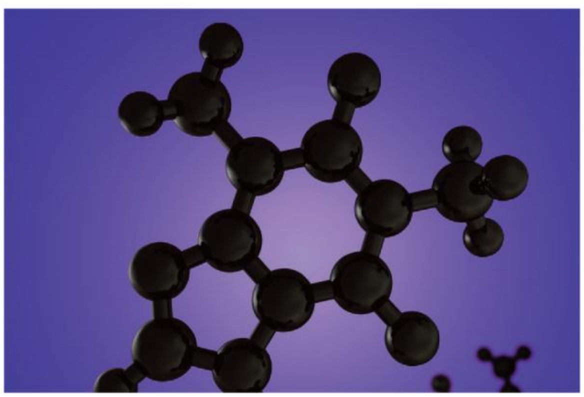
Canadian Food Inspection Agency / Agence canadienne d'inspection des aliments

Food Safety Action Plan

REPORT

2010-2011 Targeted Surveys

Chemistry



Arsenic Speciation in Rice and Rice Products, Breakfast and Infant Cereals, Fruit Products, Bottled Water, and Seaweed Products

TS-CHEM-10/11

Canada

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Executive Summary

The Food Safety Action Plan (FSAP) aims to modernize and enhance Canada's food safety system. As a part of the FSAP enhanced surveillance initiative, targeted surveys are used to test various foods for specific chemical hazards.

The main objectives of this survey were to:

- generate baseline surveillance data for total arsenic levels in rice and rice products, breakfast and infant cereals, fruit products, bottled water, and seaweed products;
- examine the proportions of inorganic arsenic in rice and rice products, breakfast and infant cereals, fruit products, bottled water, and seaweed products; and
- compare the arsenic speciation results for rice and pear products in this survey with the 2009-2010 FSAP arsenic speciation survey.

Arsenic is a naturally occurring element found in trace amounts in rock, soil, water and air. The primary routes of human exposure to arsenic are through drinking water and food. The presence of arsenic in food and water is generally considered to be normal accumulation from the environment. Arsenic levels in food are usually low; however, the levels are usually higher in aquatic organisms (such as seaweed, fish and seafood) than they are in drinking water or vegetables. Arsenic can exist in both organic and inorganic forms in food, the inorganic forms being more toxic. The ratio of inorganic to organic arsenic species can vary widely depending on the source of contamination and the commodities in which it is present. While inorganic arsenic is the predominant species in drinking water, organic arsenic forms predominate in aquatic organisms, such as seaweed, fish and seafood. The proportion of inorganic and organic arsenic in other foods can vary significantly. Chronic exposure to inorganic arsenic may lead to a variety of detrimental health effects in humans, most notably cancer[10].

A total of 1071 food samples of domestic and imported origins were collected at Canadian retail stores (280 rice and rice products, 355 breakfast and infant cereals, 251 fruit products, 95 bottled waters, and 90 seaweed products). The samples were tested to determine the total arsenic content and the levels of various organic and inorganic species present.

Most of the products (1034 of 1071 samples or 96.5%) contained detectable levels of total arsenic. Seaweed products contained the highest average level of total arsenic at 26.30 parts per million (ppm) or 26300 parts per billion (ppb), followed by breakfast and infant cereals at 100.54 ppb, rice and rice products at 89.38 ppb, fruit products at 12.95 ppb, and bottled water at 2.06 ppb. As expected, the determination of the levels of inorganic and organic species of arsenic in each sample indicated that the ratio of inorganic arsenic to total arsenic (inorganic and organic species) varies with product type. Although seaweed products have the highest reported levels of total arsenic, seaweed products typically have very little inorganic arsenic. The average percentage of inorganic arsenic ranged from 22% to 99%, depending on the product type.

There is an established arsenic tolerance in fruit juice, fruit nectar, beverages when ready-to-serve and water in sealed containers other than spring or mineral water specified in Table I of *Division 15* of the Food and Drug Regulations (*FDR)*. Health Canada has informed industry and the CFIA that the current tolerances listed in Table I of Division 15 in the *FDR* are under review[5]. It is still noted that the arsenic tolerance (which is under review) was not exceeded in any of the fruit juice or nectar products tested. Three samples of bottled water had levels of total arsenic which exceeded the Canadian drinking water guidelines for arsenic. There are no Canadian regulations for total or inorganic arsenic in the other product types analyzed in this survey, so compliance to a numerical standard could not be assessed. None of the samples were determined to pose a concern to human health. Appropriate follow-up actions were initiated that reflected the magnitude of the human health concern.

1 Introduction

1.1 Food Safety Action Plan

In 2007, the Canadian government launched a five year initiative in response to a growing number of product recalls and concerns about food safety. This initiative, called the Food and Consumer Safety Action Plan (FCSAP), aims to modernize and strengthen the food safety regulatory system. The FCSAP initiative unites multiple partners in ensuring safe food for Canadians.

The Canadian Food Inspection Agency's (CFIA) Food Safety Action Plan (FSAP) is one element of the government's broader FCSAP initiative. The goal of FSAP is to identify risks in the food supply, limit the possibility that these risks occur, improve import and domestic food controls and identify food importers and manufacturers.

Within FSAP there are twelve main areas of activity, one of which is risk mapping and baseline surveillance. The main objective of this area is to better identify, assess, and prioritize potential food safety hazards through risk mapping, information gathering, and testing of foods from the Canadian marketplace. Targeted surveys are one tool used to test for the presence and level of a particular hazard in specific foods. Targeted surveys are largely directed towards the 70% of domestic and imported foods that are regulated solely by the *Food and Drugs Act* and *Regulations*, and are generally referred to as non-federally registered commodities.

1.2 Targeted Surveys

Targeted surveys are pilot surveys used to gather information regarding the potential occurrence of chemical residues in defined commodities. The surveys are designed to answer specific questions. Therefore, unlike monitoring activities, testing of a particular chemical hazard is targeted to commodity types and/or geographical areas.

Due to the vast number of chemical hazards and food commodity combinations, it is not possible, nor should it be necessary, to use targeted surveys to identify and quantify all chemical hazards in foods. To identify food-hazard combinations of greatest potential health risk, the CFIA uses a combination of scientific literature, media reports, and/or a risk-based model developed by the Food Safety Science Committee (FSSC), a group of federal, provincial and territorial subject matter experts in the area of food safety. In 2008, the FSSC ranked inorganic arsenic as a priority food contaminant, particularly in seaweed products. Other commodities were included in the survey, such as rice, rice products, and breakfast/infant cereals, given that rice is a major contributor to overall dietary exposure to arsenic. Fruit products containing pear, particularly juices, were included in this survey due to increased concern about the levels of arsenic in pear[1,2]. In some geographical areas, the level of arsenic in source water may be elevated[29]. Bottled water was included in the survey, as the level of arsenic in bottled water reflects the level of arsenic (whether present naturally and/or as an environmental contaminant) in the water source.

1.3 Acts and Regulations

The *Canadian Food Inspection Agency Act* stipulates that the CFIA is responsible for enforcing restrictions on the production, sale, composition, and content of foods and food products as outlined in the *Food and Drugs Act & Regulations*.

Health Canada establishes the health-based maximum levels for chemical residues and contaminants in foods. Maximum levels for chemical contaminants in foods may be expressed as either regulatory tolerances or standards. Regulatory tolerances are listed in the *Food and Drug Regulations (FDR),* whereas standards can be viewed on Health Canada's website[3].

At present, a limited number of tolerances are established for metals in food in the *FDR* (Section B.15.001-TABLE I[4], including arsenic in specific commodities). It should be noted that these regulatory tolerances in Table 1 of Division 15 are under review by Health Canada[5]. A maximum allowable concentration of 10 parts per billion (ppb) total arsenic in drinking water exists in the Guidelines for Canadian Drinking Water Quality, which are developed by the Federal-Provincial-Territorial Committee on Drinking Water and have been published by Health Canada since 1968[6]. Please see Table A in the Appendix for a summary of the Canadian and international regulatory levels for arsenic in selected commodities.

Even in the absence of a specific tolerance or standard, all foods sold in Canada must comply with Section 4(1)(a) of the *Food and Drugs Act*. If the level of arsenic is found to be elevated, the potential risk to human health may be assessed by Health Canada in order to determine if risk management actions are required. These actions may include notification of the producer or importer, follow-up inspections, additional directed sampling, and/or product recall.

