.43
TTOLB	MUSSELS	1	Data(17.13, 2.15, 16.44, 3.31, 5.95)
TTOLB	OYSTERS	1	Data(27.77, 16.32, 6.19, 3.53, 6.05)
TTOLB	PRAWNS	1	1.2
TTOLB	SHRIMPS	1	1.2
TTOLB	SCALLOPS	1	Data(17.13, 2.15, 16.44, 3.31, 5.95)
TTOLB	CRAB	1	5.43
TTOLB	LOBSTER	1	1.2
TTOLB	COCKLES	1	Data(17.13, 2.15, 16.44, 3.31, 5.95)
TTOLB	SQUID	1	5.43

Table 47 continued Creme Data Entry Background Concentration

Chemical Code	Food Code Name	Presence Probability	Concentration ng/kg (Marker PCBs in µg/kg)
TTOLB	SPREADS, EXCL. BUTTER	1	0.07
TTOLB	OILS	1	Data(0.05, 0.01)
TTOLB	CONTAINING SPECIAL FATTY ACIDS	1	Data(0.2, 0.84, 0.59, 0, 0, 0, 0.14, 1.4, 0.43)
TTOLB	EVENING PRIMROSE AND/OR STARFLOWER	1	Data(0, 0, 0, 0, 0.05)
TTOLB	FISH OILS	1	Data(0.48, 5.11, 2.51, 1.46, 2.17, 10.11, 5.59, 0.74, 6.73, 0.91, 8.83, 4.62, 2.18, 2.3, 1.43, 2.31, 3.24, 5.26, 0.04, 2.65, 0.06, 0.1, 1.89, 2.07, 0, 4.76, 2.31)
TTOLB	FLAXSEED OIL	1	Data(0.2, 0.84, 0.59, 0, 0, 0, 0.14, 1.4, 0.43)
TTOUB	DAIRY	1	Data(0.43, 0.46, 0.34, 0.23, 0.46, 0.37, 0.31, 0.38, 0.66, 0.49, 0.5, 0.24, 0.31, 0.24, 0.31, 0.25, 0.3, 0.32, 0.36, 0.38, 0.27, 0.22, 0.3, 0.45, 0.26, 0.42, 0.51, 0.35, 0.32, 0.41, 0.4, 0.5, 0.32, 0.36, 0.45, 0.4, 0.28, 0.41, 0.37)
TTOUB	CHICKEN EGG	1	Data(0.29, 0.2, 0.29, 0.29, 0.29, 0.28, 0.33, 0.39, 0.25, 0.27, 0.42, 0.32, 0.29, 0.42, 0.33)
TTOUB	DUCK EGG	1	Data(0.29, 0.2, 0.29, 0.29, 0.29, 0.28, 0.33, 0.39, 0.25, 0.27, 0.42, 0.32, 0.29, 0.42, 0.33)
TTOUB	BEEF	1	Data(0.57, 0.51, 0.2, 0.75, 0.65, 0.63, 0.78, 0.51, 0.46)
TTOUB	LAMB	1	Data(0.73, 0.51, 0.45, 0.48, 0.47, 0.62, 0.37, 0.48, 0.42, 0.44)
TTOUB	PORK	1	Data(0.88, 0.15, 0.14, 0.23, 0.17, 0.13)
TTOUB	POULTRY	1	Data(0.45, 0.66, 0.29, 0.28, 0.24, 0.24, 0.19, 0.23, 0.18, 0.74, 0.83)
TTOUB	PHEASANT	1	Data(0.14, 0.12)
TTOUB	RABBIT	1	0.51
TTOUB	VENISON	1	Data(0.73, 0.51, 0.45, 0.48, 0.47, 0.62, 0.37, 0.48, 0.42, 0.44)
TTOUB	PORK/BEEF	1	0.51
TTOUB	OFFAL, CALF LIVER	1	Data(1.64, 1.72)
TTOUB	OFFAL, LAMB KIDNEY	1	Data(0.73, 0.51, 0.45, 0.48, 0.47, 0.62, 0.37, 0.48, 0.42, 0.44)
TTOUB	OFFAL, LAMB LIVER	1	Data(5.2, 4.25)
TTOUB	OFFAL, PORK KIDNEY	1	Data(0.88, 0.15, 0.14, 0.23, 0.17, 0.13)
TTOUB	OFFAL, PORK LIVER	1	Data(0.74, 1.2)
TTOUB	OFFAL, CHICKEN LIVER	1	Data(0.65, 0.33, 0.25)
TTOUB	OFFAL, DUCK LIVER	1	Data(0.65, 0.33, 0.25)
TTOUB	COD	1	Data(3.33, 2.35, 2.66, 6.73)
TTOUB	COLEY	1	5.44
TTOUB	HADDOCK	1	Data(15.92, 2.09, 11.7, 1.46, 2.45)
TTOUB	HAKE	1	7.25
TTOUB	HALIBUT	1	5.44
TTOUB	HOKI	1	5.44
TTOUB	JOHN DORY	1	5.44
TTOUB	MONKFISH	1	Data(2.8, 2.46, 18.98, 3.53)
TTOUB	PLAICE	1	Data(17.27, 7.95)
TTOUB	POLLACK	1	5.44
TTOUB	SEA BASS	1	5.44
TTOUB	SEA BREAM	1	5.44
TTOUB	SOLE	1	Data(11.37, 10.94, 3.15, 5.39)
TTOUB	WHITE FISH, DRIED	1	5.44

Table 47 continued Creme Data Entry Background Concentration

Chemical Code	Food Code Name	Presence Probability	Concentration ng/kg (Marker PCBs in µg/kg)
TTOUB	WHITE FISH, PROCESSED	1	5.44
TTOUB	WHITE FISH, UNSPECIFIED	1	5.44
TTOUB	WHITING	1	Data(18.14, 2.09, 17.63, 27.16, 1.29)
TTOUB	SALMON	1	Data(9.77, 12.23, 12.51, 7.32, 11.85, 7.39)
TTOUB	TUNA	1	Data(4.77, 4.65, 5.19, 6.71, 4.49)
TTOUB	TROUT	1	Data(5.04, 5.43)
TTOUB	HERRING	1	Data(7.24, 7.51, 8.75, 8.11)
TTOUB	MACKEREL	1	Data(3.96, 6.93, 15.53, 12.11, 5.9)
TTOUB	MACKEREL, PATE	1	Data(3.96, 6.93, 15.53, 12.11, 5.9)
TTOUB	SARDINES	1	7.2
TTOUB	BRISLING	1	Data(3.96, 6.93, 15.53, 12.11, 5.9)
TTOUB	ANCHOVIES	1	7.2
TTOUB	SWORDFISH	1	5.44
TTOUB	Fish ROE	1	5.44
TTOUB	SALMON, CANNED	1	Data(1.43, 1.62, 1.25, 4.27, 7.69)
TTOUB	TUNA, CANNED	1	Data(7.1, 0.49, 0.53, 5.17, 2.62)
TTOUB	HERRING, CANNED	1	Data(5.44, 4.81)
TTOUB	MACKEREL, CANNED	1	Data(3.57, 3.34)
TTOUB	SARDINES, CANNED	1	7.2
TTOUB	PROCESSED FISH, MIXED FISH	1	5.44
TTOUB	MUSSELS	1	Data(17.14, 2.15, 16.45, 3.31, 5.96)
TTOUB	OYSTERS	1	Data(30.84, 17.25, 11.48, 6.58, 11.58)
TTOUB	PRAWNS	1	1.2
TTOUB	SHRIMPS	1	1.2
TTOUB	SCALLOPS	1	Data(17.14, 2.15, 16.45, 3.31, 5.96)
TTOUB	CRAB	1	5.44
TTOUB	LOBSTER	1	1.2
TTOUB	COCKLES	1	Data(17.14, 2.15, 16.45, 3.31, 5.96)
TTOUB	SQUID	1	5.44
TTOUB	SPREADS, EXCL. BUTTER	1	0.13
TTOUB	OILS	1	Data(0.09, 0.1)
TTOUB	CONTAINING SPECIAL FATTY ACIDS	1	Data(1, 1.21, 0.87, 1.39, 0.69, 0.7, 1.55, 1.55, 0.85)
TTOUB	EVENING PRIMROSE AND/OR STARFLOWER	1	Data(0.68, 0.86, 0.73, 0.71, 0.8)
TTOUB	FISH OILS	1	Data(1.1, 5.26, 2.76, 1.66, 2.39, 10.15, 5.71, 0.88, 6.8, 1.18, 8.87, 4.83, 2.33, 2.46, 1.7, 2.57, 3.32, 5.83, 0.82, 3.19, 0.74, 0.76, 2.89, 2.47, 0.45, 5.17, 2.35)
TTOUB	FLAXSEED OIL	1	Data(1, 1.21, 0.87, 1.39, 0.69, 0.7, 1.55, 1.55, 0.85)

Table 48 Crème Data Entry for contaminated beef and pork

Chemical Code	Food Code Name	Presence Probability	Concentration ng/kg (Marker PCBs in µg/kg)
M6UB	BEEF	1	Discrete(Data(0.93, 0.78, 0.84, 1.34, 0.85, 1.13, 0.97, 0.76, 0.68), 0.989, Data(710.62, 912.56, 737.59, 147.22, 1.97, 3.22, 107.54, 23.65, 31.50, 12.34, 11.95, 0.00, 10.28, 13.24, 11.80, 10.40, 7.79), 0.011)
M6UB	BEEF MINCE	1	Discrete(Data(0.93, 0.78, 0.84, 1.34, 0.85, 1.13, 0.97, 0.76, 0.68), 0.989, Data(710.62, 912.56, 737.59, 147.22, 1.97, 3.22, 107.54, 23.65, 31.50, 12.34, 11.95, 0.00, 10.28, 13.24, 11.80, 10.40, 7.79), 0.011)
M6UB	BEEF, FAT	1	Discrete(Data(0.93, 0.78, 0.84, 1.34, 0.85, 1.13, 0.97, 0.76, 0.68), 0.989, Data(710.62, 912.56, 737.59, 147.22, 1.97, 3.22, 107.54, 23.65, 31.50, 12.34, 11.95, 0.00, 10.28, 13.24, 11.80, 10.40, 7.79), 0.011)
M6UB	BEEF, PROCESSED	1	Discrete(Data(0.93, 0.78, 0.84, 1.34, 0.85, 1.13, 0.97, 0.76, 0.68), 0.989, Data(710.62, 912.56, 737.59, 147.22, 1.97, 3.22, 107.54, 23.65, 31.50, 12.34, 11.95, 0.00, 10.28, 13.24, 11.80, 10.40, 7.79), 0.011)
M6UB	PORK	1	Discrete(Data(0.66, 0.95, 0.34, 0.62, 0.38, 0.79), 0.95, Data(1549.70, 1157.20, 1100.50, 958.10, 2567.64, 971.65, 1101.36, 1034.06, 647.50, 519.62, 916.16, 1516.30, 1417.07, 5363.78, 3896.16, 41.45, 255.98, 496.48, 629.27, 630.26, 780.26, 403.81, 476.80), 0.05)
M6UB	PORK, BACON	1	Discrete(Data(0.66, 0.95, 0.34, 0.62, 0.38, 0.79), 0.95, Data(1549.70, 1157.20, 1100.50, 958.10, 2567.64, 971.65, 1101.36, 1034.06, 647.50, 519.62, 916.16, 1516.30, 1417.07, 5363.78, 3896.16, 41.45, 255.98, 496.48, 629.27, 630.26, 780.26, 403.81, 476.80), 0.05)
M6UB	PORK, HAM	1	Discrete(Data(0.66, 0.95, 0.34, 0.62, 0.38, 0.79), 0.95, Data(1549.70, 1157.20, 1100.50, 958.10, 2567.64, 971.65, 1101.36, 1034.06, 647.50, 519.62, 916.16, 1516.30, 1417.07, 5363.78, 3896.16, 41.45, 255.98, 496.48, 629.27, 630.26, 780.26, 403.81, 476.80), 0.05)
M6UB	PORK, SAUSAGES, BREAKFAST	1	Discrete(Data(0.66, 0.95, 0.34, 0.62, 0.38, 0.79), 0.95, Data(1549.70, 1157.20, 1100.50, 958.10, 2567.64, 971.65, 1101.36, 1034.06, 647.50, 519.62, 916.16, 1516.30, 1417.07, 5363.78, 3896.16, 41.45, 255.98, 496.48, 629.27, 630.26, 780.26, 403.81, 476.80), 0.05)
M6UB	PORK, SAUSAGES, OTHER	1	Discrete(Data(0.66, 0.95, 0.34, 0.62, 0.38, 0.79), 0.95, Data(1549.70, 1157.20, 1100.50, 958.10, 2567.64, 971.65, 1101.36, 1034.06, 647.50, 519.62, 916.16, 1516.30, 1417.07, 5363.78, 3896.16, 41.45, 255.98, 496.48, 629.27, 630.26, 780.26, 403.81, 476.80), 0.05)
M6UB	PORK, PUDDINGS	1	Discrete(Data(0.66, 0.95, 0.34, 0.62, 0.38, 0.79), 0.95, Data(1549.70, 1157.20, 1100.50, 958.10, 2567.64, 971.65, 1101.36, 1034.06, 647.50, 519.62, 916.16, 1516.30, 1417.07, 5363.78, 3896.16, 41.45, 255.98, 496.48, 629.27, 630.26, 780.26, 403.81, 476.80), 0.05)
M6UB	PORK, FAT	1	Discrete(Data(0.66, 0.95, 0.34, 0.62, 0.38, 0.79), 0.95, Data(1549.70, 1157.20, 1100.50, 958.10, 2567.64, 971.65, 1101.36, 1034.06, 647.50, 519.62, 916.16, 1516.30, 1417.07, 5363.78, 3896.16, 41.45, 255.98, 496.48, 629.27, 630.26, 780.26, 403.81, 476.80), 0.05)
M6UB	PORK, PROCESSED	1	Discrete(Data(0.66, 0.95, 0.34, 0.62, 0.38, 0.79), 0.95, Data(1549.70, 1157.20, 1100.50, 958.10, 2567.64, 971.65, 1101.36, 1034.06, 647.50, 519.62, 916.16, 1516.30, 1417.07, 5363.78, 3896.16, 41.45, 255.98, 496.48, 629.27, 630.26, 780.26, 403.81, 476.80), 0.05)

