Report of the Second Hong Kong Total Diet Study: Perchlorate

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Contents

Executive Summary
The Second Hong Kong Total Diet Study:
Perchlorate

The Centre for Food Safety is conducting the Second Hong Kong Total Diet Study to estimate the latest dietary exposure of the Hong Kong population and various population subgroups to a range of chemical substances of potential food safety concern, and in turn assess the associated health risks. This report presents the dietary exposure assessment of perchlorate in food.

2. Perchlorate and its salts occur naturally in the environment and are also environmental contaminants arising from human activities. Perchlorate has been reported to occur in a wide range of foods including vegetables, fruits, milk and dairy products. Perchlorate has low acute oral toxicity in laboratory animals and the International Agency for Research on Cancer has not classified perchlorate as a carcinogen. Exposure to perchlorate at sufficiently high doses can interfere with thyroid function by reducing uptake of iodide by the thyroid gland, leading to hypothyroidism.

3. The Joint Food and Agriculture Organization of the United Nations (FAO) / World Health Organization (WHO) Expert Committee on Food Additives (JECFA) allocated a Provisional Maximum Tolerable Daily Intake (PMTDI) of 10 μg/kg body weight (bw) for perchlorate.

Results

4. Out of 187 tested TDS food items, 144 (77%) were found to contain detectable levels of perchlorate. Amongst these food items, pumpkin had the highest mean concentration (upper bound: 310 μg/kg), followed by Chinese amaranth (120 μg/kg) and Chinese parsley (67 μg/kg).

5. For the adult population (age 18+), the estimated dietary exposure of the average consumers was 0.16-0.17 μg/kg bw/day (lower bound-upper bound (LB-UB)), which accounted for 1.6-1.7% (LB-UB) of JECFA's PMTDI allocated for perchlorate. Among the high consumers (90^{th} percentile) of the adult population, the estimated dietary exposure was 0.26-0.27 μg/kg bw/day (LB-UB), which accounted for 2.6-2.7% (LB-UB) of the PMTDI. For the younger population (aged 6-17), the estimated dietary exposure of the average consumers was 0.21-0.23 μg/kg bw/day (LB-UB), which accounted for 2.1-2.3% (LB-UB) of the PMTDI. Among the high consumers of the younger population, the estimated dietary exposure was 0.36-0.38 μg/kg bw/day (LB-UB), which accounted for 3.6-3.8% (LB-UB) of the PMTDI.

Conclusion and Recommendations

6. The exposure estimates for the Hong Kong populations from this study do not pose a health risk associated with the dietary intake of perchlorate. Although perchlorate has been found in a wide range of food, the estimated dietary exposures to perchlorate for both average and high consumers among local adult and younger populations remain well below the health-based guidance values established by the international organisation.

7. To minimise the risks associated with exposure to perchlorate, the public is encouraged to maintain a balanced and varied diet to support overall health and

reduce the risk of exposure to contaminants, including perchlorate, from a limited range of food.

Chapter 1
Background

1.1 Total Diet Study (TDS) is a tool for estimating population chronic dietary exposure to a wide range of chemicals across the whole diet within one study, which is an internationally well-recognised approach for quantifying the presence of chemical substances in the food supply and for estimating dietary exposure. The Food and Agriculture Organization of the United Nations (FAO) and the World Health Organization (WHO) have been promoting and supporting the TDS approach since the 1970's. The Centre for Food Safety (CFS) conducted the First Hong Kong Total Diet Study (1st HKTDS) in 2010-2014.[1]

Introduction of the Second Hong Kong Total Diet Study (2nd HKTDS)

1.2 With the availability of an updated set of food consumption data as obtained from the Second Population-based Food Consumption Survey (2nd FCS) (2018-2020), the CFS has taken the opportunity to conduct the Second Hong Kong Total Diet Study (2nd HKTDS). The 2nd HKTDS aims to estimate the latest dietary exposure of the Hong Kong population and various population subgroups to a range of chemical substances of potential food safety concern, and in turn assess the associated health risks.

1.3 Similar to the 1st HKTDS, the 2nd HKTDS comprises selection of chemical substances, development of a TDS food list, food sampling, sample preparation, laboratory analysis, dietary exposure estimation and publication of results. The 2nd HKTDS covers the majority of foods normally consumed by the Hong Kong population, with laboratory analysis conducted for over 130 chemical substances in total, covering mainly contaminants and pesticide residues in food and for the first time, some food additives of local concern.

Perchlorate

Previous studies conducted by the CFS

1.4 The CFS conducted a Risk Assessment Study on "Perchlorate in Tea and Tea Beverages" in 2017-18, in which different types of dried tea leaves and tea beverages were collected and analysed in "as consumed" status for their perchlorate concentrations. The study revealed that perchlorate was present in the majority (96%) of samples. Mean levels of perchlorate from samples of "Dried tea leaves" ranged from 50 µg/kg to 300 µg/kg while samples of "Tea beverages" ranged from 0.59 µg/L to 3.4 µg/L. The estimated dietary exposure to perchlorate due to consumption of tea and tea beverages for local average consumers, high consumers and individual age-gender population subgroups were all below 1% of the provisional maximum tolerable daily intake (PMTDI) established by the Joint FAO/WHO Expert Committee on Food Additives (JECFA) in 2010. The study concluded that adverse health outcome due to perchlorate exposure of the Hong Kong adult population from dried tea leaves and tea beverages commonly available in the local market was remote.[2]

1.5 Perchlorate was not covered in the 1st HKTDS. It was selected as one of the testing parameters for the 2nd HKTDS to assess the dietary exposure to perchlorate of the Hong Kong population in light of the attention that perchlorate has received abroad in earlier years, and monitor its potential health risks in a more comprehensive manner as previous dietary exposure assessments in Hong Kong were limited to dried tea leaves and tea beverages. Moreover, the inclusion of perchlorate in the 2nd HKTDS also aligns with international practices, as food safety authorities such as the U.S. Food and Drug Administration (FDA) also include perchlorate in their TDS.