2 Survey Details

2.1 Total Arsenic and Arsenic Speciation in Foods

Arsenic is an element that naturally occurs in the earth's crust. Although arsenic can be found in its elemental form (As), it is more commonly found in combination with other elements. Inorganic arsenic compounds are formed when arsenic is combined with oxygen, chlorine and sulphur, which naturally occur in soils and rocks. Organic arsenic compounds are formed when arsenic is combined with carbon and hydrogen, which may occur as the result of plant or animal metabolism.

In the past, inorganic arsenic compounds have been used as a wood preservative and as components of agricultural chemicals[7]. However, the practice of using inorganic arsenic compounds for agricultural purposes[8] and for the treatment of wood destined for residential use has been discontinued in Canada due to health concerns[9]. Organic arsenic compounds are used as pesticide components (such as in the herbicide/insecticide monosodium methyl arsenate and in the herbicide disodium methyl arsenate) and some compounds are used as additives in animal feed[10]. Organic arsenic compounds are also used in automobile batteries, in semiconductors, and in light-emitting diodes[11]. Arsenic in the environment may be deposited in the air, water and soil via wind distribution, or may be deposited in water via runoff or leaching. Arsenic may be absorbed by humans via ingestion of contaminated food and/or water, or through inhalation of contaminated dust.

Most human exposure to arsenic is through consumption of drinking water and food[12]. Total arsenic intake for a typical North American adult has been estimated to be approximately 50 micrograms per day (µg/day), with inorganic arsenic comprising 20-40% of the total dietary arsenic intake[13].

Generally speaking, inorganic arsenic species (i.e., $As^{3+}$and As^{5+}) are more toxic than organic arsenic species. Organic arsenic species include arsenocholine (AsC), arsenobetaine (AsB), monomethylarsonic acid (MMA) and dimethylarsinic acid (DMA)[14]. Most cases of human toxicity from arsenic have been associated with exposure to elevated inorganic arsenic. Besides being potent human carcinogens, oral exposure to the inorganic forms may result in dermal, cardiovascular, respiratory, gastrointestinal, haematological, hepatic, and neurological effects[14]. Animal toxicity data has also suggested that oral exposure to inorganic arsenic may lead to increased risk of reproductive issues[15]. In the case of organic arsenic, the gastrointestinal tract, the renal and urinary systems appear to be the most sensitive targets in humans[14].

Rice has been identified as a major contributor to human exposure of arsenic in the diet[16]. Rice is believed to be particularly susceptible to arsenic contamination compared to other grains, as it is generally grown under flooded conditions[16]. Groundwater contamination by arsenic has been reported in many rice-growing countries, most notably in Bangladesh, China and India[17], where levels of arsenic contamination in water in these areas can range up to 0.21 milligrams per liter (mg/L) (210 ppb)[17]. The rice plants absorb and accumulate arsenic from the water used for flooding the fields. The amount of arsenic in the rice grains and finished rice products for human consumption will be related to the arsenic levels in the water used for cultivation of the rice plants. As inorganic arsenic dissolves more readily in water than organic arsenic[18], rice grains and rice products generally have more inorganic than organic arsenic. Concerns over the levels of inorganic arsenic contamination in rice have been rising for a variety of reasons, one of them being that rice is a heavily consumed food commodity, accounting for nearly 50% of the grain consumption in the world[19].

2.2 Rationale

The CFIA does not have regular monitoring activities that target arsenic and speciated arsenic in processed foods, grains, or in bottled water. The CFIA’s Children’s Food Project has examined the levels of total arsenic (but not speciated arsenic) in rice products and fruit and vegetable products, including juices, targeted at children. As such, there was a need for surveillance data on the presence and levels of total and speciated (inorganic, organic) arsenic in breakfast and infant cereals, rice and rice products, fruit products, bottled water, and seaweed products of domestic and imported origin. Data on the levels of inorganic arsenic in rice, fruit, bottled water and seaweed products are important information for health risk assessments.

Rice, fruit products and bottled water are consumed by all age groups in Canada. Rice available for consumption reached 7.0 kg per person in 2008 in Canada[20]. Rice products are growing in popularity, particularly for individuals with gluten sensitivities or lactose intolerance. Fruits, vegetables, and their associated products available for consumption reached 39.3 kg per person in 2008 in Canada[21]. In 2006, 29% of Canadian households drank primarily bottled water as opposed to tap water[22]. The per capita annual consumption of bottled water in Canada was 66 L, and that volume had been steadily increasing over the previous decade[23].

The CFIA has issued a public advisory to avoid the consumption of hijiki seaweed, as this seaweed accumulates higher levels of inorganic arsenic than other forms of seaweed[24]. Although seaweed is not a staple product in Canada, it is an important dietary component for specific sub-groups of the population.

2.3 Sample Distribution

In the 2010-2011 Arsenic Speciation Survey, 1071 samples were collected at grocery and specialty stores in 11 Canadian cities (Halifax, Saint John, Ottawa, Toronto, Montréal, Québec City, Calgary, Saskatoon, Vancouver, Kelowna, and Winnipeg). The samples included 355 breakfast and infant cereals, 280 rice and rice products, 251 fruit products, 95 bottled waters, and 90 seaweed products.

2.4 Method Details

Survey samples were analyzed by the CFIA Dartmouth laboratory. Samples were tested "as sold" (i.e., uncooked or unprepared) to determine both the total and speciated arsenic content. The results of the two methods will be discussed separately as the two methods are not directly comparable. For the purposes of this report, species refers to a specific form of arsenic and speciation refers to the distribution of arsenic species in a particular sample.

Total Metals Screen

Survey samples were analyzed using a total metals screen methodology, which is a rapid analysis of 12 different metals including arsenic. This method does not provide speciation information, but gives total arsenic concentration only. The method uses microwave-assisted acid digestion to break down the sample with detection by Inductively Coupled Plasma Mass Spectrometry (ICP-MS). This method provides the best measure of the total amount of arsenic in a sample.

Arsenic Speciation Method

This method quantifies inorganic arsenic (in the form of As^{3+} and As^{5+}) and organic arsenic species (AsB (arsenobetaine), AsC (arsenocholine), MMA (monomethylarsonic) and DMA (dimethylarsinic acid)) in food by High Performance Liquid Chromatography-Inductively Coupled Plasma Mass Spectrometry (LC-ICP-MS) (see Table 1). All results are reported as elemental arsenic (rather than the organic species, eg. arsenobetaine is $C_5H_{11}AsO_5$ and is reported as the As concentration only). The limits of detection (LOD) for all product types tested are presented in Table 2. The limit of quantitation (LOQ) was calculated as three times the LOD. It should be noted that other species may be present in the sample, however, this method is applicable for the species mentioned above. The sum of the individual arsenic species measured may not correspond to the total arsenic concentration measured by the total metals screen method.

Table 1 - Arsenic species examined in the current targeted survey

Species	Form	Synonym	Chemical formula	Toxicity
As^{3+}	Inorganic	Arsenious acid, Arsenite	$As(OH)_3$	Highly toxic
As^{5+}	Inorganic	Arsenic acid, Arsenate	H_3AsO_4	Highly toxic
AsC	Organic	Arsenocholine	$C_5H_{14}AsBrO$	Relatively non-toxic
AsB	Organic	Arsenobetaine	$C_5H_{11}AsO_2$	Relatively non-toxic
MMA	Organic	Monomethylarsonic acid	CH_3AsO_3Na	Low toxicity
DMA	Organic	Dimethylarsinic Acid, Cacodylic acid	$C_2H_7AsO_2$	Low toxicity

Table 2 - Limits of detection (LODs) for arsenic species in the current targeted survey

Species	LOD (ppb) in Rice, Rice Products and Breakfast Cereals	LOD (ppb) in Fruit Products	LOD (ppb) in Bottled Water	LOD (ppb) in Seaweed Products
Total Arsenic	1	1	1	1
AsC	0.39	0.52	0.06	N/A
AsB	0.41	0.23	0.08	N/A
As^{3+}	0.68	0.66	0.08	10.0
DMA	0.70	0.36	0.04	5.0
MMA	0.98	0.58	0.09	13.0
As^{5+}	4.80	2.67	0.13	10.0

N/A = these species are not currently detectable by the arsenic speciation method used

2.5 Limitations

The current targeted survey was designed to provide a snapshot of the levels of arsenic in the targeted commodities and has the potential to highlight commodities that warrant further investigation. A wide variety of products were sampled; they were categorized primarily based on their descriptions as recorded by the sampler. Due to the diverse assortment of products sampled, it is difficult to make comparisons of, or come to any conclusions regarding, specific product types and their countries of origin.

