Risk Assessment Studies

Report No. 59

Chemical Hazard Evaluation

Perchlorate in Tea and Tea Beverages

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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

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Glossary

A brief explanation of terms is given below.

Term	Explanation
Tea leaves	Leaves of the tea plant, *Camellia sinensis*.
Tea	Tea infusion or tea drink made by pouring boiling water onto tea leaves or tea powder.
Tea beverage	Ready-to-drink or ready-to-serve tea based beverages.
Tea product	Tea leaves, and powder or beverages that contain tea or tea extract as an ingredient.

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EXECUTIVE SUMMARY

Perchlorate is a chemical that found naturally in the environment. It is also an environmental contaminant arising from the use of perchlorate-containing fertilisers and from industrial uses like manufacturing and processing of rocket propellants, explosives, fireworks and air-bag inflators. As a result of its ubiquitous nature, presence of perchlorate in foods is not unexpected.

2. Perchlorate at sufficiently high doses can interfere with bodily production of thyroid hormones. The Joint FAO/WHO Expert Committee on Food Additives (JECFA) established a Provisional Maximum Tolerable Daily Intake (PMTDI) of 0.01 mg/kg bw/day (i.e. 10 μg/kg bw/day) for perchlorate in 2010.

3. This study serves (i) to determine the levels of perchlorate in dried tea leaves and tea beverages commonly available in the local market; (ii) to estimate the dietary exposure to perchlorate of the Hong Kong adult population arising from the consumption of these tea products; and (iii) to assess the associated health risk.

Results

4. A total of 305 samples of tea products (including dried tea leaves and tea beverages) commonly consumed by the Hong Kong population was analysed for perchlorate.

5. Results of the study showed that perchlorate was present in the majority (96%) of samples. A wide variation of perchlorate levels was detected in dried tea leaf samples ranging from a level below detection limit to 1100 μg/kg. "Semi-fermented tea" had the highest mean perchlorate level (250 μg/kg), followed by "Floral tea" (150 μg/kg), "Non-fermented tea" (140 μg/kg), "Genmai tea (dried)" (79 μg/kg) and "Fully-fermented tea / Post-fermented tea" (69 μg/kg). Assuming all perchlorate in dried tea leaves was released into tea infusion after brewing, the highest mean perchlorate level among different types of tea is 1.6 μg/L, a relatively low level when compared with the guideline value for perchlorate (70 μg/L) in drinking water recommended by the World Health Organization (WHO).

6. For tea beverages, the levels of perchlorate detected were low in general. The mean level of perchlorate was highest for "Milk tea" (3.1 μg/L), followed by "Lemon tea" (1.3 μg/L), "Milk tea with pearls" (0.84 μg/L), "Genmai tea (beverages)" (0.78 μg/L) and "Flavoured tea / Tea drinks" (0.59 μg/L).

7. Dietary exposure assessment showed that exposure to perchlorate due to the consumption of tea and tea beverages were 0.012

μg/kg bw/day for average consumers and 0.031 μg/kg bw/day for high consumers, accounting for 0.12% and 0.31% of the PMTDI (i.e. 10 μg/kg bw/day) established by JECFA respectively. In other words, 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.

Conclusions and Recommendations

8. Perchlorate is present in the majority (96%) of the dried tea leaf / tea beverage samples collected.

9. The estimated dietary exposures to perchlorate from dried tea leaves and tea beverages for average consumers, high consumers and individual age-gender population subgroups were all below 1% of the PMTDI (10 μg/kg bw/day) established by JECFA. Hence, 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.

Risk Assessment Studies –

Perchlorate in Tea and Tea Beverages

OBJECTIVES

This study aims (i) to determine the levels of perchlorate in dried tea leaves and tea beverages commonly available in the local market; (ii) to estimate the dietary exposure to perchlorate of the Hong Kong adult population arising from the consumption of these tea products; and (iii) to assess the associated health risk.

BACKGROUND

2. Perchlorate is a chemical that occurs naturally in the environment. It is found in deposits of nitrate and potash, and can be formed in the atmosphere [1]. Perchlorate can also be produced industrially and is considered an environmental contaminant, originating from inappropriate storage or disposal of perchlorate for use in rocket propellants, explosives, fireworks, flares and air-bag inflators[2].

3. Perchlorate consists of one chlorine atom surrounded by four oxygen atoms in a tetrahedral geometry (Figure 1). Salts of perchlorate are highly soluble in water. The dissociated perchlorate ion is very stable and has little tendency to adsorb to mineral or organic surfaces. Therefore,

perchlorate persists in groundwater, and its mobility in surface or groundwater is so high that perchlorate essentially moves with the flow of water. Since perchlorate is an ionic compound, it does not volatise from soil or water surfaces and accumulates in groundwater and surface water in areas where the products containing perchlorate are manufactured or used, or in soil previously treated with perchlorate containing fertilisers[3,4].

