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Chemical Hazard Evaluation

Dietary Exposure to Non-Dioxin-Like Polychlorinated Biphenyls of Hong Kong Adult Population

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EXECUTIVE SUMMARY

This risk assessment study determined the sum of the six indicator non-dioxin-like polychlorinated biphenyls (NDL-PCBs) in selected food items available in Hong Kong in order to estimate the dietary exposure of the Hong Kong adult population to NDL-PCBs.

2. Polychlorinated biphenyls (PCBs) are a group of 209 congeners with similar basic structure, but differing in the number of chlorines and chlorination pattern. PCBs do not occur naturally. They have been massively produced commercially for over four decades and were widely used in a number of industrial and commercial applications. Because of their persistent nature in the environment and their adverse effects on human health, many countries banned the production and use of PCBs since the 1970s.

3. PCBs can be divided into two groups according to their toxicological properties. The first group contains 12 congeners and is called dioxin-like PCBs (DL-PCBs). DL-PCBs have toxicological properties similar to dioxins. The rest of the PCBs do not show a dioxin-like toxicological profile and are termed non-dioxin-like PCBs (NDL-PCBs). The PCB congeners found in food matrices are mainly NDL-PCBs which therefore form a significant portion of human PCB dietary exposure. Concerns on NDL-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.

4. In 2005, the Scientific Panel on Contaminants in the Food Chain of European Food Safety Authority (EFSA) concluded that the sum of the six

NDL-PCBs (Σ_6PCB; 28, 52, 101, 138, 153 and 180) comprises about 50% of the total NDL-PCBs in food and is considered to be a suitable representative for all NDL-PCBs. The sum of these six indicator NDL-PCBs (Σ_6PCBs) are then used to monitor the contamination levels of NDL-PCBs in Europe according to the European legislation.

5. International health-based guidance values (HBGVs) have not been developed for NDL-PCBs. This is because toxicological database on individual NDL-PCB is limited and interpretation of the results of the toxicological and epidemiological studies of NDL-PCBs was confounded by the presence of DL-PCBs in technical mixtures. However, some European countries have developed "a guidance value" of 10 ng/kg bw/day for Σ_6PCBs. This study adopts this guidance value in order to assess the health risk posed by NDL-PCBs on the local adult population.

Results

6. A total of 284 composite samples were tested for six indicator NDL-PCBs. Of the 284 composite samples analysed, 59 composite samples (21%) were detected with at least one indicator PCB congener. Among these 59 composite samples, majority (i.e. 50 samples) belonged to the food group "fish and seafood and their products" which was also found to contain the highest level of Σ_6PCBs (mean: 0.89 μg/kg (lower bound) - 0.93 μg/kg (upper bound)).

7. As regards dietary exposure to NDL-PCBs of the local adult population, the lower bound and upper bound exposure estimates of Σ_6PCBs for average of the population were found to be 0.68 and 1.38 ng/kg bw/day (i.e. 6.8 and 13.8% of the HBGV) respectively. For high consumers, the lower bound and upper bound exposure estimates were found to be 3.08 and 3.84 ng/kg bw/day (i.e. 30.8 and 38.4% of the HBGV) respectively.

8. In this study, the main dietary source of NDL-PCBs was "fish and seafood and their products" which contributed to 84.3% of the total exposure. About 50% of the total exposure were contributed by the following four fish species, salmon (cooked salmon and salmon sashimi: 19.9%), mandarin fish (14.7%), pomfret fish (8.5%) and yellow croaker (7.5%).

Conclusions and Recommendations

9. The dietary exposures to Σ_6PCBs of the average and high consumers of the local population were below HBGV. Hence, the local population was unlikely to experience undesirable health effects of NDL-PCBs.

10. Prevention and reduction of human exposure should be done through source-directed measures. International efforts in the elimination of PCBs and their subsequent contaminations of food are essential to reduce the dietary exposure to PCBs of the population.

11. By virtue of the dietary exposure to Σ_6PCBs in adults alone, the findings of the present study did not provide sufficient justifications to warrant changes to the basic dietary advice on healthy eating. The public is advised to maintain a balanced and varied diet which includes a wide variety of fruit and

vegetables so as to avoid excessive exposure to any contaminants 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.

Risk Assessment Studies –

Dietary Exposure to Non-Dioxin-Like Polychlorinated Biphenyls of Hong Kong Adult Population

OBJECTIVES

This study aims to determine the sum of the six indicator non-dioxin-like polychlorinated biphenyls (NDL-PCBs) in selected food items, to estimate the dietary exposure to NDL-PCBs of the Hong Kong adult population and to assess the associated health risks.

BACKGROUND

2. The term polychlorinated biphenyls (PCBs) refers to a family of chemicals characterised by a common biphenyl molecular structure (Figure 1) with two linked benzene rings to which some or all of the hydrogen atoms have been replaced by chlorine (Cl) atoms. The chemical formula of PCBs is $C_{12}H_{10-n}Cl_n$, where n ranges from 1 to 10. As an example, 2,2',3,4,4',5'-hexachlorobiphenyl (PCB congener number 138) would have a Cl attached at positions 2, 3, and 4 of the left benzene ring and positions 2', 4', and 5' of the right benzene ring (Figure 2). Depending on the number of chlorine atoms and their positions on the two rings, 209 different congeners are theoretically possible; however, only about 130 of these have been identified in commercial or technical products[1].

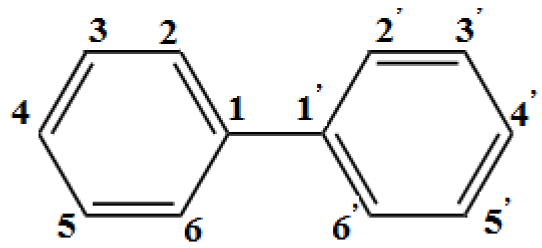

Figure 1. A Biphenyl Molecular Structure.

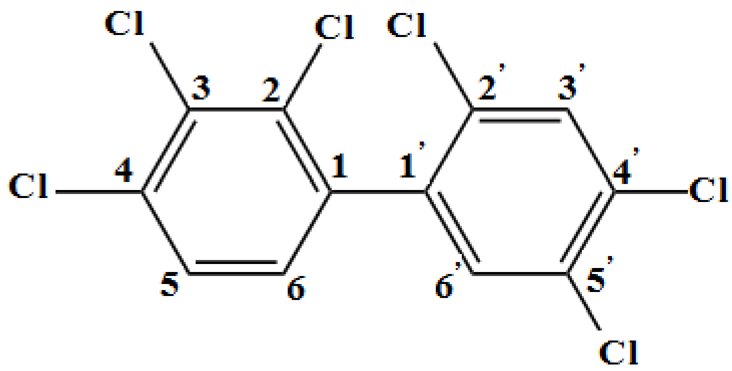

Figure 2. 2,2',3,4,4',5'-hexachlorobiphenyl (PCB-138).

3. PCBs do not occur naturally[1]. They have been massively produced commercially for over four decades by direct chlorination of biphenyl. Depending on the production process, PCBs have been produced as complex technical mixtures[1]. The technical mixtures, produced by different manufacturers and under different brand names (e.g. Aroclor, Clophen, Pyralene, Fenclor, Delor, etc.), differed significantly as to the number and content of individual PCB congeners[2]. Even among similar mixtures, significant lot-to-lot differences in congeneric composition occurred[1]. PCBs were widely used since 1929 in a number of industrial and commercial

applications such as hydraulic and heat transfer systems, cooling and insulating fluids in transformers and capacitors, pigments, dyes and as plasticisers in paints[3].

4. Because of their persistent nature in the environment and their adverse effects on human health, many countries banned the production and use of PCBs since 1970s[1]. It was estimated that roughly 1.2 million metric tons of PCBs were produced world-wide between 1929 and 1977. Of this total, more than 635,000 tons was produced in North America. West Germany has also produced significant quantities of PCBs, possibly in the order of 200,000 to 300,000 tons. Several other European countries, including France, Italy and Spain also produced PCBs[4]. PCBs are covered by the Stockholm Convention on Persistent Organic Pollutants (POPs) which requires the signed Parties to take measures to eliminate or reduce the release of POPs into the environment[5]. Today, the major source of exposure to PCBs is environmental cycling of PCBs previously released into the environment[6].