Sources of perchlorate exposure

1.6 Perchlorate is an inorganic ion comprising a chlorine atom bound to four oxygen atoms. It is very stable in water, and its salts are highly soluble in water.[3]

1.7 Perchlorate occurs naturally in the environment and can be formed in the atmosphere, eventually precipitating into soil and groundwater.[3] It is also an environmental contaminant resulting from the use of perchlorate-containing fertilizers and from industrial activities such as the manufacturing and processing of rocket propellants, explosives, fireworks, and airbag inflators.[3,4,5] Additionally, water disinfection using chlorine-based biocidal products may oxidise into perchlorate, serving as another potential source of contamination.[6]

1.8 Perchlorate has been widely detected in water, soil, dust and the atmosphere resulting from both naturally and anthropogenic sources.[4,5,7,8,9] In the environment, perchlorate can quickly diffuse in groundwater and surface water, leading to its widespread presence.[7] Plants that grow on contaminated soil or are irrigated with contaminated water can accumulate perchlorate in the fruit and vegetables.[7,8]. It may also be transferred to animals and their milk through the consumption of perchlorate-contaminated feed or water.[10] Ingestion of food and water is the primary source of human exposure to perchlorate.[3,4,5,7,11,12]

Perchlorate in foods

1.9 In overseas studies, perchlorate has been identified in a wide range of foods including vegetables, fruits, milk and dairy products, rice, infant formula, fish and fish products, tea leaves and herbs for preparation of infusions, juices and alcoholic beverages.[3,6,8,10] JECFA reviewed the occurrence data of perchlorate in foods reported from Asia and North America in 2010. Mean perchlorate levels in vegetables and fruits were in the range of 4.8-110 μg/kg and 0.5-28 μg/kg

respectively.[3] In 2024, the European Food Safety Authority (EFSA) evaluated the occurrence data on perchlorate in food submitted by member states between 2016 and 2022.[9] Mean perchlorate levels (LB-UB) in vegetables and vegetable products, and fruit and fruit products were in the range of 10.23-15.15 μg/kg and 1.05-6.72 μg/kg respectively.[9]

1.10 Previous exposure assessments carried out by the JECFA, FDA and EFSA have shown that vegetables, fruits, milk and their products are important contributors to perchlorate exposure.[3,6,8,9,11,12]

Health effects of perchlorate

1.11 The key toxicological issue for perchlorate is its ability to competitively inhibit uptake of iodide by the thyroid gland and thus the potential of causing hypothyroidism.[3,4]

1.12 In humans, iodide is transported into thyroid follicular cells against a concentration gradient by the sodium iodide symporter (NIS) molecule. Once gaining entry to the thyroid follicular cells, iodide is subsequently oxidised to iodine which is essential for the production of thyroid hormones for normal growth and metabolism. Since perchlorate anion is similar to the iodide ion in its size, shape and charge, it competes with iodide at the NIS and inhibits the uptake of iodide. Such inhibition by perchlorate reduces the amount of iodide available for the synthesis of thyroid hormones, resulting in the reduction in the concentrations of the circulating thyroid hormones and depletion of the thyroid hormone stores. Clinical hypothyroidism occurs when there is a sustained reduction in iodide uptake by the thyroid.[3,4,13]

1.13 It is important to note that clinical hypothyroidism has adverse implications for structural and functional brain development in foetus, infant and

child and for metabolism and the functioning of cardiovascular, gastrointestinal, skeletal, neuromuscular and reproductive systems in adults.[3,5,13,14] Given the mode of action of perchlorate, the key vulnerable groups are pregnant women, foetuses, newborns, young infants, individuals with hypothyroidism and possibly those with iodine-deficient diets.[6,7,13]

Kinetics and metabolism

1.14 Perchlorate is rapidly absorbed in both humans and experimental animals following oral exposure.[3,4,5] It has been detected in serum, plasma, urine, saliva and breast milk of humans exposed to the chemical and exhibits a short half-life of 6.0-9.3 hours (mean 8.1 hours) in human blood serum.[8] Perchlorate undergoes relatively little, if any, metabolism in humans, with more than 90% of ingested doses excreted in the urine.[3,4]

Toxicity

Acute and long-term toxicity

1.15 Perchlorate has low acute oral toxicity in laboratory animals and has no genotoxicity concern based on the available data.[3,8] Although increased thyroid tumour incidence was observed in rats and mice following chronic exposure to perchlorate, perchlorate is not likely to pose a risk of thyroid cancer in humans.[3,8,14]. The International Agency for Research on Cancer (IARC) has not classified perchlorate as carcinogenic.[4]

1.16 In fact, potassium perchlorate has been used as a thyrostatic drug for the treatment of hyperthyroidism, particularly for managing thyrotoxicosis caused by large iodine loads such as those associated with the use of the antiarrhythmic drug amiodarone.[3,8,9] While no adverse effects have been reported for patients with

administered doses of 200 mg/day or lower for prolonged period, clinical use of perchlorate for patient treatment following repeated treatment with ≥ 400 mg potassium perchlorate per day (4 mg perchlorate anion/kg bw per day) could result in adverse effects including skin rash, nausea, lymphadenopathy and blood dyscrasias, with evidence suggesting a direct relationship between the incidence and severity of the effects and the treatment dose and duration.[8,9]

Health-based guidance value

1.17 JECFA evaluated the health risk of perchlorate in 2010 and developed a Provisional Maximum Tolerable Daily Intake (PMTDI) of 10 μg/kg bw/day for perchlorate.[3].