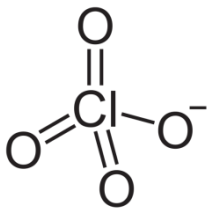


Figure 1. Perchlorate ion

4. Perchlorate is efficiently taken up via plant roots. As water transpires from the leaves, perchlorate remains behind due to its involatility and accumulates in the leaf tissue. It may be transferred to animals and their milk through the consumption of perchlorate-contaminated feed or water[2,4,5,6]. Due to its high solubility, perchlorate is likely to be easily eliminated from most organisms and not expected to biomagnify in aquatic trophic webs[7]. Ingestion of food and water is the primary source of human exposure to perchlorate[6,8].

Perchlorate in Foods

5. In overseas studies, perchlorate has been reported to occur in a wide range of foods including vegetables, fruits, milk and dairy products, rice, infant formula, fish and fish products, tea and herbs for infusions, juices and alcoholic beverages (Appendix 1) [1,4,9].

6. The Joint FAO/WHO Expert Committee on Food Additives (JECFA) reviewed the occurrence data on perchlorate in 2010 and observed the highest mean concentrations in vegetables (range of means 4.8-110 μg/kg), fruits (range of means 0.5-28 μg/kg), vegetable and fruit juices (26 μg/kg), and infant formulae (10 μg/kg) [1].

7. Previous exposure assessments carried out by JECFA[1], the US Food and Drug Administration (FDA)[10,11] and the European Food Safety Authority (EFSA)[4,9] have shown that vegetables, fruits, milk and their products are important contributors to perchlorate exposure.

Sources of Perchlorate Contamination

8. The presence of perchlorate in food and drinking water has been attributed to several natural and anthropogenic sources.

Natural formation in the atmosphere and surface water

9. Evidence suggested that perchlorate can form naturally as a result of environmental processes, such as lightning and volcanic eruptions, and oxidation with ozone of chlorinated species in water[12,13]. The natural formation of perchlorate in the atmosphere and in surface water could contribute to its presence in food and water. The currently available information does not allow conclusions on the contribution of the naturally formed perchlorate in the atmosphere and in surface water to the overall contamination of food and drinking water. However, this is expected to be a minor source[4].

Use of perchlorate-containing fertilisers and irrigation water

10. The use of fertilisers of natural origin, in which perchlorate may be present, is considered an anthropogenic source of perchlorate contamination. The well-known example is Chilean nitrate, which may contain up to 1.5% of perchlorate[14]. The use of perchlorate-containing fertilisers may lead to substantial concentrations in fruits and vegetables due to the efficient uptake of perchlorate via plant roots. Similarly, irrigation of plants with perchlorate-contaminated water can contribute to the accumulation of perchlorate in fruits and vegetables[4,5].

Industrial emission

11. Industrial emission of perchlorate in the environment, particularly in relation to the use of ammonium perchlorate in solid propellants for rocket and missiles, is another anthropogenic source of food and water contamination[4]. For example, the historical environmental release of ammonium perchlorate from the manufacturing, testing and disposal of rocket fuel and the demilitarisation of weaponry is considered the main source of contamination of the Colorado River, resulting in the contamination of drinking water in the South West of the USA[15,16].

Degradation of chlorine-based disinfectants

12. The formation of perchlorate as a by-product during the degradation of chlorine-based disinfectants has also been considered a potential source of contamination. Chlorinated agents used for water potabilisation purposes, particularly sodium and calcium hypochlorite, can degrade to perchlorate. Hence, the use of such drinking water in food production and preparation can lead to the presence of perchlorate in foods and beverages. The German Federal Institute for Risk Assessment (BfR) considered the contact of foods with water previously treated with chlorinated biocidal products for disinfection purposes a probable main entry path for perchlorate to get into food[17]. Furthermore, minor contributions are expected from the application of sodium and calcium hypochlorite in the disinfection of food preparation areas and from other applications such as biocidal or plant protection products[4].

Toxicity

Kinetics and metabolism

13. Perchlorate is rapidly absorbed in both humans and experimental animals following oral exposure[6]. 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[18,19,20,21,22,23,24,25,26]. Perchlorate undergoes relatively little, if any, metabolism in humans, with more than 90% of ingested doses excreted in the urine[4,6,27,28].