Table 48 continued Creme Data Entry for contaminated beef and pork

Chemical Code	Food Code Name	Presence Probability	Concentration ng/kg (Marker PCBs in µg/kg)
M6UB	PORK/BEEF, PROCESSED	1	Discrete(Data(0.79), 0.95, Data(1549.70, 1157.20, 1100.50, 958.10, 2567.64, 971.65, 1101.36, 1034.06, 647.50, 519.62, 916.16, 1516.30, 1417.07, 5363.78, 3896.16, 41.45, 255.98, 496.48, 629.27, 630.26, 780.26, 403.81, 476.80), 0.05)
M6UB	PORK/BEEF, SAUSAGES	1	Discrete(Data(0.79), 0.95, Data(1549.70, 1157.20, 1100.50, 958.10, 2567.64, 971.65, 1101.36, 1034.06, 647.50, 519.62, 916.16, 1516.30, 1417.07, 5363.78, 3896.16, 41.45, 255.98, 496.48, 629.27, 630.26, 780.26, 403.81, 476.80), 0.05)
M6UB	OFFAL, CALF LIVER	1	Discrete(Data(3.18, 2.94), 0.989, Data(710.62, 912.56, 737.59, 147.22, 1.97, 3.22, 107.54, 23.65, 31.50, 12.34, 11.95, 0.00, 10.28, 13.24, 11.80, 10.40, 7.79), 0.011)
M6UB	OFFAL, BOVINE KIDNEY	1	Discrete(Data(0.93, 0.78, 0.84, 1.34, 0.85, 1.13, 0.97, 0.76, 0.68), 0.989, Data(710.62, 912.56, 737.59, 147.22, 1.97, 3.22, 107.54, 23.65, 31.50, 12.34, 11.95, 0.00, 10.28, 13.24, 11.80, 10.40, 7.79), 0.011)
M6UB	OFFAL, PORK KIDNEY	1	Discrete(Data(0.66, 0.95, 0.34, 0.62, 0.38, 0.79), 0.95, Data(1549.70, 1157.20, 1100.50, 958.10, 2567.64, 971.65, 1101.36, 1034.06, 647.50, 519.62, 916.16, 1516.30, 1417.07, 5363.78, 3896.16, 41.45, 255.98, 496.48, 629.27, 630.26, 780.26, 403.81, 476.80), 0.05)
M6UB	OFFAL, PORK LIVER	1	Discrete(Data(0.46, 0.57), 0.95, Data(1549.70, 1157.20, 1100.50, 958.10, 2567.64, 971.65, 1101.36, 1034.06, 647.50, 519.62, 916.16, 1516.30, 1417.07, 5363.78, 3896.16, 41.45, 255.98, 496.48, 629.27, 630.26, 780.26, 403.81, 476.80), 0.05)
M6UB	OFFAL, PORK LIVER, PROCESSED	1	Discrete(Data(0.46, 0.57), 0.95, Data(1549.70, 1157.20, 1100.50, 958.10, 2567.64, 971.65, 1101.36, 1034.06, 647.50, 519.62, 916.16, 1516.30, 1417.07, 5363.78, 3896.16, 41.45, 255.98, 496.48, 629.27, 630.26, 780.26, 403.81, 476.80), 0.05)
M6UB	OFFAL, PORK TROTTERS AND TAILS	1	Discrete(Data(0.66, 0.95, 0.34, 0.62, 0.38, 0.79), 0.95, Data(1549.70, 1157.20, 1100.50, 958.10, 2567.64, 971.65, 1101.36, 1034.06, 647.50, 519.62, 916.16, 1516.30, 1417.07, 5363.78, 3896.16, 41.45, 255.98, 496.48, 629.27, 630.26, 780.26, 403.81, 476.80), 0.05)
TTNUB	BEEF	1	Discrete(Data(0.51, 0.46, 0.16, 0.67, 0.59, 0.55, 0.71, 0.45, 0.4), 0.989, Data(884.34, 472.55, 625.79, 214.24, 1.89, 3.47, 147.65, 50.62, 53.16, 23.25, 15.45, 7.36, 16.52, 19.87, 15.63, 17.87, 10.66, 7.47, 9.25, 1.91), 0.011)
TTNUB	BEEF MINCE	1	Discrete(Data(0.51, 0.46, 0.16, 0.67, 0.59, 0.55, 0.71, 0.45, 0.4), 0.989, Data(884.34, 472.55, 625.79, 214.24, 1.89, 3.47, 147.65, 50.62, 53.16, 23.25, 15.45, 7.36, 16.52, 19.87, 15.63, 17.87, 10.66, 7.47, 9.25, 1.91), 0.011)
TTNUB	BEEF, FAT	1	Discrete(Data(0.51, 0.46, 0.16, 0.67, 0.59, 0.55, 0.71, 0.45, 0.4), 0.989, Data(884.34, 472.55, 625.79, 214.24, 1.89, 3.47, 147.65, 50.62, 53.16, 23.25, 15.45, 7.36, 16.52, 19.87, 15.63, 17.87, 10.66, 7.47, 9.25, 1.91), 0.011)
TTNUB	BEEF, PROCESSED	1	Discrete(Data(0.51, 0.46, 0.16, 0.67, 0.59, 0.55, 0.71, 0.45, 0.4), 0.989, Data(884.34, 472.55, 625.79, 214.24, 1.89, 3.47, 147.65, 50.62, 53.16, 23.25, 15.45, 7.36, 16.52, 19.87, 15.63, 17.87, 10.66, 7.47, 9.25, 1.91), 0.011)

Table 48 continued Creme Data Entry for contaminated beef and pork

Chemical Code	Food Code Name	Presence Probability	Concentration ng/kg (Marker PCBs in µg/kg)
TTNUB	PORK	1	Discrete(Data(0.81, 0.13, 0.13, 0.2, 0.15, 0.11), 0.95, Data(171.09, 151.61, 108.16, 278.41, 206.68, 137.08, 132.85, 124.24, 53.53, 57.72, 139.01, 279.39, 164.06, 890.21, 748.59, 23.42, 43.78, 76.16, 136.17, 75.84, 189.28, 106.36, 41.44), 0.05)
TTNUB	PORK, BACON	1	Discrete(Data(0.81, 0.13, 0.13, 0.2, 0.15, 0.11), 0.95, Data(171.09, 151.61, 108.16, 278.41, 206.68, 137.08, 132.85, 124.24, 53.53, 57.72, 139.01, 279.39, 164.06, 890.21, 748.59, 23.42, 43.78, 76.16, 136.17, 75.84, 189.28, 106.36, 41.44), 0.05)
TTNUB	PORK, HAM	1	Discrete(Data(0.81, 0.13, 0.13, 0.2, 0.15, 0.11), 0.95, Data(171.09, 151.61, 108.16, 278.41, 206.68, 137.08, 132.85, 124.24, 53.53, 57.72, 139.01, 279.39, 164.06, 890.21, 748.59, 23.42, 43.78, 76.16, 136.17, 75.84, 189.28, 106.36, 41.44), 0.05)
TTNUB	PORK, SAUSAGES, BREAKFAST	1	Discrete(Data(0.81, 0.13, 0.13, 0.2, 0.15, 0.11), 0.95, Data(171.09, 151.61, 108.16, 278.41, 206.68, 137.08, 132.85, 124.24, 53.53, 57.72, 139.01, 279.39, 164.06, 890.21, 748.59, 23.42, 43.78, 76.16, 136.17, 75.84, 189.28, 106.36, 41.44), 0.05)
TTNUB	PORK, SAUSAGES, OTHER	1	Discrete(Data(0.81, 0.13, 0.13, 0.2, 0.15, 0.11), 0.95, Data(171.09, 151.61, 108.16, 278.41, 206.68, 137.08, 132.85, 124.24, 53.53, 57.72, 139.01, 279.39, 164.06, 890.21, 748.59, 23.42, 43.78, 76.16, 136.17, 75.84, 189.28, 106.36, 41.44), 0.05)
TTNUB	PORK, PUDDINGS	1	Discrete(Data(0.81, 0.13, 0.13, 0.2, 0.15, 0.11), 0.95, Data(171.09, 151.61, 108.16, 278.41, 206.68, 137.08, 132.85, 124.24, 53.53, 57.72, 139.01, 279.39, 164.06, 890.21, 748.59, 23.42, 43.78, 76.16, 136.17, 75.84, 189.28, 106.36, 41.44), 0.05)
TTNUB	PORK, FAT	1	Discrete(Data(0.81, 0.13, 0.13, 0.2, 0.15, 0.11), 0.95, Data(171.09, 151.61, 108.16, 278.41, 206.68, 137.08, 132.85, 124.24, 53.53, 57.72, 139.01, 279.39, 164.06, 890.21, 748.59, 23.42, 43.78, 76.16, 136.17, 75.84, 189.28, 106.36, 41.44), 0.05)
TTNUB	PORK, PROCESSED	1	Discrete(Data(0.81, 0.13, 0.13, 0.2, 0.15, 0.11), 0.95, Data(171.09, 151.61, 108.16, 278.41, 206.68, 137.08, 132.85, 124.24, 53.53, 57.72, 139.01, 279.39, 164.06, 890.21, 748.59, 23.42, 43.78, 76.16, 136.17, 75.84, 189.28, 106.36, 41.44), 0.05)
TTNUB	PORK/BEEF, PROCESSED	1	Discrete(Data(0.45), 0.95, Data(171.09, 151.61, 108.16, 278.41, 206.68, 137.08, 132.85, 124.24, 53.53, 57.72, 139.01, 279.39, 164.06, 890.21, 748.59, 23.42, 43.78, 76.16, 136.17, 75.84, 189.28, 106.36, 41.44), 0.05)
TTNUB	PORK/BEEF, SAUSAGES	1	Discrete(Data(0.45), 0.95, Data(171.09, 151.61, 108.16, 278.41, 206.68, 137.08, 132.85, 124.24, 53.53, 57.72, 139.01, 279.39, 164.06, 890.21, 748.59, 23.42, 43.78, 76.16, 136.17, 75.84, 189.28, 106.36, 41.44), 0.05)
TTNUB	OFFAL, CALF LIVER	1	Discrete(Data(1.44, 1.55), 0.989, Data(884.34, 472.55, 625.79, 214.24, 1.89, 3.47, 147.65, 50.62, 53.16, 23.25, 15.45, 7.36, 16.52, 19.87, 15.63, 17.87, 10.66, 7.47, 9.25, 1.91), 0.011)
TTNUB	OFFAL, BOVINE KIDNEY	1	Discrete(Data(0.51, 0.46, 0.16, 0.67, 0.59, 0.55, 0.71, 0.45, 0.4), 0.989, Data(884.34, 472.55, 625.79, 214.24, 1.89, 3.47, 147.65, 50.62, 53.16, 23.25, 15.45, 7.36, 16.52, 19.87, 15.63, 17.87, 10.66, 7.47, 9.25, 1.91), 0.011)

