The First Hong Kong Total Diet Study Report No. 2

The First Hong Kong Total Diet Study: Inorganic Arsenic

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EXECUTIVE SUMMARY

The Centre for Food Safety (CFS) is conducting the First Hong Kong Total Diet Study (the 1st HKTDS) aiming to estimate dietary exposures of the Hong Kong population and various population subgroups to a range of substances, including contaminants and nutrients, and thus assess any associated health risks. This report presents the dietary exposure assessment of a metallic contaminant, inorganic arsenic.

2. Arsenic is a metalloid that occurs in inorganic and organic forms, which are found in the environment from both natural sources and human activities. Food is recognised as the major source of inorganic arsenic exposure and low levels of inorganic arsenic in foods may be unavoidable due to its ubiquitous nature in the modern industrial world.

3. In general, inorganic forms of arsenic are more toxic to humans than organic ones while the trivalent form (arsenite) is more toxic than the pentavalent form (arsenate). The main adverse effects in human after long-term ingestion of inorganic arsenic are cancer, skin lesions, cardiovascular disease, neurotoxicity and diabetes.

4. In 2010, the Joint Food and Agriculture Organization (FAO) / World Health Organization (WHO) Expert Committee on Food Additives (JECFA) determined the inorganic arsenic benchmark dose lower confidence limit for a 0.5% increased incidence of lung cancer in human ($BMDL_{0.5}$) which computed to be 3.0 μg/kg body weight (bw) /day (2 – 7 μg/kg bw/day) and withdrew the Provisional Tolerable Weekly Intake (PTWI) of 15 μg/kg bw/week (i.e. 2.1 μg/kg bw/day) to inorganic arsenic established in 1988 as it was no longer

appropriate. The BMDL is the lower confidence limit of a point on the dose-response curve that characterises adverse effect (in the case of inorganic arsenic, i.e. 0.5% increased incidence of lung cancer in human), to account for uncertainty in the data. In fact, the BMDL can not be regarded as a safety reference value, in which exposure level below this point does not mean there is no health risk. Furthermore, the margins of exposure (MOEs) are also calculated by taking relative cancer potency and exposure estimates into account to provide an indication of the level of health concern without actually quantifying the risk (i.e. the higher the MOE, the lower the health concern, and vice versa). MOEs can be used for priority setting for risk management actions.

Results

5. A total of 600 composite samples were tested for inorganic arsenic. (They composed of 150 different foods with 3 purchases collected and prepared on each of the four occasions from March 2010 to February 2011. A total of 1,800 individual samples have been taken.) About half of the composite samples (51%) were detected with inorganic arsenic (Limits of detection (LOD) were 3 and 1.5 μg/kg in food and water respectively). Among the 15 food groups, "eggs and their products" contained the highest inorganic arsenic level (mean: 23 μg/kg), followed by "fish and seafood and their products" (mean: 15 μg/kg), and "vegetables and their products" (mean: 9 μg/kg). Besides, the mean inorganic arsenic level in "cereals and their products" was 8 μg/kg. On the other hand, all samples of dairy products and fats and oils were not detected with inorganic arsenic. At food item level, water spinach was found to contain the highest level (mean: 74 μg/kg, ranged from 35 to 120 μg/kg), followed by

salted egg (mean: 58 μg/kg) and oyster (mean: 58 μg/kg), whereas no water sample from our study has been detected with inorganic arsenic.

6. The dietary exposures to inorganic arsenic were 0.22 and 0.38 μg/kg bw/day for average and high consumer of the population, respectively, and those of the individual age-gender population subgroups ranged from 0.19 to 0.26 μg/kg bw/day and from 0.33 to 0.46 μg/kg bw/day for average and high consumers, respectively. All the dietary exposure estimates were below the range of $BMDL_{0.5}$ determined by JECFA, with the MOEs ranging from 9 to 32 and from 5 to 18 for average and high consumer of the population respectively. Having considered the carcinogenic risk of inorganic arsenic, efforts should be made to reduce the exposure to inorganic arsenic of the population.

7. The main dietary source of inorganic arsenic was "cereals and their products" which contributed to 53.5% of the total exposure, followed by "beverages, non-alcoholic", "vegetables and their products" and "fish and seafood and their products" which contributed to 13.0%, 10.4% and 7.9% of the total exposure, respectively.

8. Rice is the major contributor of the dietary exposure to inorganic arsenic, in which the cooked white rice alone accounted for 45.2% of total exposure. The findings that rice was the major contributor were consistent with data reported in other countries where rice is the staple food.

Conclusions and Recommendations

9. The dietary exposures to inorganic arsenic of the population were below the range of $BMDL_{0.5}$ as determined by JECFA, with the MOEs ranging

from 9 to 32 and from 5 to 18 for average and high consumer of the population, respectively. Having considered the carcinogenic risk of inorganic arsenic, efforts should be made to reduce the exposure to inorganic arsenic of the population.

10. The food trade is advised to observe good agricultural practices to minimise inorganic arsenic contamination of foods, such as avoid using arsenic contaminated water for irrigation.

11. The findings of the current study are not sufficient to warrant changes in basic dietary advice on healthy eating, i.e. have a balanced and varied diet, and take cereals, such as rice, noodles, oatmeal and bread, as the major dietary source. Those individuals, who wish to reduce the exposure to inorganic arsenic, can consider choosing more other cereals, which generally contain lower levels of inorganic arsenic than rice, as part of their diet, and observe the following advices: wash rice thoroughly but without excessive washing as some nutrients may be lost, and discard the washed water before cooking so as to reduce the arsenic levels, especially the inorganic form.

The First Hong Kong Total Diet Study:

Inorganic Arsenic

BACKGROUND

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

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

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

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

Inorganic Arsenic

4. This report focused on one of the substances covered in the 1st HKTDS, i.e. inorganic arsenic, the more toxic form of arsenic. The dietary exposures of the Hong Kong population to inorganic arsenic as well as its associated health risk would be assessed.