1.18 In May 2025, EFSA updated the tolerable daily intake (TDI) of perchlorate from 0.3 μg/kg bw/day to 1.4 μg/kg bw/day, based on the inhibition of thyroid iodine uptake in healthy adults. This TDI takes into account the sensitivity of the foetus to maternal thyroid hormone disturbance and uncertainty around the impact of iodine deficiency on the effects of perchlorate during foetal development. The TDI is applicable for both a short-term (approximately 2-week period) and chronic exposures based on the mode of action of perchlorate and its toxicokinetic properties.[9]

Chapter 2
Methodology and Laboratory Analysis

Methodology of the 2nd HKTDS

2.1 Based on the 2nd FCS, 187 TDS food items (involving 15 food groups) were selected for the Study. Six individual samples of each TDS food item were collected throughout Hong Kong and prepared individually to "as consumed" status on each of the two sampling occasions from February 2023 to January 2024. A total of 2,244 individual food samples were collected and prepared individually, and combined into 374 composite samples for laboratory chemical analysis.

2.2 The analytical results were combined with the food consumption data of the local population to estimate dietary exposure to the selected chemical substances included in this study. Dietary exposure estimation was performed with the aid of an in-house web-based computer system, the Exposure Assessment System 2 (EASY2), which involved food mapping and weighting of data. The mean and 90th percentile exposure levels were used to represent the dietary exposure of the average and high consumers of the local population, respectively. In this report, the estimated dietary exposure to perchlorate of the average and high consumers was compared with the health-based guidance value, i.e. the PMTDI allocated to perchlorate, to assess the associated health risks.

2.3 Details of the methodology are given in the same series of reports on Methodology.

Laboratory analysis of perchlorate

2.4 Laboratory analysis of perchlorate was conducted by the Food Research Laboratory (FRL) of the CFS. All 374 composite samples prepared from 2,244 individual samples of the 187 TDS food items taken from the two occasions were tested.

2.5 For the analysis of perchlorate in water sample (bottled water and drinking water), 25 g of the composite sample was diluted with 1% (v/v) formic acid in methanol then proceeded to using liquid chromatography-tandem mass spectrometry (LC-MS/MS) analysis.

2.6 For the analysis in food samples, 2 g of the composite sample was added with water for water content adjustment, and then extracted by shaking with 1% (v/v) formic acid in methanol as described in the extraction method of EURL QuPPe method. The above extract was centrifuged and filtered upon ultrafiltration with use of 10 KDa Molecular Weight Cuttoff centrifugal filter. The clean extract was appropriately diluted with the initial mobile phase compositions, and filtered for subsequent LC-MS/MS analysis.

2.7 Perchlorate was separated by using Thermo Hypercarb Porous Graphitic Carbon column (100 mm x 2.1 mm, 5 μm) under gradient elution conditions with acetic acid-acidified mobile phases. The analytical confirmation and quantification were performed by tandem mass spectrometry with use of perchlorate-$^{18}O_4$ as internal standard.

2.8 The limits of detection (LODs) for perchlorate were 0.10 μg/kg in water samples and 1.0 μg/kg in food samples.

Treatment of analytical results

2.9 In this study, data were treated with both lower bound (LB) and upper bound (UB) approaches. The approaches present the two extreme scenarios, considering that the true value for results below the LOD may actually be any value between zero and the achieved LOD. The LB scenario assumes that the chemical is absent; thus, a value of zero is assigned to results reported as <LOD. The UB scenario assumes that the chemical is present at the level of the LOD; thus, a value of the corresponding LOD is assigned to results reported as <LOD.

Chapter 3
Results and Discussion

Concentrations of perchlorate in TDS Foods

3.1 A total of 374 composite samples, comprising 187 TDS food items and 15 food groups, on 2 occasions were tested for perchlorate. More than 75% of the TDS food items, involving 249 composite samples in 14 food groups, were found to contain detectable levels of perchlorate. The results in 15 TDS food groups are summarised in Table 1 and the detailed analytical results of all the 187 TDS food items tested are shown in Appendix 1.