Care must be taken when interpreting results. The data cannot be considered representative of total and speciated arsenic levels in all foodstuffs from specific countries of origin. In addition, country of origin could not be verified for many of the products tested. The products tested were consistent with CFIA labelling guidelines (use of “Imported by”, “Packaged by”, or “Imported for”, etc.)[25], but many did not contain additional label information specifying the country of origin (production) of the foodstuff. As a result, no inferences or conclusions were made regarding the data with respect to country of origin. Regional differences, impact of product shelf-life or cost of the commodity on the open market were not examined in this survey.

The data reported here-in is for arsenic concentrations per weight of food as sold, rather than per serving size or as consumed. For example, the arsenic levels are reported for raw rice grains.

3 Results and Discussion

3.1 Overview of Arsenic Results

The results for total arsenic and arsenic speciation analyses are reported in µg/kg (ppb). As previously described, two distinct methods were used to generate these two datasets. The results from the total metals screen method were used to evaluate the total arsenic concentration, while the results from the arsenic speciation method were used to evaluate the concentrations of six individual arsenic species. Given that two distinct analytical methods were used, it is not possible to directly contrast the total arsenic results from the two separate methods.

Figure 1 presents the number of samples per product type, and illustrates the number of samples with detectable levels of total arsenic. The minimum, maximum and average levels of total arsenic are presented in Table 3 (in order of increasing average total arsenic levels). Seaweed products had the highest overall level of total arsenic while bottled water had the lowest total arsenic level. Among the remaining products types, the total arsenic level decreased in the order: breakfast/infant cereals, rice and rice products, and fruit products. The levels of total arsenic observed were consistent with the levels of arsenic reported in other scientific studies and previous surveys [12-14, 16-19, 27-29,31-35].

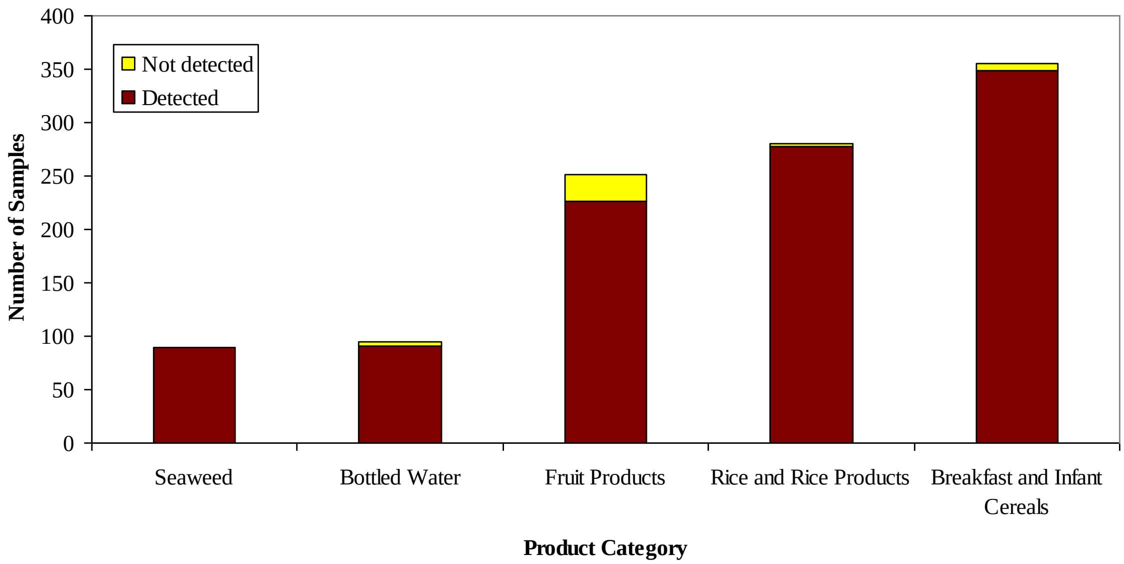


Figure 1 - Distribution of samples by product type (arranged by increasing number of samples with detectable levels of total arsenic)

Table 3 – Minimum, maximum, and average levels of total arsenic in product types (arranged in order of increasing average total arsenic levels)

Product Category	Number of Samples	Number of Positive Samples	Percentage of Positive Samples	Minimum (ppb)	Maximum (ppb)	Average (ppb)
Water	95	91	96	< LOD	20.80	2.06
Fruit Products	251	226	90	< LOD	85.80	12.95
Rice and Rice Products	280	278	99	< LOD	848.00	89.38
Breakfast and Infant Cereals	355	349	98	< LOD	496.00	100.54
Seaweed	90	90	100	1130 (1.13 ppm)	91300 (91.30 ppm)	26 900 (26.90 ppm)

As described in section 2.4, the arsenic speciation method detects six forms of arsenic, including four organic species (DMA, MMA, AsC and AsB) and two inorganic species (As^{3+} and As^{5+}). The inorganic arsenic forms are more toxic than the organic arsenic forms. The percentage contribution of each species for each product type is illustrated in Figure 2. For most product types, the predominant species of arsenic observed was As^{3+} (inorganic), except for seaweed, in which DMA (organic) predominated. For bottled water, almost all of the arsenic species detected are inorganic arsenic species (As^{3+} and As^{5+}), resulting in an inorganic content of nearly 100%. Rice and rice products, breakfast and infant cereals, and fruit products were associated with a relatively high percentage of inorganic arsenic. The relative proportion of inorganic and inorganic arsenic species is consistent with the results of other scientific studies and previous FSAP surveys[20-23, 25-29, 32-35].

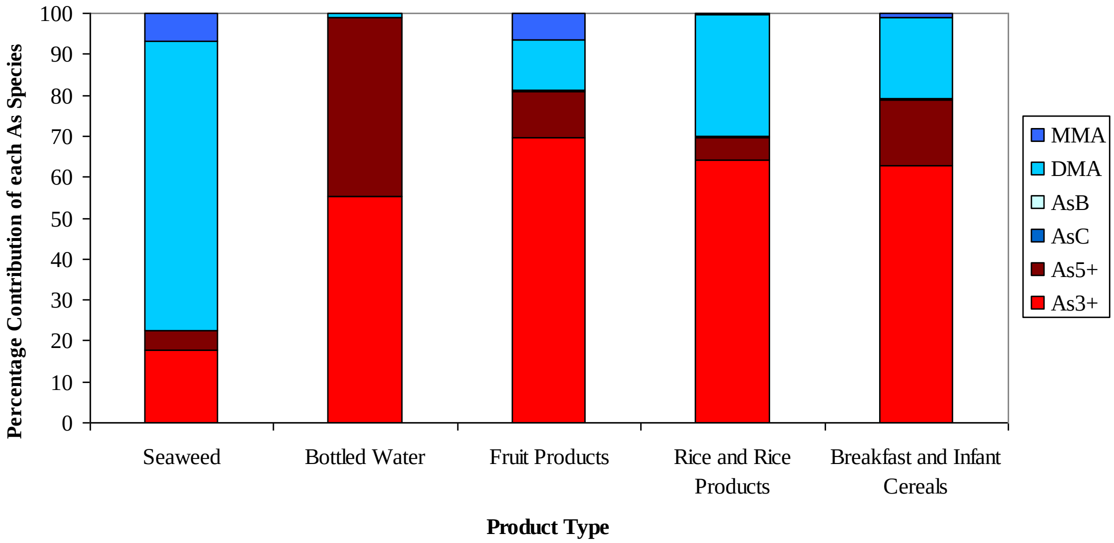


Figure 2 - Average percentage contribution of arsenic species detected in survey samples
*****Note: Red denotes inorganic species and blue indicates organic species**.**

There are, at present, metal tolerances established in the *FDR* (Section B.15.001-TABLE I)[3] for arsenic in fruit juice, fruit nectar, beverages when ready-to-serve and water in sealed containers other than mineral water or spring water. These regulatory tolerances in Table 1 of Division 15 are under review by Health Canada[5]. There are no tolerances for arsenic in rice, rice products, breakfast and infant cereals, fruit products (excluding juices and nectars) or seaweed products. For this reason, compliance with a numerical standard for arsenic in rice, rice products, breakfast and infant cereals, fruit products (excluding juices and nectars) or seaweed products could not be assessed. The results were evaluated by the CFIA and, where appropriate, Health Canada was consulted on the observed arsenic levels. None of the samples were determined to pose a concern to human health.