5. Arsenic was usually analysed as total arsenic in most studies and sometimes exposures of inorganic arsenic were estimated by assigning inorganic arsenic levels derived from conversion factors applied. However, the proportion of inorganic arsenic in some foods was found to vary widely, and thus using actual data of inorganic arsenic contents could improve assessments of dietary exposure of inorganic arsenic, rather than using generalised conversion factors from total arsenic measurement.[1] As such, in 1st HKTDS, the actual data of inorganic arsenic contents in food as consumed were used for the dietary exposures.

Sources of Inorganic Arsenic

6. Arsenic is a metalloid that occurs in inorganic and organic forms, which are found in the environment from both natural sources and human activities. Arsenic is present in soil, ground water and plants while arsenic compounds are also used in the manufacture of transistors, lasers, semiconductors, glass, pigments, etc, and to a lesser extent, as pesticides, feed additives and pharmaceuticals. Primary route of exposure in humans to arsenic is mainly through ingestion of foods and drinking water.[1,2,3]

7. Foods and beverages usually contain inorganic arsenic at levels not exceeding 100 μg/kg with mean values generally less than 30 μg/kg. However, seaweed, rice and some fish and seafood commodities, as well as food crops grown in arsenic-contaminated soils, may have higher inorganic arsenic levels and their proportions of inorganic arsenic to the total arsenic vary a lot. Some available data on inorganic arsenic levels in food products as well as their proportions to the total arsenic are given in Table 1 below.[1, 4]

Table 1: The Proportions of Inorganic Arsenic to the Total Arsenic among Different Types of Food

Food	Proportion of Inorganic Arsenic to Total Arsenic	Inorganic Arsenic Levels in μg/kg
Rice	17 – 100%	10 – 510
Vegetables	33 – 74%	8 – 610
Fish and fish products (including shellfish)	Usually less than 10% (15% in shellfish from areas with some degree of arsenic contamination)	1 – 1,200
Hijiki	More than 50%	30,000 – 130,000
Seaweed other than hijiki	Less than 15%	Normally below 2000

8. Food products of terrestrial origin generally contain low levels of arsenic, and their inorganic arsenic content is also low. Rice, however, appears to be an exception. It has been reported that rice has the tendency to accumulate arsenic in comparison to other grain crops tested to date, with whole grain (brown) rice having higher arsenic levels than polished (white) one and its proportion of inorganic arsenic varies from 17% to 100% of total arsenic, with concentrations ranged from 10 to 510 μg/kg. [1, 4]

9. On the other hand, fish and seafood products have a high total arsenic content (typically 2,000 – 60,000 μg/kg dry mass), in which usually less than 10% of them in fish and fish products and about 15% of them in shellfish are inorganic arsenic and their levels of inorganic arsenic are typically < 200 μg/kg dry mass, but with some notable exceptions, for example, more than 50% of total arsenic in seaweed hijiki are inorganic arsenic with levels usually ranging from 30,000 to 130,000 μg/kg and in blue mussel contained inorganic arsenic with levels up to 30,000 μg/kg dry mass.[4]

10. Concentrations of arsenic in ground water, major sources of drinking water, are usually less than 10 μg/L but they can reach 5000 μg/L in some areas, in which it is mainly present as inorganic arsenic.[4]

Toxicity

11. Absorption of arsenic depends on the chemical species, its solubility and the matrix. Soluble arsenic compounds in water are highly bioavailable. Inorganic arsenic is rapidly cleared from blood in humans and is metabolised primarily by stepwise reduction of pentavalent arsenic (arsenate) to trivalent arsenic (arsenite) followed by oxidative addition of methyl groups. Most ingested inorganic arsenic is excreted via the kidney within a few days as inorganic arsenate and arsenite and as the pentavalent methylated metabolites, with lesser amounts of the trivalent methylated metabolites and thioarsenical metabolities.

12. Arsenic toxicity depends on the chemical form and its solubility and varies among animal species and with route of administration. In general, inorganic forms of arsenic are more toxic to humans than organic ones while the

trivalent form (arsenite) is more toxic than the pentavalent form (arsenate).[1] Soluble inorganic arsenic is acutely toxic to human, and ingestion of large doses leads to gastrointestinal symptoms, disturbances of cardiovascular and nervous system functions, and eventually death. In survivors, bone marrow depression, haemolysis, hepatomegaly, melanosis, polyneuropathy and encephalopathy may be observed. The estimated fatal doses ranged from 2 g to 21 g and cases with non-fatal outcome have been reported after oral doses of 1 – 4 g up to 8 – 16 g arsenic.[5]

13. The main adverse effects reported to be associated with long-term ingestion of inorganic arsenic by humans are cancer, skin lesions, cardiovascular disease, neurotoxicity and diabetes.

14. In 2004, International Agency for Research on Cancer (IARC) concluded that there was sufficient evidence in humans that arsenic in drinking-water caused cancers of the urinary bladder, lung and skin and the evidence for carcinogenicity in experimental animals was limited.[6] In 2009, the IARC again concluded that arsenic in drinking-water caused cancers of the urinary bladder, lung and skin in human and that the evidence was "limited" for cancers of the kidney, liver and prostate in human. IARC has classified arsenic and inorganic arsenic compounds as Group 1 agent, i.e. carcinogenic to human, and other organic arsenic compounds as either Group 2B (i.e. possibly carcinogenic to humans) or Group 3 (i.e. not classifiable as to their carcinogenicity to humans).[7]

15. In 2010, the Joint Food and Agriculture Organization (FAO) / World Health Organization (WHO) Expert Committee on Food Additives (JECFA)

determined the inorganic arsenic benchmark dose lower confidence limit for a 0.5% increased incidence of lung cancer in human ($BMDL_{0.5}$). The $BMDL_{0.5}$ was computed to be 3.0 µg/kg body weight (bw) /day (2 – 7 µg/kg bw/day) with the following uncertainties: the assumptions on total exposure extrapolated from the drinking water, and extrapolation of the $BMDL_{0.5}$ to other populations due to the influence of nutritional status, such as low protein intake, and other lifestyle factors on the effects observed in the studied population. Therefore, JECFA withdrew the Provisional Tolerable Weekly Intake (PTWI) of 15 µg/kg bw/week to inorganic arsenic established in 1988 since the previous PTWI (15 µg/kg bw/week = 2.1 µg/kg bw/day) is in the region of $BMDL_{0.5}$ of 2 – 7 µg/kg bw/day. [1] The BMDL is the lower confidence limit of a point on the dose-response curve that characterises adverse effect (in the case of inorganic arsenic, i.e. 0.5% increased incidence of lung cancer in human), to account for uncertainty in the data. In fact, the BMDL can not be regarded as a safety reference value, and when dietary exposure below the BMDL, it does not mean that there is no health risk.[8]

