The First Hong Kong Total Diet Study Report No. 1

The First Hong Kong Total Diet Study: Dioxins and Dioxin-like Polychlorinated Biphenyls (PCBs)

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Centre for Food Safety

Food and Environmental Hygiene Department

The Government of the Hong Kong Special Administrative Region

Correspondence:
Risk Assessment Section
Centre for Food Safety
Food and Environmental Hygiene Department
43/F, Queensway Government Offices,
66 Queensway, Hong Kong.
Email: enquiries@fehd.gov.hk

Contents

List of Figures

List of Tables

EXECUTIVE SUMMARY

The Centre for Food Safety (CFS) is conducting the First Hong Kong Total Diet Study (the 1st HKTDS) aiming to estimate dietary exposures of the Hong Kong population and various population subgroups to a range of substances, including contaminants and nutrients, and thus assess any associated health risks. This report presents the dietary exposure assessment of a group of persistent organic pollutants (POPs), "dioxins and dioxin-like polychlorinated biphenyls (PCBs)".

2. "Dioxins" refers to polychlorinated dibenzo-para-dioxins (PCDDs) and polychlorinated dibenzofurans (PCDFs), whereas "dioxin-like PCBs" refers to polychlorinated biphenyls (PCBs) that exhibit toxicological properties similar to dioxins. Due to similarity in toxicity profiles and mechanisms of action, dioxins and dioxin-like PCBs are generally considered together as a group although their sources are different. Dioxins and dioxin-like PCBs persist in the environment and bioaccumulate in the food chain. Foods of animal origin, such as meat, dairy products, eggs and fish tend to have higher concentrations of dioxins and dioxin-like PCBs.

3. Concerns on dioxins and dioxin-like PCBs are mainly due to their toxic effects on a number of systems, including endocrine and immune systems, the developing nervous system and their cancer-causing potentials. Three congeners, 2,3,7,8-tetraCDD (TCDD), 2,3,4,7,8-pentaCDF and PCB 126 have been identified as human carcinogens.

4. Due to their persistency and toxicity, PCDDs, PCDFs and PCBs have been listed as POPs under the Stockholm Convention, which requires the

signed Parties to take measures to eliminate or reduce the release of POPs into the environment.

5. In 2001, the Joint Food and Agriculture Organization (FAO) /World Health Organization (WHO) Expert Committee on Food Additives (JECFA) established a provisional tolerable monthly intake (PTMI) of 70 picograms (pg)/kg of body weight (bw) / month for PCDDs, PCDFs and dioxin-like PCBs expressed as toxic equivalent (TEQ). The TEQ value was computed using the toxic equivalency factors (TEFs) established by WHO which were assigned to 17 PCDD/PCDF congeners and 12 dioxin-like PCB congeners for comparing their toxicities relative to the most toxic one TCDD.

Results

6. A total of 142 composite samples were tested for dioxins and dioxin-like PCBs. (They composed of 71 different foods with 3 purchases collected and prepared on each of the two occasions from June to November 2010. A total of 426 individual samples have been taken.) All 142 composite samples were detected with at least one of the dioxin and dioxin-like PCB congeners, in which about two-third (66%) of the test results were found to be above the limits of detection (LOD) of individual dioxin and dioxin-like PCB congeners. Among all the food groups, “fish and seafood and their products” contained the highest level (mean: 0.440 pg TEQ/g), followed by “eggs and their products” (mean: 0.137 pg TEQ/g), “fat and oils” (mean: 0.094 pg TEQ/g) and “meat, poultry and game and their products” (mean: 0.091 pg TEQ/g). The top three food items with highest levels of dioxins and dioxin-like PCBs belonged to the same food group “fish and seafood and their

products" and they were mandarin fish (mean: 1.056 pg TEQ/g), oyster (mean: 0.926 pg TEQ /g) and pomfret fish (mean: 0.885 pg TEQ/g).

7. The dietary exposures to dioxins and dioxin-like PCBs were 21.92 and 59.65 pg TEQ/ kg bw/month for average and high consumer of the population, respectively, which amounted to 31.3% and 85.2% of PTMI.

8. The main dietary source of dioxins and dioxin-like PCBs was "fish and seafood and their products" which contributed to 61.9% of the total exposure, and was followed by "meat, poultry and game and their products" and "mixed dishes" which contributed to 20.0% and 7.0% of the total exposure, respectively. Fish and fishery products are particularly significant source of dioxins and dioxin-like PCBs which accounted for 55.6% of total exposure. Similar findings were also revealed in other dietary exposure studies that aquatic food and meat were the major food contributors.

Conclusions and Recommendations

9. The dietary exposures to dioxins and dioxin-like PCBs were 21.92 and 59.65 pg TEQ/kg bw/month for average and high consumer of the population, respectively which were below the PTMI. Therefore, the general population was unlikely to experience major undesirable health effects of dioxins and dioxin-like PCBs. Nevertheless, having considered their carcinogenic risk, effort should be made to reduce the dietary exposure to dioxins and dioxin-like PCBs of the population.

10. Prevention and reduction of human exposure should be done through source-directed measures. International efforts in the reduction of dioxin

emission and their subsequent contaminations of food are essential to reduce the dietary exposure to dioxins and dioxin-like PCBs of the population.

11. The public is advised to trim fat from meat and consume low fat dairy products. The public is also advised to have a balanced and varied diet which includes a wide variety of fruit and vegetables so as to avoid excessive exposure to dioxins and dioxin-like PCBs from a small range of food items. As fish contain many essential nutrients, such as omega-3 fatty acids and high quality proteins, moderate consumption of a variety of fish is recommended.

The First Hong Kong Total Diet Study:

Dioxins and Dioxin-like Polychlorinated Biphenyls (PCBs)

BACKGROUND

Total Diet Study (TDS) has been recognised internationally as the most cost effective way to estimate dietary exposures to food chemicals or nutrients for various population groups and to assess their associated health risks. It provides a scientific basis for assessing food safety risks and regulating food supply. Since 1960s, various countries, such as the United Kingdom (UK), the United States of America (USA), Canada, Australia, New Zealand and Mainland China, have been conducting their own TDS.

Introduction of the First Hong Kong Total Diet Study (1st HKTDS)

2. This was the first time carrying out the TDS in Hong Kong by the Centre for Food Safety (CFS). It aims to estimate dietary exposures of the Hong Kong population and various population subgroups to a range of substances, including contaminants and nutrients, and thus assess any associated health risks.

3. The 1st HKTDS is a large and complex project that comprises sampling and food preparation, laboratory analysis and dietary exposure estimation. It covered the majority of food normally consumed by the Hong Kong population with laboratory analysis of over 130 substances, including contaminants and nutrients.

Dioxins and Dioxin-like PCBs

4. This report focused on a group of substances covered in the 1st HKTDS, i.e. dioxins and dioxin-like polychlorinated biphenyls (PCBs). The dietary exposures of the Hong Kong population to dioxins and dioxin-like PCBs as well as their associated health risk would be assessed.