Table 48 continued Creme Data Entry for contaminated beef and pork

Chemical Code	Food Code Name	Presence Probability	Concentration ng/kg (Marker PCBs in μg/kg)
TTNUB	OFFAL, PORK KIDNEY	1	Discrete(Data(0.81, 0.13, 0.13, 0.2, 0.15, 0.11), 0.95, Data(171.09, 151.61, 108.16, 278.41, 206.68, 137.08, 132.85, 124.24, 53.53, 57.72, 139.01, 279.39, 164.06, 890.21, 748.59, 23.42, 43.78, 76.16, 136.17, 75.84, 189.28, 106.36, 41.44), 0.05)
TTNUB	OFFAL, PORK LIVER	1	Discrete(Data(0.61, 1), 0.95, Data(171.09, 151.61, 108.16, 278.41, 206.68, 137.08, 132.85, 124.24, 53.53, 57.72, 139.01, 279.39, 164.06, 890.21, 748.59, 23.42, 43.78, 76.16, 136.17, 75.84, 189.28, 106.36, 41.44), 0.05)
TTNUB	OFFAL, PORK LIVER, PROCESSED	1	Discrete(Data(0.61, 1), 0.95, Data(171.09, 151.61, 108.16, 278.41, 206.68, 137.08, 132.85, 124.24, 53.53, 57.72, 139.01, 279.39, 164.06, 890.21, 748.59, 23.42, 43.78, 76.16, 136.17, 75.84, 189.28, 106.36, 41.44), 0.05)
TTNUB	OFFAL, PORK TROTTERS AND TAILS	1	Discrete(Data(0.81, 0.13, 0.13, 0.2, 0.15, 0.11), 0.95, Data(171.09, 151.61, 108.16, 278.41, 206.68, 137.08, 132.85, 124.24, 53.53, 57.72, 139.01, 279.39, 164.06, 890.21, 748.59, 23.42, 43.78, 76.16, 136.17, 75.84, 189.28, 106.36, 41.44), 0.05)
TTOUB	BEEF	1	Discrete(Data(0.57, 0.51, 0.2, 0.75, 0.65, 0.63, 0.78, 0.51, 0.46), 0.989, Data(1403.25, 727.29, 970.63, 340.43, 2.40, 4.45, 235.30, 80.32, 83.78, 36.84, 24.65, 12.00, 25.81, 31.14, 24.35, 27.91, 16.68, 12.00, 14.00, 2.90), 0.011)
TTOUB	BEEF MINCE	1	Discrete(Data(0.57, 0.51, 0.2, 0.75, 0.65, 0.63, 0.78, 0.51, 0.46), 0.989, Data(1403.25, 727.29, 970.63, 340.43, 2.40, 4.45, 235.30, 80.32, 83.78, 36.84, 24.65, 12.00, 25.81, 31.14, 24.35, 27.91, 16.68, 12.00, 14.00, 2.90), 0.011)
TTOUB	BEEF, FAT	1	Discrete(Data(0.57, 0.51, 0.2, 0.75, 0.65, 0.63, 0.78, 0.51, 0.46), 0.989, Data(1403.25, 727.29, 970.63, 340.43, 2.40, 4.45, 235.30, 80.32, 83.78, 36.84, 24.65, 12.00, 25.81, 31.14, 24.35, 27.91, 16.68, 12.00, 14.00, 2.90), 0.011)
TTOUB	BEEF, PROCESSED	1	Discrete(Data(0.57, 0.51, 0.2, 0.75, 0.65, 0.63, 0.78, 0.51, 0.46), 0.989, Data(1403.25, 727.29, 970.63, 340.43, 2.40, 4.45, 235.30, 80.32, 83.78, 36.84, 24.65, 12.00, 25.81, 31.14, 24.35, 27.91, 16.68, 12.00, 14.00, 2.90), 0.011)
TTOUB	PORK	1	Discrete(Data(0.88, 0.15, 0.14, 0.23, 0.17, 0.13), 0.95, Data(270.00, 240.00, 170.00, 439.74, 336.13, 219.73, 213.20, 200.81, 86.61, 92.28, 218.45, 434.05, 257.46, 1429.27, 1191.88, 36.57, 69.60, 120.94, 213.24, 123.50, 300.70, 169.06, 67.69), 0.05)
TTOUB	PORK, BACON	1	Discrete(Data(0.88, 0.15, 0.14, 0.23, 0.17, 0.13), 0.95, Data(270.00, 240.00, 170.00, 439.74, 336.13, 219.73, 213.20, 200.81, 86.61, 92.28, 218.45, 434.05, 257.46, 1429.27, 1191.88, 36.57, 69.60, 120.94, 213.24, 123.50, 300.70, 169.06, 67.69), 0.05)
TTOUB	PORK, HAM	1	Discrete(Data(0.88, 0.15, 0.14, 0.23, 0.17, 0.13), 0.95, Data(270.00, 240.00, 170.00, 439.74, 336.13, 219.73, 213.20, 200.81, 86.61, 92.28, 218.45, 434.05, 257.46, 1429.27, 1191.88, 36.57, 69.60, 120.94, 213.24, 123.50, 300.70, 169.06, 67.69), 0.05)
TTOUB	PORK, SAUSAGES, BREAKFAST	1	Discrete(Data(0.88, 0.15, 0.14, 0.23, 0.17, 0.13), 0.95, Data(270.00, 240.00, 170.00, 439.74, 336.13, 219.73, 213.20, 200.81, 86.61, 92.28, 218.45, 434.05, 257.46, 1429.27, 1191.88, 36.57, 69.60, 120.94, 213.24, 123.50, 300.70, 169.06, 67.69), 0.05)
TTOUB	PORK, SAUSAGES, OTHER	1	Discrete(Data(0.88, 0.15, 0.14, 0.23, 0.17, 0.13), 0.95, Data(270.00, 240.00, 170.00, 439.74, 336.13, 219.73, 213.20, 200.81, 86.61, 92.28, 218.45, 434.05, 257.46, 1429.27, 1191.88, 36.57, 69.60, 120.94, 213.24, 123.50, 300.70, 169.06, 67.69), 0.05)

Table 48 continued Creme Data Entry for contaminated beef and pork

Chemical Code	Food Code Name	Presence Probability	Concentration ng/kg (Marker PCBs in µg/kg)
TTOUB	PORK, PUDDINGS	1	Discrete(Data(0.88, 0.15, 0.14, 0.23, 0.17, 0.13), 0.95, Data(270.00, 240.00, 170.00, 439.74, 336.13, 219.73, 213.20, 200.81, 86.61, 92.28, 218.45, 434.05, 257.46, 1429.27, 1191.88, 36.57, 69.60, 120.94, 213.24, 123.50, 300.70, 169.06, 67.69), 0.05)
TTOUB	PORK, FAT	1	Discrete(Data(0.88, 0.15, 0.14, 0.23, 0.17, 0.13), 0.95, Data(270.00, 240.00, 170.00, 439.74, 336.13, 219.73, 213.20, 200.81, 86.61, 92.28, 218.45, 434.05, 257.46, 1429.27, 1191.88, 36.57, 69.60, 120.94, 213.24, 123.50, 300.70, 169.06, 67.69), 0.05)
TTOUB	PORK, PROCESSED	1	Discrete(Data(0.88, 0.15, 0.14, 0.23, 0.17, 0.13), 0.95, Data(270.00, 240.00, 170.00, 439.74, 336.13, 219.73, 213.20, 200.81, 86.61, 92.28, 218.45, 434.05, 257.46, 1429.27, 1191.88, 36.57, 69.60, 120.94, 213.24, 123.50, 300.70, 169.06, 67.69), 0.05)
TTOUB	PORK/BEEF, PROCESSED	1	Discrete(Data(0.51), 0.95, Data(270.00, 240.00, 170.00, 439.74, 336.13, 219.73, 213.20, 200.81, 86.61, 92.28, 218.45, 434.05, 257.46, 1429.27, 1191.88, 36.57, 69.60, 120.94, 213.24, 123.50, 300.70, 169.06, 67.69), 0.05)
TTOUB	PORK/BEEF, SAUSAGES	1	Discrete(Data(0.51), 0.95, Data(270.00, 240.00, 170.00, 439.74, 336.13, 219.73, 213.20, 200.81, 86.61, 92.28, 218.45, 434.05, 257.46, 1429.27, 1191.88, 36.57, 69.60, 120.94, 213.24, 123.50, 300.70, 169.06, 67.69), 0.05)
TTOUB	OFFAL, CALF LIVER	1	Discrete(Data(1.64, 1.72), 0.989, Data(1403.25, 727.29, 970.63, 340.43, 2.40, 4.45, 235.30, 80.32, 83.78, 36.84, 24.65, 12.00, 25.81, 31.14, 24.35, 27.91, 16.68, 12.00, 14.00, 2.90), 0.011)
TTOUB	OFFAL, BOVINE KIDNEY	1	Discrete(Data(0.57, 0.51, 0.2, 0.75, 0.65, 0.63, 0.78, 0.51, 0.46), 0.989, Data(1403.25, 727.29, 970.63, 340.43, 2.40, 4.45, 235.30, 80.32, 83.78, 36.84, 24.65, 12.00, 25.81, 31.14, 24.35, 27.91, 16.68, 12.00, 14.00, 2.90), 0.011)
TTOUB	OFFAL, PORK KIDNEY	1	Discrete(Data(0.88, 0.15, 0.14, 0.23, 0.17, 0.13), 0.95, Data(270.00, 240.00, 170.00, 439.74, 336.13, 219.73, 213.20, 200.81, 86.61, 92.28, 218.45, 434.05, 257.46, 1429.27, 1191.88, 36.57, 69.60, 120.94, 213.24, 123.50, 300.70, 169.06, 67.69), 0.05)
TTOUB	OFFAL, PORK LIVER	1	Discrete(Data(0.74, 1.2), 0.95, Data(270.00, 240.00, 170.00, 439.74, 336.13, 219.73, 213.20, 200.81, 86.61, 92.28, 218.45, 434.05, 257.46, 1429.27, 1191.88, 36.57, 69.60, 120.94, 213.24, 123.50, 300.70, 169.06, 67.69), 0.05)
TTOUB	OFFAL, PORK LIVER, PROCESSED	1	Discrete(Data(0.74, 1.2), 0.95, Data(270.00, 240.00, 170.00, 439.74, 336.13, 219.73, 213.20, 200.81, 86.61, 92.28, 218.45, 434.05, 257.46, 1429.27, 1191.88, 36.57, 69.60, 120.94, 213.24, 123.50, 300.70, 169.06, 67.69), 0.05)
TTOUB	OFFAL, PORK TROTTERS AND TAILS	1	Discrete(Data(0.88, 0.15, 0.14, 0.23, 0.17, 0.13), 0.95, Data(270.00, 240.00, 170.00, 439.74, 336.13, 219.73, 213.20, 200.81, 86.61, 92.28, 218.45, 434.05, 257.46, 1429.27, 1191.88, 36.57, 69.60, 120.94, 213.24, 123.50, 300.70, 169.06, 67.69), 0.05)

7.4 Results expressed on WHO-TEQ (1998) basis

7.4.1 Background exposure

Table 49 Range of LB - UB summary statistics of exposure to Total WHO TEQ (1998) expressed as pg/kg bw/d and % contribution to the total mean average daily intake

Group Names	Range of LB - UB TOTAL WHO TEQ (1998) pg/kg bw/d								
	% Contribution	Mean	Med	P75	P90	P95	P97.5	P98	P99
DAIRY, MILKS	8.7-8.8	0.03-0.03	0.02-0.02	0.04-0.04	0.06-0.07	0.08-0.09	0.1-0.1	0.1-0.1	0.1-0.2
DAIRY, CREAMS	2.7-2.7	0.009-0.01	0.001-0.001	0.01-0.01	0.02-0.03	0.04-0.04	0.05-0.06	0.06-0.07	0.08-0.09
DAIRY, YOGHURTS	1-1	0.003-0.004	0	0.004-0.005	0.01-0.01	0.02-0.02	0.02-0.02	0.02-0.02	0.03-0.03
DAIRY, CHEESE	7.3-7.3	0.02-0.03	0.02-0.02	0.03-0.04	0.06-0.06	0.08-0.09	0.1-0.1	0.1-0.1	0.1-0.1
DAIRY, BUTTER	6.5-6.5	0.02-0.02	0.009-0.01	0.03-0.03	0.06-0.06	0.08-0.09	0.1-0.1	0.1-0.1	0.2-0.2
DAIRY	26-26	0.08-0.1	0.07-0.08	0.1-0.1	0.2-0.2	0.2-0.2	0.2-0.3	0.3-0.3	0.3-0.3
EGGS, CHICKEN	2.1-2.6	0.007-0.009	0.004-0.006	0.01-0.01	0.02-0.02	0.02-0.03	0.03-0.04	0.03-0.04	0.03-0.05
EGGS, DUCK	0.008-0.01	0.00003-0.00004	0	0	0	0	0	0	0
EGGS	2.1-2.6	0.007-0.01	0.004-0.007	0.01-0.01	0.02-0.02	0.02-0.03	0.03-0.04	0.03-0.04	0.03-0.05
MEAT AND MEAT PRODUCTS, BEEF	12-11	0.04-0.04	0.02-0.02	0.06-0.06	0.1-0.1	0.1-0.1	0.2-0.2	0.2-0.2	0.2-0.2
MEAT AND MEAT PRODUCTS, LAMB	3-2.8	0.01-0.01	0	0	0.04-0.04	0.07-0.07	0.1-0.1	0.1-0.1	0.1-0.1
MEAT AND MEAT PRODUCTS, PORK	7-7.7	0.02-0.03	0.009-0.01	0.03-0.04	0.06-0.08	0.09-0.1	0.1-0.1	0.1-0.1	0.2-0.2
MEAT AND MEAT PRODUCTS, POULTRY	2.6-2.4	0.008-0.009	0.003-0.003	0.008-0.008	0.02-0.02	0.03-0.04	0.06-0.06	0.07-0.07	0.1-0.1
MEAT AND MEAT PRODUCTS, OTHER	0.009-0.009	0.00003-0.00003	0	0	0	0	0	0	0
MEAT AND MEAT PRODUCTS, MIXED MEAT	0.03-0.03	0.0001-0.0001	0	0	0	0	0	0	0
OFFAL, BEEF	0.01-0.01	0.00004-0.00004	0	0	0	0	0	0	0
OFFAL, LAMB	0.3-0.3	0.001-0.001	0	0	0	0	0	0	0.002-0.002
OFFAL, PORK	0.03-0.03	0.0001-0.0001	0	0	0	0	0	0	0.001-0.002
OFFAL, POULTRY	0.002-0.002	0.000006-0.000006	0	0	0	0	0	0	0
MEAT AND MEAT PRODUCTS	25-24	0.08-0.09	0.06-0.07	0.1-0.1	0.2-0.2	0.2-0.2	0.3-0.3	0.3-0.3	0.3-0.3

Table 49 continued Range of LB - UB summary statistics of exposure to Total WHO TEQ (1998) expressed as pg/kg bw/d and % contribution to the total mean average daily intake

Group Names	Range of LB - UB TOTAL WHO TEQ (1998) pg/kg bw/d								
	% Contribution	Mean	Med	P75	P90	P95	P97.5	P98	P99
FISH AND FISH PRODUCTS, WHITE FISH	2.5-2.2	0.008-0.008	0	0.003-0.004	0.02-0.02	0.05-0.05	0.09-0.09	0.1-0.1	0.1-0.1
FISH AND FISH PRODUCTS, OILY FISH	37-34	0.1-0.1	0	0.001-0.03	0.5-0.5	0.7-0.8	1.1-1.1	1.2-1.2	1.5-1.5
FISH AND FISH PRODUCTS, MIXED FISH	0.002-0.002	0.000007-0.000007	0	0	0	0	0	0	0
FISH AND FISH PRODUCTS, SHELLFISH	0.4-0.3	0.001-0.001	0	0	0	0.001-0.001	0.004-0.004	0.006-0.006	0.05-0.05
FISH AND FISH PRODUCTS, OTHER	0.02-0.02	0.00006-0.00006	0	0	0	0	0	0	0
FISH AND FISH PRODUCTS	40-36	0.1-0.1	0-0.002	0.05-0.08	0.5-0.5	0.8-0.8	1.1-1.1	1.2-1.2	1.5-1.5
FAT/DAIRY SPREADS EXCL BUTTER	2.8-4.6	0.009-0.02	0.007-0.01	0.01-0.02	0.02-0.04	0.03-0.05	0.03-0.06	0.04-0.07	0.04-0.08
OILS	1.1-3.1	0.004-0.01	0.003-0.01	0.005-0.02	0.008-0.02	0.01-0.03	0.01-0.03	0.01-0.04	0.01-0.04
FATS AND OILS EXCL BUTTER	4-7.7	0.01-0.03	0.01-0.02	0.02-0.04	0.02-0.05	0.03-0.06	0.04-0.08	0.04-0.08	0.05-0.1
SUPPLEMENTS, OILS/FATTY ACIDS	2.9-3.2	0.009-0.01	0	0	0.008-0.01	0.03-0.04	0.06-0.08	0.07-0.1	0.2-0.3
SUPPLEMENTS	2.9-3.2	0.009-0.01	0-0	0-0	0.008-0.01	0.03-0.04	0.06-0.08	0.07-0.1	0.2-0.3
TOTAL	100-100	0.3-0.4	0.2-0.3	0.3-0.4	0.7-0.7	1-1	1.3-1.3	1.4-1.5	1.8-1.8