5. According to their toxicological properties, PCBs can be divided into two groups. The first group contains 12 congeners which have toxicological properties similar to dioxins and are therefore called dioxin-like PCBs (DL- PCBs)[6]. They can bind to the aryl hydrocarbon (Ah) receptor (i.e. similar to dioxins) and their toxic effects include immuno- and reproductive toxicity, carcinogenic potency, negative influence on the development of central nervous system, etc[1, 2]. The rest of PCBs do not show a dioxin-like toxicological profile and are termed NDL-PCBs. The NDL-PCBs do not bind to the Ah receptor. They have interactions with several other receptors and show effects on the nervous system, the thyroid and the endocrine system after

a relatively high incidental intake or after bio-accumulation in the body upon long-term intake[1, 2]. The PCB congeners found in food matrices are mainly NDL-PCBs and therefore they form a significant portion of human PCB dietary exposure[7, 8]. The NDL-PCBs are often considered to be less toxic than DL-PCB congeners[9].

6. The Centre for Food Safety (CFS) has conducted the first Hong Kong Total Diet Study (1st HKTDS) for estimating the dietary exposure to dioxins and DL-PCBs and concluded that the dietary exposure to dioxins and DL-PCBs for average and high consumer of the population was below the provisional tolerable monthly intake (PTMI) established in 2001 by the Joint Food and Agriculture Organization (FAO) /World Health Organization (WHO) Expert Committee on Food Additives (JECFA). In other words, the general population was unlikely to experience major undesirable health effects of dioxins and DL-PCBs. As regards dietary exposure to NDL-PCBs, local data are lacking.

7. At present, information about the total content of NDL-PCBs is still limited. It is however unpractical and very expensive for monitoring or enforcement purposes to analyse each time all PCB congeners. It has been known that some PCB congeners present in commercial mixtures are particularly persistent (e.g. PCB-138, 153 and 180)[7] and are therefore recurrently found in the food and environment. PCB-52 and 101 are also found in significant amounts in some contaminated foodstuffs or are indicators of recent contamination[7]. As a result, they have been considered to be PCB tracers in many studies.

8. In 2005, the Scientific Panel on Contaminants in the Food Chain of European Food Safety Authority (EFSA) concluded that the sum of the six NDL-PCBs (Σ_6PCB; 28, 52, 101, 138, 153 and 180), the so-called "indicator PCBs", comprised about 50% of total NDL-PCB in food and was considered to be a suitable representative for all NDL-PCBs[2]. These six indicator NDL-PCBs are now being used to monitor the contamination levels of NDL-PCBs in food in the European Union (EU) according to the European legislation[10, 11, 12]. Furthermore, the EU Commission has laid down maximum levels for Σ_6PCBs in food[13, 14, 15]. In this risk assessment study, the six indicator NDL-PCBs (PCB-28, 52, 101, 138, 153 and 180) were analysed in selected food items in order to estimate the dietary exposure of Hong Kong adult population to NDL-PCBs.

Physical and Chemical Properties of Polychlorinated Biphenyls

9. Commercial PCB mixtures are odourless, tasteless and colourless to light-yellow oily liquids or solids[1, 2]. PCBs are inert chemicals; they resist both acids and alkalis. They have low flammability, low heat conductivities, good electrical insulating properties and high dielectric constants. These properties make them useful in a wide variety of applications, including dielectric fluids in transformers and capacitors, heat transfer fluids, and lubricants[1, 2].

10. PCBs have very low water solubility and in general the solubility decreases with increased chlorination. All congeners of PCBs are lipophilic and their lipophilicity increases with increasing degree of chlorination[1, 2]. Some PCBs are volatile; congeners with a higher degree of chlorination are less

volatile than those with a lower degree. Since NDL-PCBs are lipophilic and persistent in the environment, they tend to accumulate in the food chain and are stored in fatty tissues[1, 2].

Sources of NDL-PCBs

11. Uses of PCBs have been banned by most countries since 1970s. However, PCBs can still be released into the environment from improper dumping of PCB wastes, disposal of PCB-containing consumer products into landfills not designed to handle hazardous waste and poorly-maintained waste sites that contain PCBs. PCBs may also be released into the environment by the burning of wastes in municipal and industrial incinerators. Once released into the environment, PCBs are circulated globally by atmospheric transport and cycled within the ecosystem[1, 2, 6].

12. Due to the poor water solubility, concentrations of PCBs in drinking water and surface water are very low. However, releases of PCBs to air from inadequate incineration and waste sites contaminate soil and aquatic sediments, leading to bioaccumulation and biomagnification of PCBs through food chains because PCBs degrade very slowly[1, 2, 3]. NDL-PCBs would concentrate in the fatty tissues of seafood or meat and poultry, and animals with a longer lifespan may have a higher potential accumulation of NDL-PCBs in their fat tissue.

13. Overseas studies showed that in food, the highest contamination level was always observed in fish followed by dairy products, meat and eggs[16, 17, 18, 19]. The lowest contamination was observed in foods of plant origin[10]. In Europe, some fish such as European eels were reported to contain high

levels of PCBs because of their high fat content, benthic and carnivorous feeding behaviour. Nonetheless, the levels of Σ_6PCBs varied a lot (from 1.55 μg/kg to more than 1427 μg/kg)[16, 17], probably depending on the degree of contamination of the study areas. Table 1 summarises the contamination levels of Σ_6PCBs in some food groups and food items reported by EFSA in 2012[16].

Table 1. Contamination Levels (μg/kg) (upper bound) of Σ_6PCBs in Food[*] Reported by EFSA[16].

	Mean	50th percentiles	95th percentiles
Muscle meat fish (excluding eels) (fresh weight)	14.82	3.79	58.62
– farmed salmon and trout	4.72	2.70	15.18
– other farmed fish	8.27	6.85	21.27
– seafood	1.84	0.62	7.57
Hen eggs and egg products (fat weight)	12.27	3.07	58.80
Raw milk and dairy products (fat weight)	9.00	8.93	15.93
Meat from bovine animals (fat weight)	11.00	6.52	31.20
Butter (fat weight)	3.09	2.22	7.50

[*]samples collected between 1995 and 2010.

Sources of Dietary Exposure

14. Food is the main source of exposure to PCBs for the general population[6]. EFSA estimated that more than 90% of the NDL-PCB exposure in the general population was via food[2]. In 2000, the US Agency for Toxic Substances and Disease Registry (ATSDR) reported that the major dietary sources of PCBs were fish, meat, and dairy products[1].

15. More recently, EFSA collected a total of 19,181 food samples in the period 1995 and 2010 from 26 European countries for the analysis of the occurrence of NDL-PCBs. The major contributor to total exposure was either the food category fish and seafood products or meat and meat products in the groups of adolescent, adult, elderly and very elderly. It was followed by milk and dairy products, and animal and vegetable oils and fats[16]. Similar results were reported in studies conducted in Belgium and France[18, 19]. Many studies also showed a general trend of decrease in dietary exposure to NDL-PCBs of populations over the years[1, 16, 19, 20].

Toxicity

16. Despite the abundance of NDL-PCBs, there is a lack of toxicity data of individual NDL-PCBs. The main problem with the majority of existing toxicity data on NDL-PCBs is that many previous studies have been carried out using technical mixtures. The coexistence of NDL- and DL-PCBs in these technical mixtures makes it impossible to distinguish the specific effects of NDL-PCBs from those of DL congeners[2, 8].

<u>Kinetics and metabolism</u>

17. PCBs are readily absorbed from the gastrointestinal tract into the body by passive diffusion[2]. In animal experiments, absorption of the lower chlorinated congeners (>90% absorption) is better than that of the higher chlorinated congeners (about 75%)[2, 10]. Once absorbed, PCBs are distributed preferentially to the liver and muscle tissue.