5. "Dioxins" refers to polychlorinated dibenzo-para-dioxins (PCDDs), and polychlorinated dibenzofurans (PCDFs) whereas "dioxin-like PCBs" refers to polychlorinated biphenyls (PCBs) that exhibit toxicological properties similar to dioxins. Dioxins and dioxin-like PCBs are persistent organic pollutants (POPs) covered by the Stockholm Convention on Persistent Organic Pollutants, which requires the signed Parties to take measures to eliminate or reduce the release of POPs into the environment.[1]

Chemical and Physical Properties

6. Dioxins are a group of polychlorinated, planar aromatic compounds with similar structures, chemical and physical properties, including 75 PCDD and 135 PCDF congeners. Among them, 17 congeners substituted with chlorine atoms in positions 2, 3, 7 and 8 of the two aromatic rings are of toxicological concern, and they exhibit a similar toxicological profile with 2,3,7,8-tetrachlorodibenzo-para-dioxin (TCDD), the most toxic congener. PCBs are chlorinated aromatic compounds that are synthesised by direct chlorination of biphenyl with substitution in positions 1 to 10 of the two rings. Among the 209 possible congeners, only 12 congeners with either non-ortho or

mono-ortho substituted PCBs show toxicological properties that are similar to dioxins.[2, 3]

7. They are hydrophobic and lipophilic and extremely resistant to chemical and biological degradation and therefore persist in the environment and bioaccumulate in the food chain.[3, 4] They often have similar toxicity profiles and mechanisms of action and thus are generally considered together as a group although their sources are different.[5]

Sources of Dioxins and Dioxin-like PCBs

8. Dioxins are ubiquitous in the environment, occurring naturally (e.g. volcanic eruptions and forest fires), and as by-products of combustion (e.g. waste incineration) and various industrial processes (e.g. production of chemicals, chlorine bleaching of paper pulp and smelting). In contrast, PCBs were manufactured in the past for a variety of industrial uses such as electrical insulators or dielectric fluids and specialised hydraulic fluids, and their uses have been banned by most countries since 1970s.[2, 6] However, their release into the environment still occurs from the disposal of large scale electrical equipment and waste. Besides, PCBs is also listed under Annex C of the Stockholm Convention, as one of the unintentionally produced POPs with possible formation in combustion and incineration processes.[7]

9. Sources of dioxins and dioxin-like PCBs entering the food chain include new emissions, mainly via the air route, and remobilisation of deposits or reservoirs in the environment. Due to their persistency, a large part of current exposure is due to the releases of dioxins and dioxin-like PCBs that

occurred in the past. In general, levels of dioxins and dioxin-like PCBs in the air are very low, except in the vicinity of incinerators without the appropriate air pollution control systems. Due to the poor water solubility, their concentrations in drinking water and surface water are also very low. However, releases to air from inadequate incineration and waste sites contaminate soil and aquatic sediments, leading to bioaccumulation and bioconcentration through food chains. Dioxins would concentrate in the fatty tissues of meat and poultry or seafood, and animals with a longer lifespan may have a higher potential accumulation of dioxins in their fat tissue. Foods of animal origin such as meat, dairy products, eggs and fish tend to have higher concentrations of dioxins and dioxin-like PCBs.[5, 8]

Toxicity

10. Dioxins or dioxin-like compounds in dietary fat pass easily from the gut into the blood. In human and laboratory animal experiments, an oral dose of TCDD showed 50 – 90% absorption. The distribution of PCDDs and PCDFs between blood and organs is determined by lipid partitioning and protein binding. In experimental animals, PCDDs and PCDFs are excreted almost exclusively in the bile, excretion in urine being a minor route. Faecal excretion of unmetabolised PCDDs and PCDFs is also an important elimination route in human.

11. In experimental animals, the acute toxicity of different dioxin congeners varies widely between and among species, e.g. the oral median lethal doses were 0.6 and > 5000 μg/kg of body weight (bw) in guinea pigs and

hamsters respectively. However, acute toxicity data on individual dioxin-like PCB congeners in mammals were limited. [2]

12. In human, skin lesions known as chloracne, which is persistent, have been observed when short-term exposure to high levels of dioxins and dioxin-like PCBs in occupational settings or following industrial accidents. For long-term environmental exposure, a range of toxicity may be caused, including immunotoxicity, developmental and neurodevelopmental effects, and effects on thyroid and steroid hormones and reproductive function. Fetus or neonate is considered as the most sensitive life stage.

13. Regarding the carcinogenicity of dioxins and dioxin-like PCBs, experimental animal and epidemiological studies in occupational settings indicate carcinogenicity at multiple sites in a range of animal species and human. The International Agency for Research on Cancer (IARC) classified TCDD in Group 1 (i.e. carcinogenic to humans) and some other dioxins in Group 3 (i.e. not classifiable as to their carcinogenicity to humans) in 1997 and classified PCBs as a group in Group 2A (i.e. probably carcinogenic to humans) in 1987. In addition, IARC in 2009 has classified two more compounds, namely 2,3,4,7,8-pentaCDF and PCB 126 in Group 1. [5, 9, 10, 11]

14. These substances are not genotoxic and their mechanism of carcinogenesis involves the aryl hydrocarbon receptor (AhR). It is considered that there is a threshold for carcinogenicity and the establishment of a tolerable intake based on non-cancer end points can also address any carcinogenic risk.[2, 5]

Toxic Equivalency Factor (TEF) Scheme

15. Different congeners of dioxins and dioxin-like PCBs exhibit different toxicity levels. To facilitate risk assessment and regulatory control of dioxins, since the early 1990's, the World Health Organization (WHO) has established toxic equivalency factors (TEFs) for comparing the toxicities of individual PCDDs, PCDFs and PCBs relative to the most toxic one TCDD, which is used as a reference and given a TEF of 1. In 1998, WHO has derived and issued a set of TEF values (WHO 1998 TEF) for 17 congeners of PCDD/PCDFs and 12 congeners of dioxin-like PCBs, which has been commonly adopted in most available overseas studies. In the subsequent evaluation in 2005, a number of TEF values have been further changed and the WHO-TEF scheme (WHO 2005 TEF) was updated. A summary of WHO 1998 and WHO 2005 TEF values is given in Appendix 1.

16. The concentration of dioxins and dioxin-like PCBs was expressed as the toxic equivalent (TEQ) and was calculated by summing up the contribution from each congener, which was calculated by multiplying the concentration of congener with the corresponding TEF. [4]

Safety Reference Values

17. In 2001, the Joint Food and Agriculture Organization /WHO Expert Committee on Food Additives (JECFA) established a provisional tolerable monthly intake (PTMI) of 70 picograms (pg)/kg bw/ month for PCDDs, PCDFs and dioxin-like PCBs expressed as TEQ. [2]

Sources of Dietary Exposure

18. International studies showed that consumption of foods of animal origin was the major route of human exposure to dioxins and dioxin-like PCBs which contributed about 80 – 95% of total exposure, and meat, dairy products and fish were the major food sources. Other minor routes of exposures include breathing and skin contact. [3, 6, 8]