Table 1: Perchlorate contents (µg/kg) in TDS food groups of the 2nd HKTDS

	TDS food groups	TDS food items within food group		Composite samples within food group [a]		Range within food group (µg/kg) [b]
		Total number tested	Number with detectable levels (% within groups)	Total number tested	Number with detectable levels	
1	Cereals and their products	21	14 (67)	42	26	ND-77
2	Vegetables and their products	42	38 (90)	84	73	ND-610
3	Legumes, nuts and seeds and their products	9	7 (78)	18	11	ND-14
4	Fruits	18	15 (83)	36	22	ND-8.7
5	Meat, poultry and game and their products	17	8 (47)	34	11	ND-69
6	Eggs and their products	3	3 (100)	6	6	7.1-45
7	Fish and seafood and their products	24	12 (50)	48	16	ND-22
8	Dairy products	8	8 (100)	16	16	2.1-15
9	Fats and oils	2	0 (0)	4	0	ND-ND
10	Beverages, alcoholic	2	2 (100)	4	4	1.1-1.9
11	Beverages, non-alcoholic	12	11 (92)	24	18	ND-5.1
12	Mixed dishes	12	12 (100)	24	20	ND-26
13	Snack foods	1	1 (100)	2	2	4.2-8.2
14	Sugars and confectionery	5	4 (80)	10	7	ND-39
15	Condiments, sauces and herbs	11	9 (82)	22	17	ND-110
	Total	187	144 (77)	374	249	

Notes:

[a] Two composite samples were tested for each TDS food item.

[b] Concentration levels are rounded to 2 significant figures. ND denotes non-detected, i.e. results less than limit of detection (LOD).

3.2 Among the 15 TDS food groups, 14 were found to contain TDS food items with detectable levels of perchlorate. Notably, all food items in the food groups of "Eggs and their products", "Dairy products", "Beverages, alcoholic",

"Mixed dishes" and "Snack foods" tested positive for perchlorate. In contrast, no food items from the 'Fats and oils' group showed any presence of perchlorate.

3.3 By comparing perchlorate levels across 187 TDS food items, pumpkin was identified having the highest mean concentration (upper bound: 310 µg/kg), followed by Chinese amaranth (120 µg/kg) and Chinese parsley (67 µg/kg). The analytic results align with findings from overseas studies and literature, which report that perchlorate occurs in a wide range of foods, with the highest mean concentration typically found in vegetables.

Dietary exposure to perchlorate

3.4 Table 2 shows the overall dietary exposure estimates of local adult, women of child bearing age and younger populations to perchlorate. For the adult population, the estimated dietary exposure of the average consumers was 0.16-0.17 µg/kg bw/day (LB-UB), which accounted for 1.6-1.7% (LB-UB) of the PMTDI allocated for perchlorate. Among the high consumers (90^{th} percentile) of the adult population, the estimated dietary exposure was 0.26-0.27 µg/kg bw/day (LB-UB), which accounted for 2.6-2.7% (LB-UB) of the PMTDI.

3.5 Exposure estimates for women of child bearing age were similar to those for the general adult population. Average consumers among women of child bearing age had the same exposure range (i.e. 0.16-0.17 µg/kg bw/day, LB-UB) as average adults, corresponding to 1.6-1.7% (LB-UB) of the PMTDI. However, high consumers of women of child bearing age showed slightly lower exposure (i.e. 0.25-0.26 µg/kg bw/day, LB-UB) compared to high-consuming adults, representing 2.5-2.6% (LB-UB) of the PMTDI.

3.6 For the younger population, the estimated dietary exposure of the average consumers was 0.21-0.23 µg/kg bw/day (LB-UB), which accounted for 2.1-2.3%

(LB-UB) of the PMTDI. Among the high consumers of the younger population, the estimated dietary exposure was 0.36-0.38 μg/kg bw/day (LB-UB), which accounted for 3.6-3.8% (LB-UB) of the PMTDI (Table 2).

Table 2: Estimates of overall dietary exposure to perchlorate for the average and high consumers of the local adult and younger populations and their contribution to Provisional Maximum Tolerable Daily Intake (PMTDI)

Population	Dietary Exposure (LB-UB) (μg/kg bw/day)		% PMTDI (LB-UB)	
	Average consumers	High consumers	Average consumers	High consumers
Adults aged 18+	0.16-0.17	0.26-0.27	1.6-1.7	2.6-2.7
Women of child bearing age (Female aged 18-49)	0.16-0.17	0.25-0.26	1.6-1.7	2.5-2.6
Younger population aged 6-17	0.21-0.23	0.36-0.38	2.1-2.3	3.6-3.8

Exposure of the high consumers refers to the exposure at 90th percentile.
LB and UB denotes lower bound and upper bound respectively.
Figures for dietary exposure estimates and contribution to PMTDI are rounded to 2 significant figures.

3.7 Further details on age-gender subgroup analysis on dietary exposure to perchlorate are presented in Table 3 and Figure 1. Among all individual age groups, the dietary exposure estimates to perchlorate of the average and high consumers were all below 5% of the PMTDI allocated for perchlorate. The study findings revealed that the dietary exposure to perchlorate would be of low health risk to the average and high consumers of the local adult and younger populations, at both the population level and age-gender subgroup level.

3.8 Even though EFSA established a lower TDI of 1.4 μg/kg bw/day in 2025, the dietary exposures of local populations remained below this level.