16. For risk assessment, the margins of exposure (MOEs) take relative cancer potency and exposure estimates into account for providing an indication of the level of health concern without actually quantifying the risk. The MOE is defined as the ratio of $BMDL_{0.5}$ from the human data to the estimated dietary exposure to inorganic arsenic in the local population. The higher the MOE, the lower the health concern, and vice versa. The MOEs can be used for priority setting for risk management actions, in which the level of regulatory or non-regulatory intervention can take account of the size of the MOE.

The Previous Local Study

17. The Food and Environmental Hygiene Department (FEHD) conducted a study on "Dietary Exposure to Heavy Metals of Secondary School Students" in 2002, in which three metallic contaminants, namely arsenic, cadmium and mercury, were chosen for the study. The estimated exposures to inorganic arsenic for an average and high consumer of secondary school student were 2.52 μg/kg bw/week (i.e. 0.36 μg/kg bw/day) and 6.77 μg/kg bw/week (i.e. 0.97 μg/kg bw/day), respectively. The food group "seafood other than fish" (51%) made the greatest contribution to the exposure to inorganic arsenic, and was followed by the food groups "fish" (26%) and "cereals and their products" (10%).

18. It was noted that there were certain limitations in the previous study. The levels of inorganic arsenic were calculated by multiplying a conversion factor of 0.1 (with the assumption that 10% of total arsenic was inorganic one in all food groups) by the total arsenic levels extracted from the database of the Food Surveillance Programme of FEHD. In the Food Surveillance Programme, which is mainly for enforcement purposes, analyses for arsenic were determined in terms of total arsenic rather than inorganic arsenic and the limit of detection (LOD) was 76 μg/kg, which was considered high if used for research studies. A value of ½ LOD was assigned to samples with levels below LOD as a conservative approach. Hence, it would lead to overestimation of dietary exposures from both seafood products and other foods (in which the majority of samples were not detected with total arsenic). The application of a generalised conversion factor might have influenced the main food contributors to dietary

exposure since the proportions of inorganic arsenic to the total arsenic vary widely among different foods even under same food groups.

19. The persistent concern over health risk of inorganic arsenic and the limitations of the previous study, inorganic arsenic was selected in the 1st HKTDS to re-examine the issue with a view to obtaining a more precise estimate of dietary exposure to inorganic arsenic by using more sophisticated methods of analysis on inorganic arsenic with a lower detection limit.

METHODOLOGY AND LABORATORY ANALYSIS

Methodology of the 1st HKTDS

20. The 1st HKTDS involved purchasing samples of food commonly consumed throughout Hong Kong, preparing them as consumed, 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) [9], to obtain the dietary exposures.

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

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

23. Details of the methodology are given in the same series of report on Methodology.[10]

Laboratory Analysis of Inorganic Arsenic

24. Laboratory analysis of inorganic arsenic was conducted by the Food Research Laboratory (FRL) of the CFS. Inorganic arsenic refers to the sum of arsenite (As(III)) and arsenate (As(V)). Having taken into account the occurrence in food, all samples of the 150 TDS food items taken from the four occasions have been tested for inorganic arsenic. The composite samples were solubilised in concentrated hydrochloric acid. After reduction, arsenite was extracted into chloroform. The arsenite in chloroform was then back extracted to diluted hydrochloric acid. Subsequently, the organic matters were destructed by dry-ashing. The resulting ash was dissolved in hydrochloric acid and the inorganic arsenic content was quantified by hydride generation inductively coupled plasma mass spectrometry. [Note: This procedure was also known to extract a small amount of monomethylarsenic species (MMA).] The limits of detection (LOD) and the limits of quantification (LOQ) were 3 and 10 μg/kg in food, and 1.5 and 5 μg/kg in water, respectively.

RESULTS AND DISCUSSION

Concentrations of Inorganic Arsenic in TDS Foods

25. A total of 600 composite samples on four occasions were tested for inorganic arsenic and the results in 15 TDS food groups are summarised in Table 2 and the results in 150 TDS food items are shown in Appendix 1. About half of the composite samples (51%) were detected with inorganic arsenic. According to the recommendation of WHO on evaluation of low-level contamination of food in treatment for those non-detected results,[11] all non-detected results were assigned with levels at half of LOD for expressing the inorganic arsenic content as well as estimating the dietary exposures throughout the report.

Table 2: Inorganic Arsenic Content (μg/kg) in TDS Food Groups of the 1st HKTDS

Food Group	Number of composite samples	% of composite samples < LOD	Mean (μg/kg)#	[range]
Cereals and their products	76	29	8	[ND – 46]
Vegetables and their products	140	49	9	[ND – 120]
Legumes, nuts and seeds and their products	24	63	4	[ND – 14]
Fruits	68	78	4	[ND – 88]
Meat, poultry and game and their products	48	54	4	[ND – 27]
Eggs and their products	12	33	23	[ND – 93]
Fish and seafood and their products	76	17	15	[ND – 74]
Dairy products	20	100	1.5	[ND]
Fats and oils	8	100	1.5	[ND]
Beverages, alcoholic	8	50	3	[ND – 7]
Beverages, non-alcoholic	40	95	2	[ND – 12]
Mixed dishes	48	21	6	[ND – 19]
Snack foods	4	0	8	[6 – 10]
Sugars and confectionery	8	63	4	[ND – 8]
Condiments, sauces and herbs	20	40	8	[ND – 65]
Total	600	49		

Notes:

\# As only 49% of results are below limit of detection (LOD), half of LOD is used for all results less than LOD in calculating the mean concentration.