19. Human milk is considered to be one of the important bio-indicators for monitoring the human exposure to dioxins and dioxin-like PCBs, as the levels of these substances in human milk can reflect the level of contamination in the living environment as well as in the food chain. WHO has used human milk for monitoring levels of dioxins and dioxin-like PCBs in human body for several decades and a general downward trend in the dioxin levels in human milk was revealed in Europe from 1988 to 2002.[12] Concerning the local situation, Hong Kong had participated in the recent rounds of the WHO-Coordinated Human Milk Survey. Local results showed that the mean concentrations of dioxins and dioxin-like PCBs in human milk in 2001/2002 and 2009 were 12.92 pg TEQ/g lipid and 9.84 pg TEQ/g lipid respectively, which represented a 24% decrease in the levels in human milk between the two periods.[13, 14]

Previous Local Study

20. In 2002, the Food and Environmental Hygiene Department (FEHD) conducted a study on dietary exposure to dioxins of secondary school students[15] based on the data collected under the food surveillance programme between 1999 and 2001. In the study, 74% of the test results of individual congeners were below the limits of detection (LOD), and dioxin concentrations in the 88 food samples ranged from 0.01 to 1.32 pg TEQ (PCDD/PCDF)/g and the highest level was found in a poultry sample. The dietary exposures of secondary school students to dioxins alone were estimated to be 0.85 and 2.07 pg TEQ (PCDD/PCDF) /kg bw/day (equal to 25.5 and 62.1 pg TEQ (PCDD/PCDF) /kg bw/month) for average and high consumers (i.e. 95th percentile exposure level) respectively, by applying the previous WHO 1998 TEF values of PCDDs and PCDFs. The estimated dietary exposures to dioxins alone for average and high consumers amounted to 36% and 89% of PTMI for dioxins and dioxin-like PCBs. Meat and poultry and their products (41% of the total exposure) were the major dietary sources of dioxins, and followed by the seafood (30%) and milk and milk products (25%).

21. If dioxin-like PCBs were taken into account, the daily total exposure would be increased and overseas studies indicated that the exposure to dioxin-like PCBs was approximately the same as that to dioxins. Hence, there is a chance for the high consumers to have dioxin exposure above the PTMI and they may expose to higher risks of undesirable health effects, although the average secondary school student would be unlikely to experience major toxicological effects of dioxins.

22. It was noted that there were certain limitations in the previous study. The samples were analysed without any further food preparation, in fact, the dioxin and dioxin-like PCB levels may be altered during food preparation. The old set of WHO 1998 TEF was applied and no dioxin-like PCBs were tested. Besides, more precise laboratory technique is now available to lower the limits of detection so that a more precise estimate of dietary exposure to dioxins can be obtained.

23. In view of the significant contribution of dioxin-like PCBs in the total exposure, both dioxin and dioxin-like PCB concentrations in food samples should be obtained for giving a better estimate of the total dietary exposure, in which the associated health risk could be assessed. Furthermore, it could provide data for monitoring the trend of local situation in future. Hence, the local population exposures to both dioxins and dioxin-like PCBs are assessed in the 1st HKTDS.

METHODOLOGY AND LABORATORY ANALYSIS

Methodology of the 1st HKTDS

24. The 1st HKTDS involved purchasing samples of food commonly consumed throughout Hong Kong, preparing them as consumed and combining the foods into food composites, homogenising them, and then analysing them for a range of substances. The analytical results were then combined with food consumption information of various population groups, which were

captured from the Hong Kong Population-based Food Consumption Survey (FCS) [16], to obtain the dietary exposures.

25. One hundred and fifty TDS food items were selected for the study, based on the food consumption data of the FCS. Three samples of each TDS food item were collected and prepared in a form of food normally consumed on four occasions from March 2010 to February 2011. A total of 1,800 samples were collected and combined into 600 composite samples for laboratory analysis.

26. Among the 150 TDS food items, 71 of them were selected for testing of dioxins and dioxin-like PCBs with reference to their occurrence in food and they are mainly foods of animal origin and their products and oily food. The list of 71 TDS food items is provided in Appendix 2. Having taken into account resource limitation, samples taken from two occasions (i.e. June to August 2010 and September to November 2010, respectively) were tested.

27. Dietary exposure estimation was performed with the aid of an in-house developed web-based computer system, Exposure Assessment System, named as EASY, which involved food mapping and weighting of data. The mean and 95th percentile of the exposure levels were used to represent the dietary exposures of average and high consumer of the population respectively.

28. Details of the methodology are given in the same series of report on Methodology.[17]

Laboratory Analysis of Dioxins and Dioxin-like PCBs

29. Laboratory analysis of dioxins and dioxin-like PCBs was conducted by the Government Laboratory (GL). The analysis included the 29 congeners with WHO-TEF values as listed in Appendix 1.

30. The dioxin and dioxin-like PCB levels in food samples were analysed by High Resolution Gas Chromatograph/High Resolution Mass Spectrometry (HRGC/HRMS). Stable isotope labelled analogs of the 15 2,3,7,8-substituted PCDDs/PCDFs and 12 dioxin-like PCB congeners were spiked quantitatively into a measured amount of sample, which was then extracted by organic solvents. Various cleanup columns were used to clean up the sample extract. After sample clean-up, the PCDDs/PCDFs and dioxin-like PCBs in the sample extract were fractionated with carbon columns. After fractionation, the sample extract were concentrated to near dryness and prior to GC analysis, 1,2,3,4-$^{13}C_{12}$-TCDD and 1,2,3,7,8,9-$^{13}C_{12}$-HxCDD were added to the fraction as injection internal standards for dioxins analysis. $^{13}C_{12}$-PCB congeners 70, 111, 138, 170 were added to the fraction as injection internal standards for dioxin-like PCBs analysis.

31. The analytes were separated by HRGC and were detected by HRMS set at a resolution of ≥ 10,000 in Selected Ion Requisition (SIR) mode. Identification was done by comparing the retention time and the ion-abundance ratio of two exact m/z of the analytes with the retention time of the corresponding isotope labelled standard and the theoretical ion-abundance ratio of the two exact m/z. The concentrations of 1,2,3,7,8,9-HxCDD and OCDF were determined using the internal standard technique. Those for the other

PCDDs/PCDFs, and dioxin-like PCB congeners were determined using the isotope dilution technique. The limits of detection (LODs) and the limits of quantification (LOQs) of the 29 congeners of dioxins and dioxin-like PCBs were shown in the Table 1.

Table 1: Limits of Detection (LODs) (pg/g) and Limits of Quantification (LOQs) (pg/g) of the 29 Congeners of Dioxins and Dioxin-like PCBs

Compound	LOD (pg/g)	LOQ (pg/g)	Compound	LOD (pg/g)	LOQ (pg/g)
PCDDs			Non-ortho PCBs		
2,3,7,8-TetraCDD	0.003	0.01	PCB 77	0.001	0.01
1,2,3,7,8-PentaCDD	0.006	0.02	PCB 81	0.001	0.01
1,2,3,4,7,8-HexaCDD	0.005	0.02	PCB 126	0.002	0.02
1,2,3,6,7,8-HexaCDD	0.006	0.02	PCB 169	0.001	0.01
1,2,3,7,8,9-HexaCDD	0.005	0.02			
1,2,3,4,6,7,8-HeptCDD	0.008	0.03	Mono-ortho PCBs		
OctaCDD	0.009	0.04	PCB 105	0.002	0.02
PCDFs			PCB 114	0.002	0.02
2,3,7,8-TetraCDF	0.003	0.01	PCB 118	0.002	0.02
1,2,3,7,8-PentaCDF	0.003	0.01	PCB 123	0.002	0.02
2,3,4,7,8-PentaCDF	0.004	0.01	PCB 156	0.001	0.01
1,2,3,4,7,8-HexaCDF	0.003	0.01	PCB 157	0.001	0.01
1,2,3,6,7,8-HexaCDF	0.003	0.01	PCB 167	0.001	0.01
1,2,3,7,8,9-HexaCDF	0.004	0.02	PCB 189	0.001	0.01
2,3,4,6,7,8-HexaCDF	0.004	0.01			
1,2,3,4,6,7,8-HeptCDF	0.004	0.01			
1,2,3,4,7,8,9-HeptCDF	0.006	0.02			
OctaCDF	0.014	0.05			