18. The liver is the main site of metabolism of PCBs[6]. Several NDL-PCB congeners are metabolised to hydroxylated metabolites and/or methylsulfonyl metabolites. In general, highly chlorinated congeners are less readily metabolised than the less-chlorinated congeners[2]. As a result, the highly-chlorinated congeners tend to remain in the body longer than that of the less-chlorinated congeners. Due to their lipophilic nature, the highly chlorinated congeners tend to become more concentrated in adipose tissues[6].

19. Elimination of PCBs is mainly through the excretion of the polar hydroxylated metabolite in urine and faeces. There is significant elimination of unchanged PCBs and their methylsulfonyl metabolites via breast milk[2].

Endocrine effect

20. Recent studies have clearly shown that NDL-PCBs have endocrine system modulating properties with effects on several hormonal systems including the thyroid, steroid and retinoid systems[21]. In rats, PCB-180 (a NDL-PCB) caused a dose-dependent decrease in circulating levels of thyroid hormones[8]. NDL-PCBs and hydroxylated metabolites may bind to the hormone receptor and affect thyroid hormone status by inhibiting the binding of thyroid hormones to transthyretin, which is an important transport protein for thyroid hormones in rats[2, 8, 21]. Transthyretin plays also a significant role in human foetal brain development because it is responsible for transport of thyroid hormones via placental and blood-brain barriers[8].

21. Both estrogenic activity and anti-estrogenic activity have been observed for NDL-PCBs and hydroxylated metabolites of lower chlorinated

NDL-PCBs[2, 10]. *In vivo* animal studies, using single congener, showed estrogenic effects such as increases in uterine weight, and changes in oestrogen and progesterone receptors[2]. PCB-180 caused a decrease in testosterone and an increase in luteinising hormone and follicle stimulating hormone levels in male offspring[8, 21]. These changes, together with a decrease in prostate weight and a decrease in epididymal sperm counts at the high exposure level, suggested the possibility of testicular damage which is consistent with the antiandrogenic activity observed for all tested PCBs *in vitro*.[21]

Neurobehavioural effects

22. Exposure to NDL-PCBs during development also induced long-lasting behavioural alterations.[21]. PCB-180 was reported to alter emotional responses of female rats to unfamiliar environment[8]. *In vitro* and *in vivo* studies showed that NDL-PCBs perturb neurotransmitter transport and signalling pathways essential for neuronal differentiation, growth and function[21].

Carcinogenicity and genotoxicity

23. In 1987, the International Agency for Research on Cancer (IARC) classified PCBs as a group as probably carcinogenic to humans (Group 2A). In 2013, IARC re-evaluated the carcinogenicity of PCBs. On the basis of sufficient evidence of carcinogenicity in humans and experimental animals, the IARC classified PCBs as carcinogenic to humans (Group 1) without distinction in DL- or NDL- congeners[22]. Additionally, DL-PCBs were also classified in Group 1 on the basis of extensive evidence of an AhR-mediated mechanism of

carcinogenesis that was identical to that of 2,3,7,8-tetrachlorodibenzopara-dioxin, and sufficient evidence of carcinogenicity in experimental animals[22]. It should be noted that in assessing the carcinogenic potential of PCBs no clear distinction was made between DL-PCBs and NDL-PCBs.

24. The US Centers for Disease Control and Prevention (CDC) considered that PCBs were not directly genotoxic[23]. EFSA also considered that technical PCB mixtures were not mutagenic at gene or chromosome level because of the negative results of *in vitro* and *in vivo* genotoxicity studies[2].

Health-Based Guidance Values (HBGVs)

25. Although the absence of mutagenicity indicates a threshold approach is appropriate for hazard characterisation, international HBGVs have not been developed for NDL-PCBs. This is because toxicological database on individual NDL-PCBs is limited and interpretation of the results of the toxicological and epidemiological studies of NDL-PCBs was confounded by the presence of DL-PCBs in technical mixtures[2, 8]. However, some European countries have developed "a guidance value" for indicator NDL-PCBs in order to provide risk managers with a health-based guideline to prevent adverse effects of exposure to indicator NDL-PCBs. Based on the immunological effects observed in monkeys, a daily reference dose of 20 ng/kg bw/day was proposed for chronic-duration oral exposure to all PCBs by the ATSDR in 2000[1]. This daily reference dose was also adopted by the International

Programme on Chemical Safety (IPCS)[24], the National Institute for Public Health and the Environment of the Netherlands (RIVM)[25] and the French Food Safety Agency (AFSSA)[7, 17]. In addition, since the sum of the six indicator NDL-PCBs accounts for almost 50% of total NDL-PCBs present in food, AFSSA adopted "a guidance value" of 10 ng/kg bw/day for the sum of the six indicator NDL-PCBs[26]. In 2008, the Norwegian Scientific Committee for Food Safety (VKM) also used 10 ng/kg bw/day for the six indicator NDL-PCBs as a reference value in its evaluation of the NDL-PCBs in the diet of Norwegians[27].

Regulatory Control

26. There is currently no international standard for the maximum allowable level of NDL-PCBs in foods. However, EC has established maximum levels of NDL-PCBs (i.e. maximum levels for the Σ_6PCBs) for food. Commission Regulation (EC) No 1881/2006, as amended by the Commission Regulation (EU) No 1259/2011, established maximum levels for the Σ_6PCBs in some specific foodstuffs[13, 14, 15].

27. The US Food and Drug Administration (FDA) also established temporary tolerances for total PCB in some food[28]. Whereas, in China, GB 2762-2012 specified the maximum level of PCB (expressed as the sum of seven PCBs: PCB-28, PCB-52, PCB-101, PCB-118, PCB-138, and PCB-153 and PCB-180) in aquatic animals and their products[29].

28. There is no specific regulation on NDL-PCBs in foods in Hong Kong. Nevertheless, all foods for sale in Hong Kong must be fit for human consumption.

METHODOLOGY AND LABORATORY ANALYSIS

Methodology

29. To estimate the dietary exposures to NDL-PCBs of Hong Kong adult population, this study analysed the amount of the six indicator NDL-PCBs (i.e. PCB-28, 52, 101, 138, 153 and 180) in selected food samples collected in the 1st HKTDS.

30. 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)[30], to obtain the dietary exposures of Hong Kong adult population.

31. Based on the food consumption data of the FCS, 150 food items were selected for the 1st HKTDS and they were sampled on four different occasions from March 2010 to February 2011. On each occasion, three samples of each TDS food item were collected and prepared in a form of food

normally consumed. Hence, a total of 1,800 samples were collected and combined into 600 composite samples for laboratory analysis.

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

33. Details of the methodology of the 1st HKTDS are delineated in its report on Methodology[31].

34. In the present study, 71 out of the 150 TDS food items, mainly foods of animal origin and oily foods, were selected for analysing the amount of NDL-PCBs with consideration of the likelihood of occurrence of NDL-PCBs in these food items. PCBs are stable and persistent chemicals; hence the use of TDS food items collected in 2010 and 2011 would not affect the amount of NDL-PCBs detected in the samples. The list of these 71 TDS food items is provided in Appendix 1. In total, 284 composite samples of 71 TDS food items taken from the four occasions were tested.

Laboratory Analysis of NDL-PCBs

35. Laboratory analysis of NDL-PCBs was conducted by the Food Research Laboratory (FRL) of CFS. A total of 284 composite samples have been tested for 6 NDL-PCB congeners including PCB-28, PCB-52, PCB-101, PCB-138, PCB-153 and PCB-180 (Table 2).