Acute and long-term toxicity

14. Perchlorate has low acute oral toxicity in laboratory animals[29] and has no genotoxicity[4] concern based on the available data. Although increased thyroid tumour incidence was observed in rats and mice following chronic exposure to perchlorate[30,31,32], perchlorate is not likely to pose a risk of thyroid cancer in humans and the International Agency for Research on Cancer (IARC) has not classified perchlorate as carcinogenic[1,4,6,33,34]. In fact, potassium perchlorate has been used for the medical treatment of hyperthyroidism. No adverse effects were reported with administered doses of 200 mg/day or lower for prolonged period[4].

Health effect

15. 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[1].

16. 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[6,11,35,36]. Clinical hypothyroidism occurs when there is a sustained reduction in iodide uptake by the thyroid.

17. It is important to note that the condition 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[1]. 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[1].

Health-Based Guidance Values

18. Health-Based Guidance Values (HBGVs) form the yardstick of risk assessment. It is considered to pose no appreciable health risk to consumers if intake of a chemical is below its HBGV. Dietary exposure is usually expressed as a percentage of the corresponding HBGV.

19. 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.

Regulatory Limits/Guideline Values

20. At present, the Codex Alimentarius Commission has not established any maximum limits (MLs) for perchlorate. There are also no regulations stipulating the MLs for perchlorate in foods in the US, the European Union (EU), Australia, New Zealand, Canada, Mainland China, Japan, Taiwan and Hong Kong.

21. Although there are currently no regulatory MLs for perchlorate in food in Europe, the European Commission (EC) introduced in 2013 'reference' or provisional enforcement levels of perchlorate for intra-EU trade for those food groups considered to be the most significant contributors of the dietary exposure to perchlorate [37] (Table 1). Competent authorities of the EU Member States can determine to what extent they enforce the levels of perchlorate as reference for intra-EU trade for their domestic production / products placed in their domestic market[38].

Table 1. Levels of perchlorate as reference for intra-EU trade introduced by the EC[38]

Food	**Level (µg/kg)**
Fruits and vegetables	100
with the exception of	
- *Cucurbitaceae* and leafy vegetables except	200
• celery and spinach grown in glasshouse/undercover	500
• herbs, lettuce and salad plants, including rucola, grown in glasshouse/under cover	1000
Dried spices (except dried herbs and paprika), dried hops	500
Tea (*Camellia sinensis*), dried	750
Herbal and fruit infusions, dried	750
Foods for infants and young children (ready-to-eat)	20
Other food	50

22. In 2016, the World Health Organization (WHO), based on the PMTDI (10 μg/kg bw/day) established by JECFA for perchlorate, recommended a guideline value for perchlorate of 70 μg/L in drinking water. WHO also opined that the concentrations of perchlorate in drinking-water are generally below 10 μg/L.

Local Situation

23. In Hong Kong, tea ranks just after water as the second most commonly consumed beverage[39]. According to Census and Statistics Department, more than 13 000 tonnes of tea leaves were imported in 2016 from different places across the globe[40]. Based on the degree of fermentation and processing procedures, tea leaves are usually divided into six different types: green, white, yellow, oolong, black (called red tea in China), and post-fermented tea (also called dark tea or Pu-er-type tea) (Table 2). As regards perchlorate, there is limited information in the literature about its presence and levels in different types of tea leaves[41,42,43,44,45,46].

Table 2. Classification of tea leaves according to their degree of fermentation

Degree of fermentation	Tea leaves	Examples
Non-fermented	Green tea	Green tea, Biluochun, Longjing
Semi-fermented	White tea, Yellow tea, Oolong tea	Jasmine, Tieguanyin, Shouwei, Oolong, Shuixian
Fully-fermented	Black tea, Chinese red tea	Earl Grey, English Breakfast Tea, Darjeeling Tea, Ceylon Tea, Chinese Black Tea, Gongfu Tea
Post-fermented	Dark tea or Pu-er-type tea	Liuan, Pu-er

24. In early 2016, local media reported that some Mainland-produced tea leaves available in Europe were found to contain perchlorate. These reports attracted much public attention. In response, the Centre for Food Safety (CFS) collected 30 imported tea leaf samples in the local market for testing of perchlorate and all samples passed the tests.

25. To further address the public concern over the presence of perchlorate in tea and its associated health risk, the CFS conducted this study (i) to determine the levels of perchlorate in dried tea leaves and tea beverages commonly available in the local market; (ii) to estimate the dietary exposure to perchlorate of the Hong Kong adult population arising from the consumption of these tea products; and (iii) to assess the associated health risk. Results of the current study may also provide additional local occurrence data of perchlorate in tea for the preparation of the CFS' second total diet study, which will include the estimation of the dietary exposure to perchlorate of the local population.