RESULTS AND DISCUSSION

Concentrations of Dioxins and Dioxin-like PCBs in TDS Foods

32. A total of 142 composite samples on two occasions were tested for dioxins and dioxin-like PCBs and the test results in TDS food groups are summarised in Table 2 and the results of 71 TDS food items are shown in Appendix 2. All 142 composite samples were detected with at least one of the dioxin and dioxin-like PCB congeners, in which about two-third (66%) of the test results were found to be above LODs of individual dioxin and dioxin-like PCB congeners. According to the recommendation of the WHO on evaluation of low-level contamination of food in treatment for those non-detected results[18], all non-detected results were assigned with levels at half of LOD for expressing their contents as well as estimating the dietary exposures throughout the report. Besides, the WHO 2005 TEF values were used for calculating the TEQs of the samples.

33. Among all the food groups, “fish and seafood and their products” was contained the highest dioxin and dioxin-like PCB level (mean: 0.440 pg TEQ/g), and was followed by “eggs and their products” (mean: 0.137 pg TEQ/g), “fats and oils” (mean: 0.094 pg TEQ/g) and “meat, poultry and game and their products” (mean: 0.091 pg TEQ/g).

Table 2: Dioxin and Dioxin-like PCB Contents (pg TEQ /g) in TDS Food Groups of the 1st HKTDS

Food Group	Number of composite samples	% of test results < LOD	Mean (pg TEQ /g) [range] #	
Cereals and their products	24	45	0.021	[0.007 – 0.085]
Meat, poultry and game and their products	24	23	0.091	[0.012 – 0.257]
Eggs and their products	6	16	0.137	[0.020 – 0.302]
Fish and seafood and their products	38	20	0.440	[0.009 – 1.270]
Dairy products	10	57	0.021	[0.007 – 0.072]
Fats and oils	4	33	0.094	[0.011 – 0.282]
Beverages, non-alcoholic	6	58	0.011	[0.007 – 0.015]
Mixed dishes	22	40	0.018	[0.007 – 0.039]
Others	8	53	0.013	[0.008 – 0.030]
Total	142	34		

Notes:

As less than 60% of results are below limits of detection (LODs), half of LOD is used for all results less than LOD in calculating the concentrations.

34. Under food group “fish and seafood and their products”, the mean levels of dioxins and dioxin-like PCBs ranged from 0.012 pg TEQ/g to 1.056 pg TEQ/g. Mandarin fish was found to contain the highest level (mean: 1.056 pg TEQ/g), and was followed by oyster (mean: 0.926 pg TEQ /g) and pomfret fish (mean: 0.885 pg TEQ/g), in which they are also the top three items with the highest levels among all the 71 food items. However, the results of the current study can not conclude whether freshwater fish or seawater fish would contain higher levels of dioxins and dioxin-like PCBs.

35. The proportions of dioxins alone and dioxin-like PCBs were compared among the four food groups with the highest levels and are shown in Table 3. Higher proportions of dioxin-like PCBs were found in two food groups “fish and seafood and their products” (58.9%) and “fats and oils”

(69.3%) while higher proportions of dioxin alone were found in other two groups "eggs and their products" (71.0%) and "meat, poultry and game and their products" (62.3%). Although there were variations of proportions between dioxins alone and dioxin-like PCBs, it showed that both dioxins and dioxin-like PCBs would also contribute to our source of exposure.

Table 3: The Proportions of Dioxins and Dioxin-like PCBs to the Sum of Dioxins and Dioxin-like PCBs among the Four TDS Food Groups with the Highest Levels of the 1st HKTDS

Food Group	Mean (pg TEQ/g)#			% †	
	Total*	Dioxins alone	Dioxin-like PCBs	Dioxins alone	Dioxin-like PCBs
Fish and seafood and their products	0.440	0.181	0.259	41.1	58.9
Eggs and their products	0.137	0.097	0.040	71.0	29.0
Fats and oils	0.094	0.029	0.065	30.7	69.3
Meat, poultry and game and their products	0.091	0.057	0.034	62.3	37.7

Notes:

As less than 60% of results are below limits of detection (LODs), half of LOD is used for all results less than LOD in calculating the concentrations.

* Total is the sum of dioxins and dioxin-like PCBs.

† % is the percentage of dioxins alone or dioxin-like PCBs to the sum of dioxins and dioxin-like PCBs.

Dietary Exposure of Dioxins and Dioxin-like PCBs

36. Dietary exposures to dioxins and dioxin-like PCBs of average and high consumer of the population, respectively, were 21.92 pg TEQ/kg bw/month and 59.65 pg TEQ/kg bw/month (Table 4), which amounted to 31.3% and 85.2% of PTMI. Furthermore, 3.1 % of the population was estimated to exceed the PTMI.

Table 4: Comparison between PTMI and Dietary Exposures (pg TEQ /kg bw/month) to Dioxins and Dioxin-like PCBs for an Average and High Consumer of the Population

PTMI (pg TEQ/kg bw/month)	Dietary Exposure (pg TEQ/kg bw/month)	
	Average	High Consumer
70	21.92 (31.3% of PTMI)	59.65 (85.2% of PTMI)

37. By comparing the exposures of different genders, dietary exposures to dioxins and dioxin-like PCBs among female population (average: 21.97 pg TEQ/kg bw/month) are significantly higher than those among male population (average: 21.86 pg TEQ/kg bw/month) (t-test, $p< 0.001$).

38. Dietary exposures of the individual age-gender population subgroups ranged from 17.81 pg TEQ/kg bw/month of male aged 20 – 29 to 26.25 pg TEQ/kg bw/month of male aged 60 – 69 for average population and from 45.91 pg TEQ/kg bw/month of male aged 20 – 29 to 73.49 pg TEQ/kg bw/month of male aged 60 – 69 for high consumers (see Figure 1). The breakdowns of dietary exposures of the individual age-gender population subgroups are shown in Appendix 3.