7.4.2 *Incident exposure (1998 TOTTEQ)*

Table 50 Contamination impact – UB Mean, Median and higher percentile exposure to Total WHO TEQ (1998) expressed as pg/kg bw/d and % contribution to the total mean average daily intake

Group Names	Post incident UB TOTAL WHO TEQ (1998) pg/kg bw/d								
	% Contribution	Mean	Med	P75	P90	P95	P97.5	P98	P99
DAIRY, MILKS	1.6	0.03	0.02	0.04	0.07	0.09	0.1	0.1	0.2
DAIRY, CREAMS	0.5	0.01	0.001	0.01	0.03	0.04	0.06	0.07	0.09
DAIRY, YOGHURTS	0.2	0.004	0	0.005	0.01	0.02	0.02	0.02	0.03
DAIRY, CHEESE	1.3	0.03	0.02	0.04	0.06	0.09	0.1	0.1	0.1
DAIRY, BUTTER	1.2	0.02	0.01	0.03	0.06	0.09	0.1	0.1	0.2
DAIRY	4.7	0.10	0.08	0.1	0.2	0.2	0.3	0.3	0.3
EGGS, CHICKEN	0.5	0.009	0.006	0.01	0.02	0.03	0.04	0.04	0.05
EGGS, DUCK	0.002	0.00004	0						
EGGS	0.5	0.010	0.006	0.01	0.02	0.03	0.04	0.04	0.05
MEAT AND MEAT PRODUCTS, BEEF	9.4	0.2	0.02	0.06	0.1	0.2	0.2	0.2	0.6
MEAT AND MEAT PRODUCTS, LAMB	0.5	0.01	0		0.04	0.07	0.10	0.1	0.1
MEAT AND MEAT PRODUCTS, PORK	76	1.6	0.02	0.06	1.9	7.7	16	19	32
MEAT AND MEAT PRODUCTS, POULTRY	0.4	0.009	0.003	0.008	0.02	0.04	0.06	0.07	0.10
MEAT AND MEAT PRODUCTS, OTHER	0.002	0.00003	0						
MEAT AND MEAT PRODUCTS, MIXED MEAT	0.2	0.005	0						
OFFAL, BEEF	0.006	0.0001	0						
OFFAL, LAMB	0.06	0.001	0						0.002
OFFAL, PORK	0.1	0.003	0						0.002
OFFAL, POULTRY	0.0003	0.000006	0						
MEAT AND MEAT PRODUCTS	86	1.8	0.08	0.2	2.3	8.4	17	21	36

Table 50 continued Contamination impact – UB Mean, Median and higher percentile exposure to Total WHO TEQ (1998) expressed as pg/kg bw/d and % contribution to the total mean average daily intake

Group Names	Post incident UB TOTAL WHO TEQ (1998) pg/kg bw/d								
	% Contribution	Mean	Med	P75	P90	P95	P97.5	P98	P99
FISH AND FISH PRODUCTS, WHITE FISH	0.4	0.008	0	0.004	0.02	0.05	0.09	0.10	0.1
FISH AND FISH PRODUCTS, OILY FISH	6.0	0.1	0	0.03	0.5	0.7	1.1	1.2	1.5
FISH AND FISH PRODUCTS, MIXED FISH	0.0003	0.000007	0						
FISH AND FISH PRODUCTS, SHELLFISH	0.06	0.001	0			0.001	0.004	0.006	0.05
FISH AND FISH PRODUCTS, OTHER	0.003	0.00006	0						
FISH AND FISH PRODUCTS	6.5	0.1	0.002	0.08	0.5	0.8	1.1	1.2	1.5
FAT/DAIRY SPREADS EXCL BUTTER	0.8	0.02	0.01	0.02	0.04	0.05	0.06	0.07	0.08
OILS	0.6	0.01	0.010	0.02	0.02	0.03	0.03	0.04	0.04
FATS AND OILS EXCL BUTTER	1.4	0.03	0.02	0.04	0.05	0.06	0.08	0.08	0.10
SUPPLEMENTS, OILS/FATTY ACIDS	0.6	0.01	0	N/A	0.01	0.04	0.08	0.10	0.3
SUPPLEMENTS	0.6	0.01	0	0	0.01	0.04	0.08	0.10	0.3
TOTAL	100	2.1	0.3	0.7	2.8	8.6	17	21	36

8 References

Ahlborg UG, Becking GC, Birnbaum LS, Brouwer A, Derks HJGM, Feeley M, Golor G, Hanberg A, Larsen JC, Liem AKD, Safe SH, Schlatter C, Waern F, Younes M, and Yrj+ñnheikki E. (1994) Toxic equivalency factors for dioxin-like PCBs: Report on WHO-ECEH and IPCS consultation, December 1993. Chemosphere Vol.28 /6 p. 1049-1067. Available at: http://www.sciencedirect.com/science/article/pii/0045653594903247

Andersson P, McGuire J, Rubio C, Gradin K, Whitelaw ML, Pettersson S, Hanberg A, and Poellinger L. (2002) A constitutively active dioxin/aryl hydrocarbon receptor induces stomach tumors. Proc Natl. Acad. Sci U. S. A. Vol.99 /15 p. 9990-9995.

Andersson P, Ridderstad A, McGuire J, Pettersson S, Poellinger L, and Hanberg A. (2003) A constitutively active aryl hydrocarbon receptor causes loss of peritoneal B1 cells. Biochem. Biophys. Res Commun. Vol.302 /2 p. 336-341.

Ankarberg EH, Concha G, Darnerud PO, Aune M, Tornkvist A, and Glynn A. (2007) Dietary intake of polychlorinated dibenzo-p-dioxins, dibenzofurans and polychlorinated biphenyls in Swedish consumers. Organohalogen Compounds Vol.69 p. 1965-1968.

Arnich N, Sirot V, Rivière G, Jean J, Noël L, Guérin T, Leblanc JC (2012) Dietary exposure to trace elements and health risk assessment in the 2nd French Total Diet Study. Food Chem Toxicol. 2012 Jul;50(7):2432-49. doi: 10.1016/j.fct.2012.04.016

ATSDR. (1994) Toxicological profile for chlorodibenzofurans (CDFs). Department of Health and Human Services, Public Health Service.

ATSDR. (1998) Toxicological profile for Chlorinated Dibenzo-p-dioxins (CDDs). Department of Health and Human Services, Public Health Service.

ATSDR. (2000) Toxicological profile for polychlorinated biphenyls (PCBs). Department of Health and Human Services, Public Health Service.

ATSDR. (2001) Polychlorinated Biphenyls. Department of Health and Human Services, Public Health Service. Available at: www.atsdr.cdc.gov/tfacts17.pdf

Aylward LL, Brunet RC, Carrier G, Hays SM, Cushing CA, Needham LL, Patterson DG, Gerthoux PM, Brambilla P, and Mocarelli P. (2005) Concentration-dependent TCDD elimination kinetics in humans: toxicokinetic modeling for moderately to highly exposed adults from Seveso, Italy, and Vienna, Austria, and impact on dose estimates for the NIOSH cohort. J Expo Anal Environ Epidemiol Vol.15 /1 p. 51-65. Available at: http://europepmc.org/abstract/MED/15083163

Aylward LL, Hays SM, LaKind JS, and Ryan JJ. (2003) Rapid communication: partitioning of persistent lipophilic compounds, including dioxins, between human milk lipid and blood lipid: an initial assessment. J Toxicol. Environ Health A. Vol.66 /1 p. 1-5.

Baars AJ, Bakker MI, Baumann RA, Boon PE, Freijer JI, Hoogenboom LA, Hoogerbrugge R, van Klaveren JD, Liem AK, Traag WA, and de VJ. (2004) Dioxins, dioxin-like PCBs and non-dioxin-like PCBs in foodstuffs: occurrence and dietary intake in The Netherlands. Toxicol. Lett. Vol.151 /1 p. 51-61.

Baccarelli A, Giacomini SM, Corbetta C, Landi MT, Bonzini M, Consonni D, Grillo P, Patterson DG, Pesatori AC, and Bertazzi PA. (2008) Neonatal thyroid function in Seveso 25 years after maternal exposure to dioxin. PLoS Med Vol.5 /7 p. e161-e161. Available at: http://pubget.com/paper/18666825

Bentley J. (1983) Incineration of PCBs. In: Barros, M.C., Könemann, H., & Visser, R., ed. Proceedings of the PCB Seminar. The Hague, Ministry of the Environment, pp. 281-288.

Bergkvist C, Oberg M, Appelgren M, Becker W, Aune M, Ankarberg EH, Berglund M, and Hakansson H. (2008) Exposure to dioxin-like pollutants via different food commodities in Swedish children and young adults. Food. Chem. Toxicol. Vol.46 /11 p. 3360-3367.

Bernard A, Hermans C, and Broeckaert F. (1999) Food contamination by PCBs and dioxins. Nature Vol.401 p. 231-232.

BMELV. (2011) Background information: Dioxins in feed fats. Bundesministerium für Ernährung,Landwirtschaft und Verbraucherschutz Available at: http://www.bmelv.de/SharedDocs/Standardartikel/EN/Food/DioxinSummaryReport.html

Bognár A. (2002) Tables on weight yield of food and retention factors of food constituents for the calculation of nutrient composition of cooked foods (dishes). Bundesforschungsanstalt für Ernährung.

Bord Bia. (2008) Meat and Livestock Review & Outlook 2008/09. Available at: http://www.bordbia.ie/industryservices/information/publications/MeatLivestockReview/Meat%20and%20Livestock%20-%20Review%202008-09.pdf

Borrello S, Brambilla G, Candela L, Diletti G, Gallo P, Iacovella G, Iovane G, Limone A, Migliorati G, Pinto O, Sarnelli P, Serpe L, Scortichini G, and Di Domenico A. (2008) Management of the 2008 "Buffalo Milk Crisis" in the Campania Region under the Perspective of Consumer Protection. Organohalogen Compounds Vol.70 p. 891-893.
Buckley J and Larkin H. (1998) Health surveillance of cattle in the vicinity of a chemical industrial complex. Veterinary Record Vol.143 p. 323-326.
Buckley-Golder D. (1999) Compilation of EU Dioxin Exposure and Health Data. Summary Report. Report produced for European Commission DG Environment UK Department of the Environment Transport and the Regions (DETR).
Bumb RR, Crummet WB, Cutie SS, Gledhil JR, Hummel RH, Kagel RO, Lamparski LL, Luoma EV, Miller DL, Nestrick TJ, Shadoff LA, Stehl RH, and Woods JS. (1980) Trace chemistries of fire: A source of chlorinated dioxins. Science Vol.210 p. 385-389.
Carlson DB and Perdew GH. (2002) A dynamic role for the Ah receptor in cell signaling? Insights from a diverse group of Ah receptor interacting proteins. J Biochem. Mol Toxicol. Vol.16 /6 p. 317-325.
Carvalhaes G, Brooks P, and Krauss T. (1999) Lime as the source of PCDD/F contamination in citrus pulp pellets from Brazil. Organohalogen Compounds Vol.41
Casey DK, Lawless JS, and Wall PG. (2010) A tale of two crises: the Belgian and Irish dioxin contamination incidents. British Food Journal Vol.112 p. 1077-1091.
Cederberg T. (2004) Levels of dioxins and PCB in Danish food and human milk – assessment of dietary intake. Poster Presentation. Presented at the Dioxin2004 symposium, September 6-10, 2004 Available at: http://www.food.dtu.dk/Admin/Public/DWSDownload.aspx?File=Files%2FFiler%2FProjektbeskrivelser%2FPOPs+in+human+milk%2FPOPs_in_human_milk_Dioxin2004poster.pdf
Cederberg T, Sorensen S, Lund KH, and Friis-Wandall S. (2010) Danish monitoring of dioxins and PCB in food and feed during the years 2000 to 2009 - Levels, time trend and human exposure. Organohalogen Compounds Vol.72 p. 952-955.
Chan W. (1995) Meat Poultry and Game: Fifth Supplement to the Fifth Edition of McCance and Widdowson's The Composition of Foods. Royal Society of Chemistry and Ministry of Agriculture, Fisheries and Food. Available at: http://books.google.ie/books?id=MrAzN1YdGtkC
Chan W. (1996) Meat Products and Dishes: Sixth Supplement to the Fifth Edition of McCance and Widdowson's The Composition of Foods. Royal Society of Chemistry and Ministry of Agriculture, Fisheries and Food. Available at: http://books.google.ie/books?id=KKTr6tW-MUkC
Chan W, Brown J, and Buss DH. (1994) Miscellaneous Foods: Fourth Supplement to the Fifth Edition of McCance and Widdowson's The Composition of Foods. /v. 4 Royal Society of Chemistry and Ministry of Agriculture, Fisheries and Food. Available at: http://books.google.ie/books?id=xh98QgAACAAJ
Cleverly D, Ferrario J, Byrne C, Riggs K, Joseph D, and Hartford P. (2007) A general indication of the Contemporary background levels of PCDDs, PCDFs, and coplanar PCBs in the ambient air over rural and remote areas of the United States. Environ Sci Technol. Vol.41 /5 p. 1537-1544.
Creme Software Ltd. (2006) Creme 2 Software.
Creme Software Ltd. (2013a) Creme Food Version 3.6.9. Available at: http://www.cremefood.com/food/home/
Creme Software Ltd. (2013b) Creme User Manual for Creme Food® 3.6.12.
CRL. (2009) Analytical capacities of National Reference Laboratories (NRLs) and Official Laboratories (OFLs) in case of dioxin incidents in the feed and food chain and conclusions for management in crisis situations. CRL for Dioxins and PCBs in Feed and Food. http://ec. europa. eu/food/food/chemicalsafety/contaminants/emergency_analyses_en. pdf State Institute for Chemical and Veterinary Analysis of Food, Freiburg, Germany.
CSO. (2012) Meat Supply Balance by Type of Meat, Year and Statistic. Available at: http://www.cso.ie/px/pxeirestat/Database/eirestat/Supply%20Balances/Supply%20Balances_statbank.asp?SP=Supply%20Balances&Planguage=0 (Accessed 2012)
CSO. (2013) Meat Supply Balance by Type of Meat, Year and Statistic. Available at: http://www.cso.ie/px/pxeirestat/Database/eirestat/Supply%20Balances/Supply%20Balances_statbank.asp?SP=Supply%20Balances&Planguage=0 (Accessed 2012)
DAFM. (2008) AIM 2008 Bovine Statistics Report. Issued by NBAS Division, Backweston Campus. Available at: http://www.agriculture.gov.ie/media/migration/animalhealthwelfare/animalidentificationandmovement/cattlemovementmonitoringsystem/AIM%20Bovine%20Statistics%20Report%202008%20Ver1.pdf
DAFM. (2011) Personal Communication.