Table 3: Estimates of dietary exposure to perchlorate for the average and high consumers of age-gender subgroups and their contribution to the Provisional Maximum Tolerable Daily Intake (PMTDI)

Age-gender groups	Dietary Exposure (LB-UB) (µg/kg bw/day)		% PMTDI (LB-UB)	
	Average consumers	High consumers	Average consumers	High consumers
Adults				
Adults aged 18-49	0.14-0.16	0.23-0.24	1.4-1.6	2.3-2.4
● Male	0.13-0.14	0.20-0.21	1.3-1.4	2.0-2.1
● Female	0.16-0.17	0.25-0.26	1.6-1.7	2.5-2.6
Adults aged 50-64	0.17-0.18	0.29-0.30	1.7-1.8	2.9-3.0
● Male	0.16-0.17	0.26-0.28	1.6-1.7	2.6-2.8
● Female	0.18-0.19	0.29-0.31	1.8-1.9	2.9-3.1
Adults aged 65+	0.17-0.18	0.28-0.30	1.7-1.8	2.8-3.0
● Male	0.16-0.17	0.28-0.29	1.6-1.7	2.8-2.9
● Female	0.18-0.19	0.29-0.30	1.8-1.9	2.9-3.0
Adults aged 18+	0.16-0.17	0.26-0.27	1.6-1.7	2.6-2.7
● Male	0.14-0.16	0.23-0.24	1.4-1.6	2.3-2.4
● Female	0.17-0.18	0.27-0.29	1.7-1.8	2.7-2.9
Younger Population				
Children aged 6-11	0.26-0.28	0.42-0.45	2.6-2.8	4.2-4.5
Adolescents aged 12-17	0.16-0.18	0.27-0.29	1.6-1.8	2.7-2.9
● Male	0.16-0.18	0.27-0.29	1.6-1.8	2.7-2.9
● Female	0.16-0.18	0.27-0.28	1.6-1.8	2.7-2.8

Exposure of high consumers refer to the exposure at 90th percentile.
LB and UB denotes lower bound and upper bound respectively.
Figures for dietary exposure estimates and contribution to PMTDI are rounded to 2 significant figures.

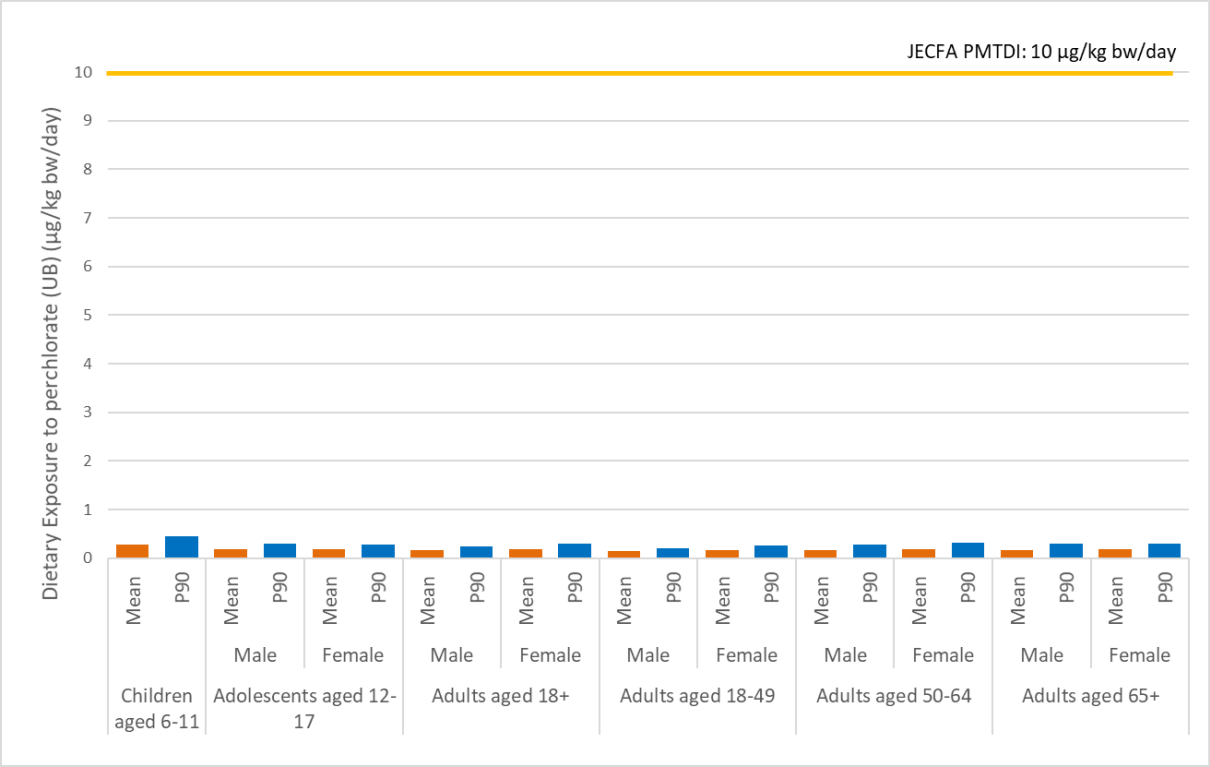

Figure 1: Dietary exposure to perchlorate in age-gender subgroups (UB) (µg/kg bw/day)

Major food contributors of perchlorate

3.9 Dietary exposure (based on LB exposure) to perchlorate for the average consumers from 15 TDS food groups are shown in Table 4. For the adult population, the primary dietary sources of perchlorate identified in the study were "Vegetables and their products", accounting for 49% of total dietary exposure, followed by "Non-alcoholic beverages" at 26% and "Mixed dishes" at 7.6%. Similarly, for the younger population, the top three dietary sources of perchlorates were the same: "Vegetables and their products" contributed 41% of total dietary exposure, followed by "Non-alcoholic beverages" at 21% and "Mixed dishes" at 9.9%. Notably, regarding the percentage contribution to the total dietary exposure from three food groups, "Dairy products", "Sugars and confectionery" and "Snack food", there was about 3 to 5 times difference between adults and the younger

population. The marked difference could be attributed to the different eating behaviour and nutrient needs of the populations. Also, youngsters have smaller body weights which results in a higher exposure ratio.