For bottled water, the total arsenic levels were assessed against the Guidelines for Canadian Drinking Water Quality[6] for arsenic in drinking water. Three samples of bottled water had arsenic levels which exceeded the guideline level. Health Canada provided an opinion that short-term exposure to these arsenic levels was unlikely to pose a concern to human health.

3.2 Arsenic Result by Product Type

The following sections present the results for total arsenic and speciated arsenic in each of the product categories. In these sections, the results of this targeted survey were compared to the results of the 2009-2010 FSAP Arsenic Speciation targeted survey conducted by the CFIA[26] where feasible (Tables 5 and 8, and Figures 4 and 6). Breakfast and infant cereals, bottled water and seaweed products were not among the commodities analyzed for arsenic in 2009-2010, so comparison to the current survey results was not possible.

3.2.1 Rice and Rice Products

A total of 280 rice and rice products (12 domestic, 203 imported, 65 unverifiable origin) were analyzed according to the protocols described in Section 2.4. Rice is not grown in Canada so products listed as domestic were manufactured or processed in Canada using imported ingredients. Rice and rice product samples originated from 18 countries. A total of 14 product categories were investigated, including raw white rice, raw brown rice, raw other rice (included black, red and unspecified types of rice), rice beverages, rice crackers, rice flour, rice noodles, rice paper, rice pudding, rice cakes, other rice products (including rice bars, rice biscuits and porridge/baking mixes), rice chips, rice flakes, and rice bran.

A summary of total arsenic levels in rice and rice products is presented in Table 4. All samples of rice grains and 206 of the 208 rice product samples analyzed contained detectable levels of total arsenic. The average levels of total arsenic ranged from 9 ppb (rice pudding) to 571 ppb (rice bran). Among the rice grains, brown rice had almost twice the average level of total arsenic (226 ppb) of white rice (104 ppb) or unspecified rice (151 ppb). Among the rice products, rice bran (571 ppb) and rice cakes (186 ppb) had the highest average levels of total arsenic. The outer layer of rice (the bran) is highest in arsenic. As brown rice is less processed than white rice, the levels of arsenic tend to be higher in brown rice than in white rice[27].

Table 4 - Total arsenic concentrations in rice and rice products in the total metals screen arranged in order of decreasing average total arsenic level

Commodity	Product Category	Number of Samples	Number of Positive Samples	Percentage of Positive Samples	Minimum (ppb)	Maximum (ppb)	Average (ppb)
Rice	Brown Rice	16	16	100	89.80	351.00	225.92
	Rice – Other*	7	7	100	8.63	337.00	150.95
	White Rice	49	49	100	34.40	205.00	104.36
Rice Products	Rice Bran	1	1	100		570.87	
	Rice Cakes	11	11	100	136.00	258.00	186.00
	Rice Flour	25	25	100	44.50	369.00	125.25
	Rice Crackers	30	30	100	47.74	878.00	114.68
	Rice Chips	2	2	100	82.10	117.00	99.55
	Rice Flakes	2	2	100	70.70	97.33	84.02
	Other Rice Products	5	5	100	55.70	116.00	78.18
	Rice Noodles	24	24	100	2.52	147.00	75.43
	Rice Paper	19	19	100	7.42	60.60	25.17
	Rice Beverage	72	71	99	3.73	49.70	21.50
	Rice Pudding	17	16	94	< LOD	21.70	9.26

- "Rice – Other" category includes black rice, red rice and samples labelled as "rice" (unspecified as to whether this is white, brown, black or red rice)

Results from the arsenic speciation method indicate that most of the arsenic present in rice and rice products are the inorganic forms As^{3+} and As^{5+} (Figure 3). However, rice beverages and rice pudding contained a higher proportion of organic species than the other rice product types. The average inorganic arsenic (As^{3+} and As^{5+}) content was 70% in rice and rice product products.

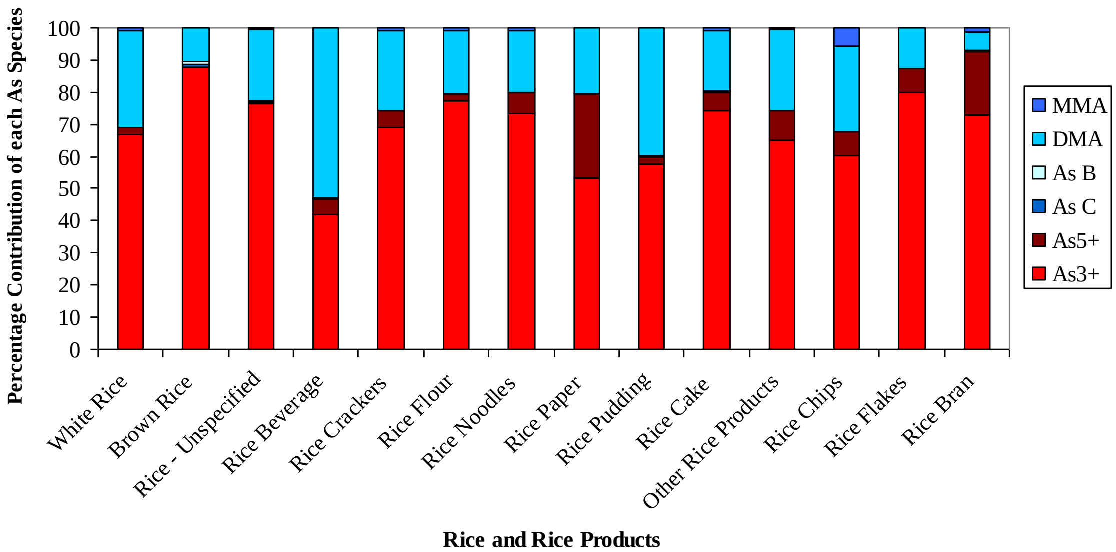


Figure 3 - Average percentage contribution of arsenic species detected in rice samples
*Note: Red denotes inorganic species and blue indicates organic species.

The total and speciated arsenic levels in rice and rice products were consistent with results reported in the scientific literature[12,13,14].

The total and speciated arsenic results for rice and for rice beverages in the current and the previous FSAP surveys were compared. As seen in Table 5, most of the rice and rice beverage samples in both the current survey and in the previous year's survey contained detectable levels of total arsenic. The results are consistent from year to year for the sample types examined. For the three commodity types common to both survey years, rice beverages were associated with the lowest minimum, maximum and average levels of total arsenic. Similarly, brown rice was associated with the highest minimum, maximum and average levels of total arsenic.

Table 5 - Comparison of total arsenic concentrations in rice products (from total metals screen) in 2009-2010 and 2010-2011 targeted surveys

Commodity	Survey Year	Number of Samples	Percentage of Positive Samples	Minimum (ppb)	Maximum (ppb)	Average (ppb)
White Rice	2009-2010	19	100	35	190	136
	2010-2011	49	100	34	205	104
Brown Rice	2009-2010	36	100	50	386	241
	2010-2011	16	100	90	351	226
Rice Beverages*	2009-2010	40	100	15	40	20
	2010-2011	72	99	4	50	22

*Rice Beverages did not include sake

As seen in Figure 4 below, the percentage contribution of each species of arsenic was similar in the 2009-2010 and 2010-2011 surveys. Inorganic arsenic (especially As^{3+}) was predominant in rice samples tested in both the current survey and in the previous year's survey. The percentage of inorganic arsenic in rice beverages was somewhat lower in the 2010-2011 survey than in the previous year's survey but it is not clear why this is so. As the beverage samples are picked up from the retail sector, there is no historical information available about the source of the rice used in manufacturing the finished products.