ND denotes non-detected, i.e. results less than LOD.

26. All composite samples were found containing inorganic arsenic below their relevant limits as stipulated in the Food Adulteration (Metallic Contamination) Regulations, Cap. 132 Sub. Leg. V. The highest inorganic arsenic level was detected in food group "eggs and their products" (mean: 23 μg/kg), followed by "fish and seafood and their products" (mean: 15 μg/kg), and "vegetables and their products" (mean: 9 μg/kg). However, majority (95%) of non-alcoholic beverage samples, and all samples of "dairy products" and "fats and oils" were not detected with inorganic arsenic.

27. By comparing the inorganic arsenic levels in 150 food items, water spinach was found to contain the highest level (mean: 74 μg/kg, ranged from 35 to 120 μg/kg), followed by salted eggs (mean: 58 μg/kg) and oyster (mean: 58 μg/kg). Although literatures have been reported that water is one of the most significant sources of inorganic arsenic exposure, no water sample from our study has been detected with inorganic arsenic.

Dietary Exposure to Inorganic Arsenic

28. Dietary exposures to inorganic arsenic of average and high consumer of the population were 0.22 μg/kg bw/day and 0.38 μg/kg bw/day respectively. The average dietary exposures to inorganic arsenic among male and female were 0.23 μg/kg bw/day and 0.21 μg/kg bw/day respectively. Furthermore, dietary exposures to inorganic arsenic of the individual age-gender population subgroups ranged from 0.19 μg/kg bw/day of female aged 20 – 29 to 0.26 μg/kg bw/day of male aged 60 – 69 for average consumers and from 0.33 μg/kg bw/day of female aged 20 – 29 to 0.46 μg/kg bw/day of male aged 60 – 69 for high consumers (see Figure 1). The breakdowns of dietary exposures of the individual age-gender population subgroups are shown in Appendix 2.

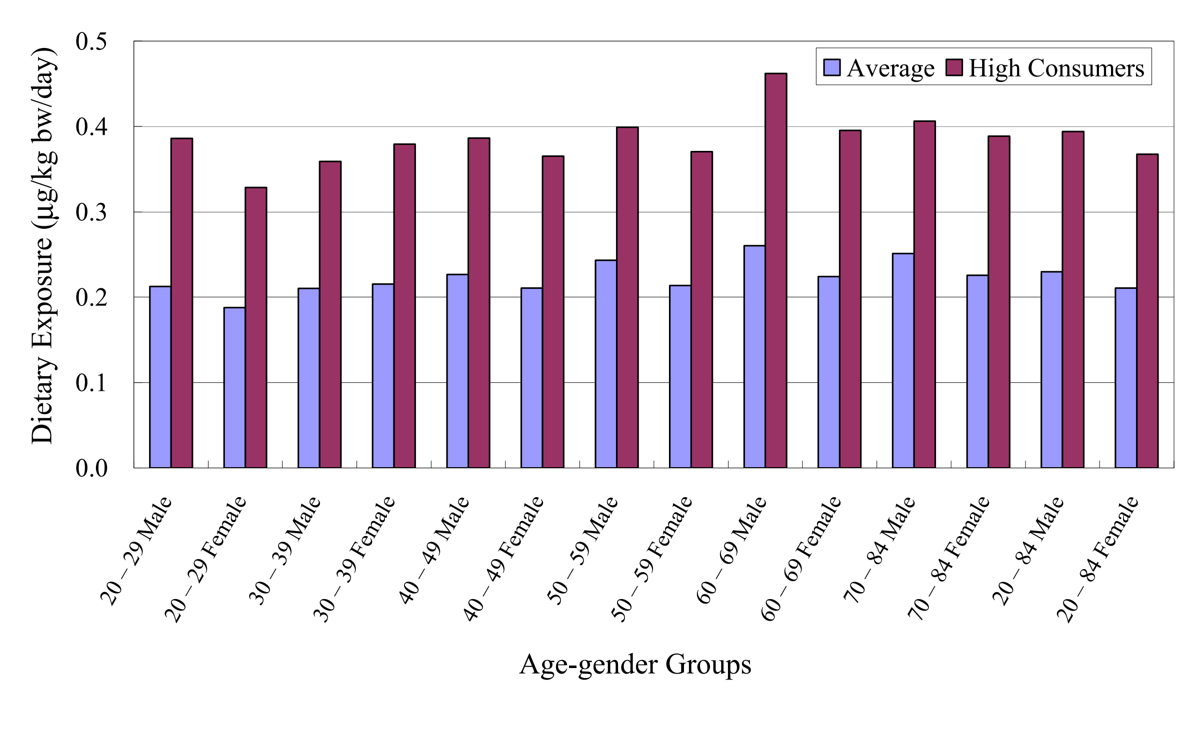

Figure 1 Dietary Exposures to Inorganic Arsenic for the Average and High Consumers of Individual Age-gender Groups of the 1st HKTDS

29. All dietary exposures were below the $BMDL_{0.5}$ with the MOEs of inorganic arsenic ranging from 9 to 32 and from 5 to 18 for average and high consumer of the population, respectively (Table 3). The higher the MOE, the lower the health concern. However, currently there is no international recommendation on the MOE values that are regarded as of health concern. Therefore, although JECFA has already commented that the previous PTWI of inorganic arsenic was no longer appropriate, the dietary exposures were also compared with the PTWI (15 µg/kg bw/week = 2.1 µg/kg bw/day), which were contributed to 10% and 18% of PTWI for average and high consumer of the population respectively. Nevertheless, as inorganic arsenic is an important

factor for cancer risk, efforts should be made to reduce the exposure to inorganic arsenic for the population.

Table 3: Dietary Exposures (μg/kg bw/day) to Inorganic Arsenic for an Average and High Consumer of the Population and their MOEs

	Average	High Consumer
Dietary Exposure (μg/kg bw/day)	0.22	0.38
MOEs	9 – 32	5 – 18

Major Food Contributors

30. Dietary exposures to inorganic arsenic for an average of population from the 15 TDS food groups are shown in Table 4 and their contributions to total dietary exposure are shown in Figure 2.