36. The NDL-PCB levels in food samples were analysed by Gas Chromatograph/Mass Selective Detector (GC/MSD). Stable isotope labelled analogs of 6 congeners were spiked quantitatively into a measured amount of sample, which was then extracted by pressurised liquid extraction. The sample extract was cleaned up by sulphuric acid and a column of various packing materials. After sample cleanup, the sample solution was concentrated to near dryness. Prior to GC analysis, $^{13}C_{12}$-PCB-188 was added to the fraction as recovery standard for NDL-PCBs analysis. The limits of detection (LODs) and the limits of quantification (LOQs) of the 6 congeners of NDL-PCBs were 0.01 and 0.05 μg/kg respectively.

Table 2. Individual NDL-PCBs Congeners Analysed.

Congener number	Chlorine substitution pattern
PCB-28	2,4,4'-trichlorobiphenyl
PCB-52	2,2',5,5'-tetrachlorobiphenyl
PCB-101	2,2',4,5,5'-pentachlorobiphenyl
PCB-138	2,2',3,4,4',5'-hexachlorobiphenyl
PCB-153	2,2',4,4',5,5'-hexachlorobiphenyl
PCB-180	2,2',3,4,4',5,5'-heptachlorobiphenyl

Treatment of Analytical Values below the LOD

37. In this study, analytical results of food samples were given in product fresh weight (μg/kg fw or ng/g fw) in order to conduct dietary exposure. Besides, data (i.e. concentrations of indicator PCBs in each composite sample as well as dietary exposure estimations) were treated by the lower bound (LB) and upper bound (UB) approach. That is, at the LB, results below the LOD were replaced by zero whilst at the UB, results below the LOD were replaced

by the value reported as the LOD[32]. This approach compares the two extreme scenarios, based on the consideration that the true value for results <LOD may actually be any value between zero and the LOD. The LB scenario assumes that the chemical is absent; therefore, to results reported as < LOD a value of zero is assigned. The UB scenario assumes that the chemical is present at the level of the LOD; thus, to results reported as < LOD a value of the corresponding LOD is assigned.

RESULTS AND DISCUSSION

Sum of the Six Indicator NDL-PCBs in Foods

38. A total of 284 composite samples on four occasions between March 2010 and February 2011 was tested for the six indicator NDL-PCBs. The sum of the six indicator NDL-PCBs (Σ_6PCBs) in different food groups are summarised in Table 3 and the results of 71 food items are shown in Appendix 1. Of the 284 composite samples analysed, 59 composite samples (21%) were detected with at least one indicator PCB congener. Among these 59 composite samples, majority (i.e. 50 samples) belonged to the food group "fish and seafood and their products". Other items with detected indicator NDL-PCBs included beef, butter, ice-cream and chocolate.

39. As regards the concentration of Σ_6PCBs in different food groups, "fish and seafood and their products" contained the highest levels of Σ_6PCBs, followed by "fats and oils" and "meat, poultry and game and their products". The mean concentration of "fish and seafood and their products" ranged from

0.89 to 0.93 μg/kg (LB-UB), "fats and oils" from 0.17 to 0.22 μg/kg (LB-UB) and "meat, poultry and game and their products" from 0.01 to 0.07 μg/kg (LB-UB) (Table 3).

Table 3. Estimated Σ_6PCBs in Food Groups. (Mean concentrations (μg/kg) are presented as lower bound (LB) and upper bound (UB).)

Food group	No. of composite samples	% of samples < LOD*	Mean (μg/kg fresh weight) [range]	
			LB #	UB #
Cereals and their products	48		**< LOD in all samples**	
Meat, poultry and game and their products	48	94	0.01 [0.00 – 0.19]	0.07 [0.06 – 0.23]
Eggs and their products	12		**< LOD in all samples**	
Fish and seafood and their products	76	34	0.89 [0.00 – 7.4]	0.93 [0.06 – 7.4]
Dairy products	20	95	0.01 [0.00 – 0.11]	0.06 [0.06 – 0.15]
Fats and oils	8	50	0.17 [0.00 – 0.46]	0.22 [0.06 – 0.50]
Beverages, non-alcoholic	12		**< LOD in all samples**	
Mixed dishes	44		**< LOD in all samples**	
Others@	16	94	0.00 [0.00 – 0.10]	0.07 [0.06 – 0.14]
Total	284	79		

* LOD: limit of detection; values rounded off to whole figure.
\# Values < 0.1 μg/kg rounded off to one significant figure while values ≥ 0.1 μg/kg rounded off to two significant figures.
@ Others include fried potato, potato chips, chocolate and oyster sauce.

40. Under the food group "fish and seafood and their products", the concentration of Σ_6PCBs ranged from 0.00 to 7.4 μg/kg at the LB and ranged from 0.06 to 7.4 μg/kg at the UB (Table 3). When compared with the levels of Σ_6PCBs in the food group "Muscle meat fish" reported by EFSA (Table 1), the levels found in this study were lower[16, 17].

41. As regards the concentration level of individual items, salmon fish was found to contain the highest level (4.4 – 6.3 μg/kg; mean: 5.7 μg/kg at the

UB), followed by oyster (2.6 – 4.5 μg/kg; mean: 3.4 μg/kg at the UB), mandarin fish (0.67 – 7.4 μg/kg; mean: 3.1 μg/kg at the UB), yellow croaker fish (1.3 – 2.2 μg/kg; mean: 1.7 μg/kg at the UB) and pomfret fish (0.90 – 1.6 μg/kg; mean: 1.2 μg/kg at the UB). In fact, these food items were the top five items with the highest levels of Σ_6PCBs detected in this study (Appendix 1). Due to their lipophilic nature, PCBs, especially the highly chlorinated congeners, are known to accumulate in lipid-rich tissues. This explains why fish like salmon, yellow croaker fish and pomfret fish with relatively high fat contents (ranging from 7.4 – 20%) have higher levels of Σ_6PCBs (Appendix 2).

42. Butter was the only item under "fats and oils" with detected indicator PCBs (0.22 – 0.50 μg/kg, mean: 0.38 μg/kg at the UB) while beef was the only item under "meat, poultry and their products" with detected indicator PCBs (0.06 – 0.23 μg/kg, mean: 0.16 μg/kg at the UB). In general, the contamination levels of Σ_6PCBs in butter and beef in this study were found to be lower than the results reported in other studies (Table 1)[16, 19].

Indicator PCB Congener Profiles

43. In terms of indicator PCB congener profiles, the most prevalent congeners in this study were PCB-138 and PCB-153, both with a detection rate of 21% (i.e. 59 of 284 composite samples). The second and third commonly detected congeners were PCB-101 and PCB-180, detected in 17% and 11% of the analysed composite samples respectively. The detection rates of PCB-28 and PCB-52 were the lowest, with detection rates below 6%. In general, these

results were in line with findings reported in other similar studies[2, 10, 18, 33]. However, variations of contribution by each congener were observed among different food groups. Details of the PCB congener profiles for individual composite samples can be found in Appendix 2.

44. All the six indicator congeners were detected in the food group "fish and seafood and their products". However, in the food groups "meat, poultry and game and their products", "dairy products" and "fats and oils", only PCB-153 and PCB-138 were detected. The congener profile for the food group "fish and seafood and their products" is shown in Figure 3 which also shows that the mean concentration of PCB-153 was the highest in "fish and seafood and their products".