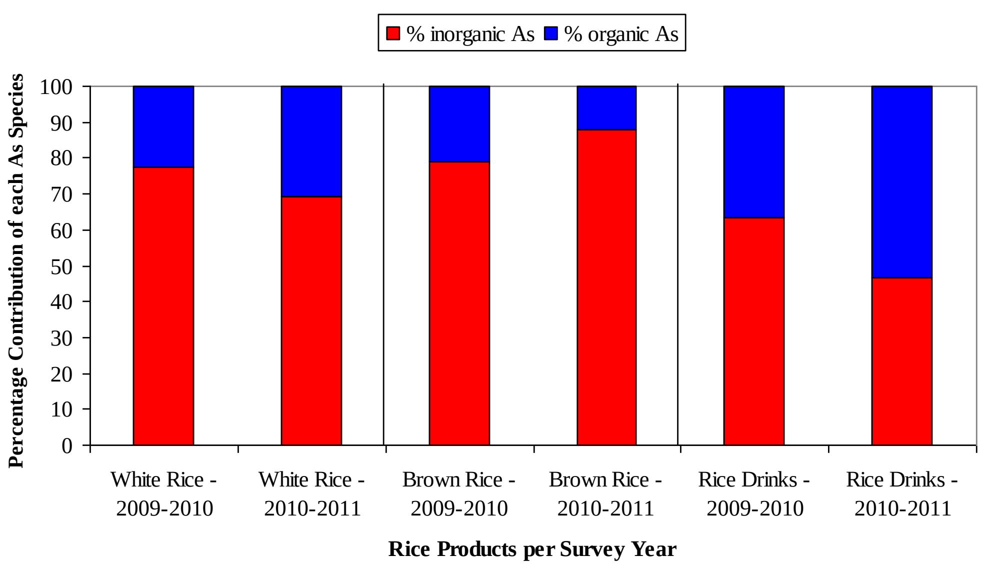


Figure 4 - Average percentage contribution of arsenic species detected in rice and rice products in the 2009-2010 and 2010-2011 targeted surveys

3.2.2 Breakfast and Infant Cereals

A total of 355 breakfast and infant cereals (111 domestic, 122 imported, 122 unverifiable origin) were analyzed according to the protocols described in Section 2.4. Products listed as domestic were manufactured or processed in Canada but may not identify the country of origin of the grain ingredients. Breakfast and infant cereal samples originated from 15 countries. All cereals were divided into rice-based and non-rice-based cereals. Rice-based cereals listed rice as one of the main ingredients of the cereal. Non-rice-based cereals listed rice or a rice product (e.g. rice syrup) as a minor ingredient, did not list rice as an ingredient, or the ingredient list could not be verified. The cereals were further subdivided into infant cereals and breakfast cereals (intended for adults and children). The non-rice-based breakfast cereals consisted of wheat, corn, oat, other (kamut and flax seed cereals) and mixed grain cereals. The non-rice-based infant cereals consisted of oat, wheat, mixed grain, or unverifiable grain cereals.

A summary of total arsenic levels in breakfast and infant cereals is presented in Table 6. All but six of the 355 samples analyzed contained detectable levels of total arsenic. The average levels of total arsenic ranged from 4.18 ppb (non-rice-based mixed grain breakfast cereal containing rice syrup) to 186.23 ppb (brown rice-based infant cereal).

Table 6 - Total arsenic concentrations in cereal products based on the total metals screen (in order of decreasing total arsenic level per commodity type)
Note: BC = Breakfast Cereal, IC = Infant Cereal

Commodity	Product Category	Number of Samples	Number of Positive Samples	Percentage of Positive Samples	Minimum (ppb)	Maximum (ppb)	Average (ppb)
Rice-based Cereals	IC - Rice (Brown)	9	9	100	118.00	246.00	186.23
	BC - Rice (White)	16	16	100	32.60	294.00	183.99
	BC - Rice (Brown)	43	43	100	43.67	470.00	180.28
	BC - Rice - May contain other grains*	13	13	100	29.50	425.00	164.63
	IC- Rice (Unspecified type of rice)	2	2	100	114.18	181.00	147.59
	IC - Rice (White)	71	71	100	20.50	344.00	130.82
	BC - Rice - (Mixed rice)	53	53	100	15.00	354.00	122.71
	IC - Rice - Mixed with other grains	9	9	100	12.40	63.60	33.96
Non-Rice-based Cereals	IC	6	6	100	7.85	214.30	84.46
	BC - Mixed grains - Contains rice as minor ingredient	29	29	100	9.46	496.00	51.93
	BC - Oat	10	10	100	8.51	67.70	33.56
	BC - Mixed grains - No rice or rice product listed in ingredients	31	30	97	< LOD	248.00	31.57
	BC - Other**	3	3	100	18.00	32.80	24.23

Commodity	Product Category	Number of Samples	Number of Positive Samples	Percentage of Positive Samples	Minimum (ppb)	Maximum (ppb)	Average (ppb)
	BC - Wheat	35	32	91	< LOD	240.00	20.66
	BC - May contain rice***	12	11	92	< LOD	29.10	10.56
	BC - Corn	11	10	91	< LOD	10.20	6.87
	BC - Mixed Grains - Contains rice syrup	2	2	100	3.71	4.65	4.18

Note: BC = Breakfast Cereal, IC = Infant Cereal
* BC - Rice - may contain other grains: clear from the available product information that the product was a rice-based cereal, however, a complete ingredient list was not available to determine whether other grains or grain products were present
** BC - Other: kamut and flax seed cereals
*** BC - may contain rice: clear from the available product information that rice was not a major ingredient, however, a complete ingredient list was not available to determine whether rice or rice products were present

Results from the arsenic speciation method indicate that most of the arsenic species present in breakfast and infant cereals were inorganic forms (As^{3+} and As^{5+}). Figures 5A and 5B below presents the average arsenic species percentage for each of the cereal commodities tested. The average inorganic arsenic (As^{3+} and As^{5+}) content was 79% in breakfast and infant cereal products

Figure 5A:

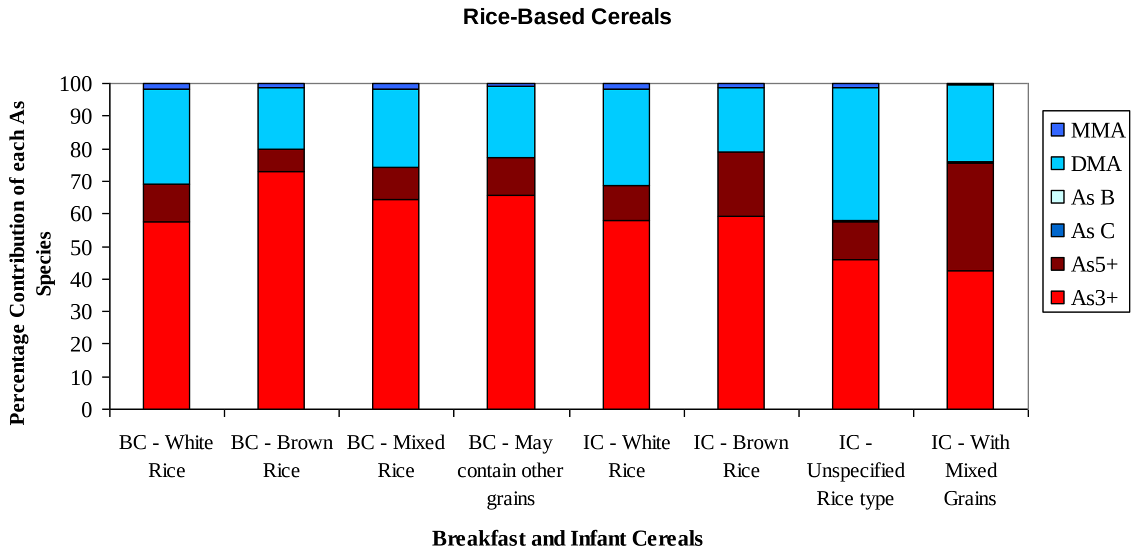
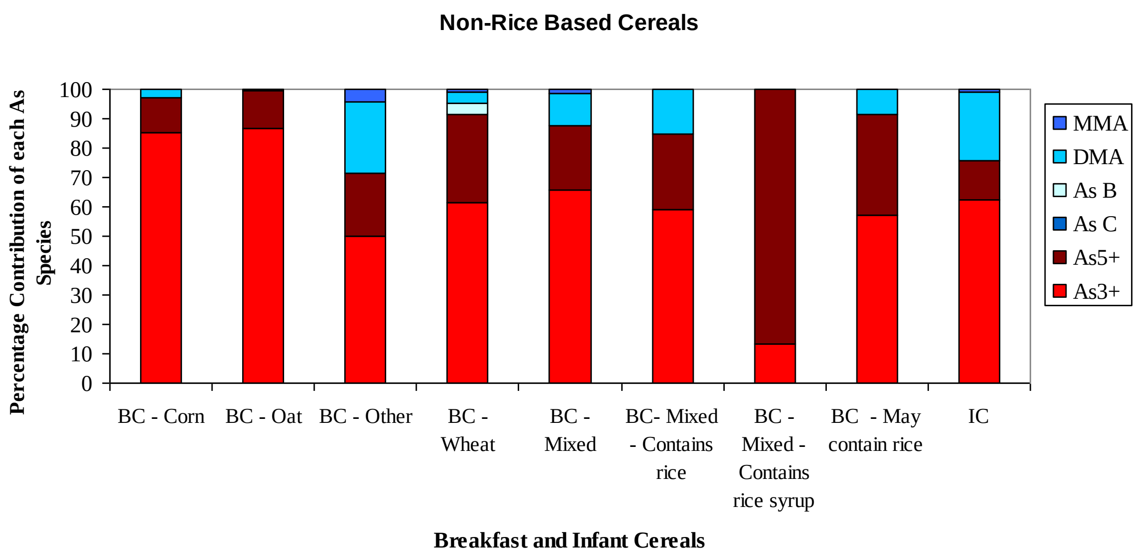