Table 4: Dietary exposure to perchlorate for average consumers and percentage contribution from TDS food groups

TDS food groups	Adults aged 18+		Younger population aged 6-17	
	Dietary Exposure (LB) (µg/kg bw/day)	% Contribution to total dietary exposure	Dietary Exposure (LB) (µg/kg bw/day)	% Contribution to total dietary exposure
Vegetables and their products	0.077	49%	0.086	41%
Beverages, non-alcoholic	0.041	26%	0.044	21%
Mixed dishes	0.012	7.6%	0.021	9.9%
Cereals and their products	0.0075	4.8%	0.012	5.6%
Meat, poultry and game and their products	0.0050	3.2%	0.0075	3.5%
Eggs and their products	0.0042	2.7%	0.0090	4.3%
Fruits	0.0032	2.0%	0.0044	2.1%
Dairy products	0.0031	2.0%	0.021	9.7%
Condiments, sauces and herbs	0.0012	0.77%	0.0024	1.1%
Fish and seafood and their products	0.0010	0.66%	0.0016	0.75%
Legumes, nuts and seeds and their products	0.00095	0.61%	0.0015	0.72%
Beverages, alcoholic	0.00056	0.36%	0.0000082	0.0039%
Sugars and confectionery	0.00014	0.093%	0.00073	0.34%
Snack foods	0.00010	0.066%	0.00048	0.23%
Fats and oils	0	0%	0	0%

Figures for dietary exposure estimates and % contribution to overall dietary exposure are based on lower bound estimation and rounded to 2 significant figures.

3.10 As mentioned in paragraphs 3.4 and 3.5, among the average consumers of both the adult and younger populations, the LB dietary exposure to perchlorate only contributed to less than 3% of the PMTDI allocated for perchlorate. With the rather small absolute dietary exposure estimates of perchlorate as contributed by each

of the different TDS food groups in this study, readers should be cautious when interpreting the relative importance of each of the dietary exposure contributors identified in this study.

Comparison with other places

3.11 The data on estimates of dietary exposure to perchlorate locally and those reported from other places (including Chinese Mainland, Kuwait and the USA) using TDS or similar methodology, were summarised in Table 5.[11,15,16] The available dietary exposure estimates for the population of Hong Kong, Chinese Mainland, Kuwait and the USA were below the PMTDI of 10 μg/kg bw/day established by JECFA. In comparison, the average dietary exposure estimates from the current study for local adult and younger populations fell within the observed range reported from other places.

Table 5. A comparison of dietary exposure to perchlorate locally and those reported in other places

Country / place	Population subgroups	Average exposure (μg/kg bw/day)	High percentile exposure (μg/kg bw/day)	Reference
Hong Kong SAR*	6-17 yrs	0.21 – 0.23	0.36-0.38#	This study
	18+ yrs	0.16 – 0.17	0.26-0.27#	
Chinese Mainland	18-45 yrs male	0.449	/	Li et al. (2025)
Kuwait	6-9 yrs	0.385		Alomirah et al. (2016)
	10-19 yrs	0.207		
	20-49 yrs	0.140		
	50+ yrs	0.155		
USA*	6 yrs children	0.28 – 0.31	/	Abt et al. (2016)
	10 yrs children	0.16 – 0.18		
	14-16 yrs teen girls	0.10 – 0.12		
	14-16 yrs teen boys	0.11 – 0.13		
	25-30 yrs female	0.09 – 0.11		
	25-30 yrs male	0.09 – 0.12		
	40-45 yrs female	0.09 – 0.12		
	40-45 yrs male	0.10 – 0.13		
	60-65 yrs female	0.10 – 0.12		
	60-65 yrs male	0.09 – 0.11		
	70+ yrs female	0.10 – 0.11		
	70+ yrs male	0.09 – 0.11		

Note:
* Lower bound-upper bound exposure were presented.
# Exposure of high consumers refer to the exposure at 90th percentile.

3.12 However, caution should be exercised in making any direct comparison of the data due to the differences in time when the reported studies were conducted, the approaches of capturing and handling food consumption data, the sampling strategies adopted, the analytical methods used and the methods of treating analytical results below detection limits, etc.

Limitations of the Study

3.13 In this study, the sampling of limited numbers of limited food items, combined with the subsequent use of food mapping approach to assign perchlorate concentrations in applicable foods would introduce uncertainties in the dietary exposure assessment to perchlorate for the local population.

3.14 Other limitations have been described in the Report on the 2nd HKTDS: Methodology.

Chapter 4
Conclusion and Recommendations

4.1 The exposure estimates for the Hong Kong populations from this study do not pose a health risk associated with the dietary intake of perchlorate. Although perchlorate has been found in a wide range of food, the estimated dietary exposures to perchlorate for both average and high consumers among local adult and younger populations remain well below the health-based guidance values established by the international organisation/authority.

4.2 To minimise the risks associated with exposure to perchlorate, the public is encouraged to maintain a balanced and varied diet to support overall health and reduce the risk of exposure to contaminants, including perchlorate, from a limited range of food.