31. In our findings, the main dietary source of inorganic arsenic was "cereals and their products" which contributed to 53.5% of the total exposure, followed by "beverages, non-alcoholic", "vegetables and their products" and "fish and seafood and their products" which contributed to 13.0%, 10.4% and 7.9% of the total exposure, respectively. Similar findings were also revealed in other dietary exposure studies such as those conducted in the UK[12] and Mainland China[13].

32. According to the findings of TDS conducted in other places such as the UK and Mainland China, the main dietary sources of inorganic arsenic were cereals, vegetables and beverages, in which cereals contributed 31% and 45% of the total dietary exposures and vegetables contributed 17% and 18% and beverages contributed 20% and 18%, in the UK and Mainland China,

respectively. Although fish and shellfish contained higher levels of total arsenic than the other food, fish and shellfish were not found to be a main contributor to the dietary exposure to inorganic arsenic as the majority of arsenic in fish and in shellfish is organic form.[1] Fish and seafood contributed 3% and 4.3% of the total dietary exposure in the UK and Mainland China respectively.[12,] Moreover, drinking water can be a significant source of arsenic exposure in places where drinking water contains relatively high levels of arsenic.

Table 4: Dietary Exposure (μg/kg bw/day) to Inorganic Arsenic for an Average Individual in the Population by TDS Food Groups

TDS Food Group	Dietary Exposure in μg/kg bw/day #	% contribution of total exposure
Cereals and their products	0.12	53.5
Vegetables and their products	0.02	10.4
Legumes, nuts and seeds and their products	0.00	0.3
Fruits	0.01	3.3
Meat, poultry and game and their products	0.01	3.2
Eggs and their products	0.00	0.4
Fish and seafood and their products	0.02	7.9
Dairy products	0.00	0.6
Beverages, alcoholic	0.00	0.6
Beverages, non-alcoholic	0.03	13.0
Mixed dishes	0.01	5.4
Condiments, sauces and herbs	0.00	1.0
Other food groups (including fats and oils, snack foods, sugars and confectionery)	0.00	0.2
Total	0.22†	100.0†

Notes:

\# As only 49% of results are below limit of detection (LOD), half of LOD is used for all results less than LOD in calculating the exposure estimates.

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

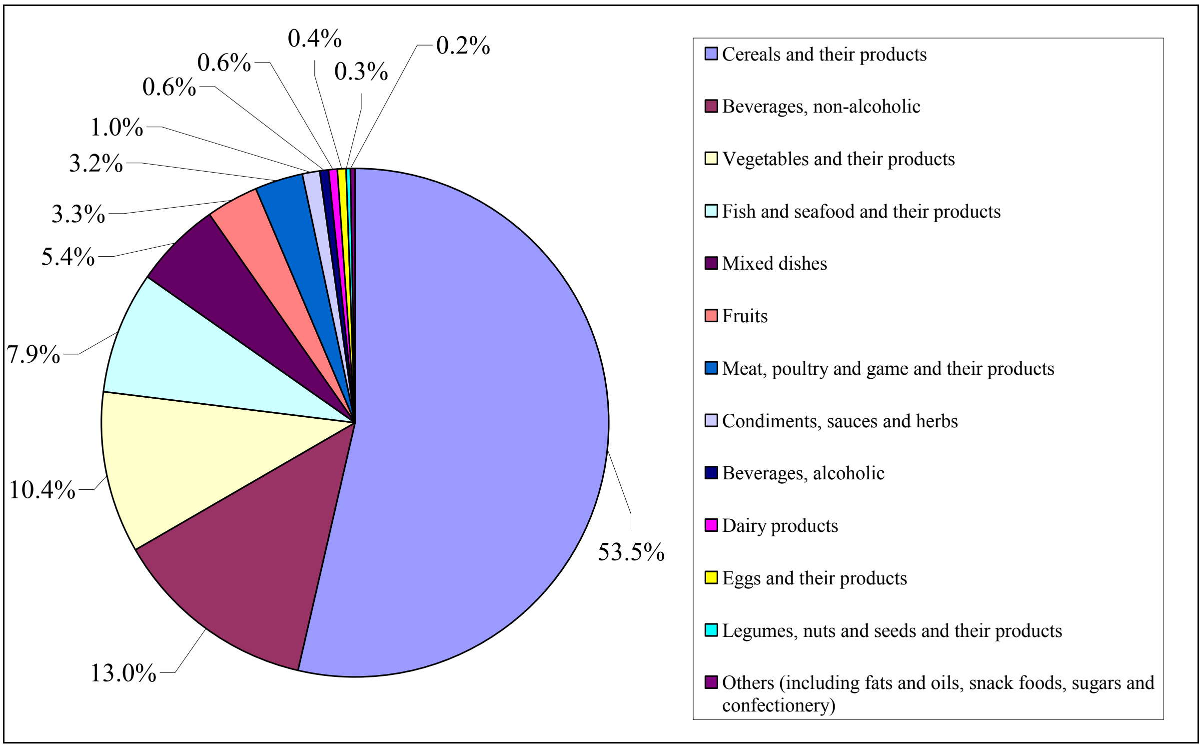

Figure 2: Percentage Contribution to Dietary Exposure to Inorganic Arsenic by Food Groups

<u>Rice</u>

33. In food group "cereals and their products", cooked white rice (including congee) is a particularly significant source of inorganic arsenic. This food item alone accounted for 45.2% of total exposure, or 84.5% of the contribution by the food group "cereals and their products". The finding that rice was the major contributor of inorganic arsenic dietary exposures was consistent with data reported in other countries where rice is the staple food . Moreover, among the samples in this food group, cereals including noodles, bread and oatmeal were found containing low levels of inorganic arsenic (mean levels ranged from 1.5 to 9 μg/kg), in contrast cooked white rice and cooked unpolished rice contained relatively high levels of inorganic arsenic, in which

levels detected in unpolished rice (mean: 43 μg/kg) were nearly double those of white rice (mean: 22 μg/kg). However, in terms of dietary exposure, the cooked unpolished rice (including congee) only contributed 1.3% of total exposure to inorganic arsenic. Besides, among individuals consumed unpolished rice (including congee) (about 5% of the population), the exposures to inorganic arsenic from unpolished rice (including congee) alone were 0.06 μg/kg bw/day and 0.18 μg/kg bw/day for average and high consumers of unpolished rice respectively. From the perspective of food safety and nutrition, no benefit and risk analysis can be made regarding the intake of unpolished rice based on information available.