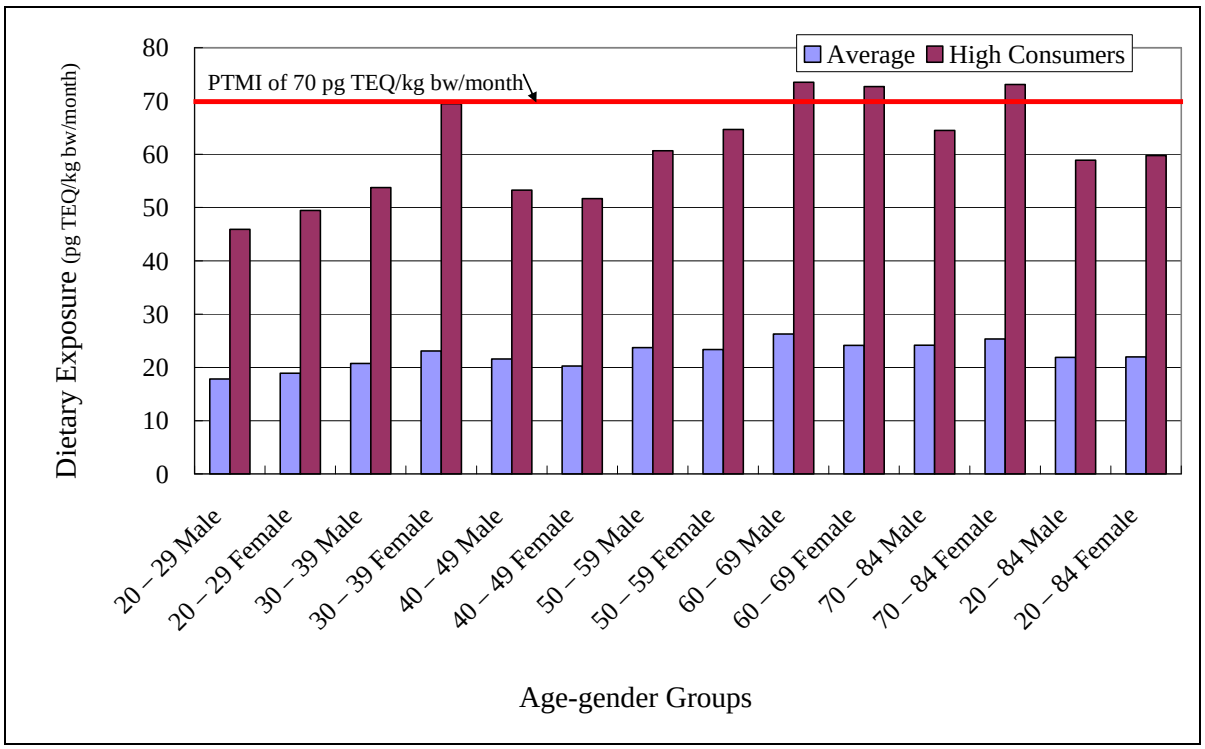

Figure 1: Dietary Exposures to Dioxin and Dioxin-like PCBs for the Average and High Consumers of the Individual Age-gender Groups of the 1st HKTDS

39. Among the various age-gender population subgroups, all the estimated dietary exposures of average population were found below the PTMI (the highest one contributed 37.5% of PTMI) but those of high consumers of the following three subgroups, namely male aged 60 – 69 (73.49 pg TEQ/kg bw/month), female aged 60 – 69 (72.71 pg TEQ/kg bw/month) and female aged 70 – 84 (73.09 pg TEQ/kg bw/month), were found slightly exceeding the PTMI (amounted to 105.0%, 103.9% and 104.4% of PTMI, respectively). In addition, the estimated dietary exposure (69.48 pg TEQ/kg bw/month) of high consumer of female aged 30 – 39, who fall into the age of childbearing, was close to the PTMI (99.3% of PTMI).

40. Therefore, the general population was unlikely to experience major undesirable health effects of dioxins and dioxin-like PCBs. Although high consumers of some population subgroups were found being close to or slightly exceeding the PTMI, an intake above the PTMI does not automatically mean that health is at risk provided that the average intake over long period is not exceeded as PTMI is emphasised on a lifetime exposure.

Major Food Contributors

41. Dietary exposures to dioxins and dioxin-like PCBs for an average of the population by the TDS food groups are shown in Table 5 and their contributions to the total dietary exposures are shown in Figure 2.

Table 5: Dietary Exposure (pg TEQ/kg bw/month) to Dioxins and Dioxin-like PCBs for an Average of the Population in TDS Food Groups

TDS Food Group	Dietary Exposure (pg TEQ/kg bw/month)#	% contribution of total exposure
Cereals and their products	1.08	4.9
Meat, poultry and game and their products	4.39	20.0
Eggs and their products	0.30	1.4
Fish and seafood and their products	13.58	61.9
Dairy products	0.28	1.3
Fats and oils	0.16	0.7
Beverages, non-alcoholic	0.58	2.7
Mixed dishes	1.52	7.0
Others	0.03	0.1
Total	21.92†	100.0†

Notes:

As less than 60% of results are below limit of detection (LOD), half of LOD is used for all results less than LOD in calculating the exposure estimates.

† Figures may not add up to total due to rounding.

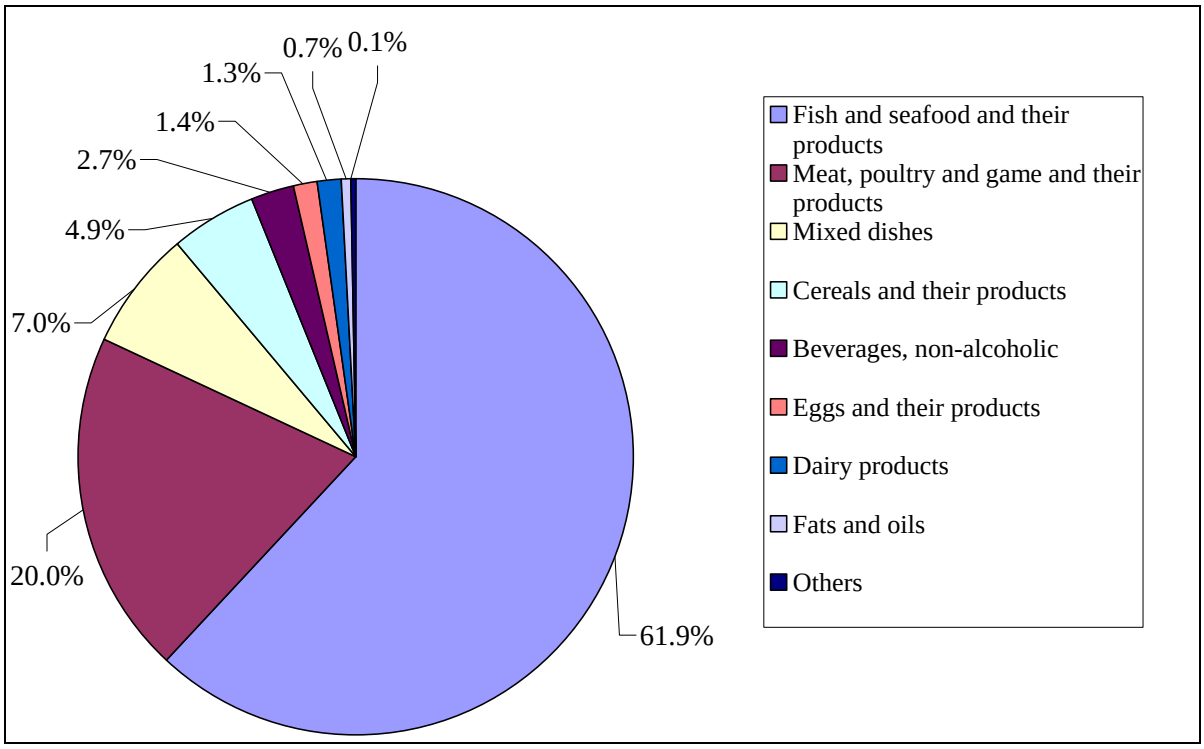

Figure 2: Food Groups Contributing to Dietary Exposure to Dioxins and Dioxin-like PCBs

42. In our findings, the main dietary source of dioxins and dioxin-like PCBs was “fish and seafood and their products” which contributed to 61.9% of the total exposure, and was followed by “meat, poultry and game and their products” and “mixed dishes” which contributed to 20.0% and 7.0% of the total exposure, respectively. Similar findings were also revealed in other dietary exposure studies that aquatic food and meat are the major food contributors. However, dairy products only contributed to 1.3% of the total exposure although it has been reported to be one of the major sources of exposure in the

western diet. It may be due to the difference in consumption pattern of dairy products.