SCOPE OF STUDY

26. To analyse the levels of perchlorate in dried tea leaves (*Camellia sinensis*) and tea beverages commonly consumed by the local population, dried tea leaves including non-fermented tea, semi-fermented tea, fully-fermented, post-fermented tea, floral tea and genmai tea, as well as tea beverages such as milk tea, lemon tea, flavoured tea and milk tea with "pearls" were collected from various retail outlets such as tea houses, supermarkets, convenience stores, fast-food shops, restaurants and take-away tea shops.

METHODOLOGY AND LABORATORY ANALYSIS

Methodology

27. A total of 305 samples of dried tea leaves and tea beverages was collected between June and August 2017 from the local retail markets. For the purpose of this study, these samples were classified into nine groups, namely "Non-fermented tea", "Semi-fermented tea", "Fully-fermented tea / Post-fermented tea", "Floral tea", "Genmai tea", "Lemon tea", "Flavoured tea / Tea drinks", "Milk tea" and "Milk tea with pearls".

28. As tea is the form consumed by members of the public, the amount of perchlorate released from dried tea leaves into tea infusion is estimated, for dietary exposure assessment, basing on the common local practice of tea preparation. A preliminary study conducted by the Food Research Laboratory of the CFS showed that most of the perchlorate is released from dried tea leaves into infusions when two grams of dried tea leaves are infused twice with 150 ml boiled distilled water (100^{o}C) for five minutes (i.e. two brews). Therefore, the levels of perchlorate in tea infusions are estimated by assuming that all perchlorate in dried tea leaves are released into 300 ml distilled water (total volume for two brews) under the abovementioned brewing conditions. For tea prepared from tea powder, the level of perchlorate is estimated by following the manufacturer's instructions (e.g. the amount of water recommended by the manufacturer) on the labels and assuming all the powder is consumed.

29. The perchlorate levels in tea and tea beverages were combined with food consumption information captured from the Hong Kong Population-based Food Consumption Survey (2005-2007) to obtain the dietary exposures of local adult population. In practice, the estimation of dietary exposure 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 exposure levels of average and high consumers of the local population (consumers only) respectively. The estimated exposure level would then compared with the PMTDI of 10 µg/kg bw/day and was expressed as a percentage of this benchmark.

Laboratory Analysis

30. Laboratory analysis of perchlorate was conducted by the Food Research Laboratory of the CFS. All samples were tested on an individual sample basis and in the state that they were purchased.

31. For dried tea leaf samples, the homogenised samples were extracted by shaking with ammonium formate solution. The extract was then cleaned up by solid phase extraction. For tea beverage samples, the homogenised samples were filtered through centrifugal membrane filters only. Isotopically labelled perchlorate was added as internal standard for quantification. The level of perchlorate was determined by ion chromatography - tandem mass spectroscopy (IC-MS/MS). Limit of Detection (LOD) of perchlorate in tea leaves and tea beverages were 1 µg/kg and 0.1 µg/L respectively.

RESULTS AND DISCUSSION

Occurrence of Perchlorate

32. In this study, a total of 305 samples of "Non-fermented tea", "Semi-fermented tea", "Fully-fermented tea / Post-fermented tea", "Floral tea", "Genmai tea", "Lemon tea", "Flavoured tea / Tea drinks", "Milk tea" and "Milk tea with pearls" was collected from the local retail market and analysed for perchlorate.

33. Perchlorate was found in the majority (96%) of the dried tea leaves and tea beverages collected in this study. 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. Samples with non-detectable perchlorate were mainly prepackaged tea drinks (11 out of 13 samples) in which tea was probably just one of the many ingredients. The average and median perchlorate levels in different tea groups are summarised in Appendix 2.

Dried tea leaves

34. The levels of perchlorate detected varied widely among the dried tea leaf samples, ranging from a level below detection limit to 1100 µg/kg (Table 3). "Semi-fermented tea" had the highest mean perchlorate level (250 µg/kg), followed by "Floral tea" (150 µg/kg) and "Non-fermented tea"

(140 µg/kg) while "Fully-fermented tea / Post-fermented tea" had the lowest (69 µg/kg).