Figure 5B:



Figures 5A and 5B - Average percentage contribution of arsenic species detected in breakfast and infant samples

*Note: Red denotes inorganic species and blue indicates organic species; BC = Breakfast Cereal, IC = Infant Cereal

As the samples were purchased at retail, there was no information available on where the product ingredients were grown and therefore the source of the arsenic is not known. There is limited scientific information on the arsenic levels in cereal grains like wheat, corn and oats. The scientific literature indicates that rice grown in flooded fields and other plants (including wheat, barley and corn) grown in soil contain mainly inorganic arsenic[16]. Most of the breakfast and infant cereals tested in this survey contained mainly inorganic arsenic species. Some data suggests that the arsenic levels are significantly lower in wheat compared to rice, and that the level in the wheat depends on the arsenic content in the soil[28]. These trends were observed in this survey, where the average arsenic levels were generally higher in rice-based cereals relative to mixed grain cereals or cereals which did not contain rice.

3.2.3 Fruit Products

A total of 251 fruit products (67 domestic, 76 imported, 108 unverifiable origin) were analyzed according to the protocols described in Section 2.4. Domestic products were manufactured or processed in Canada but may not identify the country of origin of the fruit ingredients. Fruit product samples originated from 13 countries and were divided into 12 product types: pear drink, fruit snack, juice blends, grape juice, juice – other (fieldberry, wildberry), pear juice, guava nectar, pear nectar, pear baby food, canned pears, dried pear, and pear teas.

A summary of total arsenic levels detected in fruit products is presented in Table 7. Most of the samples (226/251) contained detectable levels of total arsenic. Pear drink and pear tea samples did not have detectable levels of total arsenic. The average levels of total arsenic ranged from 1.91 ppb (guava nectar) to 26.33 ppb (dried fruit snacks). Dried fruit snacks and dried pear had the highest total arsenic levels, consistent with the fact that the drying process is known to concentrate metal residues. The source of arsenic contamination in the fruit product samples in this survey is not known.

Table 7 - Total arsenic concentrations in fruit products based on the total metals screen (arranged in order of decreasing average total arsenic levels)

Product Category	Number of Samples	Number of Positive Samples	Percentage of Positive Samples	Minimum (ppb)	Maximum (ppb)	Average (ppb)
Fruit Snack	28	28	100	3.11	73.80	26.33
Dried Pear	2	2	100	10.50	40.30	25.40
Juice Blends	42	37	88	1.65	85.80	18.01
Pear Nectar	37	30	81	1.05	31.30	10.78
Pear Baby Food	66	60	91	1.02	36.30	9.71
Pear Juice	49	47	96	1.44	26.40	9.38
Juice - Other	2	2	100	3.54	8.86	6.20
Canned Pear	19	17	90	1.16	18.00	5.05
Grape Juice	1	1	100		4.09	
Guava Nectar	2	2	100	1.39	2.42	1.91
Pear Drink	1	0	0		< LOD	
Pear Tea	2	0	0	< LOD	< LOD	< LOD

Figure 6 presents the average arsenic species percentage for each of the fruit product commodities tested. Results from the arsenic speciation method indicate that the most prevalent arsenic species in fruit products are inorganic forms (As^{3+} and As^{5+}). The average inorganic arsenic (As^{3+} and As^{5+}) content was 81% in fruit products.

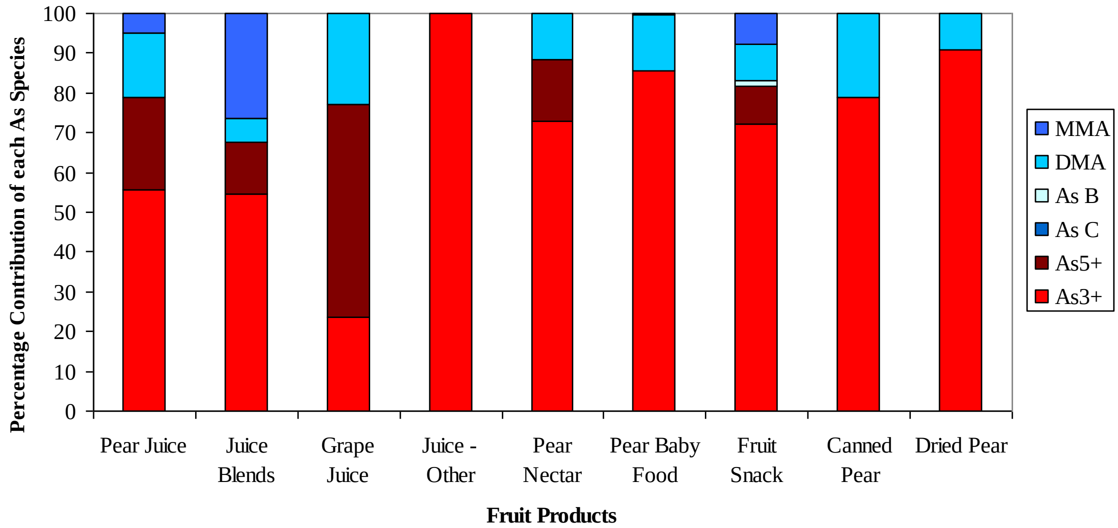


Figure 6. Average percentage of arsenic species detected in fruit product samples
*Note: Red denotes inorganic species and blue indicates organic species.

Pear products were analyzed in both the 2009-2010 and 2010-2011 CFIA FSAP targeted surveys. As seen in Table 8, most of the pear product samples in both the current survey and in the previous year's survey contained detectable levels of total arsenic. In both survey years, the pear products had total arsenic levels which were significantly lower than the total arsenic levels in rice and rice products. In both survey years, pear snacks were associated with the highest minimum, maximum and average levels of total arsenic among pear products tested. The maximum and average total arsenic levels for pear baby food and pear nectar are very low but were almost three times higher in 2010-2011 than in 2009-2010. The reasons for this difference are not clear. As all the pear nectar and pear baby food samples were picked up at the retail level, there is no historical information available about the source of the pears used in manufacturing the final products.