43. In food group "fish and seafood and their products", fish and fishery products are particularly significant source of dioxins and dioxin-like PCBs, which accounted for 55.6% of total exposure, or 89.8% of the contribution to the food group "fish and seafood and their products" in total. About half of the exposure from fish (i.e. 25% of total exposure) was contributed by the following four fish species, grass carp (8.1% of total exposure), golden thread (6.2%), pomfret fish (6.0%) and mandarin fish (4.7%). Mandarin fish and pomfret fish were also found to contain the highest levels of dioxins and dioxin-like PCBs and these two fish species together were contributed to about 10% of exposure.

44. In food group "meat, poultry and game and their products", chicken and beef products accounted for 6.9% and 6.4% of total exposure, or 34.4% and 32.2% of the contribution to this food group in total, respectively.

Comparison with the Previous Local Study and Studies in Other Places

45. As LODs were lower in our current study, more samples were detected with dioxin and dioxin-like PCB congeners. Fish and seafood products were found to contain nearly double the dioxin contents found in the previous local study in 2002 (Median concentration in previous study: 0.099 pg TEQ (PCDD/PCDF)/g; mean concentration in current study: 0.181 pg TEQ (PCDD/PCDF)/g) although higher levels in previous study were expected due

to higher LODs adopted in the previous study. Hence, continue monitoring on the situation may be required to be considered.

46. Even the both dioxins and dioxin-like PCBs have been included in our current study, the dietary exposures of dioxins and dioxin-like PCBs estimated in our current study were still lower than those of dioxins alone estimated in the previous local study in 2002 for both average and high consumers (the dietary exposures of secondary school students in previous study were estimated to be 25.5 and 62.1 pg TEQ (PCDD/PCDF)/kg bw/month for average and high consumers respectively).

47. The dietary exposures of the Hong Kong population in the 1st HKTDS were also compared to those obtained from other places and are summarised in Table 6. It can be seen that the dietary exposure estimated in our study compares favourably to exposure estimates obtained from other places.

48. However, direct comparison of the data has to be done with caution due to the difference in time when the studies were carried out, research methodology, methods of collection of consumption data, methods of contaminant analysis, methods of treating results below detection limits, and the difference of TEF schemes applied.

Table 6: A Comparison of Dietary Exposures of Dioxins and Dioxin-like PCBs

Places	Dietary exposure (pg TEQ/kg bw/month)	
	Average	High Consumer
USA[19] (TDS 2001 -2004)	18.2 [a b c]	
Australia[20] (2004)	15.6 (aged 2 and above) [a d]	40.6 (aged 2 and above) (95th percentile) [a d]
Hong Kong *	21.92 [c]	59.65 (95th percentile) [c]
Japan[21] (2009)	25.2 [e]	
UK[22] (TDS 2001)	27 (adult) [a d]	51 (adult) (97.5th percentile) [a d]
China[23] (TDS 2000)	4.5 – 28.8 (adult male) [a d]	
The Netherlands (2001)	39 [e]	
Finland [24] (1991-99)	55.5 (adult) [a d]	
Sweden [24] (1999)	56.1 [a d]	

a WHO TEF 1998

b PCDD/PCDFs only

c Median bound – assumed results reported as being below the LOD are at ½ LOD.

d Upper bound – assumed results reported as being below the LOD are at the LOD

e Lower bound – assumed results reported as being below the LOD are zero

* Data from current study

Limitations of the Study

49. With limited laboratory resource, small number of samples were analysed and only food likely to contain dioxins, which were mainly foods of animal origin and their products, were selected for testing, which may lead to

under-estimation. Besides, other limitations were described in the report on methodology.

CONCLUSIONS AND RECOMMENDATIONS

50. The dietary exposures to dioxins and dioxin-like PCBs were 21.92 and 59.65 pg TEQ/kg bw/month for average and high consumer of the population, respectively, which amounted to 31.3% and 85.2% of PTMI. Therefore, the general population was unlikely to experience major undesirable health effects of dioxins and dioxin-like PCBs. Nevertheless, having considered their carcinogenic risk, effort should be made to reduce the dietary exposure to dioxins and dioxin-like PCBs of the population.

51. Food of animal origin, particularly fish, meat and poultry, is the predominant route of exposure to dioxins and dioxin-like PCBs.

52. Prevention and reduction of human exposure should be done through source-directed measures. International efforts in the reduction of dioxin emission and their subsequent contaminations of food are essential to reduce the dietary exposure to dioxins and dioxin-like PCBs of the population. In 2006, Codex Alimintarius Commission has issued a “Code of Practice for the Prevention and Reduction of Dioxin and Dioxin-like PCB Contamination in Foods and Feeds”, which gives guidance to national authorities, farmers, and feed and food manufacturers on preventive measures.

53. The public is advised to trim fat from meat and consume low fat dairy products. The public is also advised to have a balanced and varied diet which includes a wide variety of fruit and vegetables so as to avoid excessive exposure to dioxins and dioxin-like PCBs from a small range of food items. As fish contain many essential nutrients, such as omega-3 fatty acids and high quality proteins, moderate consumption of a variety of fish is recommended.

54. CFS will continue to monitor the situation of dioxins and dioxin-like PCBs in food as well as their dietary exposure of the population.