Table 3. Levels of perchlorate detected in dried tea leaf samples

Items in each group	No. of samples	Mean perchlorate levels* (µg/kg) [range]
Semi-fermented tea leaves	**76**	**250 [1.2-1100]**
Jasmine tea leaves	20	300 [35-1100]
Tieguanyin tea leaves	16	250 [65-690]
Shouwei tea leaves	10	240 [26-650]
Oolong tea leaves	21	220 [19-530]
Shuixian tea leaves	9	190 [1.2-760]
Floral tea	**25**	**150 [1.4-470]**
Non-fermented tea leaves	**54**	**140 [ND-790]****
Biluochun tea leaves	5	190 [22-310]
Green tea leaves	34	140 [ND-790]**
Longjing tea leaves	15	130 [50-340]
Genmai tea (dried)	**16**	**79 [ND-840]****
Fully-fermented tea leaves / Post-fermented tea leaves	**75**	**69 [1.3-660]**
Liuan tea leaves	5	190 [52-320]
Black tea leaves	50	64 [1.3-660]
Pu-er tea leaves	20	50 [1.7-190]

***** Rounded to 2 significant figures.

**ND: not detected, a value of LOD/2 was assigned for samples with perchlorate level below LOD (1 µg/kg) when calculating the mean concentration.

Semi-fermented tea

35. Five types of semi-fermented tea leaves with a total of 76 samples were analysed for perchlorate. "Jasmine tea leaves" had the highest mean perchlorate level (300 µg/kg), followed by "Tieguanyin tea leaves" (250 µg/kg) and "Shouwei tea leaves" (240 µg/kg). In fact, these three types of tea leaves had the highest levels of perchlorate among all dried tea leaves analysed.

36. In this study, semi-fermented tea leaves were found to contain the highest levels of perchlorate; however, another study showed that Oolong tea (a semi-fermented tea leaves) contained a lower level of perchlorate when compared with other tea leaves analysed[47].

Fully-fermented tea / Post-fermented tea

37. "Fully-fermented tea / Post-fermented tea" had the lowest mean perchlorate level (69 µg/kg). Other studies also reported that Pu-er tea (a post-fermented tea) contained a comparable level of perchlorate (70.6 µg/kg and 71 µg/kg) [42,44]. In this study, the mean perchlorate level in "Pu-er tea leaves" was 50 µg/kg which was the lowest among all dried tea leaves analysed.

38. “Fully-fermented tea / Post-fermented tea” are tea which have undergone a prolonged period (usually from several months to many years depending on the methods and the operation conditions) of microbial fermentation with significant changes in the microbial community.

39. Pu-er tea is produced by microbial fermentation of fresh *Camellia sinensis* and *Protecbacteria* which was found to be one of the most commonly observed bacterial groups during the process of fermentation[48]. It has also been shown that members of the *Proteobacteria* were capable of reducing perchlorate under anaerobic condition. However, the relationship between the lower perchlorate levels in Pu-er tea and the presence of *Protecbacteria* has not been confirmed.

Tea / Tea infusion

40. To assess the dietary exposure to perchlorate due to the consumption of tea products, the levels of perchlorate in tea infusions from dried tea leaves and tea from tea powder are estimated according to the procedures mentioned in para. 28 and summarised in Table 4.

Table 4. Levels of perchlorate in tea / tea infusions prepared from dried tea leaves

Items in each group	No. of samples	Mean perchlorate levels* (μg/L) [range]
Semi-fermented tea[#]	76	1.6 [0.0080-7.3]
Floral tea[#]	25	0.98 [0.0093-3.1]
Non-fermented tea[#,^]	54	0.96 [ND-5.3][†]
Genmai tea (dried)[#]	16	0.53 [ND-5.6][†]
Fully-fermented tea / Post-fermented tea [#]	75	0.46 [0.0087-4.4]

***** Rounded to 2 significant figures.

[#] Tea prepared from dried tea leaves -- perchlorate level in tea was estimated assuming all perchlorate was released in two brews when two grams of tea leaves were infused in 150 ml boiling distilled water for five minutes.

[^] Five samples were tea powder -- perchlorate level in tea from tea powder was estimated assuming that tea was prepared according to manufacturer's instruction and all tea powder was consumed.

[†] ND: not detected, a value of LOD/2 was assigned for samples with perchlorate level below LOD (1 μg/kg) when calculating the mean concentration.

41. It was observed that the mean levels of perchlorate in tea were low (0.46 to 1.6 μg/L) and generally comparable with those reported in US FDA's Total Diet Study (2008-2012)[11].

Tea beverages

42. Among all tea beverages, "Milk tea" had the highest mean perchlorate level (3.1 μg/L), followed by "Lemon tea" (1.3 μg/L) and "Milk tea with "pearls"" (0.84 μg/L), while "Flavoured tea / Tea drinks" had the lowest (0.59 μg/L) (Table 5).