Table 8 - Comparison of total arsenic concentrations in pear products (from total metals screen method) in 2009-2010 and 2010-2011

Commodity	Survey Year	Number of Samples	Percentage of Positive Samples	Minimum (ppb)	Maximum (ppb)	Average (ppb)
Pear Snacks	2009-2010	41	100	2	91	36
	2010-2011	28	100	3	74	26
Pear Juice	2009-2010	23	96	<LOD	26	7
	2010-2011	49	96	1	26	9
Pear Baby Food	2009-2010	33	94	<LOD	9	3
	2010-2011	66	91	1	36	10
Pear Nectar	2009-2010	11	100	2	5	3
	2010-2011	37	81	1	31	11

As seen in Figure 7 below, the percentage inorganic content was higher in the 2010 – 2011 survey year for pear baby food, pear nectar and pear snacks but not for pear juice. This difference is particularly marked for pear snacks. As the pear snack samples were picked up at the retail level, there is no historical information available about the source of the pears used in manufacturing the final products.

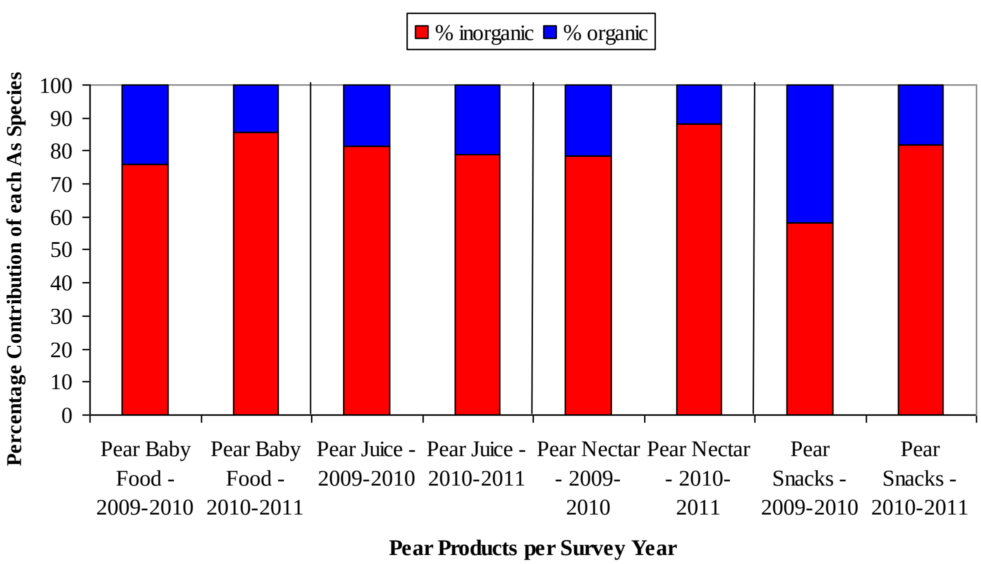


Figure 7. Average percentage contribution of arsenic species detected in pear products in the 2009-2010 and 2010-2011 targeted surveys

3.2.4 Bottled Water

A total of 95 bottled waters (93 imported, two of unverifiable origin) were analyzed according to the protocols described in Section 2.4. Bottled water samples originated from 18 countries. Bottled waters were divided into five product types: mineral water, carbonated mineral water, carbonated water, carbonated spring water, and spring water.

A summary of total arsenic levels in bottled water is presented in Table 9. Most of the samples (91/95) contained detectable levels of total arsenic. All product types contained at least one sample with detectable levels of total arsenic. The average level of total arsenic ranged from 0.95 ppb (carbonated spring water) to 4.24 ppb (mineral water). Mineral water and carbonated mineral water samples had the highest total arsenic levels.

Table 9 - Total arsenic concentrations in bottled waters in the total metals screen (arranged in order of decreasing average total arsenic level)

Product Category	Number of Samples	Number of Positive Samples	Percentage of Positive Samples	Minimum (ppb)	Maximum (ppb)	Average (ppb)
Mineral Water	14	13	93	< LOD	20.80	4.24
Carbonated Mineral Water	63	61	97	< LOD	14.00	1.95
Carbonated Water	1	1	100		1.32	
Spring Water	4	4	100	0.94	1.86	1.28
Carbonated Spring Water	13	12	92	< LOD	1.97	0.95

Results from the arsenic speciation method indicate that most of the arsenic species present in bottled water products are inorganic forms (As^{3+} and As^{5+}). Figure 8 below presents the average arsenic species percentage for each of the bottled water product types tested. The average inorganic arsenic (As^{3+} and As^{5+}) content was 99% in bottled water products.

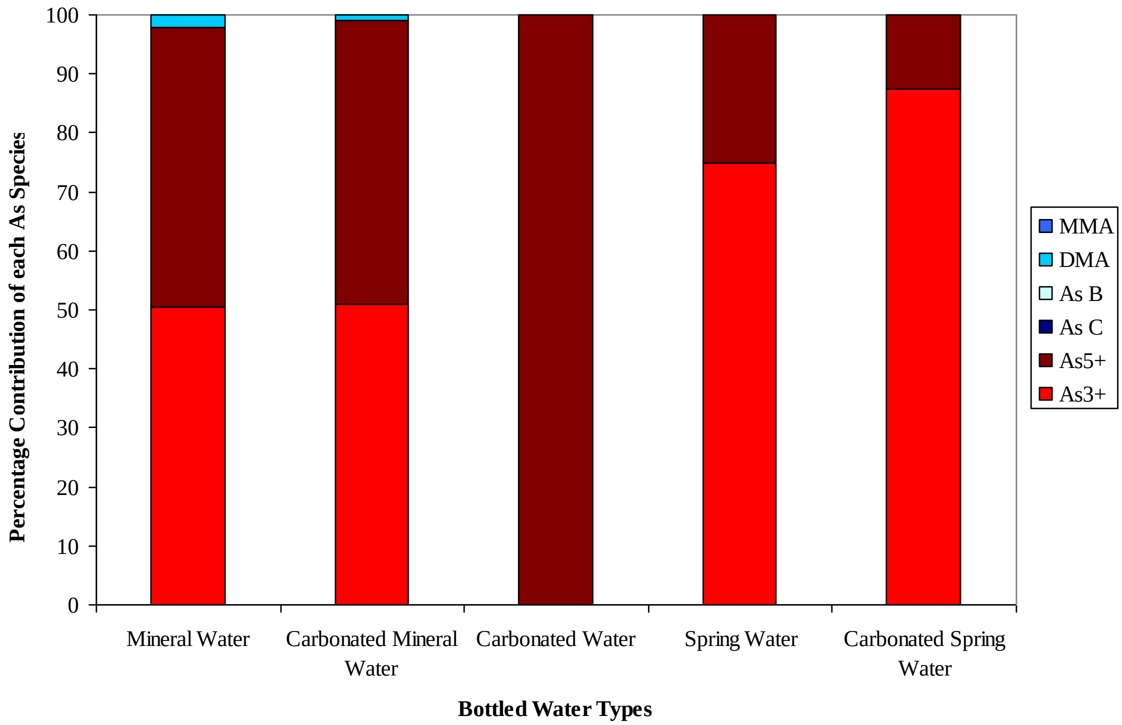


Figure 8 - Average percentage of arsenic species detected in bottled water samples
*Note: Red denotes inorganic species and blue indicates organic species.

The levels of arsenic in bottled water are mainly related to the levels of arsenic in the source water. Scientific studies have shown appreciable levels of arsenic in groundwater in many countries[29], and a predominance of As^{5+} in bottled waters[30]. As expected, inorganic arsenic forms (as As^{3+} and As^{5+}) were predominant. An organic form of arsenic, DMA, was observed in some bottled water samples. Only three of the 95 water samples exceeded the 10 ppb maximum allowable concentration of total arsenic in the Guidelines for Canadian Drinking Water Quality published by Health Canada[31]. Health Canada was consulted on the levels of arsenic in these bottled water products and it was determined that the samples were unlikely to pose a human health concern.

3.2.5 Seaweed Products

A total of 90 seaweed products (5 domestic, 77 imported and eight of unverifiable origin) were analyzed according to the protocols described in Section 2.4. Seaweed product samples originated from ten countries. Seaweed products were divided into 11 product types: dried seaweed, roasted seaweed, dried kelp, dried wakame, dried sea vegetable, dried laver, dried nori, miso, other seaweed products (including seaweed paste, seaweed snacks, seaweed chips, and samples described only as seaweed products), and dried dulse.