REFERENCES

1 United Nations Environment Programme. Stockholm Convention on Persistent Organic Pollutants (POPs). Geneva, Secretariat of the Stockholm Convention. [cited at 18 July 2011] Available from URL: http://chm.pops.int/

2 World Health Organization (WHO). Safety Evaluation on Certain Food Additives and Contaminants: Polychlorinated dibenzodioxins, polychlorinated dibenzofurans, and coplanar polychlorinated biphenyls; WHO Food Additives Series: 48. Geneva: WHO; 2002. Available from URL: http://www.inchem.org/documents/jecfa/jecmono/v48je20.htm

3 European Food Safety Authority (EFSA). Results of the monitoring of dioxin levels in food and feed. EFSA Journal 2010: 8(3): 1385. Available from URL: http://www.efsa.europa.eu/fr/efsajournal/doc/1385.pdf

4 Van den Berg M, Birnbaum LS, Denison M, De Vito M, Farland W, Feeley M, et al. The 2005 World Health Organization Reevaluation of Human and Mammalian Toxic Equivalency Factors for Dioxins and Dioxin-like Compounds. Toxicological Sciences 2006; 93(2): 223-41

5 WHO. Exposure to dioxins and dioxin-like substances: A major public health concern. WHO 2010. Available from URL: http://www.who.int/entity/ipcs/features/dioxins.pdf

6 FAO/WHO. Codex Code of Practice for the Prevention and Reduction of Dioxin and Dioxin-like PCB Contamination in Foods and Feeds (CAC/RCP 62-2006). Available from URL: http://www.codexalimentarius.net/download/standards/10693/CXP_062e.pdf

7 United Nations Environment Programme. Stockholm Convention on Persistent Organic Pollutants (POPs): About the Convention. [cited at 30 Nov 2011] Available from URL: http://chm.pops.int/Convention/tabid/54/Default.aspx

8 European Commission (EC). Fact Sheet on Dioxin in Feed and Food. Brussels, July 2001. Available from URL: http://ec.europa.eu/dgs/health_consumer/library/press/press170_en.pdf

9 International Agency for Research on Cancer (IARC). Summaries & Evaluations: Polychlorinated biphenyls (Group 2A). IARC Monographs on the Evaluation of Carcinogenic Risks to Humans, Supplement 7, 1987, p. 322. Available from URL: http://www.inchem.org/documents/iarc/suppl7/polychlorinatedbiphenyls.html

10 IARC. Summaries & evaluations: Polychlorinated dibenzo-para-dioxins. IARC Monographs on the Evaluation of Carcinogenic Risks to Humans, Vol. 69, 1997, p.33. Available from URL: http://www.inchem.org/documents/iarc/vol69/dioxin.html

11 WHO IARC Monograph Working Group. Special Report: Policy – A review of human carcinogens – Part F: Chemical agents and related occupations. The Lancet Oncology 2009; 10(12): 1143-4

12 WHO. Biomonitoring of Human Milk. [cited at 7 Nov 2011] Available from URL: http://www.who.int/foodsafety/chem/POPtechnicalnote.pdf

13 Environmental Protection Department (EPD). Hong Kong Special Administrative Region Implementation Plan for the Stockholm Convention on Persistent Organic Pollutants (POPs). Hong Kong: EPD; 2006. Available from URL: http://www.epd.gov.hk/epd/english/international_conventions/pops/files/HKSARIP_En.pdf

[14] Department of Health (DH). Research Study Persistent Organic Pollutants in Human Milk. Hong Kong: DH [unpublished provisional data]

[15] Food and Environmental Hygiene Department (FEHD). Dietary Exposure to Dioxins of Secondary School Students. Hong Kong: FEHD; 2002. Available from URL: http://www.cfs.gov.hk/english/programme/programme_rafs/files/DietaryExposureFull.pdf

[16] FEHD. Hong Kong Population-Based Food Consumption Survey 2005-2007 Final Report. Hong Kong: FEHD; 2010. Available from URL: http://www.cfs.gov.hk/english/programme/programme_firm/files/FCS_final_report.pdf

[17] FEHD. The First Hong Kong Total Diet Study: Methodology. Hong Kong: FEHD; 2011. Available from URL: http://www.cfs.gov.hk/english/programme/programme_firm/files/1st_HKTDS_Report_e.pdf

[18] WHO. GEMS/Food-EURO Second Workshop on Reliable Evaluation of Low-level Contamination of Food – Report of a Workshop in the Frame of GEMS/Food-EURO. WHO; May 1995. Available from URL: http://www.who.int/foodsafety/publications/chem/en/lowlevel_may1995.pdf

[19] U.S. Food and Drug Administration (FDA). PCDD/PCDF Exposure Estimates from TDS Samples Collected in 2001 – 2004. [cited 11 July 2011] Available from URL: http://www.fda.gov/Food/FoodSafety/FoodContaminantsAdulteration/ChemicalContaminants/DioxinsPCBs/ucm077498.htm

[20] Food Standards Australia New Zealand (FSANZ). Dioxins in Food Dietary Exposure Assessment and Risk Characterisation. Technical Report Series No. 27. Australia: FSANZ; May 2004. Available from URL: http://www.foodstandards.gov.au/_srcfiles/FINAL%20DEA-RC%20Report%20Dioxin%2024May04final.pdf

[21] Ministry of Health, Labour and Welfare (MHLW). The Findings of Survey on Daily Dietary Exposure to Dioxin in 2009. [Article in Japanese] Oct 2010, MHLW: Japan. [cited 21 Nov 2011] Available from URL: http://www.mhlw.go.jp/topics/bukyoku/iyaku/syoku-anzen/dioxin/sessyu09/index.html

[22] Food Standard Agency (FSA) of the UK. Dioxins and Dioxin-like PCBs in the UK Diet: 2001 Total Diet Study Samples. Food Survey Information Sheets 38/03; July 2003. Available from URL: http://www.food.gov.uk/multimedia/pdfs/fsis38_2003.pdf

[23] Li J, Wu Y, Zhang L and Zhao Yun. Dietary Intake of Polychlorinated Dioxins, Furans and Dioxin-like Polychlorinated Biphenyls from Foods of Animal Origin in China. Food Additives and Contaminants 2007; 24(2): 186 – 93

[24] EC. Reports on Tasks for Scientific Cooperation: Assessment of Dietary Intake of Dioxins and Related PCBs by the population of EU Member States. Belgium: EC; June 2000. Available from URL: http://ec.europa.eu/dgs/health_consumer/library/pub/pub08_en.pdf

Appendix 1

Summary of the WHO-Toxic Equivalency Factor (TEF) Scheme for Dioxins and Dioxin-like PCBs in 1998 and 2005

Compound		WHO 1998 TEF	WHO 2005 TEF
PCDDs	2,3,7,8-TetraCDD	1	1
	1,2,3,7,8-PentaCDD	1	1
	1,2,3,4,7,8-HexaCDD	0.1	0.1
	1,2,3,6,7,8-HexaCDD	0.1	0.1
	1,2,3,7,8,9-HexaCDD	0.1	0.1
	1,2,3,4,6,7,8-HeptCDD	0.01	0.01
	OctaCDD	0.0001	**0.0003**
PCDFs	2,3,7,8-TetraCDF	0.1	0.1
	1,2,3,7,8-PentaCDF	0.05	**0.03**
	2,3,4,7,8-PentaCDF	0.5	**0.3**
	1,2,3,4,7,8-HexaCDF	0.1	0.1
	1,2,3,6,7,8-HexaCDF	0.1	0.1
	1,2,3,7,8,9-HexaCDF	0.1	0.1
	2,3,4,6,7,8-HexaCDF	0.1	0.1
	1,2,3,4,6,7,8-HeptCDF	0.01	0.01
	1,2,3,4,7,8,9-HeptCDF	0.01	0.01
	OctaCDF	0.0001	**0.0003**
Non-ortho PCBs	PCB 77	0.0001	0.0001
	PCB 81	0.0001	**0.0003**
	PCB 126	0.1	0.1
	PCB 169	0.01	**0.03**
Mono-ortho PCBs	PCB 105	0.0001	**0.00003**
	PCB 114	0.0005	**0.00003**
	PCB 118	0.0001	**0.00003**
	PCB 123	0.0001	**0.00003**
	PCB 156	0.0005	**0.00003**
	PCB 157	0.0005	**0.00003**
	PCB 167	0.00001	**0.00003**
	PCB 189	0.0001	**0.00003**

The changes in TEF are highlighted in bold.