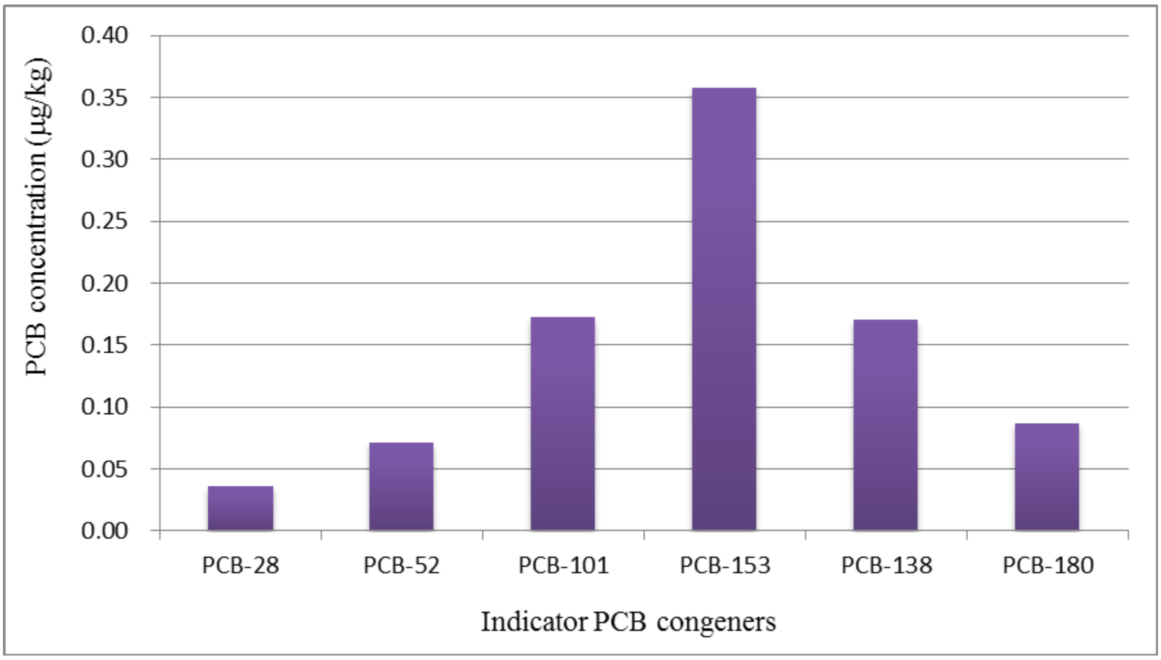

Figure 3. Mean (Upper Bound) PCB Congener Profile (µg/kg fw) in "Fish and Seafood and their Products".

Dietary Exposure to the Sum of Six Indicator NDL-PCBs

45. The LB and UB dietary exposure estimates to Σ_6PCBs for the average and high consumers of the local population and their contribution to the HBGV are shown in Table 4.

46. Dietary exposure to Σ_6PCBs in the adult population, using LB and UB concentrations, was estimated to range from 0.68 to 1.38 ng/kg bw/day (i.e. 6.8 – 13.8% of the HBGV) and from 3.08 to 3.84 ng/kg bw/day (i.e. 30.8 – 38.4% of the HBGV) for the average and high consumers of the population respectively.

Table 4. Comparison between HBGV and Dietary Exposures to the Sum of Six Indicator NDL-PCBs for the Average and High Consumers of the Population.

HBGV (ng/kg bw/day)	Dietary Exposure (ng/kg bw/day) (% of HBGV)*			
	Lower Bound		Upper Bound	
	Average	High Consumer#	Average	High Consumer#
10	0.68 (6.8%)	3.08 (30.8%)	1.38 (13.8%)	3.84 (38.4%)

* Values rounded off to two decimal places for dietary exposure and one decimal place for % of HBGV.

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

47. Further analysis of dietary exposures of the individual age-gender population subgroups was performed and the results are shown in Figures 4 and 5 and Appendix 3. The highest dietary exposure among all age-gender population subgroups was found in females aged 30 – 39 (0.79 – 1.54 ng/kg

bw/day (LB-UB) for the average of the population; 3.35 – 4.56 ng/kg bw/day (LB-UB) for the high consumers.

48. All in all, among the various age-gender population subgroups, all the estimated dietary exposures of the average and high consumers of the population were below the HBGV (< 46%). Therefore, they were unlikely to experience undesirable health effects arising from NDL-PCBs.

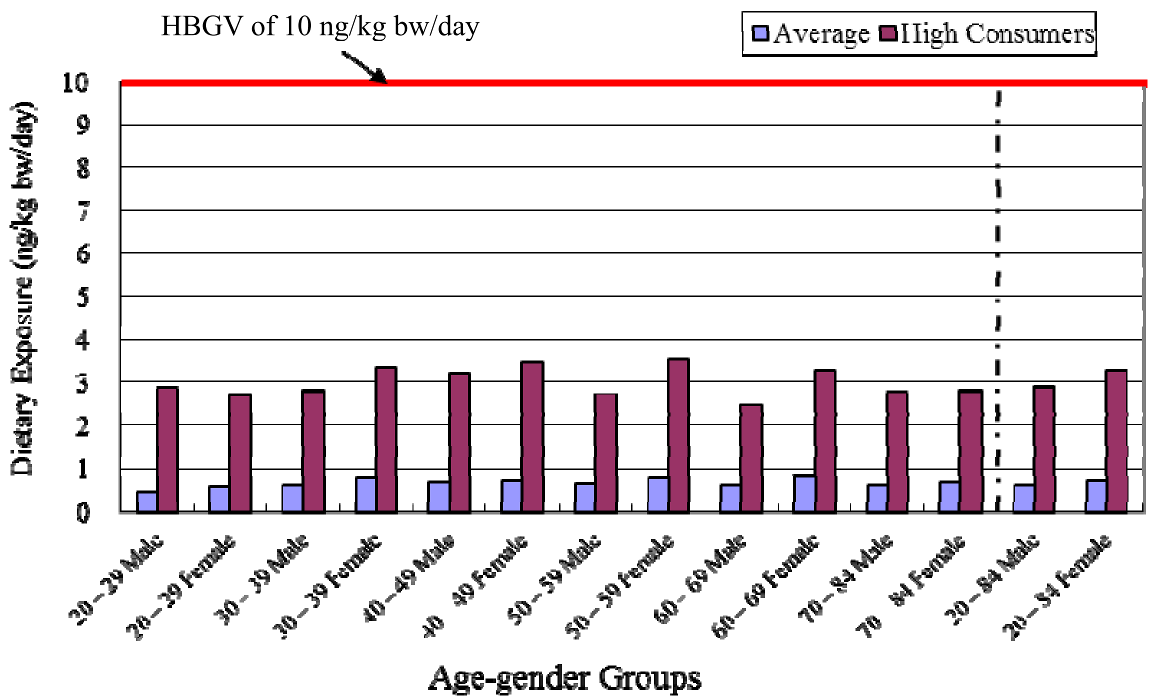

Figure 4. Dietary Exposures (Lower Bound) to the Sum of Six Indicator NDL-PCBs for the Average and High Consumers of the Individual Age-gender Groups.

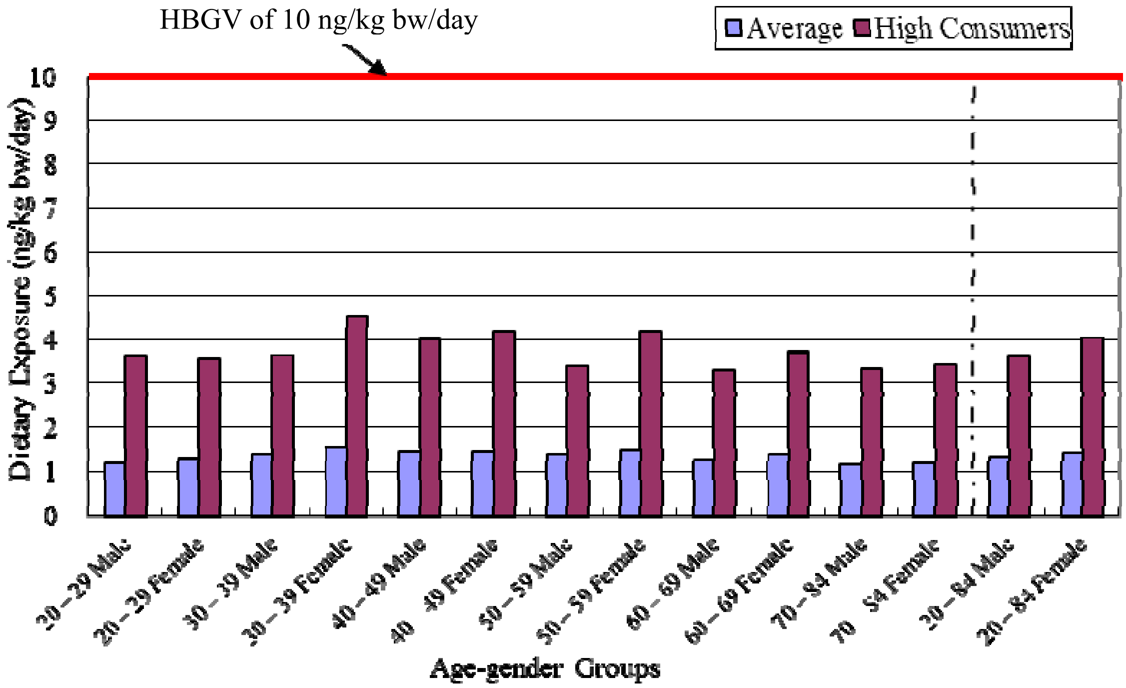

Figure 5. Dietary Exposures (Upper Bound) to the Sum of Six Indicator NDL-PCBs for the Average and High Consumers of the Individual Age-gender Groups.