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Appendix 1

Perchlorate contents (μg/kg) detected in TDS food items of the 2nd HKTDS

TDS Food Item [a]	Perchlorate Contents (μg/kg) [b]		
	Mean [c]	1st Sampling Occasion	2nd Sampling Occasion
Cereals and their products			
Biscuit / Cookie	2.3	2.0	2.6
Bread, plain	6.3	9.2	3.4
Bread, raisin	39	73	4.6
Breakfast cereals	0.70-1.2	1.4	ND
Bun, with savoury filling, baked	3.3	3.0	3.5
Bun, with savoury filling, steamed	3.8	2.6	4.9
Bun, with sweet filling, steamed	4.2	4.5	3.9
Cake	6.4	4.7	8.0
Corn	0.65-1.2	ND	1.3
Corn starch	1.4	1.5	1.2
Deep-fried dough, Chinese style	2.8	3.1	2.4
Noodles, Chinese / Japanese style	–	ND	ND
Noodles, instant	–	ND	ND
Noodles, rice	–	ND	ND
Oats / Oatmeal	–	ND	ND
Pasta, Western style	–	ND	ND
Pastries, Chinese style	5.8	3.5	8.0
Pie / Tart	3.3	3.5	3.0
Pineapple bun	40	2.9	77
Rice, unpolished	–	ND	ND
Rice, white	–	ND	ND
Vegetables and their products			
Bamboo fungus	–	ND	ND
Bamboo shoot	3.1	1.1	5.0
Beet root	5.3	2.5	8.0
Bitter melon	13	18	7.6
Blanching chives	8.2	12	4.4
Broccoli / Cauliflower	12	3.1	20
Cabbage, Chinese (including Pe-tsai / Celery cabbage)	22	29	14
Cabbage, Chinese flowering	48	25	71
Cabbage, European variety	12	19	5.9
Cabbage, Pak-choi Chinese	28	23	33
Cabbage, Pak-choi Chinese, dried	3.2	3.7	2.6
Carrot / Radish	23	39	7.1
Celery	2.5	3.0	1.9
Chinese amaranth (Chinese spinach)	120	130	110
Chinese kale	53	89	17
Cucumber	16	25	6.7
Ear fungus	–	ND	ND
Eggplant	4.4	5.9	2.9

TDS Food Item [a]	Perchlorate Contents (μg/kg) [b]		
	Mean [c]	1st Sampling Occasion	2nd Sampling Occasion
Garlic	5.9	7.2	4.5
Ginger	2.9	2.0	3.8
Hairy gourd / wax gourd	3.1	4.1	2.1
Leaf mustard	6.1	7.1	5.1
Lettuce, Chinese / European / Indian	5.6	7.2	4.0
Mung bean sprout	–	ND	ND
Mushroom, button	1.8	2.2	1.3
Mushroom, shiitake, dried	2.4	2.5	2.2
Onion	–	ND	ND
Pea shoots	54	100	8.8
Peppers (sweet pepper / chili pepper)	5.9	6.5	5.3
Potato	6.6	4.7	8.5
Potato, fried	13	11	15
Preserved vegetables	56	78	33
Pumpkin	310-310	ND	610
Seaweed	4.3-4.8	8.6	ND
Spinach	20	28	11
Sponge gourd	5.4	3.7	7.1
Spring onion	13	19	6.0
Sweet potato	7.9	1.7	14
Tomato	1.0-1.5	2.0	ND
Water spinach	5.0	6.5	3.4
Watercress	16	17	15
Zucchini	5.4	6.6	4.2
Legumes, nuts and seeds and their products			
Fermented soybean products	4.7	7.2	2.1
Green peas	–	ND	ND
Green string beans (with pod)	12	14	9.1
Peanut	3.4-3.9	6.7	ND
Peanut butter	1.4	1.0	1.7
Red bean	–	ND	ND
Soybean curd (Tofu)	1.4	1.3	1.4
Tree nuts	1.7-2.2	3.3	ND
Vermicelli, mung bean	0.75-1.3	ND	1.5
Fruits			
Apple	–	ND	ND
Banana	1.6-2.1	3.1	ND
Cherry	1.0-1.5	ND	2.0
Dragon fruit	2.2	1.6	2.8
Dried fruits	5.7	2.6	8.7
Durian	–	ND	ND
Grapes	0.85-1.4	ND	1.7
Kiwi	0.55-1.1	ND	1.1
Longan / Lychee	1.7-2.2	3.4	ND
Mandarin / Tangerine	0.70-1.2	ND	1.4
Mango	–	ND	ND
Melon	5.3	7.0	3.5
Orange	1.7	1.9	1.5