DAFM. (2012) Cattle Movement Data 2008. Unpublished Data.
DAFM. (2013) Personal Communication.
Darnerud PO, Atuma S, Aune M, Bjerselius R, Glynn A, Grawe KP, and Becker W. (2006) Dietary intake estimations of organohalogen contaminants (dioxins, PCB, PBDE and chlorinated pesticides, e.g. DDT) based on Swedish market basket data. Food. Chem. Toxicol. Vol.44 /9 p. 1597-1606.
De Mul A, Bakker MI, Zeilmaker MJ, Traag WA, Leeuwen SP, Hoogenboom RL, Boon PE, and Klaveren JD. (2008) Dietary exposure to dioxins and dioxin-like PCBs in The Netherlands anno 2004. Regul. Toxicol. Pharmacol. Vol.51 /3 p. 278-287.
DeVito MJ, Birnbaum LS, Farland WH, and Gasiewicz TA. (1995) Comparisons of estimated human body burdens of dioxinlike chemicals and TCDD body burdens in experimentally exposed animals. Environ Health Perspect. Vol.103 /9 p. 820-831.
Diletti G, Ceci R, De Massis MR, Scortichini G, and Migliorati G. (2005) A case of eggs contamination by PCDD/Fs in Italy: analytical levels and contamination source identification. Organohalogen Compounds Vol.67
Eadon G and Kaminsky L. (1986) Calculation of 2,3,7,8-TCDD equivalent concentrations of complex environmental contaminant mixtures. Environ Health Perspect. Vol.70 p. 221-227.
EC. (1996) Council Directive 96/23/EC of 29 April 1996 on measures to monitor certain substances and residues thereof in live animals and animal products. Official Journal of the European Communities Vol.L125 p. 10-32. Available at: http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=OJ:L:1996:125:0010:0032:EN:PDF
EC. (2000a) Assessment of dietary intake of dioxins and related PCBs by the population of EU Member States. Vol.Task 3.2.5 European Commission. Available at: http://ec.europa.eu/dgs/health_consumer/library/pub/pub08_en.pdf
EC. (2000b) Communication from the Commission on the precautionary principle. COM(2000) 1 final. http://eur-lex. europa. eu/LexUriServ/LexUriServ. do?uri=COM:2000:0001:FIN:EN:PDF European Commission. Available at: http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=COM:2000:0001:FIN:EN:PDF
EC. (2001a) Community Strategy for Dioxins, Furans and Polychlorinated Biphenyls. Vol.COM(2001) 593 final Available at: http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=COM:2001:0593:FIN:EN:PDF
EC. (2001b) Council Directive 2001/102/EC of 27 November 2001 amending Directive 1999/29/EC on the undesirable substances and products in animal nutrition. Official Journal of the European Communities Vol.L6 Available at: http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=OJ:L:2002:006:0045:0049:EN:PDF
EC. (2001c) Council Regulation (EC) No 2375/2001 of 29 November 2001 amending Commission Regulation (EC) No 466/2001 setting maximum levels for certain contaminants in foodstuffs. Official Journal of the European Communities Vol.L321 Available at: http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=OJ:L:2001:321:0001:0005:EN:PDF
EC. (2002a) Commission Directive 2002/69/EC of 26 July 2002 laying down the sampling methods and the methods of analysis for the official control of dioxins and the determination of dioxin-like PCBs in foodstuffs. Official Journal of the European Communities Vol.209 /L5 Available at: http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=OJ:L:2002:209:0005:0014:EN:PDF
EC. (2002b) Commission Recommendation of 4 March 2002 on the reduction of the presence of dioxins, furans and PCBs in feedingstuffs and foodstuffs. Official Journal of the European Communities Vol.L67 Available at: http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=OJ:L:2002:067:0069:0073:EN:PDF
EC. (2002c) Directive 2002/32/EC of the European Parliament and of the Council of 7 May 2002 on undesirable substances in animal feed. Official Journal of the European Communities Vol.L140 Available at: http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=OJ:L:2002:140:0010:0021:EN:PDF
EC. (2003) The future of risk assessment in the European Union. Scientific Steering Committee. The second report on the harmonisation of risk assessment procedures. Available at: http://ec.europa.eu/food/fs/sc/ssc/out361_en.pdf
EC. (2004a) 2004/704/EC:Commission Recommendation of 11 October 2004 on the monitoring of background levels of dioxins and dioxin-like PCBs in feedingstuffs. Official Journal of the European Communities Vol.L321 /38 Available at: http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=OJ:L:2004:321:0038:0044:EN:PDF

EC. (2004b) 2004/705/EC: Commission Recommendation of 11 October 2004 on the monitoring of background levels of dioxins and dioxin-like PCBs in foodstuffs. Official Journal of the European Communities Vol.321 /L45 Available at: http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=OJ:L:2004:321:0045:0052:EN:PDF

EC. (2004c) Commission Directive 2004/44/EC of 13 April 2004 amending Directive 2002/69/EC laying down the sampling methods and the methods of analysis for the official control of dioxins and the determination of dioxin-like PCBs in foodstuffs. Official Journal of the European Communities Vol.L113 /17 Available at: http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=OJ:L:2004:113:0017:0018:EN:PDF

EC. (2004d) Regulation (EC) No 850/2004 of the European Parliament and of the Council of 29 April 2004 on persistent organic pollutants and amending Directive 79/117/EEC. Official Journal of the European Communities Vol.158 /L7 Available at: http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=OJ:L:2004:158:0007:0049:EN:PDF

EC. (2006a) Commission Recommendation of 16 November 2006 on the monitoring of background levels of dioxins, dioxin-like PCBs and non-dioxin-like PCBs in foodstuffs. Official Journal of the European Communities Vol.L322 Available at: http://eur-lex.europa.eu/LexUriServ/site/en/oj/2006/l_322/l_32220061122en00240031.pdf

EC. (2006b) Commission Recommendation of 6 February 2006 on the reduction of the presence of dioxins, furans and PCBs in feedingstuffs and foodstuffs. Official Journal of the European Communities Vol.L42 Available at: http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=OJ:L:2006:042:0026:0028:EN:PDF

EC. (2006c) Commission Regulation (EC) No 1881/2006 of 19 December 2006 setting maximum levels for certain contaminants in foodstuffs. Official Journal of the European Communities Vol.L364 Available at: http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=OJ:L:2006:364:0005:0024:EN:PDF

EC. (2006e) Commission Regulation (EC) No 1883/2006 of 19 December 2006 laying down methods of sampling and analysis for the official control of levels of dioxins and dioxin-like PCBs in certain foodstuffs. Official Journal of the European Communities Vol.L364 /20.12.2006 p. 32-43. Available at: http://eur-lex.europa.eu/LexUriServ/site/en/oj/2006/l_364/l_36420061220en00320043.pdf

EC. (2006d) Commission Regulation (EC) No 1883/2006 of 19 December 2006 laying down methods of sampling and analysis for the official control of levels of dioxins and dioxin-like PCBs in certain foodstuffs. Official Journal of the European Communities Vol.L364 /20.12.2006 p. 32-43. Available at: http://eur-lex.europa.eu/LexUriServ/site/en/oj/2006/l_364/l_36420061220en00320043.pdf

EC. (2006f) Commission Regulation (EC) No 199/2006 of 3 February 2006 amending Regulation (EC) No 466/2001 setting maximum levels for certain contaminants in foodstuffs as regards dioxins and dioxin-like PCBs. Official Journal of the European Communities Vol.L32 Available at: http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=OJ:L:2006:032:0034:0038:EN:PDF

EC. (2006g) Directive 2006/113/EC of the European Parliament and of the Council of 12 December 2006 on the quality required of shellfish waters. Official Journal of the European Communities Vol.L 376 /L14 Available at: http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=OJ:L:2006:376:0014:0020:EN:PDF

EC. (2011) Commission Recommendation of 23 August 2011 on the reduction of the presence of dioxins, furans and PCBs in feed and food. Official Journal of the European Communities Vol.L218 Available at: http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=OJ:L:2011:218:0023:0025:EN:PDF

EC. (2012) Commission Regulation 252/2012 of 21 March 2012 laying down methods of sampling and analysis for the official control of levels of dioxins, dioxin- like PCBs and non-dioxin-like PCBs in certain foodstuffs and repealing Regulation (EC) No 1883/2006. Official Journal of the European Communities Vol.L84 /23.3.2012 p. 1-22.

EC. (2013) 2013/711/EU: Commission Recommendation of 3 December 2013 on the reduction of the presence of dioxins, furans and PCBs in feed and food. Official Journal of the European Communities Vol.323 /04/12/2013 p. 37-39. Available at: http://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:32013H0711&qid=1396016870089&from=EN

EFSA. (2005) Opinion of the Scientific Panel on Contaminants in the food chain on a request from the Commission related to the presence of non dioxin-like polychlorinated biphenyls (PCB) in feed and food. The EFSA Journal Vol.284 p. 1-137. European Food Safety Authority. Available at: http://www.efsa.europa.eu/en/efsajournal/doc/284.pdf

EFSA. (2006) Guidance of the Scientific Committee on a request from EFSA related to Uncertainties in Dietary Exposure Assessment. EFSA Journal Vol.438 p. 1-54.

EFSA. (2008) Statement of EFSA on the risks for public health due to the presence of dioxins in pork from Ireland. European Food Safety Authority. Available at: http://www.efsa.europa.eu/en/efsajournal/pub/911.htm

EFSA. (2009) Transparency in Risk Assessment - Scientific Aspects Guidance of the Scientific Committee on Transparency in the Scientific Aspects of Risk Assessments carried out by EFSA. Part 2: General Principles1. EFSA Journal Vol.1051 p. 1-22.

EFSA. (2010a) Management of left-censored data in dietary exposure assessment of chemical substances. EFSA Journal 2010; 8(3):1557 Available at: http://www.efsa.europa.eu/en/efsajournal/pub/1557.htm

EFSA. (2010b) Results of the monitoring of dioxin levels in food and feed. EFSA Journal Vol.8 /3 p. 1385-European Food Safety Authority. Available at: http://www.efsa.europa.eu/en/efsajournal/doc/1385.pdf

EFSA. (2011a) Guidance of EFSA: Use of the EFSA Comprehensive European Food Consumption Database in Exposure Assessment. EFSA Journal 2011;9(3):2097

EFSA. (2011b) Overview of the procedures currently used at EFSA for the assessment of dietary exposure to different chemical substances. EFSA Journal 2011;9(12):2490

EFSA. (2012) Update of the monitoring of dioxins and PCBs levels in food and feed. EFSA Journal Vol.10 /7 p. 2832-European Food Safety Authority.

Eitzer BD and Hites RA. (1991) Vapor pressures of chlorinated dioxins and dibenzofurans. The Science of The Total Environment Vol.104 /1-2 p. 9-15. Available at: http://www.sciencedirect.com/science/article/pii/004896979190004X

Emond C, Michalek JE, Birnbaum LS, and DeVito MJ. (2005) Comparison of the use of a physiologically based pharmacokinetic model and a classical pharmacokinetic model for dioxin exposure assessments. Environmental health perspectives Vol.113 /12 p. 1666-1668. Available at: http://europepmc.org/abstract/MED/16330344

Engwall M, Broman D, Dencker L, N+ñf C, Zeb++hr Y, and Brunstr+Âm B. (1997) Toxic potencies of extracts of sediment and settling particulate matter collected in the recipient of a bleached pulp mill effluent before and after abandoning chlorine bleaching. Environmental Toxicology and Chemistry Vol.16 /6 p. 1187-1194. Wiley Periodicals, Inc. Available at: http://dx.doi.org/10.1002/etc.5620160613

EPA. (1994) Method 1613 Tetra- through Octa-Chlorinated Dioxins and Furans by Isotope Dilution HRGC/HRMS. U.S. Environmental Protection Agency Office of Water Engineering and Analysis Division (4303).