Major Food Contributors

49. Relative contribution of each food group to overall LB mean Σ_6PCBs dietary exposure for an average of the population is shown in Figure 6. As suggested in the EFSA scientific paper, the LB is considered to be a better approach for the discussion of food contributors and the reflection of the actual food group contribution to overall exposure of a contaminant (i.e. Σ_6PCBs in this study) since it is not influenced by the high numbers of samples below the LOD in some food groups[34].

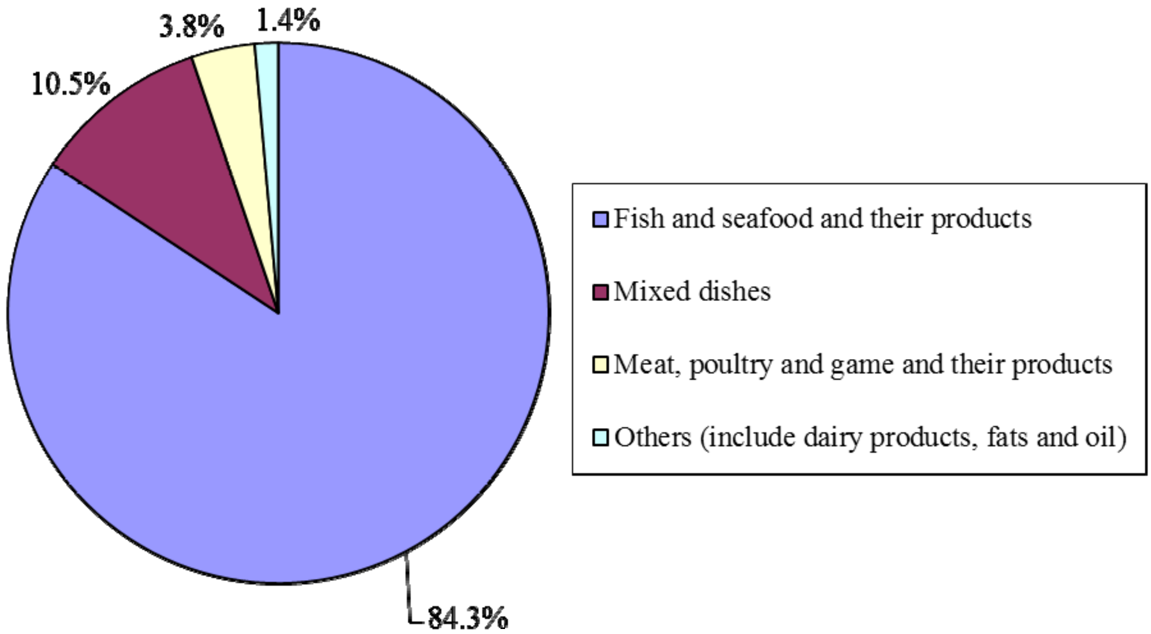

Figure 6. Relative Contribution of Each Food Group to Overall Lower Bound Mean NDL-PCBs Exposure in Local Adult Population.

50. In this study, the major contributor to the exposure of Σ_6PCBs was "fish and seafood and their products" which contributed up to 84.3% (i.e. 0.57 ng/kg bw/day at the LB) of the total exposure. The relatively high exposure contribution from "fish and seafood and their products" in the Hong Kong adult population was likely due to the relatively low contamination levels of NDL-PCBs detected in other food groups. In fact, "fish and seafood products" was also reported as the major contributor to the overall exposures in other exposure studies [2, 17, 18, 19, 33, 35, 36]. The average dietary exposures, contributed by the fish group, to Σ_6PCBs in the European adult populations ranged from 0.78 to 5.72 ng/kg bw/day (UB)* while it was 0.61 ng/kg bw/day (UB) in the local population[16].

* Values calculated from the dietary exposure to Σ_6PCBs and the relative contribution (%) of the fish group to the average exposure of the adult population of the original data source.

51. The food group “Mixed dishes”, even though all samples were not detected with NDL-PCBs, still contributed to 10.5% of the total exposure and was the second major contributor. The reason behind was that “mixed dishes” included food items such as fish sashimi, dim sum and burgers and these items contained fish, shrimps and/or beef as ingredients. The levels of these items were assigned through the mapping with the analysed samples. For instance, the level in salmon sashimi was assigned from that of salmon fish analysed.

52. The food groups “meat, poultry and game and their products”, “fat and oil” and “dairy products” altogether contributed less than 6% to the total exposure.

53. Across the whole diet, about 50% of the total exposure were contributed by the following four fish species, salmon (cooked salmon and salmon sashimi: 19.9%), mandarin fish (14.7%), pomfret fish (8.5%) and yellow croaker (7.5%).

Comparison with Findings from Other Places

54. Dietary exposure estimations of NDL-PCBs have been studied in different countries, especially the European countries. In 2012, EFSA released an update of the monitoring of levels of dioxins and PCBs in food and feed[16]. Using the data provided in the report, Table 5 summarises the exposures to Σ_6PCBs of some European adult populations and compares the exposures of these populations with that of the Hong Kong adult population.

55. It can be seen that the dietary exposure estimates, for both the average and high consumers of the local population, in our study compare favourably to the exposure estimates obtained from other countries. However, it should be noted that direct comparison of the data has to be done with caution due to considerable differences in methodology such as selection of food types, sampling strategies, approaches of capturing consumption data, analytical methods, approaches of treating analytical results below detection limits (lower, medium, and upper bounds).

Table 5. Dietary Exposure to the Sum of the Six Indicator NDL-PCBs of Adults in Different Places including Hong Kong.

Places	Dietary exposure (ng/kg bw/day) (LB – UB)	
	Average	High Consumer
Hong Kong*	0.68 – 1.38	3.08 – 3.84
Netherlands#	3.8 – 4.5	8.1 – 9.5
United Kingdom#	4.1 – 5.3	9.8 – 11.7
Germany#	4.3 – 5.3	14.4 – 15.9
Belgium#	4.6 – 5.4	14.7 – 15.3
Denmark#	5.4 – 6.3	10.8 – 11.8
Sweden#	5.7 – 6.0	12.8 – 13.1
France#	6.7 – 8.0	14.3 –15.9

*exposure data of adults aged 20 to 84 years from current study

#exposure data of adults aged 18 to 65 years during 2008-2010[16]

Limitations of the Study

56. With limited laboratory resource, a limited number of samples were analysed and only TDS food items likely to contain NDL-PCBs, which were mainly foods of animal origin and their products, were selected for analysis. For instance, not all fish species with high fat content and products of plant origin were included in the study. According to the literature, products of plant origin would represent around 4-5% of the total exposure to NDL-PCBs[16]. This could have led to an underestimation of the real exposure of the local adult population. Other limitations were described in the report on methodology of the 1st HKTDS[31].