34. The levels of inorganic arsenic in the rice consumed may vary, depending on food processing and preparation methods. It was reported that rinse washing and cooking rice with high volume water (rice to water ratio 1:6) and with excess water discarded did effectively remove both total and inorganic arsenic for some rice varieties, in which rinse washing removed 10% of both total and inorganic arsenic and cooking rice removed 35% and 45% of both total and inorganic arsenic, respectively, as compared with the uncooked rice. The removed arsenic was associated with the wash water and was found in the water discarded. Hence, rinsing or soaking rice and discarding the water before cooking can reduce arsenic levels, especially inorganic forms, provided that non-contaminated water was used for cooking. However, cooking rice with low water volume (rice to water ratio 1:1.5 – 2.5) did not change arsenic content.[1, 4, 14] Regarding the local practice, it is more common to wash rice prior to cooking and cook rice with low volume water until no water is left, in which certain amount (about 10%) of arsenic can be removed.

Water Spinach

35. Although water spinach contained the highest level of inorganic arsenic (mean: 74 μg/kg, ranged from 35 to 120 μg/kg), it only contributed 3% of total exposure. The 4 composite water spinach samples (consisting of 12 individual samples collected from the four occasions) were mainly samples of the two major cultivars, namely "green stem" water spinach and "white stem" water spinach. The cultivars of water spinach samples and the levels of inorganic arsenic detected from the four occasions are shown in Table 5. The findings revealed that the composite samples consisted of "white stem" water spinach were likely to contain higher inorganic arsenic contents than those consisted of "green stem" ones. In general, water spinach needs much more water than most other vegetable crops, in which the "white stem" and "green stem" water spinach are usually grown in aquatic conditions (similar to rice) and moist soils, respectively.[15] It was believed that vegetable crops grown hydroponically might contain higher arsenic contents than the other vegetable crops.

Table 5: The Cultivars of Water Spinach Samples and the Levels of Inorganic Arsenic Detected by Sampling Occasion

Occasion	No of samples		Inorganic arsenic level (μg/kg)
	"Green stem" water spinach	"White stem" water spinach	
First	2	1	98
Second	0	3	120
Third	3	0	43
Fourth	3	0	35

Drinking Water

36. There are concerns that drinking water can be an important source of exposure to inorganic arsenic, however, no water samples from our current study were detected with inorganic arsenic. By assigning ½ LOD value to all non-detected results in exposure estimation, drinking water contributed 6% of exposure to inorganic arsenic (i.e. 0.014 μg/kg bw/day). Even though with such conservative approach, drinking water was considered an insignificant source of inorganic arsenic exposure of the Hong Kong population.

Egg Products

37. Although the food group "eggs and their products" contained the highest inorganic arsenic level, it only contributed very little (0.4 %) to the total dietary exposure. Among the three food items in this food group, the salted egg (mean: 58 μg/kg) was found containing the highest level of inorganic arsenic, followed by the lime preserved egg (mean: 10 μg/kg), in contrast, no chicken egg samples were detected with inorganic arsenic. The presence of inorganic arsenic in the processed eggs might be due to the use of plant ash and/or loess (a kind of light-coloured soil) in the salt curing process.

Comparison with the Previous Local Study

38. The dietary exposures estimated in our current study were lower than those in the previous local study for both average and high consumers. However, one needs to be cautious when making such a comparison after taking into account the limitation of our previous study as mentioned in para. 18.

Furthermore, the food group "cereals and their products" was found to be the main food contributor in current study, which was different from that of the previous study where fish and seafood products were found to be the main contributor (77%) to the exposures. In fact, our current findings are consistent with recent overseas reports.

International Comparison

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

Table 6: A Comparison of Dietary Exposures to Inorganic Arsenic

Places	Dietary exposure of adult (μg/kg bw/day)	
	Average	High Consumer
UK # 12	0.03 – 0.09	0.07 – 0.17 (97.5th percentile)
France †	0.1	0.27 (95th percentile)
USA #	0.08 – 0.20	0.16 – 0.34 (95th percentile)
Hong Kong* #	0.22	0.38 (95th percentile)
New Zealand † 16	0.24 – 0.29	
Canada †	0.29	
Europe †	0.21 – 0.61	0.36 – 0.99 (95th percentile)
Japan # †	0.36 – 0.46	0.83 – 1.29 (95th percentile)
China #	0.24 – 0.76	

* Data are extracted from the current study.
# Exposure data were estimated based on the detection of inorganic arsenic.
† Exposure data were estimated based on the detection of total arsenic and the use of conversion factors.

40. However, direct comparison of the data has to be done with caution due to the difference in time when the studies were carried out, research methodology, methods of collection of consumption data, methods of contaminant analysis and methods of treating results below detection limits. In addition, arsenic was usually analysed as total arsenic in most studies and sometimes, exposures of inorganic arsenic were estimated by assigning inorganic arsenic levels derived from conversion factors applied, which may introduce biases in the estimates.