TDS Food Item [a]	Perchlorate Contents (μg/kg) [b]		
	Mean [c]	1st Sampling Occasion	2nd Sampling Occasion
Papaya	3.8	3.9	3.7
Peach	1.5-2.0	3.0	ND
Pear	1.7-2.2	ND	3.3
Pineapple	4.2	7.0	1.3
Watermelon	5.7	6.1	5.2
Meat, poultry and game and their products			
Beef	0.55-1.1	1.1	ND
Beef tendon	–	ND	ND
Chicken meat, other than chicken wing	5.0-5.5	10	ND
Chicken wing	–	ND	ND
Duck / goose, roasted	–	ND	ND
Ham, pork	9.5	17	2.0
Liver, goose	2.4	3.5	1.3
Liver, pig	–	ND	ND
Luncheon meat	11	2.3	20
Meat ball	–	ND	ND
Meat sausage	4.7-5.2	ND	9.3
Mutton	–	ND	ND
Pork chop	–	ND	ND
Pork ribs	–	ND	ND
Pork, barbequed	0.65-1.2	1.3	ND
Pork, other than pork chop and pork ribs	–	ND	ND
Pork, roasted	35-35	ND	69
Eggs and their products			
Egg, chicken	9.6	12	7.1
Egg, lime preserved	27	9.7	45
Egg, salted	12	8.9	16
Fish and seafood and their products			
Clam	–	ND	ND
Crab	–	ND	ND
Cuttlefish	–	ND	ND
Fish ball / fish cake	0.95-1.5	ND	1.9
Fish fillet	0.70-1.2	1.4	ND
Fish, Dace, minced	0.80-1.3	1.6	ND
Fish, Golden thread	–	ND	ND
Fish, Grass carp	–	ND	ND
Fish, Grouper	–	ND	ND
Fish, Mandarin fish	–	ND	ND
Fish, Mangrove red snapper	0.60-1.1	1.2	ND
Fish, Pomfret / Pompano	3.5-4.0	7.0	ND
Fish, Salmon	2.0	1.7	2.2
Fish, Tuna	–	ND	ND
Fish, Yellow croaker	–	ND	ND
Lobster	22	22	22
Mantis shrimp	–	ND	ND
Mussel	1.7	1.5	1.8
Oyster	–	ND	ND
Salted fish	–	ND	ND

TDS Food Item [a]	Perchlorate Contents (μg/kg) [b]		
	Mean [c]	1st Sampling Occasion	2nd Sampling Occasion
Scallop	1.6-2.1	ND	3.1
Shrimp / Prawn	1.0-1.5	2.0	ND
Shrimp / Prawn, dried	3.6	3.7	3.5
Squid	1.0-1.5	ND	2.0
Dairy products			
Cheese	9.4	15	3.7
Fermented / Cultured beverages, dairy based	5.1	4.9	5.2
Ice-cream	2.8	3.5	2.1
Milk beverages	6.0	8.1	3.9
Milk, condensed / evaporated	9.6	8.2	11
Milk, skim	3.0	2.5	3.5
Milk, whole	6.6	10	3.1
Yoghurt	4.1	3.9	4.3
Fats and oils			
Butter	–	ND	ND
Vegetable oil	–	ND	ND
Beverages, alcoholic			
Beer	1.4	1.1	1.6
Wine, red / white	1.6	1.3	1.9
Beverages, non-alcoholic			
Carbonated drink (including diet version)	0.70-1.2	1.4	ND
Coconut water	1.3-1.8	2.6	ND
Coffee	2.4	3.0	1.7
Fruit and / or vegetable juice	2.1	1.5	2.7
Malt drink	2.3	2.0	2.6
Soybean drink	1.9-2.4	3.8	ND
Tea (including lemon tea)	3.5	1.9	5.1
Tea, chrysanthemum	4.1	4.8	3.3
Tea, with milk	4.4	3.9	4.9
Tea, with milk and tapioca pearls	0.55-1.1	ND	1.1
Water, bottled, distilled / purified	-	ND	ND
Water, drinking	1.2	1.5	0.92
Mixed dishes			
Dim sum, beef ball, steamed	1.6-2.1	ND	3.2
Dim sum, Siu Mai, steamed	1.4-1.9	ND	2.8
Dumpling / spring roll, fried	6.7	9.3	4.0
Dumpling, boiled (including wonton)	2.8	2.0	3.6
Dumpling, steamed	18	26	10
Glutinous rice dumpling	2.0	1.4	2.6
Hamburger	3.8	4.6	2.9
Pizza	3.1	3.1	3.0
Rice-roll, plain, steamed	2.1-2.6	4.2	ND
Soup, Chinese style	3.8-4.3	7.6	ND
Soup, Western style	3.9	3.9	3.8
Turnip cake	7.2	7.6	6.7
Snack foods			
Potato chips	6.2	4.2	8.2
Sugars and confectionery			

TDS Food Item [a]	Perchlorate Contents (μg/kg) [b]		
	Mean [c]	1st Sampling Occasion	2nd Sampling Occasion
Chocolate	2.4	3.0	1.7
Honey	25	39	10
Jam	0.80-1.3	ND	1.6
Sugar, brown / rock	3.8	2.2	5.4
Sugar, white, granulated	–	ND	ND
Condiments, sauces and herbs			
Chicken powder / cube	11	10	11
Chinese parsley	67	110	23
Curry sauce	7.0	5.9	8.1
Oyster sauce	5.2	3.5	6.8
Salad dressing	0.70-1.2	ND	1.4
Sesame seed oil	–	ND	ND
Soy sauce	3.4	2.9	3.8
Table salt	–	ND	ND
Tomato paste / ketchup	2.9	3.9	1.8
Vinegar	4.6	3.3	5.8
White pepper	11	3.5	18

Notes:

[a] Two composite samples were tested for each TDS food item.

[b] Concentration levels are rounded to 2 significant figures. ND denotes non-detected, i.e. results less than limit of detection (LOD).

[c] Mean concentrations for those TDS food items detected in both sampling occasions are presented as a single value, whereas those detected only in one of the two sampling occasions are presented as a range (lower bound-upper bound)