Appendix 2

Dioxin and Dioxin-like PCB Contents (pg TEQ/g) in TDS Foods of the 1st HKTDS

TDS Food Item	Number of composite samples	% of test results < LOD	Mean (pg TEQ/g) [range] (ND=LOD/2)	
Cereals and their products:	**24**	**45**	**0.021**	**[0.007 – 0.085]**
Noodles, Chinese or Japanese style			0.013	[0.007 – 0.018]
Pasta, Western style			0.021	[0.007 – 0.034]
Instant noodles			0.015	[0.007 – 0.022]
Bread, plain			0.009	[0.007 – 0.010]
Bread, raisin			0.012	[0.011 – 0.014]
"Pineapple" bun			0.015	[0.009 – 0.021]
Sausage/ham/luncheon meat bun			0.022	[0.020 – 0.023]
Biscuits			0.010	[0.010 – 0.011]
Cakes			0.023	[0.013 – 0.033]
Pastries			0.026	[0.022 – 0.030]
Pastries, Chinese			0.079	[0.072 – 0.085]
Deep-fried dough			0.010	[0.008 – 0.012]
Meat, poultry and game and their products:	**24**	**23**	**0.091**	**[0.012 – 0.257]**
Beef			0.206	[0.155 – 0.257]
Mutton			0.064	[0.047 – 0.080]
Pork			0.025	[0.019 – 0.030]
Ham			0.024	[0.012 – 0.037]
Luncheon meat			0.102	[0.048 – 0.157]
Barbecued pork			0.055	[0.039 – 0.072]
Roasted pork			0.032	[0.024 – 0.040]
Pig liver			0.193	[0.147 – 0.239]
Chicken meat			0.087	[0.087 – 0.088]
Chicken, soy sauce			0.117	[0.089 – 0.146]
Roasted duck/goose			0.147	[0.119 – 0.175]
Meat sausage			0.038	[0.026 – 0.049]
Eggs and their products:	**6**	**16**	**0.137**	**[0.020 – 0.302]**
Egg, chicken			0.029	[0.020 – 0.037]
Egg, lime preserved			0.152	[0.137 – 0.168]
Egg, salted			0.230	[0.159 – 0.302]
Fish and seafood and their products:	**38**	**20**	**0.440**	**[0.009 – 1.270]**
Fish, Big head			0.690	[0.662 – 0.719]
Fish, Mandarin fish			1.056	[0.842 – 1.270]
Fish, Grass carp			0.550	[0.462 – 0.638]
Fish, Golden thread			0.390	[0.329 – 0.452]
Fish, Grouper			0.230	[0.186 – 0.275]

TDS Food Item	Number of composite samples	% of test results < LOD	Mean (pg TEQ/g) [range] (ND=LOD/2)	
Fish, Horse head			0.352	[0.296 – 0.408]
Fish, Pomfret			0.885	[0.789 – 0.982]
Fish, Sole			0.012	[0.009 – 0.014]
Fish, Tuna			0.044	[0.026 – 0.062]
Fish, Grey mullet			0.520	[0.451 – 0.589]
Fish, Salmon			0.783	[0.741 – 0.825]
Fish, Yellow croaker			0.406	[0.372 – 0.440]
Fish, Dace, minced			0.381	[0.297 – 0.466]
Fish ball/fish cake			0.035	[0.021 – 0.049]
Shrimp/ Prawn			0.077	[0.050 – 0.103]
Crab			0.824	[0.585 – 1.063]
Oyster			0.926	[0.871 – 0.980]
Scallop			0.029	[0.029 – 0.029]
Squid			0.169	[0.122 – 0.216]
Dairy products:	**10**	**57**	**0.021**	**[0.007 – 0.072]**
Milk, whole			0.009	[0.007 – 0.012]
Milk, skim			0.007	[0.007 – 0.008]
Cheese			0.049	[0.026 – 0.072]
Yoghurt			0.008	[0.008 – 0.008]
Ice-cream			0.031	[0.010 – 0.051]
Fats and oils:	**4**	**33**	**0.094**	**[0.011 – 0.282]**
Butter			0.171	[0.059 – 0.282]
Oil, vegetable			0.017	[0.011 – 0.023]
Beverages, non-alcoholic:	**6**	**58**	**0.011**	**[0.007 – 0.015]**
Tea, Milk tea			0.011	[0.009 – 0.012]
Coffee			0.011	[0.007 – 0.015]
Malt drink			0.012	[0.009 – 0.015]
Mixed dishes:	**22**	**40**	**0.018**	**[0.007 – 0.039]**
Siu Mai			0.024	[0.021 – 0.027]
Dumpling, steamed			0.022	[0.013 – 0.031]
Dumpling, pan-fried			0.020	[0.016 – 0.024]
Dumpling, including wonton			0.027	[0.023 – 0.031]
Steamed barbecued pork bun			0.014	[0.012 – 0.015]
Turnip cake			0.016	[0.013 – 0.018]
Steamed minced beef ball			0.024	[0.020 – 0.028]
Glutinous rice dumpling			0.030	[0.021 – 0.039]
Steamed rice-rolls with filling			0.009	[0.009 – 0.009]
Chinese soup			0.007	[0.007 – 0.007]
Hamburger			0.011	[0.008 – 0.014]
Others	**8**	**53**	**0.013**	**[0.008 – 0.030]**
Potato, fried			0.008	[0.008 – 0.008]

TDS Food Item	Number of composite samples	% of test results < LOD	Mean (pg TEQ/g) [range] (ND=LOD/2)	
Potato chips			0.012	[0.011 – 0.013]
Chocolate			0.021	[0.012 – 0.030]
Oyster sauce			0.013	[0.011 – 0.015]

Appendix 3

Dietary Exposure to Dioxins and Dioxin-like PCBs by Age-Gender Group (Average and High Consumer of the Population)

Age-gender Groups	Dietary Exposure [#] (pg TEQ/kg bw/month)	
	Average	High Consumer[@]
Male aged 20 – 29	17.81	45.91
Female aged 20 – 29	18.92	49.44
Male aged 30 – 39	20.74	53.73
Female aged 30 – 39	23.07	69.48
Male aged 40 – 49	21.56	53.26
Female aged 40 – 49	20.24	51.67
Male aged 50 – 59	23.73	60.68
Female aged 50 – 59	23.35	64.67
Male aged 60 – 69	26.25	**73.49**
Female aged 60 – 69	24.14	**72.71**
Male aged 70 – 84	24.15	64.47
Female aged 70 – 84	25.35	**73.09**
Male aged 20 – 84	21.86	58.91
Female aged 20 – 84	21.97	59.73
Adult aged 20 – 84	21.92	59.65

As less than 60% of results are below limit of detection (LOD), half of LOD is used for all results less than LOD in calculating the exposure estimates.

@ Exposures of high consumers refer to the exposures at 95th percentile.