EPA. (2000) Dioxin Levels in the Irish Environment 2000. Environmental Protection Agency Ireland.

EPA. (2004) Dioxin Levels in the Irish Environment 2004. Environmental Protection Agency Ireland. Available at: http://www.epa.ie/downloads/pubs/other/dioxinresults/

EPA. (2006) Dioxin Levels in the Irish Environment 2006. Environmental Protection Agency Ireland. Available at: http://www.epa.ie/downloads/pubs/other/dioxinresults/

EPA. (2007) Dioxin Levels in the Irish Environment 2007. Environmental Protection Agency Ireland. Available at: http://www.epa.ie/downloads/pubs/other/dioxinresults/

EPA. (2008) Dioxin Levels in the Irish Environment 2008. Environmental Protection Agency Ireland. Available at: http://www.epa.ie/downloads/pubs/other/dioxinresults/

EPA. (2009) Dioxin Levels in the Irish Environment 2009. Environmental Protection Agency Ireland. Available at: http://www.epa.ie/downloads/pubs/other/dioxinresults/

EPA. (2012) National Implementation Plan on Persistent Organic Pollutants. Environmental Protection Agency, Ireland.

Erickson MD. (2001) Introduction: PCB Properties, Uses, occurrence, and Regulatory History. p. xi-xxx. University Press of Kentucky.

Esposito M, Serpe FP, Neugebauer F, Cavallo S, Gallo P, Colarusso G, Baldi L, Iovane G, and Serpe L. (2010) Contamination levels and congener distribution of PCDDs, PCDFs and dioxin-like PCBs in buffalo's milk from Caserta province (Italy). Chemosphere Vol.79 /3 p. 341-348. Available at: http://www.sciencedirect.com/science/article/pii/S0045653510000512

Faqi AS, Dalsenter PR, Merker HJ, and Chahoud I. (1998) Reproductive toxicity and tissue concentrations of low doses of 2,3,7,8-tetrachlorodibenzo-p-dioxin in male offspring rats exposed throughout pregnancy and lactation. Toxicol. Appl Pharmacol. Vol.150 /2 p. 383-392.

Fattore E, Fanelli R, Turrini A, and di DA. (2006) Current dietary exposure to polychlorodibenzo-p-dioxins, polychlorodibenzofurans, and dioxin-like polychlorobiphenyls in Italy. Mol Nutr Food. Res. Vol.50 /10 p. 915-921.

Fernandes A, Gallani B, Gem M, White S, and Rose M. (2004) Trends in the dioxin and PCB content of the UK diet. Organohalogen Compounds Vol.66 p. 2027-2034.

Fiedler H. (2007) National PCDD/PCDF release inventories under the Stockholm Convention on Persistent Organic Pollutants. Chemosphere. Vol.67 /9 p. S96-108.
Fries GF. (1995) Transport of organic environmental contaminants to animal products. Rev Environ Contam. Toxicol. Vol.141:71-109. p. 71-109.
Fries GF, Paustenbach DJ, Mather DB, and Luksemburg WJ. (1999) A Congener Specific Evaluation of Transfer of Chlorinated Dibenzo-p-dioxins and Dibenzofurans to Milk of Cows following Ingestion of Pentachlorophenol-Treated Wood. Environmental Science & Technology Vol.33 /8 p. 1165-1170. American Chemical Society. Available at: http://dx.doi.org/10.1021/es981153d
Fromme H, Shahin N, Boehmer S, Albrecht M, Parlar H, Liebl B, Mayer R, Bolte G. (2009) Dietary intake of non-dioxin-like polychlorinated biphenyls (PCB) in Bavaria, Germany. Results from the Integrated Exposure Assessment Survey (INES). Gesundheitswesen. 2009 May;71(5):275-80. doi: 10.1055/s-0028-1104600
FSAI. (2001) Investigation on PCDDs/PCDFs and several PCBs in milk samples. Food Safety Authority of Ireland. Available at: http://www.fsai.ie/uploadedFiles/Monitoring_and_Enforcement/Monitoring/Surveillance/Dioxins_milk_survey.pdf
FSAI. (2002a) Investigation on PCDDs/PCDFs and several PCBs in Fish liver oil capsules. Food Safety Authority of Ireland. Available at: http://www.fsai.ie/WorkArea/DownloadAsset.aspx?id=8234
FSAI. (2002b) Investigation on PCDDs/PCDFs and several PCBs in Fish Samples (Salmon and Trout). Food Safety Authority of Ireland. Available at: http://www.fsai.ie/WorkArea/DownloadAsset.aspx?id=8236
FSAI. (2004) Investigation into the Levels of Dioxins, Furans, PCBs and some Elements in Battery, Free-Range, Barn and Organic Eggs. Food Safety Authority of Ireland. Available at: http://www.fsai.ie/WorkArea/DownloadAsset.aspx?id=8260
FSAI. (2005a) Investigation into Levels of Dioxins, Furans, PCBs and PBDEs in Food Supplements, Offal and Milk. Food Safety Authority of Ireland. Available at: http://www.fsai.ie/WorkArea/DownloadAsset.aspx?id=8280
FSAI. (2005b) Investigation into levels of dioxins, furans, PCBs and PBDEs in Irish food. Food Safety Authority of Ireland. Available at: http://www.fsai.ie/WorkArea/DownloadAsset.aspx?id=1228
FSAI. (2007) Guidance Note 10: Product Recall and Traceability. Food Safety Authority of Ireland. Available at: www.fsai.ie/gn10productrecallandtraceabilityrevision2.html
FSAI. (2010a) Investigation into levels of chlorinated and brominated organic pollutants in carcass fat, offal, eggs and milk produced in Ireland. Monitoring & Surveillance Series Food Safety Authority of Ireland. Available at: http://www.fsai.ie/WorkArea/DownloadAsset.aspx?id=9456
FSAI. (2010b) Investigation into Levels of Perfluoroalkylated Substances (PFAs) in Meat, Offal, Eggs,Fish and Milk Producted in Ireland. Food Safety Authority of Ireland. Available at: http://www.fsai.ie/WorkArea/DownloadAsset.aspx?id=10134
FSAI. (2010c) Investigation into Levels of Polychlorinated Naphthalenes (PCNs) in Carcass Fat, Offal, Fish, Eggs, Milk and Processed Products. Food Safety Authority of Ireland. Available at: http://www.fsai.ie/WorkArea/DownloadAsset.aspx?id=10133
FSAI. (2013) Local Authority Abattoir 2008 Slaughter Statistics. Unpublished Data.
Fürst P, Beck H, and Theelen R. (1992) Assessment of human intake of PCDDs and PCDFs from different environmental sources. Toxic Substances Journal Vol.12 p. 133-150.
Furst P. (2006) Dioxins, polychlorinated biphenyls and other organohalogen compounds in human milk. Levels, correlations, trends and exposure through breastfeeding. Mol Nutr Food Res. Vol.50 /10 p. 922-933.
Gehrs BC, Riddle MM, Williams WC, and Smialowicz RJ. (1997) Alterations in the developing immune system of the F344 rat after perinatal exposure to 2,3,7,8-tetrachlorodibenzo-p-dioxin: II. Effects on the pup and the adult. Toxicology. Vol.%19;122 /3 p. 229-240.
Gehrs BC and Smialowicz RJ. (1999) Persistent suppression of delayed-type hypersensitivity in adult F344 rats after perinatal exposure to 2,3,7,8-tetrachlorodibenzo-p-dioxin. Toxicology. Vol.134 /1 p. 79-88.
Geyer HJ, Schramm KW, Feicht EA, Behechti A, Steinberg C, Bruggemann R, Poiger H, Henkelmann B, and Kettrup A. (2002) Half-lives of tetra-, penta-, hexa-, hepta-, and octachlorodibenzo-p-dioxin in rats, monkeys, and humans--a critical review. Chemosphere. Vol.48 /6 p. 631-644.
Gilman A, Newhook R, and Birmingham B. (1991) An updated assessment of the exposure of Canadians to dioxins and furans. Chemosphere Vol.23 /11-12 p. 1661-1667. Available at: http://www.sciencedirect.com/science/article/pii/0045653591900145

Gray LE, Ostby JS, and Kelce WR. (1997a) A dose-response analysis of the reproductive effects of a single gestational dose of 2,3,7,8-tetrachlorodibenzo-p-dioxin in male Long Evans Hooded rat offspring. Toxicol. Appl Pharmacol. Vol.146 /1 p. 11-20.
Gray LE, Wolf C, Mann P, and Ostby JS. (1997b) In utero exposure to low doses of 2,3,7,8-tetrachlorodibenzo-p-dioxin alters reproductive development of female Long Evans hooded rat offspring. Toxicol. Appl Pharmacol. Vol.146 /2 p. 237-244.
Harper PA, Wong JY, Lam MS, and Okey AB. (2002) Polymorphisms in the human AH receptor. Chem. Biol. Interact. Vol.141 p. 161-187.
Harrad S, Wang Y., Sandaradura S., and Leeds A. (2003) Human dietary intake and excretion of dioxin-like conpounds. J Environ Monit. Vol.5 p. 224-228.
Haws LC, Su SH, Harris M, DeVito MJ, Walker NJ, Farland WH, Finley B, and Birnbaum LS. (2006) Development of a Refined Database of Mammalian Relative Potency Estimates for Dioxin-like Compounds. Toxicological Sciences Vol.89 /1 p. 4-30. Available at: http://toxsci.oxfordjournals.org/content/89/1/4.abstract
Hays SM and Aylward LL. (2003) Dioxin risks in perspective: past, present, and future. Regulatory Toxicology and Pharmacology Vol.37 /2 p. 202-217. Available at: http://www.sciencedirect.com/science/article/pii/S0273230002000442
Heres L, Hoogenboom LAP, Herbes R, Traag WA, and Urlings B. (2010) Tracing and analytical results of the dioxin contamination incident in 2008 originating from the Republic of Ireland. Food Additives & Contaminants: Part A: Chemistry, Analysis, Control, Exposure & Risk Assessment Vol.27 /12 p. 1733-1744.
Hites RA. (2011) Dioxins: an overview and history. Environ Sci Technol. Vol.45 /1 p. 16-20.
Holland B, Unwin ID, and Buss DH. (1992a) Fruits and Nuts: First Supplement to the Fifth Edition of McCance and Widdowson's the Composition of Foods. Royal Society of Chemistry and Ministry of Agriculture, Fisheries and Food. Available at: http://books.google.ie/books?id=dMlV8Fr4NRgC
Holland B, Unwin ID, McCance RA, and Buss DH. (1989) Milk products and eggs: fourth supplement to McCance and Widdowson's The composition of foods. Royal Society of Chemistry. Available at: http://books.google.ie/books?id=6ewfAQAAIAAJ
Holland B, Welch AA, and Buss DH. (1992b) Vegetable Dishes: Second Supplement to the Fifth Edition of McCance and Widdowson's The Composition of Foods. /v. 2 Royal Society of Chemistry. Available at: http://books.google.ie/books?id=P3hRMgEACAAJ
Holland B, Widdowson EM, Unwin ID, and Buss DH. (1991) Vegetables, Herbs Ans Spices: Fifth Supplement [to the Fourth Edition Of] to McCance and Widdowson's The Composition of Foods. Royal Society of Chemistry and Ministry of Agriculture, Fisheries and Food. Available at: http://books.google.ie/books?id=-M1khtZ31BwC
Hoogenboom LAP, Kan CA, Bovee TFH, van der Weg G, Onstenk C, and Traag WA. (2004) Residues of dioxins and PCBs in fat of growing pigs and broilers fed contaminated feed. Chemosphere Vol.57 /1 p. 35-42. Available at: http://www.sciencedirect.com/science/article/B6V74-4CTCSX9-5/2/3093d44f5f73d7795afcaac736623b57
Hoogenboom LAP and Traag WA. (2003) The German bakery waste incident. Organohalogen Compounds Vol.64 p. 13-16.
Hoogenboom LAP, Van Eijkeren J, Zeilmaker MJ, Mengelers MB, Herbes R, and Traag WA. (2006) A novel source for dioxins present in waste fat from gelatine production. Organohalogen Compounds Vol.68
Hoogenboom LAP, Zeilmaker MJ, Kan KA, Mengelers MB, Van Eijkeren J, and Traag WA. (2005) Kaolinic clay derived dioxins in potato by-products. Organohalogen Compounds Vol.67
Hoogerbrugge R, Bakker MI, Hijman WC, Den Boer AC, Den Hartog RS, and Baumann RA. (2004) Dioxins in Dutch Vegetables. Vol.RIVM report 310305003 RIVM. Available at: http://rivm.openrepository.com/rivm/bitstream/10029/8878/1/310305003.pdf?origin=publication_detail
House of the Oireachtas. (2009) Joint Committee on Agriculture, Fisheries and Food First Report Report on the contamination of Irish pork products. Vol.PRN No. A9/0686
Hutzinger O, Choudhry G.G., Chittim B.G., and Johnston LE. (1985) Formation of Polychiorinated Dibenzofurans and Dioxins during Combustion, Electrical Equipment Fires and PCB Incineration. Environ Health Perspect. Vol.60 p. 3-9.
IARC. (1997) Polychlorinated dibenzo-p-dioxins and polychlorinated dibenzofurans. Vol.69 p. 1-343. International Agency for Research into Cancer, Lyon.

IARC. (1999) IARC Monographs on the Evaluation of Carcinogenic Risks to Humans Overall Evaluations of Carcinogenicity: An Updating of IARC Monographs Volumes 1 to 42. IARC Monographs Vol.Supplement 7 Available at: http://monographs.iarc.fr/ENG/Monographs/suppl7/suppl7.pdf

IUNA. (1999) INFID Version 1 (1995-1999).

IUNA. (2001) North/South Ireland Food Consumption Survey. Irish Universities Nutrition Alliance Available at: http://www.iuna.net/?p=25

IUNA. (2006) INFID Version 2 (2003-2006) (National Children's Food Survey and National Teen's Food Survey).