CONCLUSIONS AND RECOMMENDATIONS

57. The dietary exposures to Σ_6PCBs of the average local population ranged from 0.68 to 1.38 ng/kg bw/day (6.8 to 13.8% of the HBGV). For high consumers of the population, the dietary exposures to Σ_6PCBs ranged from 3.08 to 3.84 ng/kg bw/day (30.8 to 38.4% of the HBGV). Therefore, the local population was unlikely to experience undesirable health effects of NDL-PCBs.

58. The most contaminated food group was the "fish and seafood and their products" and the top five items with the highest level of Σ_6PCBs detected were salmon fish, oyster, mandarin fish, yellow croaker fish and pomfret fish. Since "fish and seafood and their products" was found to be the major contributor to the total exposure of NDL-PCBs in the local population, effort

should be made to keep in view the levels of contamination of NDL-PCBs in fish and seafood worldwide and appropriate actions should be taken where necessary.

59. Prevention and reduction of human exposure should be done through source-directed measures. International efforts in the elimination of PCBs and their subsequent contaminations of food are essential to reduce the dietary exposure to PCBs of the population.

60. By virtue of the dietary exposure to Σ_6PCBs in adults alone, the findings of the present study did not provide sufficient justifications to warrant changes to the basic dietary advice on healthy eating. The public is advised to maintain a balanced and varied diet which includes a wide variety of fruit and vegetables so as to avoid excessive exposure to any contaminants 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.

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Appendix 1

Sum of 6 indicator PCBs (μg/kg) in food groups and food items.

Food Item	No. of composite samples	% of composite sample < LOD	Σ_6PCBs Mean (μg/kg) [range]			
			Lower bound		Upper bound	
Cereals and their products:	**48**	**100**	**0.00**	**–**	**0.06**	**–**
Noodles, Chinese or Japanese style			0.00	–	0.06	–
Pasta, Western style			0.00	–	0.06	–
Instant noodles			0.00	–	0.06	–
Bread, plain			0.00	–	0.06	–
Bread, raisin			0.00	–	0.06	–
"Pineapple" bun			0.00	–	0.06	–
Sausage/ham/luncheon meat bun			0.00	–	0.06	–
Biscuits			0.00	–	0.06	–
Cakes			0.00	–	0.06	–
Pastries			0.00	–	0.06	–
Pastries, Chinese			0.00	–	0.06	–
Deep-fried dough			0.00	–	0.06	–
Meat, poultry and game and their products:	**48**	**94**	**0.01**	**[0.00 – 0.19]**	**0.07**	**[0.06 – 0.23]**
Beef			0.12	[0.00 – 0.19]	0.16	[0.06 – 0.23]
Mutton			0.00	–	0.06	–
Pork			0.00	–	0.06	–
Ham			0.00	–	0.06	–
Luncheon meat			0.00	–	0.06	–
Barbecued pork			0.00	–	0.06	–
Roasted pork			0.00	–	0.06	–
Pig liver			0.00	–	0.06	–
Chicken meat			0.00	–	0.06	–
Chicken, soy sauce			0.00	–	0.06	–
Roasted duck/goose			0.00	–	0.06	–
Meat sausage			0.00	–	0.06	–
Eggs and their products:	**12**	**100**	**0.00**	**–**	**0.06**	**–**
Egg, chicken			0.00	–	0.06	–
Egg, lime preserved			0.00	–	0.06	–
Egg, salted			0.00	–	0.06	–
Fish and seafood and their products:	**76**	**34**	**0.89**	**[0.00 – 7.4]**	**0.93**	**[0.06 – 7.4]**
Fish, Big head			0.20	[0.10 – 0.41]	0.23	[0.13 – 0.44]
Fish, Mandarin fish			3.1	[0.67 – 7.4]	3.1	[0.67 – 7.4]
Fish, Grass carp			0.00	–	0.06	–
Fish, Golden thread			0.32	[0.28 – 0.35]	0.34	[0.30 – 0.37]

Food Item	No. of composite samples	% of composite sample < LOD	Σ$_6$PCBs Mean (μg/kg) [range]			
			Lower bound		Upper bound	
Fish, Grouper			0.53	[0.39 – 0.73]	0.55	[0.41 – 0.75]
Fish, Horse head			0.27	[0.22 – 0.29]	0.29	[0.24 – 0.31]
Fish, Pomfret			1.2	[0.88 – 1.5]	1.2	[0.90 – 1.6]
Fish, Sole			0.00	–	0.06	–
Fish, Tuna			0.03	[0.00 – 0.13]	0.08	[0.06 – 0.15]
Fish, Grey mullet			0.20	[0.17 – 0.23]	0.23	[0.20 – 0.26]
Fish, Salmon			5.7	[4.4 – 6.3]	5.7	[4.4 – 6.3]
Fish, Yellow croaker			1.7	[1.3 – 2.2]	1.7	[1.3 – 2.2]
Fish, Dace, minced			0.12	[0.10 – 0.13]	0.15	[0.13 – 0.16]
Fish ball/fish cake			0.00	–	0.06	–
Shrimp/ Prawn			0.02	[0.00 – 0.09]	0.08	[0.06 – 0.12]
Crab			0.35	[0.10 – 0.90]	0.39	[0.14 – 0.93]
Oyster			3.4	[2.6 – 4.5]	3.4	[2.6 – 4.5]
Scallop			0.00	–	0.06	–
Squid			0.00	–	0.06	–
Dairy products:	**20**	**95**	**0.01**	**[0.00 – 0.11]**	**0.06**	**[0.06 – 0.15]**
Milk, whole			0.00	–	0.06	–
Milk, skim			0.00	–	0.06	–
Cheese			0.00	–	0.06	–
Yoghurt			0.00	–	0.06	–
Ice-cream			0.03	[0.00 – 0.11]	0.08	[0.06 – 0.15]
Fats and oils:	**8**	**50**	**0.17**	**[0.00 – 0.46]**	**0.22**	**[0.06 – 0.50]**
Butter			0.34	[0.18 – 0.46]	0.38	[0.22 – 0.50]
Oil, vegetable			0.00	–	0.06	–
Beverages, non-alcoholic:	**12**	**100**	**0.00**	**–**	**0.06**	**–**
Tea, Milk tea			0.00	–	0.06	–
Coffee			0.00	–	0.06	–
Malt drink			0.00	–	0.06	–
Mixed dishes:	**44**	**100**	**0.00**	**–**	**0.06**	**–**
Siu Mai			0.00	–	0.06	–
Dumpling, steamed			0.00	–	0.06	–
Dumpling, pan-fried			0.00	–	0.06	–
Dumpling, including wonton			0.00	–	0.06	–
Steamed barbecued pork bun			0.00	–	0.06	–
Turnip cake			0.00	–	0.06	–
Steamed minced beef ball			0.00	–	0.06	–
Glutinous rice dumpling			0.00	–	0.06	–
Steamed rice-rolls with filling			0.00	–	0.06	–
Chinese soup			0.00	–	0.06	–
Hamburger			0.00	–	0.06	–

Food Item	**No. of composite samples**	**% of composite sample < LOD**	**Σ_6PCBs Mean (μg/kg) [range]**			
			Lower bound		**Upper bound**	
<u>Others</u>	**16**	**94**	**0.00**	**[0.00 – 0.10]**	**0.07**	**[0.06 – 0.14]**
Potato, fried			0.00	–	0.06	–
Potato chips			0.00	–	0.06	–
Chocolate			0.03	[0.00 – 0.10]	0.08	[0.06 – 0.14]
Oyster sauce			0.00	–	0.06	–

Appendix 2

Summary of indicator PCB congeners (μg/kg) among food samples with detected results and their fat contents