Limitations of the Study

41. Although seaweeds such as hijiki were reported to contain high inorganic arsenic content, the TDS food list did not include any seaweed items (including those used for preparing sushi) as only limited food consumption data of seaweeds were captured by the FCS. It might lead to underestimation of the dietary exposure to inorganic arsenic. On the other hand, although majority of non-alcoholic beverage samples were not detected with inorganic arsenic, they still contributed 13.0% of total exposures by assigning a ½ LOD to those non-detected results. If a zero value was assigned to those non-detected results, the contribution from non-alcoholic beverages would reduce to about 1% of the total exposure. Hence, it might lead to overestimation of the dietary exposure to inorganic arsenic. Besides, other limitations were described in the report on methodology.[10]

CONCLUSIONS AND RECOMMENDATIONS

42. The dietary exposures to inorganic arsenic were 0.22 and 0.38 μg/kg bw/day for average and high consumer of the population, respectively, and those of the individual age-gender population subgroups ranged from 0.19 to 0.26 μg/kg bw/day and from 0.33 to 0.46 μg/kg bw/day for average and high consumers, respectively. All dietary exposures were below the $BMDL_{0.5}$, with the MOEs ranging from 9 to 32 and from 5 to 18 for average and high consumer of the population, respectively, in which the higher the MOE, the lower the health concern. As inorganic arsenic is an important factor for cancer risk, efforts should be made to reduce the exposure to inorganic arsenic of the population.

43. Food is recognised as the major source of inorganic arsenic exposure. Because of the ubiquitous nature of inorganic arsenic in the modern industrial world, low levels of inorganic arsenic in foods may be unavoidable.

44. Rice is the major contributor of the dietary exposure to inorganic arsenic. In fact, arsenic contamination of rice is regarded as a worldwide problem. Codex Committee on Contaminants in Foods started to discuss the issue on arsenic in rice in the meeting held in March 2011. In the meeting, the committee has reviewed the current knowledge and the possible risk management option to reduce arsenic exposure in rice including the feasibility of setting maximum limit in rice. The committee has agreed to initiate new work on establishment of maximum levels for arsenic in rice with a view to its finalisation in 2013. The issue would be further discussed in the coming meeting to be held in 2012.[17] We will keep in view the latest development on

this issue and amend the local maximum level for arsenic in solid food (covering rice) if necessary.

45. The food trade is advised to observe good agricultural practices to minimise inorganic arsenic contamination of foods, such as avoid using arsenic contaminated water for irrigation.

46. The findings of the current study are not sufficient to warrant changes in basic dietary advice on healthy eating, i.e. have a balanced and varied diet, and take cereals, such as rice, noodles, oatmeal and bread, as the major dietary source. Those individuals, who wish to reduce the exposure to inorganic arsenic, can consider choosing more other cereals, which generally contain lower levels of inorganic arsenic than rice, as part of their diet, and observe the following advices: wash rice thoroughly but without excessive washing as some nutrients may be lost, and discard the washed water before cooking so as to reduce the arsenic levels, especially inorganic form.

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Appendix 1

Inorganic Arsenic Contents (μg/kg) in TDS Foods of the 1st HKTDS

TDS Food Item	Number of composite samples	% of composite samples < LOD	Mean (μg/kg) (ND=LOD/2)	[range]
Cereals and their products:	**76**	**29**	**8**	**[ND – 46]**
Rice, white			22	[16 – 26]
Rice, unpolished			43	[37 – 46]
Corn			1.5	[ND]
Noodles, Chinese or Japanese style			1.5	[ND]
Pasta, Western style			1.5	[ND]
Instant noodles			3	[ND – 4]
Noodles, rice			9	[6 – 10]
Bread, plain			5	[3 – 6]
Bread, raisin			4	[3 – 5]
"Pineapple" bun			4	[3 – 6]
Sausage/ham/luncheon meat bun			5	[4 – 6]
Chinese steamed bread			3	[ND – 5]
Biscuits			8	[4 – 11]
Cakes			8	[4 – 21]
Pastries			1.5	[ND]
Pastries, Chinese			17	[8 – 24]
Oatmeal			1.5	[ND]
Breakfast cereals			6	[3 – 7]
Deep-fried dough			10	[8 – 12]
Vegetables and their products:	**140**	**49**	**9**	**[ND – 120]**
Carrot/ Radish			1.5	[ND]
Potato			1.5	[ND]
Potato, fried			2	[ND – 5]
Broccoli			1.5	[ND]
Cabbage, Chinese			2	[ND – 4]
Cabbage, Chinese flowering			9	[6 – 15]
Cabbage, European variety			1.5	[ND]
Cabbage, Petiole Chinese			5	[3 – 9]
Celery			4	[ND – 7]
Chinese kale			3	[ND – 6]
Chinese spinach			10	[9 – 13]
Leaf mustard			8	[ND – 22]
Lettuce, Chinese			3	[ND – 4]
Lettuce, European			1.5	[ND]
Mung bean sprout			4	[ND – 5]

TDS Food Item	Number of composite samples	% of composite samples < LOD	Mean (µg/kg) (ND=LOD/2)	[range]
Spinach			5	[ND – 7]
Water spinach			74	[35 – 120]
Watercress			19	[8 – 34]
Bitter melon			4	[ND – 8]
Cucumber			9	[3 – 18]
Hairy gourd			1.5	[ND]
Pumpkin			1.5	[ND]
Sponge gourd			2	[ND – 4]
Wax gourd			1.5	[ND]
Zucchini			1.5	[ND]
Eggplant			3	[ND – 5]
Sweet pepper			1.5	[ND]
Tomato			1.5	[ND]
Garlic			9	[8 – 11]
Onion			2	[ND – 5]
Spring onion			14	[9 – 18]
Preserved vegetables			38	[11 – 48]
Mushroom, dried shiitake			45	[36 – 53]
Mushrooms			5	[4 – 6]
Ear fungus			11	[9 – 14]
Legumes, nuts and seeds and their products:	**24**	**63**	**4**	**[ND – 14]**
Green string beans, with pod			1.5	[ND]
Mung bean vermicelli			1.5	[ND]
Beancurd			1.5	[ND]
Fermented bean products			9	[ND – 14]
Peanut			6	[3 – 11]
Peanut butter			5	[ND – 13]
Fruits:	**68**	**78**	**4**	**[ND – 88]**
Apple			6	[ND – 10]
Banana			2	[ND – 5]
Dragon fruit			1.5	[ND]
Grapes			3	[ND – 6]
Kiwi fruit			1.5	[ND]
Longan/ Lychee			3	[ND – 9]
Mango			23	[ND – 88]
Melons			6	[ND – 9]
Orange			1.5	[ND]
Papaya			5	[ND – 13]
Peach			1.5	[ND]
Pear			1.5	[ND]
Persimmon			2	[ND – 5]