A summary of total arsenic levels in seaweed products is presented in Table 10. All the samples contained detectable levels of total arsenic. The levels of arsenic in seaweed are reported as parts per million (ppm). The average levels of total arsenic ranged from 9.3 ppm (dulse) to 56.8 ppm (dried kelp). Dried kelp and dried wakame had the highest total arsenic levels, consistent with the fact that the drying process is known to concentrate metal residues. The total arsenic levels in seaweed products were significantly higher than the levels in any other product types analyzed in this survey. A number of studies have indicated that seaweed absorbs and metabolises arsenic from the marine environment[19, 29, 32,33,34,35,36]. Total arsenic levels reported in the literature in seaweed are relatively high (from 1.06 to 126.0 ppm, depending on the type of seaweed and the geographical region from which the seaweed is harvested) [32,33,34,35,36].

Table 10 - Total arsenic concentrations in seaweed products in the total metals screen (in decreasing order of average total arsenic levels)
Please note the results are presented in ppm (not ppb)

Product Category	Number of Samples	Number of Positive Samples	Percentage of Positive Samples	Minimum (ppm)	Maximum (ppm)	Average (ppm)
Dried Kelp	3	3	100.0	50.90	62.50	56.80
Dried Wakame	12	12	100.0	30.30	55.40	39.80
Dried Sea Vegetable	3	3	100.0	11.20	91.30	38.20
Dried Seaweed	24	24	100.0	7.50	57.10	31.50
Roasted Seaweed	13	13	100.0	8.10	30.80	23.00
Dried Laver	2	2	100.0	14.80	30.80	22.80
Dried Nori	13	13	100.0	15.50	32.30	22.70
Miso	2	2	100.0	1.10	38.80	20.00
Other Seaweed Products*	12	12	100.0	1.10	28.80	13.90
Dried Dulse	6	6	100.0	6.10	12.40	9.30

* Other seaweed products includes seaweed paste, seaweed snacks, seaweed chips, and samples described only as seaweed products

Results from the arsenic speciation method indicate that most of the arsenic species present in seaweed products are organic forms (DMA and MMA). Figure 9 presents the average arsenic species percentage for each of the seaweed product types tested. The average inorganic arsenic (As^{3+} and As^{5+}) content was 22% in seaweed products. The levels of inorganic arsenic in seaweed reported in the literature are usually low[32,33,34,35,36].

The results observed in this survey are consistent with the findings in other studies reported in the literature.

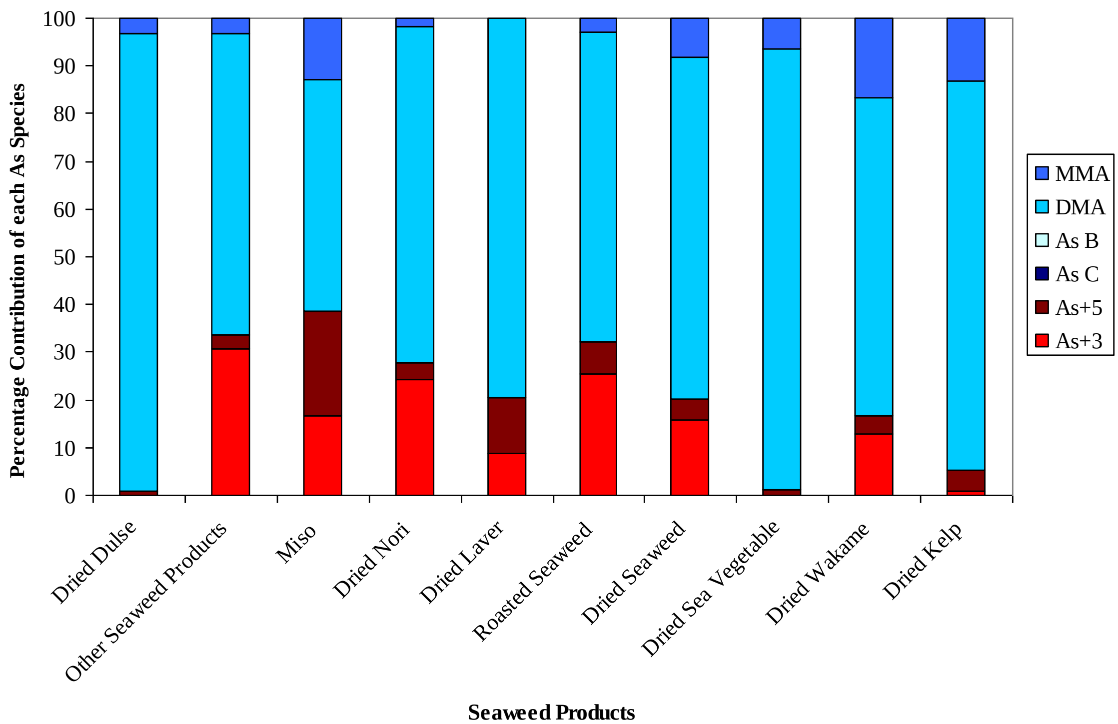


Figure 9 - Average percentage of arsenic species detected in seaweed samples
Note: Red denotes inorganic species and blue indicates organic species.
* Other seaweed products includes seaweed paste, seaweed snacks, seaweed chips, and samples described only as seaweed products

There are no Canadian tolerances in place for arsenic levels in seaweed products. Hijiki seaweed (not tested in this survey) is known to contain high levels of inorganic arsenic. For this reason, the CFIA has issued an advisory to avoid consumption due to the high levels of inorganic arsenic[24]. Previous test results obtained by Health Canada and the CFIA showed inorganic arsenic levels in hijiki seaweed between 32 ppm and 180 ppm (unpublished data). The highest level of inorganic arsenic detected in this survey in seaweed products was 0.22 ppm or 220 ppb (219.90 ppb measured) inorganic arsenic, which is considerably below the levels of inorganic arsenic previously reported in hijiki seaweed. The levels of inorganic arsenic observed in the seaweed samples in this survey are below the US and France (3000 ppb) or Australian (1000 ppb) maximum limits for inorganic arsenic in seaweed.

4 Conclusions

A total of 1071 samples were tested for total arsenic and the breakdown of organic and inorganic forms of arsenic. Of these samples, 96.5% (1034 samples) had detectable levels of total arsenic. Seaweed (the average total arsenic level was 26.90 ppm or 26900 ppb) had the highest total arsenic levels and bottled water (the average total arsenic level was 2.06 ppb) had the lowest total arsenic levels. As expected, the percentage of inorganic content was low in seaweed products and was relatively high in all other product types examined.

The survey results were compared to Canadian tolerances or standards where applicable. There is an established arsenic tolerance in fruit juice, fruit nectar, beverages when ready-to-serve and water in sealed containers (other than spring or mineral water) specified in Table I of *Division 15* of the *FDR*. Health Canada has informed industry and the CFIA that these limits listed in the *FDR* are under review. This arsenic tolerance (which is under review) was not exceeded in any of the fruit juice or nectar products tested. There are Canadian guideline levels for arsenic in drinking water. Three samples of bottled water had levels of total arsenic which exceeded the Canadian drinking water guidelines for arsenic. There are no Canadian standards or tolerances established for arsenic in any of the other foods tested in this survey. Compliance to a numerical standard could not be assessed for these products. None of the samples tested in this survey were determined to pose a concern to human health. Appropriate follow-up actions were initiated that reflected the magnitude of the human health concern.

5 Appendix

Table A - Summary of regulatory guidelines for total arsenic and inorganic arsenic in selected commodities

Commodity	Country/Organisation	Total Arsenic (ppb)	Inorganic Arsenic (ppb)
Drinking water	Canada[6]	10	-
	United States[37]	10	
	Codex[31]	10	
All foods	Canada	None	-
	United Kingdom[38]	1000 (1 ppm)	-
	China[39]	-	150
Fruit juice, fruit nectar, beverages when ready-to-serve and water in sealed containers other than mineral water or spring water*	Canada[40]	100*	-
Pear Juice Products	United States[2]	-	23 **
Apple Juice - single strength (ready to drink)	United States[41]	-	10
Seaweed Products	United States[42]	-	3000 (3 ppm)
	France[42]	-	3000 (3 ppm)
	Australia/New Zealand[43]	-	1000 (1 ppm)

* These regulatory tolerances in Table 1 of Division 15 of the Food and Drug Regulations are under review by Health Canada[5].
** This is the FDA's level of concern in regards to inorganic arsenic levels in pear juice products.

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