Milk tea

43. A total of 15 milk tea samples was collected. Among these 15 samples, three were in powdered form and hence had to be reconstituted with water according to the manufacturer's instructions. Since these reconstituted milk teas had similar nature/composition with other ready-to-drink milk tea beverages, they were considered under the category "Milk tea". The level of perchlorate in "Milk tea" ranged from 0.49 to 8.3 μg/L with an overall average of 3.1 μg/L. The higher perchlorate levels of milk tea may be due to the presence of other ingredients as well as the larger amount of tea leaves used for milk tea preparation. Though the mean perchlorate level of "Milk tea" was the highest among all tea beverages, it was still considered low when compared to the guideline value for perchlorate (70 μg/L) in drinking water recommended by WHO.

Table 5. Levels of perchlorate in tea beverages

Items in each group	No. of samples	Mean perchlorate levels* (μg/L) [range]
Milk tea[@]	15	3.1 [0.49-8.3]
Lemon tea	15	1.3 [ND-3.2][†]
Milk tea with "pearls"	10	0.84 [0.51-1.2]
Genmai tea (beverages)	4	0.78 [ND-2.5][†]
Flavoured tea / Tea drinks	15	0.59 [ND-1.8][†]

***** Rounded to 2 significant figures.

[@] Three milk tea samples were collected in powdered form. Their perchlorate levels in reconstituted forms were estimated by assuming that the powder was reconstituted with distilled water according to the manufacturer's instructions and all powder was consumed.

[†] ND: not detected, a value of LOD/2 was assigned for samples with perchlorate level below LOD (0.1 μg/L) when calculating the mean concentration.

Dietary Exposure to Perchlorate from Tea and Tea Beverages

44. The study results revealed that the dietary exposures to perchlorate from tea and tea beverages of the local population (consumers only) was 0.012 μg/kg bw/day (0.12% of the PMTDI) for average consumers and 0.031 μg/kg bw/day (0.31% of the PMTDI) for high consumers (body weight 62.24 kg, number of consumers: weighted = 3 734 432 and unweighted = 3 407). The dietary exposure estimate to perchlorate of the local average consumers arising from the consumption of tea and tea beverages was similar to the assessment conducted by the Shanghai Center for Adverse Drug Reaction Monitoring (上海市藥品和醫療器械不良反應監測中心) in 2016. The average daily exposure to perchlorate from tea leaves of the Shanghai population was reported as 0.012 μg/kg bw/day[46].

45. In this study, “Semi-fermented tea” and “Milk tea” were the two major contributors to the overall dietary exposure to perchlorate from tea and tea beverages among the average consumers, altogether accounting for around 74% of the total exposure. The large exposure contribution of these two types of tea was likely related to their high consumption amounts and relatively high perchlorate levels.

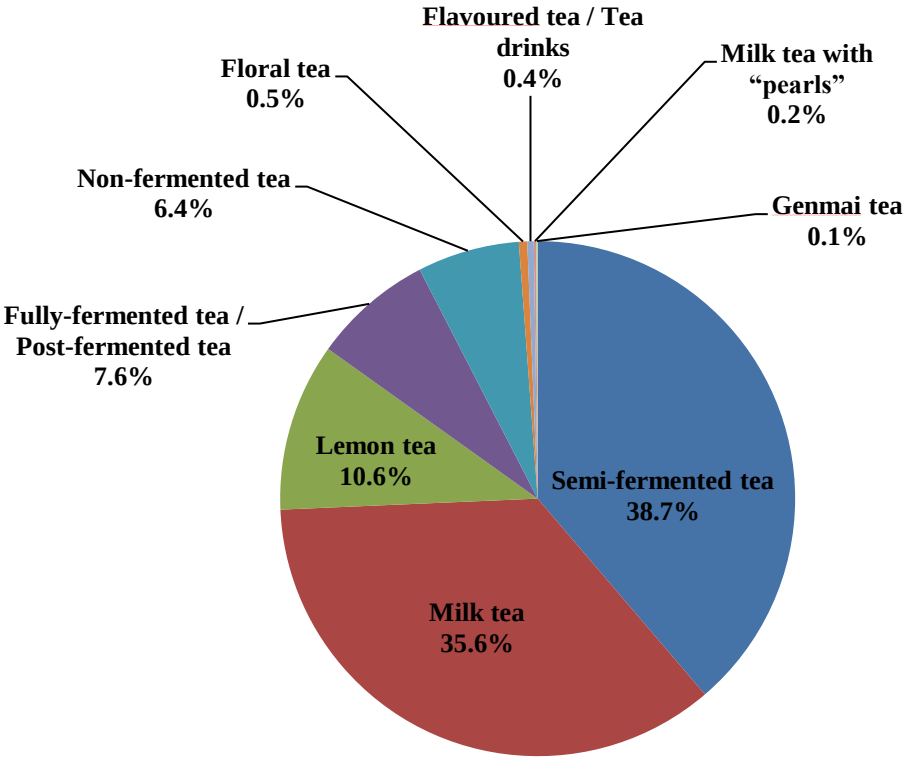
46. “Lemon tea”, “Fully-fermented tea / Post-fermented tea”, “Non-fermented tea”, “Floral tea”, “Flavoured tea / Tea drinks”, “Milk tea with “pearls”” and “Genmai tea / beverages” altogether contributed to 26% of perchlorate exposure. Dietary exposure to perchlorate from different groups of tea are summarised in Table 6 and Figure 2.