TDS Food Item	Number of composite samples	% of composite samples < LOD	Mean (µg/kg) (ND=LOD/2)	[range]
Pineapple			2	[ND – 4]
Plum			1.5	[ND]
Pummelo /Grapefruit			2	[ND – 4]
Watermelon			1.5	[ND]
Meat, poultry and game and their products:	**48**	**54**	**4**	**[ND – 27]**
Beef			12	[6 – 27]
Mutton			1.5	[ND]
Pork			1.5	[ND]
Ham			4	[3 – 5]
Luncheon meat			6	[3 – 9]
Barbecued pork			5	[ND – 8]
Roasted pork			7	[ND – 22]
Pig liver			3	[ND – 5]
Chicken meat			3	[ND – 5]
Chicken, soy sauce			1.5	[ND]
Roasted duck/goose			1.5	[ND]
Meat sausage			4	[ND – 6]
Eggs and their products:	**12**	**33**	**23**	**[ND – 93]**
Egg, chicken			1.5	[ND]
Egg, lime preserved			10	[3 – 21]
Egg, salted			58	[31 – 93]
Fish and seafood and their products:	**76**	**17**	**15**	**[ND – 74]**
Fish, Big head			5	[4 – 6]
Fish, Mandarin fish			1.5	[ND]
Fish, Grass carp			1.5	[ND]
Fish, Golden thread			20	[12 – 24]
Fish, Grouper			19	[13 – 24]
Fish, Horse head			18	[14 – 30]
Fish, Pomfret			17	[15 – 21]
Fish, Sole			3	[ND – 5]
Fish, Tuna			5	[3 – 9]
Fish, Grey mullet			12	[9 – 14]
Fish, Salmon			8	[4 – 10]
Fish, Yellow croaker			30	[6 – 55]
Fish, Dace, minced			2	[ND – 4]
Fish ball/fish cake			8	[6 – 11]
Shrimp/ Prawn			23	[15 – 30]
Crab			27	[21 – 35]
Oyster			58	[49 – 74]
Scallop			20	[7 – 34]
Squid			9	[4 – 19]

TDS Food Item	Number of composite samples	% of composite samples < LOD	Mean (µg/kg) (ND=LOD/2)	[range]
Dairy products:	**20**	**100**	**1.5**	**[ND]**
Milk, whole			1.5	[ND]
Milk, skim			1.5	[ND]
Cheese			1.5	[ND]
Yoghurt			1.5	[ND]
Ice-cream			1.5	[ND]
Fats and oils:	**8**	**100**	**1.5**	**[ND]**
Butter			1.5	[ND]
Oil, vegetable			1.5	[ND]
Beverages, alcoholic:	**8**	**50**	**4**	**[ND – 7]**
Beer			2	[ND – 5]
Red wine			5	[ND – 7]
Beverages, non-alcoholic:	**40**	**95**	**2**	**[ND – 12]**
Tea, Chinese			1.5	[ND]
Tea, Milk tea			1.5	[ND]
Coffee			1.5	[ND]
Malt drink			1.5	[ND]
Soybean drink			1.5	[ND]
Fruit and vegetable juice			5	[ND – 12]
Carbonated drink			1.5	[ND]
Tea, chrysanthemum			1.5	[ND]
Water, bottled, distilled			0.75	[ND]
Water, drinking			0.75	[ND]
Mixed dishes:	**48**	**21**	**6**	**[ND – 19]**
Siu Mai			8	[7 – 8]
Dumpling, steamed			5	[3 – 6]
Dumpling, pan-fried			3	[ND – 6]
Dumpling, including wonton			3	[ND – 7]
Steamed barbecued pork bun			3	[ND – 4]
Turnip cake			10	[7 – 13]
Steamed minced beef ball			8	[4 – 19]
Glutinous rice dumpling			12	[9 – 16]
Steamed rice-rolls with filling			7	[6 – 8]
Steamed rice-rolls, plain			10	[7 – 13]
Chinese soup			2	[ND – 5]
Hamburger			3	[ND – 5]
Snack foods:	**4**	**0**	**8**	**[6 – 10]**
Potato chips			8	[6 – 10]
Sugars and Confectionery:	**8**	**63**	**3**	**[ND – 8]**
Chocolate			5	[ND – 8]
Granulated white sugar			1.5	[ND]

TDS Food Item	Number of composite samples	% of composite samples < LOD	Mean (µg/kg) (ND=LOD/2) [range]	
Condiments, Sauces and herbs:	**20**	**40**	**8**	**[ND – 65]**
Table salt			1.5	[ND]
Soya sauce			21	[3 – 65]
Oyster sauce			12	[6 – 17]
Tomato paste/ ketchup			7	[ND – 14]
Cornstarch			2	[ND – 4]

Appendix 2

Dietary Exposures to Inorganic Arsenic by Age-gender Groups (Average and High Consumer of the Population)

Age-gender groups	Dietary Exposure # (µg/kg bw/day)	
	Average	High Consumer@
Male aged 20 – 29	0.21	0.39
Female aged 20 – 29	0.19	0.33
Male aged 30-39	0.21	0.36
Female aged 30 – 39	0.22	0.38
Male aged 40-49	0.23	0.39
Female aged 40 – 49	0.21	0.37
Male aged 50-59	0.24	0.40
Female aged 50 – 59	0.21	0.37
Male aged 60-69	0.26	0.46
Female aged 60 – 69	0.22	0.40
Male aged 70-84	0.25	0.41
Female aged 70 – 84	0.23	0.39
Male aged 20-84	0.23	0.39
Female aged 20 – 84	0.21	0.37
Adult aged 20 – 84	0.22	0.38

As only 49% of results are below limit of detection (LOD), half of LOD is used for all results less than LOD in calculating the exposure estimates.

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