IUNA. (2010) INFID Version 3 (2008-2010) (National Adults Nutrition Survey).

IUNA. (2011) The National Adult Nutrition Survey. Irish Universities Nutrition Alliance Available at: http://www.iuna.net/?p=106

IUNA. (2012) INFID Version 4 (2011-2012) (National Pre-school Nutrition Survey).

Jacob CJ, Lok C, Morley K, and Powell DA. (2010) Government management of two media-facilitated crises involving dioxin contamination of food. Public Understanding of Science Available at: http://pus.sagepub.com/content/early/2010/02/05/0963662509355737.abstract

JECFA. (2002) Safety evaluation of certain food additives and contaminants polychlorinated dibenzodioxins, polychlorinated dibenzofurans, and coplanar polychlorinated biphenyls. Vol.48 Available at: http://www.inchem.org/documents/jecfa/jecmono/v48je20.htm

Kim MK, Choi SW, Park JY, Kim DG, Bong YH, Jang JH, Song SO, Chung GS, and Guerrero P. (2009) Dioxin contamination of Chilean pork from zinc oxide in feed. Organohalogen Compounds Vol.71

Kiviranta H, Ovaskainen ML, and Vartiainen T. (2004) Market basket study on dietary intake of PCDD/Fs, PCBs, and PBDEs in Finland. Environ Int. Vol.30 /7 p. 923-932.

Kogevinas M. (2001) Human health effects of dioxins: cancer, reproductive and endocrine system effects. Hum. Reprod. Update. Vol.7 /3 p. 331-339.

Kreuzer PE, Csanídy GA, Baur C, Kessler W, Papke O, Greim H, and Filser JG. (1997) 2,3,7,8-Tetrachlorodibenzo-para-dioxin (TCDD) and congeners in infants. A toxicokinetic model of human lifetime body burden by TCDD with special emphasis on its uptake by nutrition. Archives of Toxicology Vol.71 /6 p. 383-400. Springer Berlin / Heidelberg. Available at: http://dx.doi.org/10.1007/s002040050402

Kroes R, Mueller D, Lambe J, Loewik MRH, van Klaveren J, Kleiner J, Massey R, Mayer S, Urieta I, Verger P, and Visconti A. (2002) Assessment of intake from the diet. Food and Chemical Toxicology Vol.40 /2GÇô3 p. 327-385. Available at: http://www.sciencedirect.com/science/article/pii/S0278691501001132

Kvalem HE, Knutsen HK, Thomsen C, Haugen M, Stigum H, Brantsaeter AL, Froshaug M, Lohmann N, Papke O, Becher G, Alexander J, and Meltzer HM. (2009) Role of dietary patterns for dioxin and PCB exposure. Mol Nutr Food. Res. Vol.53 /11 p. 1438-1451.

La Rocca C and Mantovani A. (2006) From environment to food: the case of PCB. Ann Ist Super Sanita Vol.42 /4 p. 410-416.

Liem AK, Furst P, and Rappe C. (2000) Exposure of populations to dioxins and related compounds. Food Addit. Contam. Vol.17 /4 p. 241-259.

Llerena JJ, Abad E, Caixach J, and Rivera J. (2001) A new episode of PCDDs/PCDFs feed contamination in Europe: The choline chloride. Organohalogen Compounds Vol.51

Llobet JM, Marti-Cid R, Castell V, and Domingo JL. (2008a) Significant decreasing trend in human dietary exposure to PCDD/PCDFs and PCBs in Catalonia, Spain. Toxicol. Lett. Vol.178 /2 p. 117-126.

Llobet JM, Marti-Cid R, Perello G, and Domingo JL. (2008b) Human dietary exposure to PCDD/PCDFs and PCBs in Catalonia, Spain. Organohalogen Compounds Vol.70 p. 1534-1537.

Mably TA, Bjerke DL, Moore RW, Gendron-Fitzpatrick A, and Peterson RE. (1992) In utero and lactational exposure of male rats to 2,3,7,8-tetrachlorodibenzo-p-dioxin. 3. Effects on spermatogenesis and reproductive capability. Toxicol. Appl Pharmacol. Vol.114 /1 p. 118-126.

Malisch R, Kypke K, van Leeuwen FX, Moy G, and Park S. (2008) Evaluation of WHO-coordinated exposure studies on levels of persistent organic pollutants (POPs) in human milk wiht regard to the global monitoring plan. Organohalogen Compounds Vol.70 p. 228-232.

Malisch R and Van Leeuwen FXR. (2003) Results of the WHO-coordinated exposure study on the levels of PCBs, PCDDs and PCDFs in human milk. Organohalogen Compounds Vol.64 p. 140-143.

Malisch R. (2000) Increase of the PCDD/F-contamination of milk, butter and meat samples by use of contaminated citrus pulp. Chemosphere Vol.40 /9-11 p. 1041-1053. Available at: http://www.sciencedirect.com/science/article/B6V74-3YGDCT1-P/2/449f2ce58b3f4e517612fe9d8fdfbe63

Marchand P, Cariou R, Venisseau A, Brosseaud A, Antignac JP, and Le Bizec B. (2010) Predicting PCDD/F and dioxin-like PCB contamination levels in bovine edible tissues from in vivo sampling. Chemosphere Vol.80 /6 p. 634-640. Available at: http://www.sciencedirect.com/science/article/pii/S0045653510005059

Marin S, Villalba P, Diaz-Ferrero J, Font G, and Yusa V. (2011) Congener profile, occurrence and estimated dietary intake of dioxins and dioxin-like PCBs in foods marketed in the Region of Valencia (Spain). Chemosphere. Vol.82 /9 p. 1253-1261.

Marnane I. (2012) Comprehensive environmental review following the pork PCB/dioxin contamination incident in Ireland. J. Environ. Monit. Vol.14 /10 p. 2551-2556. The Royal Society of Chemistry. Available at: http://dx.doi.org/10.1039/C2EM30374D

McCance RA, Holland B, Widdowson EM, Unwin ID, and Buss DH. (1988) Cereals and Cereal Products: Third Supplement to McCance and Widdowson's The Composition of Foods. Royal Society of Chemistry. Available at: http://books.google.ie/books?id=GzO7cQAACAAJ

McCance RA and Widdowson EM. (2002) McCance and Widdowson's The Composition of Foods. Royal Society of Chemistry and the Food Standards Agency. Available at: http://books.google.ie/books?id=ALDkOIwZod8C

McGovern E, McHugh B, O'Hea L, Joyce E, Tlustos C, and Glynn D. (2011) Assuring Seafood Safety. Contaminants and Residues in Irish Seafood 2004-2008. Marine Institute, Rinville, Oranmore.

McLachlan MS, Thoma H, Reissinger M, and Hutzinger O. (1990) PCDD/F in an agricultural food chain Part 1: PCDD/F mass balance of a lactating cow. Chemosphere Vol.20 /7-9 p. 1013-1020. Available at: http://www.sciencedirect.com/science/article/B6V74-487FD5V-ND/2/550df648a786f578f44fdbd3fa7248c0

McNamara C, Naddy B, Rohan D, and Sexton J. (2003) Design, development and validation of software for modelling dietary exposure to food chemicals and nutrients. Food Addit Contam Part A Chem Anal Control Expo Risk Assess Vol.20 /sup001 p. S8-S26. Taylor & Francis. Available at: http://dx.doi.org/10.1080/0265203031000152460

Mocarelli P, Gerthoux PM, Patterson DG, Milani S, Limonta G, Bertona M, Signorini S, Tramacere P, Colombo L, Crespi C, Brambilla P, Sarto C, Carreri V, Sampson EJ, Turner WE, and Needham LL. (2008) Dioxin exposure, from infancy through puberty, produces endocrine disruption and affects human semen quality. Environ Health Perspect Vol.116 /1 p. 70-77. Available at: http://pubget.com/paper/18197302

NAS. (2006) Health risks from dioxin and related compounds: Evaluation of the EPA reassessment. National Academy Press. Available at: http://www.nap.edu/catalog.php?record_id=11688.

NATO/CMS. (1988) International Toxicity Equivalency Factor (I-TEF) Method of Risk Assessment for Complex Mixtures of Dioxins and Related Compounds. Pilot Study on International Information Exchange on Dioxins and Related Compounds. Vol.176 North Atlantic Treaty Organization, Committee on Challenges of Modern Society.

Nusser SM, Carriquiry A.L., Dodd KW, and Fuller WA. (1996) A Semiparametric Transformation Approach to Estimating Usual Daily Intake Distributions. Journal of the American Statistical Association Vol.91 /436 1440. American Statistical Association. Available at: http://www.jstor.org/stable/2291570

O'Donovan JV, O'Farrell KJ, O'Mahony P, and Buckley JF. (2011) Temporal trends in dioxin, furan and polychlorinated biphenyl concentrations in bovine milk from farms adjacent to industrial and chemical installations over a 15year period. Vet. J.

O'Keeffe M, Kennedy O, Farrell F, Nolan ML, Dooley M, Byrne P, Nugent A, Cantwell H, Horne E, and Nelson V. (2001) Food Residue Database. Teagasc.

Oeberg LG and Rappe C. (1992) Biochemical formation of PCDD/Fs from chlorophenols. Chemosphere Vol.25 /1-2 p. 49-52. Available at: http://www.sciencedirect.com/science/article/pii/0045653592904779

Ohsako S, Miyabara Y, Nishimura N, Kurosawa S, Sakaue M, Ishimura R, Sato M, Takeda K, Aoki Y, Sone H, Tohyama C, and Yonemoto J. (2001) Maternal exposure to a low dose of 2,3,7,8-tetrachlorodibenzo-p-dioxin (TCDD) suppressed the development of reproductive organs of male rats: dose-dependent increase of mRNA levels of 5alpha-reductase type 2 in contrast to decrease of androgen receptor in the pubertal ventral prostate. Toxicol. Sci. Vol.60 /1 p. 132-143.

Okey AB, Franc MA, Moffat ID, Tijet N, Boutros PC, Korkalainen M, Tuomisto J, and Pohjanvirta R. (2005) Toxicological implications of polymorphisms in receptors for xenobiotic chemicals: The case of the aryl hydrocarbon receptor. Toxicol. Appl. Pharmacol. Vol.207 p. 43-51.

Olie K, Vermeulen PL, and Hutzinger O. (1977) Chlorodibenzo-p-dioxins and chlorodibenzofurans are trace components of fly ash and flue gas of some municipal incinerators in the Netherlands. Chemosphere Vol.6 p. 455-459.
Paepke O. (1998) PCDD/F: human background data for Germany, a 10-year experience. Environ. Health Perspect Vol.106 /Suppl. 2 p. 723-731.
Perello G, Gomez-Catalan J, Castell V, Llobet JM, and Domingo JL. (2012) Assessment of the temporal trend of the dietary exposure to PCDD/Fs and PCBs in Catalonia, over Spain: health risks. Food Chem Toxicol Vol.50 /2 p. 399-408. Available at: http://europepmc.org/abstract/MED/21763388
Phillips DL, Pirkle JL, Burse VW, Bernert JT, Jr., Henderson LO, and Needham LL. (1989) Chlorinated hydrocarbon levels in human serum: effects of fasting and feeding. Arch Environ Contam. Toxicol. Vol.18 /4 p. 495-500.
Pratt IS, Anderson WA, Crowley D, Daly SF, Evans RI, Fernandes AR, Fitzgerald M, Geary MP, Keane DP, Malisch R, McBride J, Morrison JJ, Reilly A, and Tlustos C. (2012) Polychlorinated dibenzo-p-dioxins (PCDDs), polychlorinated dibenzofurans (PCDFs) and polychlorinated biphenyls (PCBs) in breast milk of first-time Irish mothers: Impact of the 2008 dioxin incident in Ireland. Chemosphere Vol.88 /7 p. 865-872. Available at: http://www.sciencedirect.com/science/article/pii/S0045653512004778
Rappe C, Kjeller LO, Kulp SE, de Wit C, Hasselsten I, and Palm O. (1991) Levels, profile and pattern of PCDDs and PCDFs in samples related to the production and use of chlorine. Chemosphere Vol.23 /11-12 p. 1629-1636. Available at: http://www.sciencedirect.com/science/article/pii/004565359190010B
Rier SE, Martin DC, Bowman RE, Dmowski WP, and Becker JL. (1993) Endometriosis in rhesus monkeys (Macaca mulatta) following chronic exposure to 2,3,7,8-tetrachlorodibenzo-p-dioxin. Fundam. Appl Toxicol. Vol.21 /4 p. 433-441.
Ryan JJ, Conacher HBS, Panopio LG, Lau BPY, Hardy JA, and Masuda Y. (1991) Gas chromatographic separations of all 136 tetra- to octapolychlorinated dibenzo-p-dioxins and polychlorinated dibenzofurans on nine different stationary phases. Journal of Chromatography A Vol.541 p. 131-183. Available at: http://www.sciencedirect.com/science/article/B6TG8-44TP5BC-4C/2/44e2d4be1607d9a920698ad194336261
Salgovicová D, Pavlovicová D (2007) Exposure of the population of the Slovak Republic to dietary polychlorinated biphenyls. Food Chem Toxicol. 2007 Sep;45(9):1641-9. Epub 2007 Feb 28
Sirot V, Tard A, Venisseau A, Brosseaud A, Marchand P, Le Bizec B, Leblanc JC (2012) Dietary exposure to polychlorinated dibenzo-p-dioxins, polychlorinated dibenzofurans and polychlorinated biphenyls of the French population: Results of the second French Total Diet Study.Chemosphere. 2012 Jul;88(4):492-500. doi: 10.1016/j.chemosphere.2012.03.004
SCF. (2000) Opinion of the SCF on the Risk Assessment of Dioxins and Dioxin-like PCBs in Food. European Commission. Available at: http://ec.europa.eu/food/fs/sc/scf/out78_en.pdf
SCF. (2001) Opinion on the risk assessment of dioxins and dioxins-like PCBs in food (update based on the new scientific information available since the adoption of the SCF opinion of 22 November 2000. European Commission. Available at: http://ec.europa.eu/food/fs/sc/scf/out90_en.pdf
Schantz SL and Bowman RE. (1989) Learning in monkeys exposed perinatally to 2,3,7,8-tetrachlorodibenzo-p-dioxin (TCDD). Neurotoxicol. Teratol. Vol.11 /1 p. 13-19.
Schecter A, Birnbaum LS, Ryan JJ, and Constable JD. (2006) Dioxins: An overview. Environmental Research Vol.101 /3 p. 419-428. Available at: http://www.sciencedirect.com/science/article/pii/S0013935105001921
Schecter A, Stanley J, Boggess K, Masuda Y, Mes J, Wolff M, Fürst P, Fürst C, Wilson-Yang K, and Chisholm B. (1994) Polychlorinated biphenyl levels in the tissues of exposed and nonexposed humans. Environ Health Perspect. Vol.102 /Suppl. 1 p. 149-158.
Schlummer M, Moser GA, and McLachlan MS. (1998) Digestive tract absorption of PCDD/Fs, PCBs, and HCB in humans: mass balances and mechanistic considerations. Toxicology and Applied Pharmacology Vol.152 /1 p. 128-137. Available at: http://europepmc.org/abstract/MED/9772208
Schmid P and Uthrich W. (2000) Dioxin contamination of kaolins (bolus alba): Monitoring of PCDDS and PCDFS in kaolin, feed and foodstuffs of animal origin. Organohalogen Compounds Vol.47
Schulz AJ, Wiesmueller T, Appuhn H, Stehr D, Severin K, Landmann D, and Kamphues J. (2005) Dioxin concentration in milk and tissues of cows and sheep related to feed and soil contamination. J Anim Physiol Anim Nutr (Berl) Vol.89 /3-6 p. 72-78. Available at: http://europepmc.org/abstract/MED/15787974
Shan L, Regan A, De Brun A, Barnett J, van der Sanden MCA, Wall P, and McConnon +. (2013) Food crisis coverage by social and traditional media: A case study of the 2008 Irish dioxin crisis. Public