Table 6. Dietary Exposure to perchlorate for average consumers and percentage contribution of different groups of tea and tea beverages

Types of Tea	**Dietary exposure to perchlorate (μg/kg bw/day)**	**% contribution to dietary exposure***
Semi-fermented tea	0.00474	38.7%
Milk tea	0.00436	35.6%
Lemon tea	0.00129	10.6%
Fully-fermented tea / Post-fermented tea	0.00092	7.6%
Non-fermented tea	0.00078	6.4%
Floral tea	0.00006	0.5%
Flavoured tea/ Tea drinks	0.00005	0.4%
Milk tea with "pearls"	0.00002	0.2%
Genmai tea	0.00001	0.1%
Total	**0.01223**	**100%**

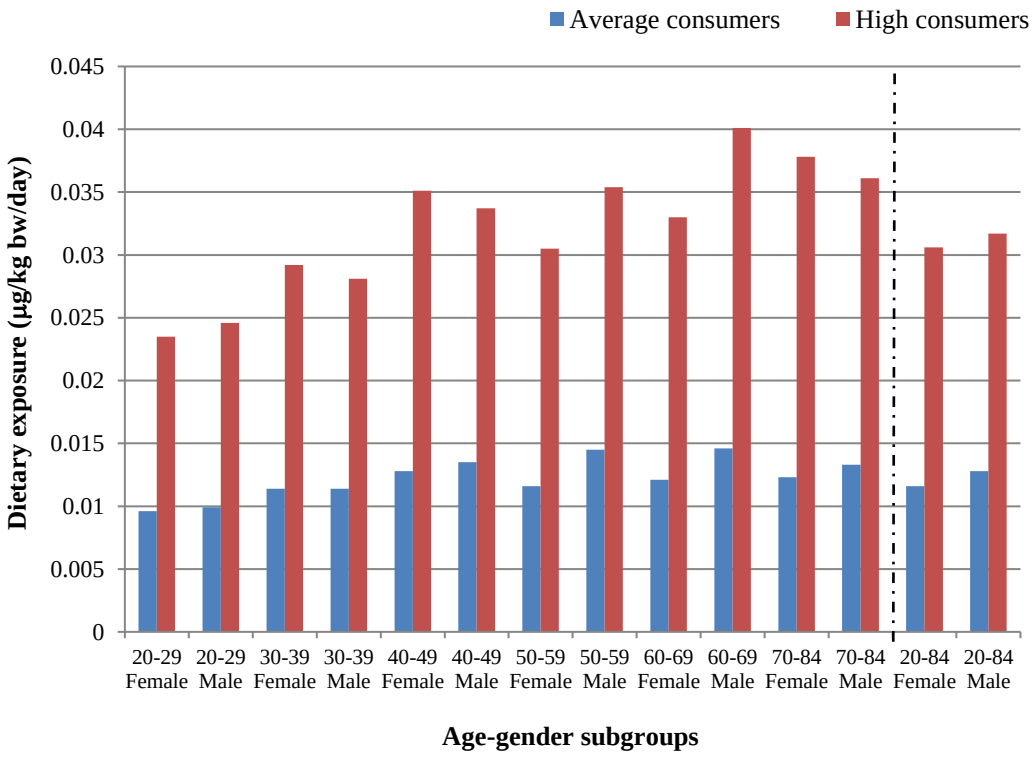
* May not sum to total due to rounding

Figure 2. Relative contribution of each group of tea to dietary exposure to perchlorate among average consumers



47. Further analysis of dietary exposure of individual age-gender population subgroups is shown in Figure 3. The dietary exposure to perchlorate due to consumption of tea and tea beverages did not indicate a health concern for all age-gender subgroups. The highest dietary exposure among all age-gender population subgroups was found in males aged 60-69 (0.015 µg/kg bw/day for average consumers and 0.040 µg/kg bw/day for high consumers).