Composite Sample	PCB-28 (μg/kg)	PCB-52 (μg/kg)	PCB-101 (μg/kg)	PCB-138 (μg/kg)	PCB-153 (μg/kg)	PCB-180 (μg/kg)	Fat content (%)
Meat, poultry and game and their products							
Beef	ND	ND	ND	0.06	0.13	ND	9.9
Beef	ND	ND	ND	0.02	0.07	ND	6.4
Beef	ND	ND	ND	0.06	0.13	ND	8.4
Fish and seafood and their products							
Fish, big head	ND	ND	0.13	0.12	0.16	ND	5.0
Fish, big head	ND	ND	0.04	0.03	0.06	ND	2.7
Fish, big head	ND	ND	0.03	0.03	0.04	ND	5.8
Fish, big head	ND	ND	0.05	0.05	0.07	ND	3.7
Fish, Mandarin fish	0.43	0.36	0.45	0.48	1.1	0.61	5.4
Fish, Mandarin fish	0.12	0.09	0.15	0.15	0.16	0.09	2.9
Fish, Mandarin fish	0.11	0.09	0.12	0.12	0.15	0.08	3.3
Fish, Mandarin fish	0.87	0.85	1.5	1.5	1.8	0.84	4.4
Fish, Golden thread	ND	ND	0.04	0.09	0.15	0.07	3.4
Fish, Golden thread	ND	ND	0.03	0.07	0.12	0.06	4.1
Fish, Golden thread	ND	ND	0.04	0.08	0.13	0.06	5.5
Fish, Golden thread	ND	ND	0.04	0.08	0.16	0.06	5.5
Fish, Grouper	ND	ND	0.07	0.14	0.26	0.11	3.1
Fish, Grouper	ND	ND	0.05	0.09	0.18	0.07	3.0
Fish, Grouper	ND	ND	0.05	0.10	0.19	0.08	3.7
Fish, Grouper	ND	ND	0.11	0.19	0.28	0.15	4.2
Fish, Horse head	ND	ND	0.03	0.05	0.11	0.03	2.9
Fish, Horse head	ND	ND	0.03	0.07	0.14	0.04	2.5
Fish, Horse head	ND	ND	0.04	0.08	0.13	0.04	5.1
Fish, Horse head	ND	ND	0.03	0.07	0.14	0.04	3.1
Fish, Pomfret	ND	ND	0.24	0.26	0.54	0.17	7.4
Fish, Pomfret	ND	ND	0.20	0.23	0.47	0.15	11
Fish, Pomfret	ND	ND	0.30	0.31	0.75	0.18	13
Fish, Pomfret	ND	ND	0.18	0.20	0.41	0.09	14
Fish, Tuna	ND	ND	0.01	0.04	0.06	0.02	0.6
Fish, Grey mullet	ND	ND	0.07	0.07	0.09	ND	9.8
Fish, Grey mullet	ND	ND	0.07	0.06	0.08	ND	12
Fish, Grey mullet	ND	ND	0.06	0.04	0.07	ND	7.5
Fish, Grey mullet	ND	ND	0.05	0.05	0.07	ND	8.7
Fish, Salmon	0.20	0.47	1.3	1.2	2.4	0.69	20
Fish, Salmon	0.20	0.58	1.2	1.1	2.3	0.73	16
Fish, Salmon	0.19	0.59	1.1	1.1	2.3	0.70	16
Fish, Salmon	0.14	0.36	1.0	0.87	1.5	0.52	16

Composite Sample	PCB-28 (µg/kg)	PCB-52 (µg/kg)	PCB-101 (µg/kg)	PCB-138 (µg/kg)	PCB-153 (µg/kg)	PCB-180 (µg/kg)	Fat content (%)
Fish, Yellow croaker	0.11	0.13	0.23	0.28	0.48	0.15	15
Fish, Yellow croaker	0.13	0.19	0.32	0.51	0.81	0.27	15
Fish, Yellow croaker	0.15	0.16	0.33	0.36	0.50	0.19	16
Fish, Yellow croaker	0.11	0.12	0.25	0.28	0.41	0.14	13
Fish, Dace, minced	ND	ND	0.04	0.03	0.05	ND	4.0
Fish, Dace, minced	ND	ND	0.04	0.04	0.05	ND	1.9
Fish, Dace, minced	ND	ND	0.04	0.04	0.05	ND	4.5
Fish, Dace, minced	ND	ND	0.03	0.03	0.04	ND	3.8
Shrimp/ Prawn	ND	ND	0.01	0.03	0.05	ND	2.0
Crab	ND	ND	ND	0.22	0.53	0.15	2.1
Crab	ND	ND	ND	0.04	0.06	ND	1.6
Crab	ND	ND	0.04	0.08	0.17	ND	3.9
Crab	ND	ND	ND	0.03	0.08	ND	3.0
Oyster	ND	0.44	1.1	0.61	2.3	ND	4.1
Oyster	ND	0.39	0.76	0.46	1.8	ND	3.7
Oyster	ND	0.23	0.43	0.32	1.6	ND	5.5
Oyster	ND	0.36	0.62	0.43	1.7	ND	3.6
Dairy products							
Ice-cream	ND	ND	ND	0.04	0.07	ND	12
Fats and oils							
Butter	ND	ND	ND	0.18	0.28	ND	81
Butter	ND	ND	ND	0.08	0.10	ND	81
Butter	ND	ND	ND	0.20	0.25	ND	81
Butter	ND	ND	ND	0.13	0.15	ND	81
Others							
Chocolate	ND	ND	ND	0.04	0.06	ND	31
Number of samples with detected congener (%)	12 (4%)	16 (6%)	47 (17%)	59 (21%)	59 (21%)	30 (11%)	

A total of 284 composite samples were tested for six indicator NDL-PCBs.
ND denotes non-detected

Appendix 3

Lower Bound and Upper Bound Dietary Exposure to the sum of the six Indicator NDL-PCBs (Σ_6PCB; 28, 52, 101, 138, 153 and 180) by Age-Gender Group (Average and High Consumer of the Population)

Age-gender Groups	Dietary Exposure (ng/kg bw/day) (% of HBGV)	
	Average	High Consumer*
Male aged 20 – 29	0.48 (4.8%) – 1.19 (11.9%)	2.88 (28.8%) – 3.63 (36.3%)
Female aged 20 – 29	0.59 (5.9%) – 1.30 (13.0%)	2.73 (27.3%) – 3.56 (35.6%)
Male aged 30 – 39	0.63 (6.3%) – 1.38 (13.8%)	2.81 (28.1%) – 3.65 (36.5%)
Female aged 30 – 39	0.79 (7.9%) – 1.54 (15.4%)	3.35 (33.5%) – 4.56 (45.6%)
Male aged 40 – 49	0.69 (6.9%) – 1.44 (14.4%)	3.22 (32.2%) – 4.00 (40.0%)
Female aged 40 – 49	0.71 (7.1%) – 1.45 (14.5%)	3.46 (34.6%) – 4.21 (42.1%)
Male aged 50 – 59	0.66 (6.6%) – 1.40 (14.0%)	2.74 (27.4%) – 3.40 (34.0%)
Female aged 50 – 59	0.80 (8.0%) – 1.47 (14.7%)	3.53 (35.3%) – 4.19 (41.9%)
Male aged 60 – 69	0.63 (6.3%) – 1.24 (12.4%)	2.46 (24.6%) – 3.32 (33.2%)
Female aged 60 – 69	0.82 (8.2%) – 1.37 (13.7%)	3.28 (32.8%) – 3.74 (37.4%)
Male aged 70 – 84	0.62 (6.2%) – 1.15 (11.5%)	2.79 (27.9%) – 3.35 (33.5%)
Female aged 70 – 84	0.68 (6.8%) – 1.21 (12.1%)	2.79 (27.9%) – 3.43 (34.3%)
Male aged 20 – 84	0.62 (6.2%) – 1.33 (13.3%)	2.89 (28.9%) – 3.62 (36.2%)
Female aged 20 – 84	0.73 (7.3%) – 1.42 (14.2%)	3.28 (32.8%) – 4.04 (40.4%)
Adult aged 20 – 84	0.68 (6.8%) – 1.38 (13.8%)	3.08 (30.8%) – 3.84 (38.4%)

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