Understanding of Science Available at: http://pus.sagepub.com/content/early/2013/01/30/0963662512472315.abstract
Shiu WY, Doucette W, Gobas FAPC, Andren A, and Mackay D. (1988) Physical-chemical properties of chlorinated dibenzo-p-dioxins. Environmental Science & Technology Vol.22 /6 p. 651-658. American Chemical Society. Available at: http://dx.doi.org/10.1021/es00171a006
Slobs W, Olling M, Derks HJGM, and de Jong APJM. (1995) Congener-specific bioavailability of PCDD/Fs and coplanar PCBs in cows: Laboratory and field measurements. Chemosphere Vol.31 /8 p. 3827-3838. Available at: http://www.sciencedirect.com/science/article/B6V74-404RMRG-2F/2/3483abc725216255f330385d42a601ff
Spitaler M, Iben C, and Tausch H. (2005) Dioxin residues in the edible tissue of finishing pigs after dioxin feeding. J Anim Physiol Anim Nutr (Berl) Vol.89 /3-6 p. 65-71. Available at: http://europepmc.org/abstract/MED/15787973
Srogi K. (2008) Levels and congener distributions of PCDDs, PCDFs and dioxin-like PCBs in environmental and human samples: a review. Environmental Chemistry Letters Vol.6 /1 p. 1-28. Springer Berlin / Heidelberg. Available at: http://dx.doi.org/10.1007/s10311-007-0105-2
Stone R. (2007) Epidemiology. Agent Orange's bitter harvest. Science. Vol.315 /5809 p. 176-179.
Tanabe S, Nakagawa Y, and Tatsukawa R. (1981) Absorption efficiency and biological half-life of individual chlorobiphenyls in rats treated with kanechlor products. Agric Biol Chem Vol.45 /3 p. 717-726. Available at: http://europepmc.org/abstract/AGR/IND81045315
Tard A, Gallotti S, Leblanc JC, and Volatier JL. (2007) Dioxins, furans and dioxin-like PCBs: occurrence in food and dietary intake in France. Food. Addit. Contam. Vol.24 /9 p. 1007-1017.
Thorpe S, Kelly M, Startin J, Harrison N, and Rose M. (2001) Concentration changes for 5 PCDD/F congeners after administration in beef cattle. Chemosphere. Vol.43 /4-7 p. 869-879.
Tlustos C. (2009a) The dioxin contamination incident in Ireland 2008. Organohalogen Compounds Vol.71 p. 1155-1159.
Tlustos C. (2009b) The dioxin crisis in Ireland 2008. Challenges in risk management and risk communication. Organohalogen Compounds Vol.71 p. 1152-1154.
Tlustos C, McHugh B, Pratt I, Tyrrell L, and McGovern E. (2007) Investigation into Levels of Dioxins, Furans, Polychlorinated Biphenyls and Brominated Flame Retardants in Fishery Products in Ireland. Vol.26
Tlustos C, Pratt I, Moylan R, Neilan R, White S, Fernandes AR, and Rose M. (2004) Investigation into levels of dioxins, furans and PCBs in battery, free range, barn and organic eggs. Organohalogen Compounds Vol.66 p. 1901-1907.
Tlustos C, Pratt I, White S, Fernandes AR, and Rose M. (2005) Investigation into levels of PCDD/Fs, PCBs and PBDEs in Irish produce. Organohalogen Compounds Vol.67 p. 1474-1477.
Tlustos C, Sheridan M, O'Sullivan D, Anderson W, and Flynn A. (2012) The dioxin contamination incident in Ireland, 2008: analytical results and congener patterns. Food Addit Contam Part A Chem Anal Control Expo Risk Assess Vol.29 /1 p. 128-138. Available at: http://pubget.com/paper/22035259
Tornkvist A, Glynn A, Aune M, Darnerud PO, and Ankarberg EH. (2011) PCDD/F, PCB, PBDE, HBCD and chlorinated pesticides in a Swedish market basket from 2005--levels and dietary intake estimations. Chemosphere. Vol.83 /2 p. 193-199.
UNECE. (1979) Convention on Long-range Transboundary Air Pollution. Available at: http://www.unece.org/env/lrtap/welcome.html
UNEP. (2001) Stockholm Convention on Persistent Organic Pollutants. Available at: http://www.pops.int
UNEP. (2011) Results of the joint Stockholm Convention Secretariat/World Health Organization human milk survey (fourth and fifth rounds). Conference of the Parties to the Stockholm Convention on Persistent Organic Pollutants Fifth meeting.
US EPA. (2003) Part II: Health Assessment of 2.3.7.8-Tetrachlorodibenzo-p-dioxin (TCDD) and related compounds. US Environmental Protection Agency.
US EPA. (2012) EPA's Reanalysis of Key Issues Related to Dioxin Toxicity and Response to NAS Comments, Volume 1. EPA/600/R-10/038F www. epa. gov/iris U.S. Environmental Protection Agency Washington, DC. Available at: http://www.epa.gov/iris/supdocs/dioxinv1sup.pdf
US EPA. (2013) Guide to Environmental Issues: Glossary of Terms & Acronyms. Available at: http://iaspub.epa.gov/sor_internet/registry/termreg/searchandretrieve/glossariesandkeywordlists/search.do?details= (accessed 10/9/2013)
Van den Berg M, Birnbaum L, Bosveld AT, Brunstrom B, Cook P, Feeley M, Giesy JP, Hanberg A, Hasegawa R, Kennedy SW, Kubiak T, Larsen JC, van Leeuwen FX, Liem AK, Nolt C, Peterson RE, Poellinger L, Safe S, Schrenk D, Tillitt D, Tysklind M, Younes M, Waern F, and Zacharewski T. (1998) Toxic equivalency

factors (TEFs) for PCBs, PCDDs, PCDFs for humans and wildlife. Environ Health Perspect. Vol.106 /12 p. 775-792.
Van den Berg M, Birnbaum LS, Denison M, De Vito M, Farland W, Feeley M, Fiedler H, Hakansson H, Hanberg A, Haws L, Rose M, Safe S, Schrenk D, Tohyama C, Tritscher A, Tuomisto J, Tysklind M, Walker N, and Peterson RE. (2006) The 2005 World Health Organization Reevaluation of Human and Mammalian Toxic Equivalency Factors for Dioxins and Dioxin-Like Compounds. Toxicological Sciences Vol.93 /2 p. 223-241. Available at: http://toxsci.oxfordjournals.org/content/93/2/223.abstract
Van den Berg M, de Jong J, Poiger H, and Olson JR. (1994) The toxicokinetics and metabolism of polychlorinated dibenzo-p-dioxins (PCDDs) and dibenzofurans (PCDFs) and their relevance for toxicity. Crit. Rev. Toxicol. Vol.24 p. 1-74.
Van den Berg M, Peterson RE, and Schrenk D. (2000) Human risk assessment and TEFs. Food. Addit. Contam. Vol.17 /4 p. 347-358.
Van Leeuwen FXR and Malisch R. (2002) Results of the third round of the WHO-coordinated exposure study on the levels of PCBs, PCDDs and PCDFs in human milk. Organohalogen Compounds Vol.56 p. 311-316.
Van Leeuwen FXR, Younes M, and eds. (2000) Assessment of the health risk of dioxins: re-evaluation of the tolerable daily intake (TDI). Geneva, Switzerland, 25-29 May 1998. Food. Addit. Contam. Vol.17 /4 p. 223-369.
Volatier JL, Tard A, and Gallotti S. (2006) Assessment of dietary intake of dioxins, furans and dioxin-like PCBs for the French Population. Organohalogen Compounds Vol.68 p. 391-394.
Wall PG, Reilly A, Heraghty M, Dalton T, Keegan J, O'Brien K, and Maloney M. (2009) Report of The Inter-Agency Review Group on the Dioxin Contamination Incident in Ireland in December 2008.
Weber R, Gaus C, Tysklind M, Johnston P, Forter M, Hollert H, Heinisch E, Holoubek I, Lloyd-Smith M, Masunaga S, Moccarelli P, Santillo D, Seike N, Symons R, Torres J, Verta M, Varbelow G, Vijgen J, Watson A, Costner P, Woelz J, Wycisk P, and Zennegg M. (2008) Dioxin- and POP-contaminated sites - contemporary and future relevance and challenges. Environmental Science and Pollution Research Vol.15 /5 p. 363-393. Springer Berlin / Heidelberg. Available at: http://dx.doi.org/10.1007/s11356-008-0024-1
Wehler EK, Hovander L, and Bergman A. (1997) New organohalogens in human plasma. Identification and quantification. Organohalogen Compounds Vol.33 p. 420-425.
Weiss J, Paepke O, Bignert A, Jensen S, Greyerz E, Agostoni C, Besana R, Riva E, Giovannini M, and Zetterstroem R. (2003) Concentrations of dioxins and other organochlorines (PCBs, DDTs, HCHs) in human milk from Seveso, Milan and a Lombardian rural area in Italy: a study performed 25 years after the heavy dioxin exposure in Seveso. Acta P+ªdiatrica Vol.92 /4 p. 467-472. Blackwell Publishing Ltd. Available at: http://dx.doi.org/10.1111/j.1651-2227.2003.tb00580.x
White SS and Birnbaum L. (2009) An Overview of the Effects of Dioxins and Dioxin-like Compounds on Vertebrates, as Documented in Human and Ecological Epidemiology. J Environ Sci Health C Environ Carcinog Ecotoxicol Rev Vol.27 /4 p. 197-211.
WHO. (1989a) Levels of PCBs, PCDDs, and PCDFs in breast milk. WHO Regional Office for Europe.
WHO. (1989b) Polychlorinated dibenzo-para-dioxins and dibenzofurans. /88 WHO.
WHO. (1993) Polychlorinated Biphenyl's and Terphenyls (Second Edition). Vol.140 WHO. Available at: http://www.inchem.org/documents/ehc/ehc/ehc140.htm#2.1.4
WHO. (1996) Levels of PCBs, PCDDs and PCDFs in human milk: Second round of WHO-coordinated exposure study. Vol.3 WHO Regional Office for Europe, Copenhagen, Denmark.
WHO. (2002) Polychlorinated dibenzodioxins, polychlorinated dibenzofurans and coplanar polychlorinated biphenyls. Vol.WHO FOOD ADDITIVES SERIES: 48 Available at: http://www.inchem.org/documents/jecfa/jecmono/v48je20.htm
WHO. (2005) Joint FAO/WHO Expert Committee on Food Additives and Contaminants, Sixty-fourth meeting. Summary and Conclusions. WHO/FAO. Rome, 8-17 February 2005.
WHO. (2009) Chapter 6: Dietary Exposure Assessment of Chemicals in Food. Principles and methods for the risk assessment of chemicals in food. Vol.EHC 240 WHO. Available at: http://www.who.int/foodsafety/chem/principles/en/index1.html
WHO ECEH/IPCS. (1998) Assessment of the health risk of dioxins: re-evaluation of the Tolerable Daily Intake (TDI). Executive Summary.
Windal I, Vandevijvere S, Maleki M, Goscinny S, Vinkx C, Focant JF, Eppe G, Hanot V, and Van LJ. (2010) Dietary intake of PCDD/Fs and dioxin-like PCBs of the Belgian population. Chemosphere. Vol.79 /3 p. 334-340.

Yakitine AL, Harrison G, and Lawrence RS. (2006) Reducing Exposure to Dioxins and Related Compounds through Foods in the Next Generation. Nutrition Reviews Vol.64 /9 p. 403-409.
Young AL, Giesy JP, Jones PD, and Newton M. (2004) Environmental fate and bioavailability of Agent Orange and its associated dioxin during the Vietnam War. Environ Sci Pollut. Res Int. Vol.11 /6 p. 359-370.