Figure 3. Dietary exposure to perchlorate for average and high consumers of individual age-gender subgroups arising from consumption of tea and tea beverages



Uncertainties and Limitations of the Study

48. While higher accuracy and precision in exposure estimation could be achieved by increasing the sample size, compromise had to be made due to finite resources. The limited number of samples analysed in the study represents a small fraction of the products available to the local consumers and provided only a snapshot of the levels of perchlorate in dried tea leaves and tea beverages.

49. In this study, all perchlorate was assumed to be released from dried tea leaves into tea infusion, leading to an over-estimation of the dietary exposure to perchlorate. Nonetheless, similar conclusion will be reached after taking the over-estimation into consideration.

CONCLUSIONS AND RECOMMENDATIONS

50. Perchlorate is present in the majority (96%) of the dried tea leaf / tea beverage samples collected.

51. The estimated dietary exposure to perchlorate from dried tea leaves and tea beverages for average consumers, high consumers and individual age-gender population subgroups were all below 1% of the PMTDI established by JECFA (10 μg/kg bw/day). Hence, 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.

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Appendix 1

Occurrence of perchlorate in food samples from different places

Food items	Number of samples	Mean perchlorate levels [range] (μg/kg or μg/L)
Vegetables [i]		
Lettuce	372	11.6
Spinach	64	111
Potato	90	4.8
Tomato	95	14
Carrot	120	10.5
Eggplant	60	78
Broccoli	115	19
Cauliflower	68	7
Cabbage	31	10
Fruits [i]		
Apple	33	0.5
Grape	39	28
Orange	50	5
Melon	98	19
Other		
Vegetable and fruit juice [i]	53	25.8
Honeydew [i]	6	0.3
Whole wheat flour [i]	38	3.5
Rice [i]	94	1
Milk [i]	221	6.8
Infant formula (powder) [i]	20	10
Fish and fishery products [i]	186	n.r. [0.32-1593]
Wine [i]	104	6
Beer [i]	144	1.04
Tea and herbs for infusion (solid) [ii]	17	56
Tea and herbs for infusion (solid) [iii]	1193	324

n.r.: not reported

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Appendix 2

Levels of perchlorate detected in dried tea leaf and tea beverage samples collected in the current study

Items in each group	No. of samples	Mean perchlorate levels*(μg/kg) [range]	Median perchlorate levels* (μg/kg or μg/L)
Dried Tea Leaves			
Non-fermented tea leaves	**54**	**140 [ND-790]****	**120**
Biluochun tea leaves	5	190 [22-310]	230
Green tea leaves	34	140 [ND-790]**	65
Longjing tea leaves	15	130 [50-340]	120
Semi-fermented tea leaves	**76**	**250 [1.2-1100]**	**180**
Jasmine tea leaves	20	300 [35-1100]	200
Tieguanyin tea leaves	16	250 [65-690]	180
Shouwei tea leaves	10	240 [26-650]	220
Oolong tea leaves	21	220 [19-530]	190
Shuixian tea leaves	9	190 [1.2-760]	120
Fully-fermented tea leaves / Post-fermented tea leaves	**75**	**69 [1.3-660]**	**24**
Liuan tea leaves	5	190 [52-320]	230
Black tea leaves[#]	50	64 [1.3-660]	5.0
Pu-er tea leaves	20	50 [1.7-190]	41
Floral tea	**25**	**150 [1.4-470]**	**80**
Genmai tea (dried)	**16**	**79 [ND-840]****	**2.6**
Tea Beverages			
Lemon tea	**15**	**1.3 [ND-3.2]****	**1.4**
Flavoured tea / Tea drinks	**15**	**0.59 [ND-1.8]****	**0.44**
Milk tea	**15**	**3.1 [0.49-8.3]**	**2.7**
Milk tea (powder)	3	19 [5.3-30]	23
Milk tea (beverages)	12	3.4 [0.49-8.3]	2.9
Milk tea with "pearls"	**10**	**0.84 [0.51-1.2]**	**0.81**
Genmai tea (beverages)	**4**	**0.78 [ND-2.5]****	**0.28**

***** Rounded to 2 significant figures.

**ND: not detected, a value of LOD/2 was assigned for samples with perchlorate level below LOD when calculating the mean concentration.

[#] Including Earl Grey, English Breakfast Tea, Darjeeling Tea, Ceylon Tea, Chinese Black Tea and Gongfu Tea.